Chapter 5 Site Conditions

5.1 Topographical Features

Outlines of topographical features of the candidate hydropower sites in Bhutan and the State of Meghalaya in India, which were selected as promising areas for hydropower development to export power to Bangladesh in the previous chapter, are described below.

5.1.1 Bhutan

(1) General Topographical Conditions

Bhutan is a small country located in the eastern Himalayas with a total area of 38,394 square kilometers. It is surrounded by steep mountains and dense forest. The country is bordered by Tibet (China) in the north and northeast, Sikkim (India) in the west, West Bengal (India) in the southwest, Assam (India) in the south and Arunachal Pradesh (India) in the east.

It is a mountainous country of extremely high altitudes and irregular, often precipitous terrain, which may vary in elevation by several hundred meters within a short distance. Elevation generally increases from south to north. The mountains are a series of parallel north-south ranges. The loftiest peaks, found in the Himalayan chain that stretches along the northern border, include Kula Kangri (7,554 m) and Chomo Lhari (7,314 m). Great spurs extend south from the main chain along the eastern and western borders. In the rest of the country are mainly ranges of steep hills separated by narrow valleys.

Bhutan has four major river systems flowing swiftly out of the Himalayas that are regularly fed by glaciers in northern Bhutan. They flow towards Duars in the south and join the Brahmaputra River in India.

The glaciers are fed by snowfalls during winter that melt slowly in summer. They cover about 10 percent of the total surface area of Bhutan and are an important renewable source of fresh water for Bhutan and downriver areas each year. Melting of glaciers along with heavy rainfall in monsoons sometimes results in flooding too. For the past few decades, glacial lakes have been rapidly forming on the surface of the debris-covered glaciers in this region.

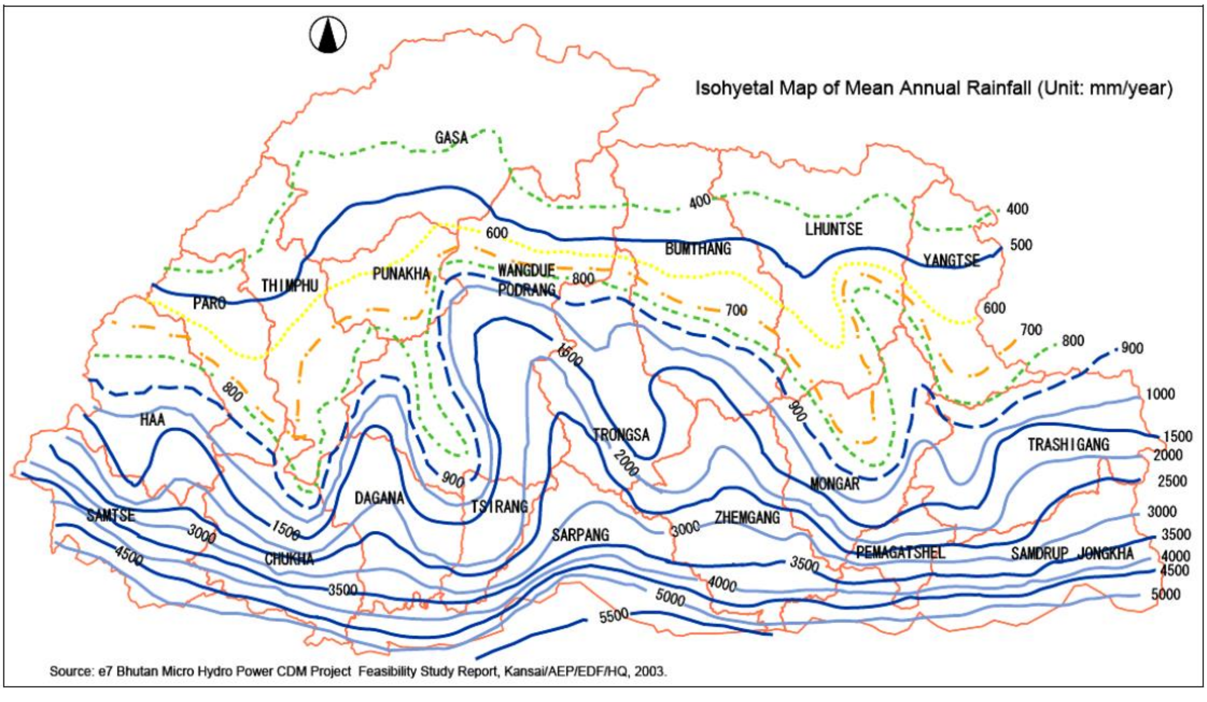
The four major river systems of Bhutan are Drangme Chhu, Puna Tsang Chhu or Sankosh, Wang Chhu, and Torsa Chhu.

Drangme Chhu, which is located in the eastern part of Bhutan, is its largest river system. It flows to the southwest and rises in the Indian state of Arunachal Pradesh. It has three major branches that form Drangme Chhu basin together, as shown in Figure 5-1.

The isohyetal map of mean annual rainfall in Bhutan is shown in Figure 5-2. According to the isohyetal map, in the southern part of Bhutan, close to the border with India, the rainfall reaches almost 4,000 mm/year. In the middle latitude areas such as Dagana, Tsirang, the southern part of Bumthang, Mongar and Trashigang Dzongkhags, the rainfall is comparatively large at 1,500-2,000 mm/year. On the other hand, areas such as Haa, Paro, Thimphu and Punakha Dzongkhags have a relatively small annual rainfall.

(Source: Wikipedia WebSite)

Figure 5-1 River Map of Eastern Bhutan



(Source: e7 Bhutan Micro Hydropower CDM Project Feasibility Study Report, Kansai/AEP/EDF/HQ, 2003)

Figure 5-2 Isohyetal Map of Mean Annual Rainfall in Bhutan (mm/yr)

(2) Candidate Hydropower Project Sites

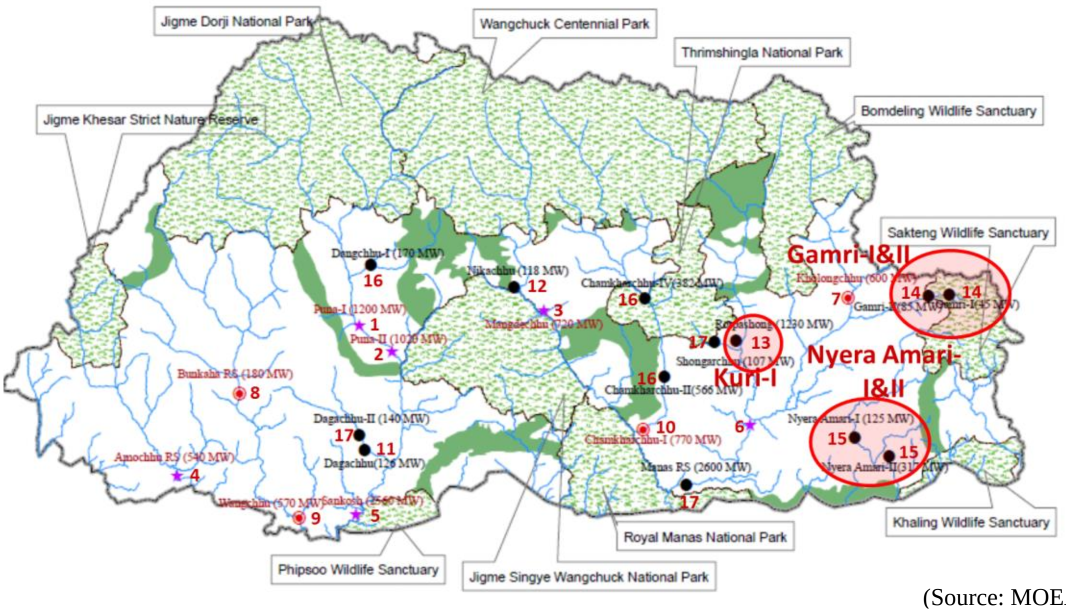
Site reconnaissance for the following hydropower projects located in eastern Bhutan, which are being studied by DGPC, was carried out for a selection of promising sites.

Table 5-1 Main Features of Candidate Hydropower Project Sites in East Bhutan

	Kuri-I	Gamri I	Gamri II	Nyera Amari I	Nyera Amari II
Installed capacity Unit size ×Units	1,230 MW (205MW×6)	45 MW	85 MW	125 MW	317 MW
Design annual energy	5,265 GWh	215.69 GWh	399.90 GWh	614 GWh	1,556 GWh
Net head	268 m	591 m	515 m	327 m	527 m
Discharge	540 m^3/s	8.62 m^3/s	18.73 m^3/s	43.26 m^3/s	68.09 m^3/s
Length of head race	10.5 km	3.132 km	4.698 km	13.22 km	13.29 km
Dam height	65 m	22 m	27 m	29 m	15 m
Catchment Area	8,808 km^2	102 km^2	214 km^2	515 km^2	818.65 km^2
Construction cost	USD 1,686.5 million	BTN 3,620 million USD 56.6 million*[1]	BTN 5,587 million USD 87.3 million*[1]	BTN 12,490 million USD 195.2 million*[1]	BTN 22,291 million USD 348.4 million*[1]
Unit construction cost per annual energy	USD 320 /MWh	USD 262 /MWh	USD 218 /MWh	USD 318 /MWh	USD 224 /MWh
Status	DPR under DPR (F/S) and to be completed at the end of 2015	Pre-F/S completed in early 2015		Pre-F/S completed in 2014.	

*[1] : 1 BTN = 0.015663 USD

(Source: JICA Survey Team)



(Source: MOEA)

Figure 5-3 Location Map of Hydropower Projects in Bhutan

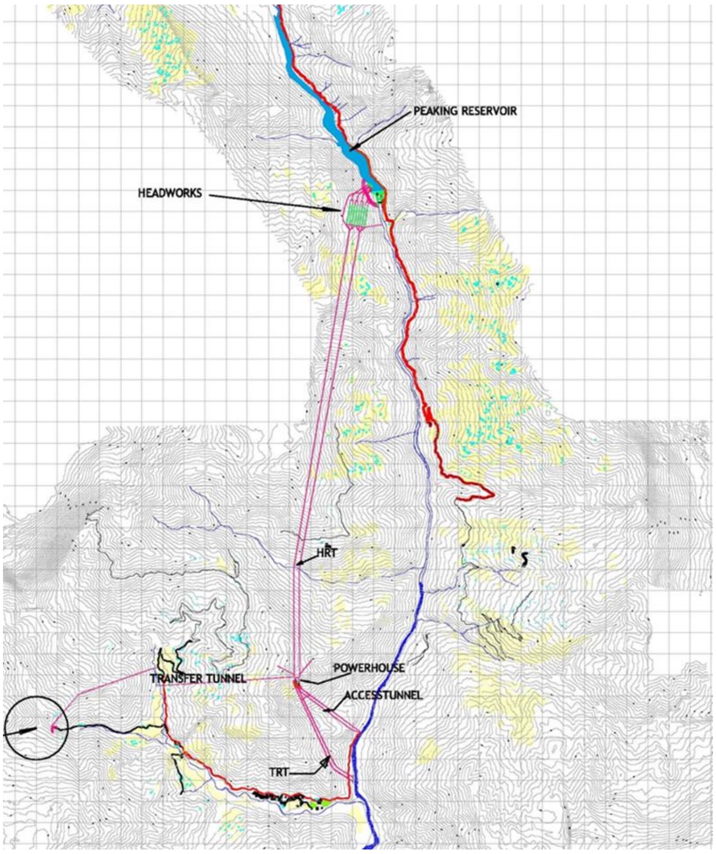
The findings and evaluations of the site reconnaissance for each site are described as follows:

(a) Kuri I

The Kuri-I project is located in the middle part of Kurichhu, a major river of eastern Bhutan, which originates from the Kula Kangri Glacier in the Tibet Autonomous Region of the People's Republic of China.

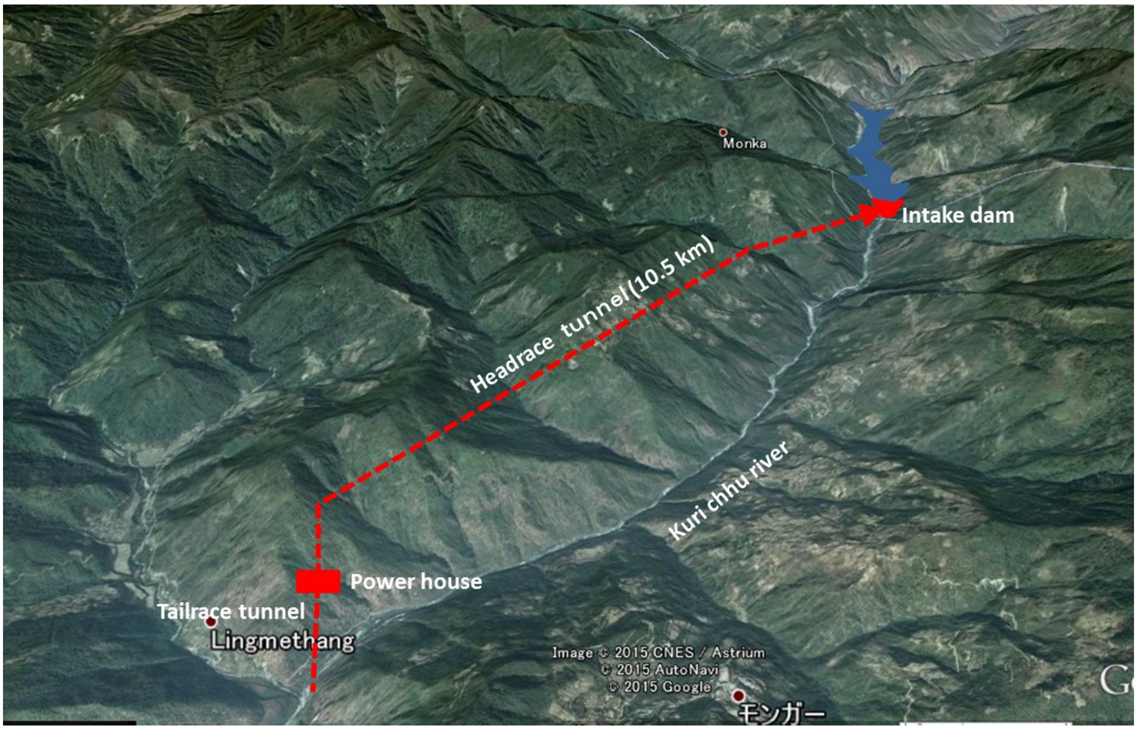
Kuri I hydropower plant utilizes the head over an 18 km long reach of Kurichhu, from Autsho village to near the confluence of Shongarchhu, in Mongar Dzongkhag. The intake dam is located 5 km downstream of Autsho, and creates a reservoir that reaches upstream to Autsho. The tailrace outlet is located around 5 km upstream of the existing Kurichhu hydropower plant.

The general layout and bird's eye view of the Kuri-I project are shown in Figure 5-4 and Figure 5-5 respectively.



(Source: Pre-Feasibility Study Report Rotpashong Hydropower Project, June 2011)

Figure 5-4 General Layout of Kuri I Project



(Source: JICA Survey Team)

Figure 5-5   Bird's Eye View of Kuri-I Project

The results of the site reconnaissance are shown below.

- General Layout
  - Since the headrace route is aligned parallel to the liner section of Kurichhu, the length of the waterway of the project is almost the same as the length of the river section from the intake to the outlet. However, the indicator showing the ratio between waterway length and head (difference in height): L/H is 40 (= slope 1/40), which is a moderate ratio for a large scale run-of-river type hydropower plant.
  - The overall layout of the waterway facilities, which are classified as a tail type arrangement, is appropriately arranged in accordance with the topographical features around the site.
  - All the facilities except the intake dam are constructed underground.
- Intake and reservoir site
  - The intake dam, which will be 67 m high, will create an approximately 4.5 km long and 300 meter wide reservoir stretching up towards Autsho Village. The upper end of the reservoir will be just downstream of the chorten next to Autsho. The total area of the reservoir will be about 0.8 square kilometers.
  - The intake dam is planned to be constructed at a narrow steep-sided valley, which is basically considered a topographically suitable site for a concrete gravity dam.
  - There are no settlements at the dam site, but part of the highway along the reservoir near the intake dam needs to be relocated due to the reservoir, and 3 permanent houses and other small facilities in Autsho village need to be resettled.

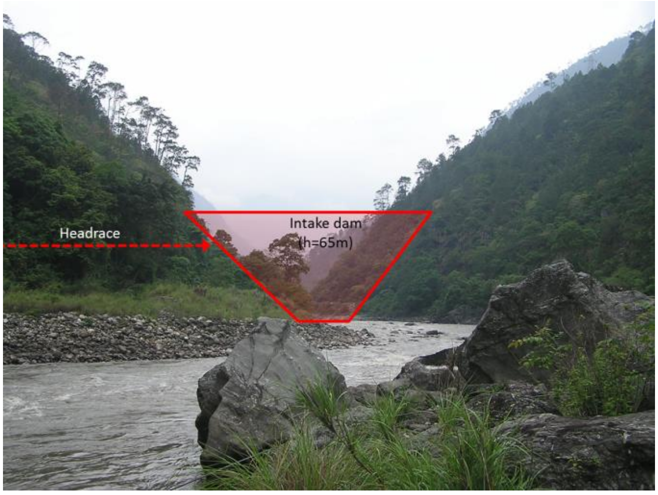


Photo 5-1　Intake Dam Site of Kuri-I Project

Photo 5-2　Upper End of the Reservoir

Photo 5-3　Right Bank at the Dam Site

Photo 5-4　Left Bank at the Dam Site

- Headrace
  - According to the Pre-feasibility Report, the two headrace tunnels will be excavated by TBM (Tunnel Boring Machine) technique. One tunnel boring machine with a cutter diameter of 11.6 m designed for continuous lining with prefabricated concrete elements should be used. The net diameter will be 10.8 m. On the other hand, according to the explanation by DGPC, the tunnels will be excavated by the conventional method. It is desirable to carefully review the possibility of excavation by TBM again after the geological surveys are carried out during the DPR stage, because excavation by TBM is generally more cost efficient than excavation by conventional methods in the case of over 10 km-long tunnels.
- Power house
  - The power house, with 180 m long, 21 m wide and 38 m high dimensions, is planned to be constructed underground near the confluence of Kurichhu and Shongarchhu. However, judging from the observed topographical conditions, an open type power house, which is generally more cost efficient than an underground type, can be constructed on the right bank near the confluence.　It is, therefore, recommended to conduct a careful comparative review of underground and open type power houses.

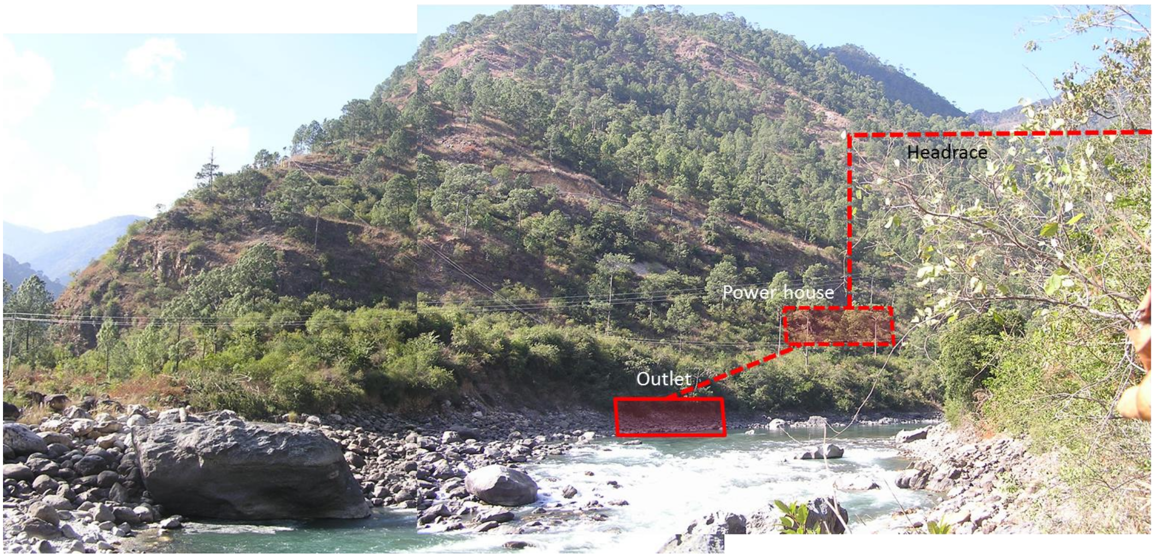


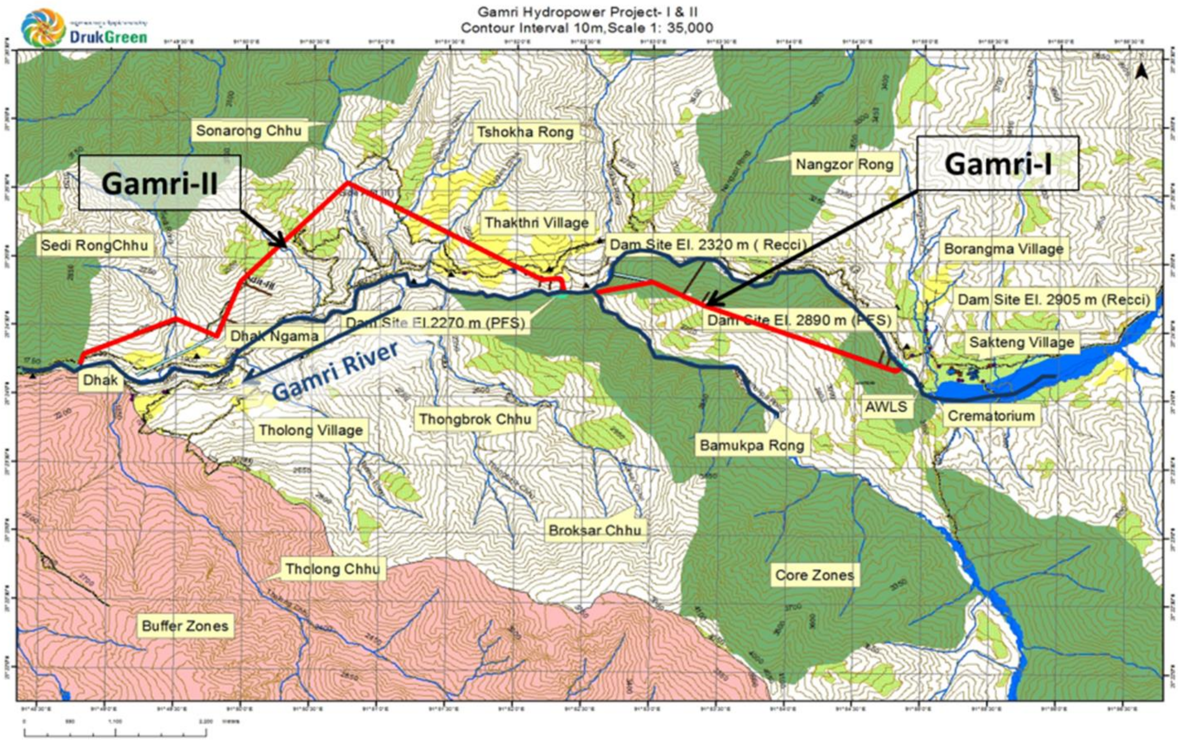
Photo 5-5 Outlet site

- Accessibility of the Project Site
  - Both the power house site and the intake dam site are located very near the existing trunk roads.
- Other important matters
  - The consequences of a dam failure downstream are high and many lives will be at risk. The underground power house, Kurichhu hydropower plant, several bridges, settlements along the river and roads will be at risk. The design flood is, therefore, estimated conservatively and linked to the estimate of the peak flood with a return period of 10,000 years. The adopted design flood is as much as 8,300 m^3/s.

(b) Gamri I & II

Gamri I and II Hydropower Projects are located under Sakteng Dzongkhag in Trashigang Dzongkhag, eastern Bhutan, in the Gamri river sub-basin. The Gamri River is a tributary to Gongrichhu which, in turn, is a tributary to Manas. It originates at an elevation of more than 4,000 m above sea level and it flows east to west. The catchment areas at the proposed dam sites of Gamri I and Gamri II are 102 and 214 km^2 respectively.

The general layout of the Gamri I and II Projects is shown in Figure 5-6.



(Source: Pre-Feasibility Study Report Gamri Hydropower Projects (I & II), June 2011)

Figure 5-6 General Layout of Gamri I and II Projects

The results of the site reconnaissance are shown below.

- General Layout
  - All project components of the Gamri I Project are located in and around the protected areas of Sakteng Wildlife Sanctuary. However, minimal destruction of the protected areas is envisaged due to the project mostly being underground. The project area covers from an altitude of EL. 2,900m around Sakteng village to EL. 2,320 m at Tsebchenang village, where the power house is proposed.
  - The project area of the Gamri II project stretches from Thakthri village to Dhag village. The major settlement around the project area is in Thakthri. Unlike Gamri I, the scheme however, does not fall under any reserved area of the Sakteng Wildlife Sanctuary. There is an approximately 60 m long open-to-sky connection tunnel at Sonarongchhu depression. The water conducting system crosses several perennial streams.
  - The intake dam site of Gamri II is located 150 m or more downstream of the outlet site of Gamri I. These projects are independent of each other, and can be individually developed.
  - The indicators showing the ratio between waterway length and head (difference in height): L/H values of Gamri I and II are 5 and 9 (= slope 1/5 and 1/9), which is a significantly good value for a small scale run-of-river type hydropower plant.
- Intake and reservoir site

<Gamri I>

  - According to the Pre-Feasibility Study Report, the proposed dam site is located approximately 700 m downstream of Sakteng village and is accessible from the existing foot track, which is about 100 m above the riverbed level of the proposed dam site. The river width at the proposed dam site at the present bed level is around 5 m, with the sound bedrock exposed on both the banks. With the design discharge of 8.43 m^3/s, a concrete gravity dam 23 m in height is proposed from the riverbed level. An access road would be required to reach the dam site. With the 23 m high dam proposed from the present riverbed level (RBL), the crest length available is around 40 m.

<Gamri II>

- According to the Pre-Feasibility Study Report, The dam site for Gamri Hydropower Project-II is located 150 m downstream of Gamri-Bamukparong Confluence. The total catchment area up to the dam site is 214 km^2. The Bamukparong, a tributary of Gamri River, contributes around 58 km^2 of the catchment.

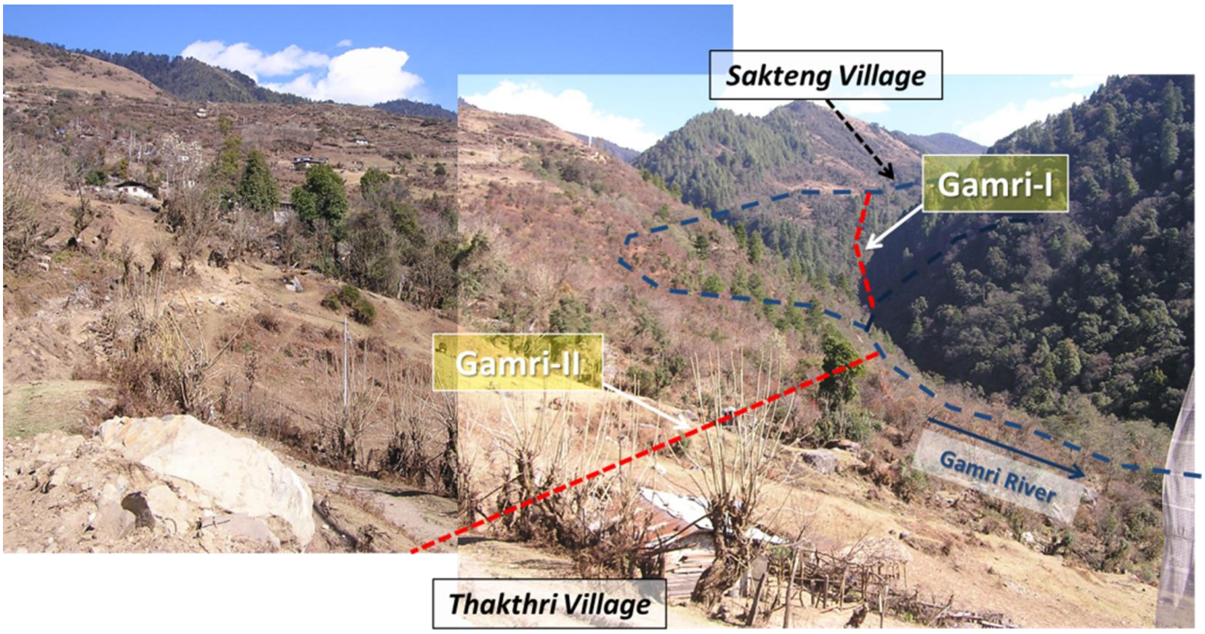


Photo 5-6 Power House Site of Gamri I & Intake Site of Gamri II

■ Headrace

<Gamri I>

- According to the Pre-feasibility Report, a headrace tunnel of 3.0m dia., horse-shoe shaped, of length 3.24 km is proposed on the left bank of Gamri. The waterway runs below the minimal settlement of Sakteng Dungkhag and irregularly passes beneath the protected areas. Therefore, the pressurized waterway is connected from the desilting chamber directly to the power house, making a total stretch of 3.24 km.
- Since the headrace route is located in and around the protected areas of Sakteng Wildlife Sanctuary, it seems reasonable to adopt a tunnel type headrace to minimize the negative impacts on the protected areas.

<Gamri II>

- According to the Pre-feasibility Report, a 3.5m dia., horse-shoe shaped headrace tunnel of length 5 km is proposed on the right bank of Gamri. The waterway crosses the major depression at Sonarongchhu. The surge shaft is proposed where no human settlement is found. The water conductor system crosses beneath agricultural and pasture land.
- Unlike Gamri I, the waterway has to cross several tributaries on the right bank of Gamri River. Due to such a topographical condition, the waterway is not shorter than the river length between the intake site and the outlet site.
- Although the headrace is designed as a pressured tunnel, it is necessary to study the possibility of adopting a non-pressured tunnel, because an open type penstock seems to be possible judging from the topographical conditions in and around the proposed power house site.

- Power house

<Gamri I>

  - The power house is planned to be underground with a vertical cover of 368 m. The site falls in the core area of the reserved sanctuary. However, in general, power houses of small or middle scale hydropower plants like this project are designed to be on the ground for economic reasons. Thus, it is recommended to study the possibility of an open type power house which would be located out of the core zone of the reserved sanctuary.

<Gamri II>

  - The power house is planned to be underground and located around 100 m above Dhak village. As mentioned in the section "General Layout", the sites of all the facilities of the project are located out of the reserved area of the Sakteng Wildlife Sanctuary. Thus, it is recommended to study the possibility of an open type power house.

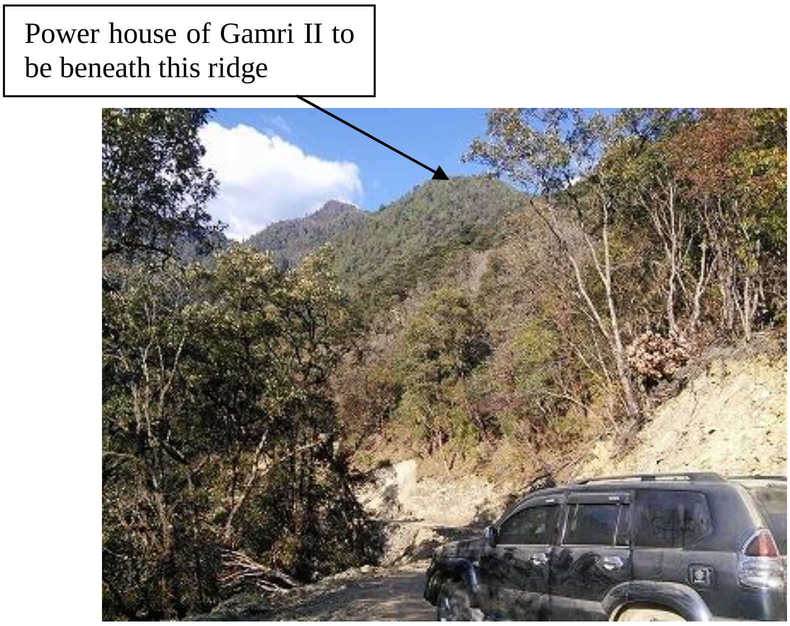


Photo 5-7 Power House Site of Gamri II

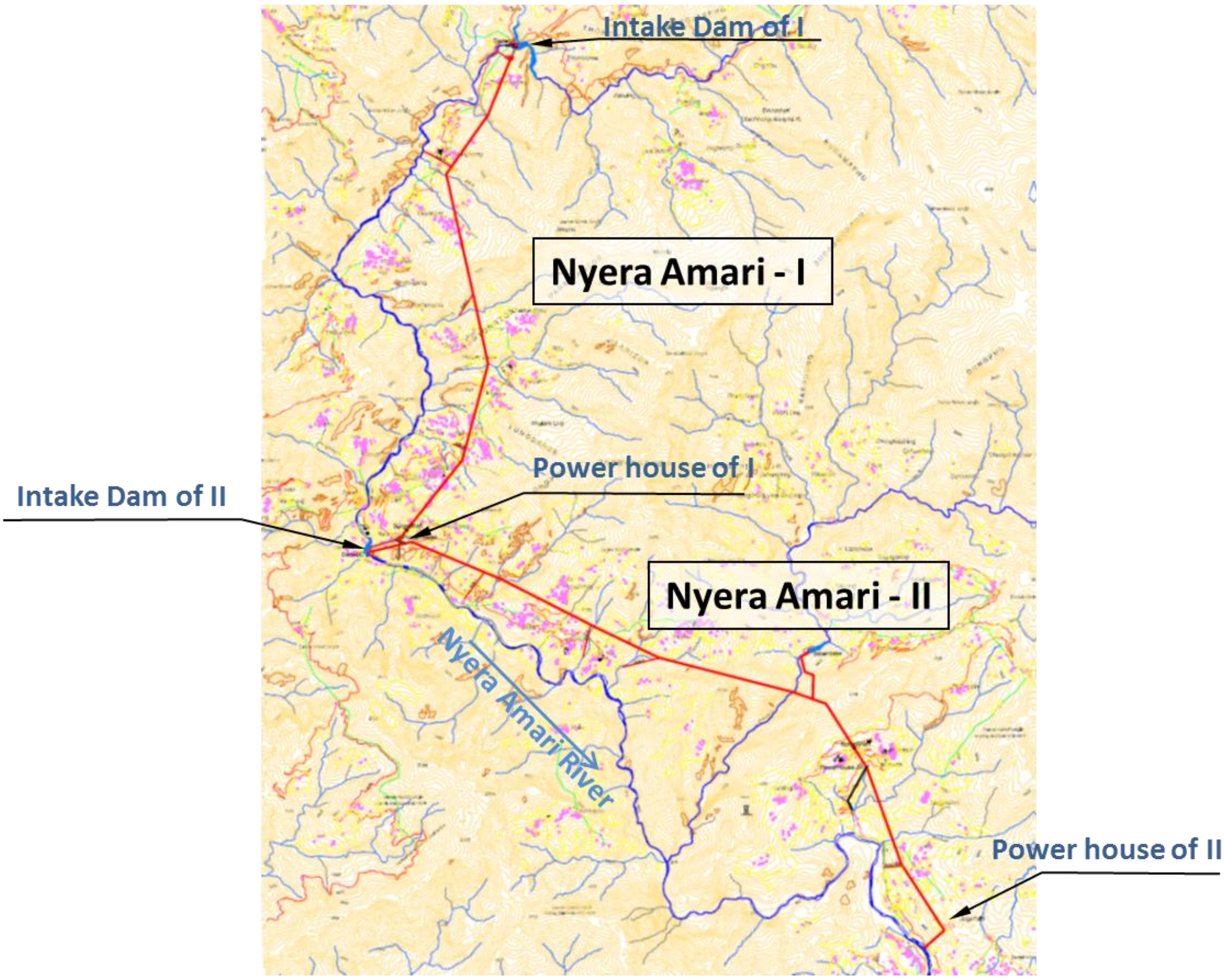
- Accessibility of the Project Site
  - There is no road connectivity towards Sakteng village, where the intake dam will be located, and the project area in particular.
  - There is a 37.3 km farm road from Rangjung to Thakthri village near the intake dam site of Gamri II, but there is still no road between Thakthri village and Sakteng village. Accordingly, major road and bridge constructions are required for the construction work of Gamri I. However, due to the core zone of reserved sanctuary, difficulties in the construction of access roads in this section are anticipated. In addition, since the existing road and roads under construction run on a several hundred meters higher part of the slope from the Gamri riverbed, the construction of access roads towards the sites near the riverbed seems to be costly, causing negative impacts on the environment of the slopes on the right bank of the river.

(c) Nyera Amari I & II

Nyera Amari I and II Hydropower Projects are planned as an integrated scheme or cascade project. The installed capacity of Nyera Amari I is 141 MW, utilizing a gross head of 390 m, and that of Nyera Amari is 332 MW, utilizing a gross head of 550 m, and hence the integrated project has a combined capacity of 473 MW. The catchment area at the intake dam site of Nyera Amari I is 518 km^2. The intake of Nyera Amari II is planned to be approximately 20 km downstream at an elevation of about

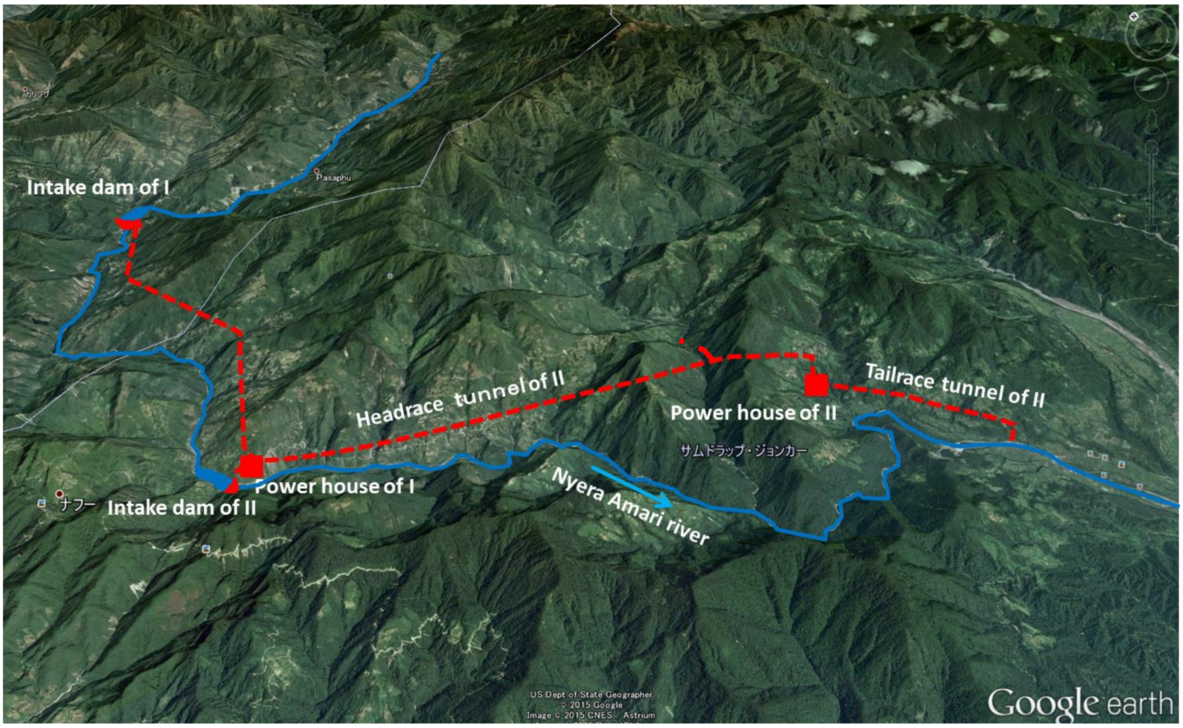
EL. 800 m under Gomdar Gewog in Samdrup Jongkhar. The catchment area at the intake dam site of Nyera Amari II is 146 km^2. The downstream project, Nyera Amari II, will utilize the turbine flow from Nyera Amari I, as the water from Nyera Amari I's tailrace tunnel will drain into the headrace tunnel of Nyera Amari II. Nyera Amari II will also utilize water from the sub-basin of Ritsong River (left bank tributary of Nyera Amari) with a catchment area of 182 km^2.

The general layout and bird's eye view of the Gamri I and II Projects are shown in Figure 5-7 and Figure 5-8 respectively.



(Source: Pre-Feasibility Study Report Nyera Amari Hydropower Project -I & II, April 2014)

Figure 5-7 General Layout of Nyera Amari I and II Projects



"Map Data: US Dept of State Geographer ©2015Google, Image ©2015CNES/Astrium, ©Auto Navi"
(Source: JICA Survey Team)

Figure 5-8 Bird's Eye View of Nyera Amari I and II Projects

The results of the site reconnaissance are shown below.

- General Layout
  - Nyera Amari I and II have been planned and designed as an integrated cascade development scheme, whereby the tail water of Nyera Amari I is conveyed directly into the headrace tunnel of Nyera Amari II, including diversion of flow derived from additional catchment downstream of the intake dam of Nyera Amari I.
  - The indicators showing the ratio between waterway length and head (difference in height): L/H values of Nyera Amari I and II are 43 and 35 (= slope 1/43 and 1/35), which are moderate or good values for a large scale run-of-river type hydropower plant.
  - All project components except for the dams and diversion weirs of both Nyera Amari I and II are located underground in the left bank of Nyera Amari River.
  - The Nyera Amari II project has a secondary diversion which is located on Risthong River, a major left tributary of Nyera Amari River. This secondary diversion weir has a catchment area of 178.65 km^2 and it will contribute an additional discharge of about 13.43 m^3/sec.
  - The power house of Nyera Amari II is located more than 5,000 m upstream of the outlet site on the river.
  - No project components of the Nyera Amari I and II Projects are located in or around protected areas.
- Intake and reservoir site

<Nyera Amari I>

  - The Dam site lies below Ramchongma village under Thrimshing Gewog, Trashigang Dzongkhag. Thrimshing is accessible through a 14 km farm road from the Samdrup Jongkhar-Trashigang highway. The newly constructed farm road passes right above Pangzam village. The Dam site is located about 150 m upstream of Pangzam village. The total catchment area above the dam site is 515 km^2.

- The 29 m high dam is located in a steep and narrow valley, topographically suitable for a concrete gravity dam. In addition, the site is in an easily accessible location since there is a farm road that runs just above the dam site on the right bank of the Nyera Amari River.

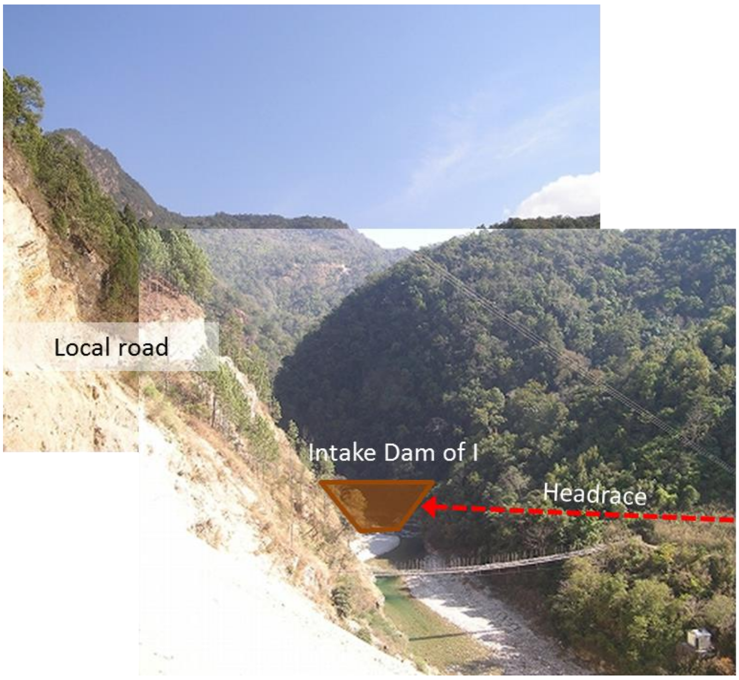


Photo 5-8 Intake Dam Site of Nyera Amari I

<Nyera Amari II>

- The diversion weir site is located in Gomdar, under Samdrup Jongkhar Dzongkhag, at an elevation of EL. 800 m. The catchment area at the dam site is 640 km^2. The weir site is accessible by an approximately 14 km farm road branching off from the Samdrup Jongkhar-Trashigang highway below Narphung.
- The site is located in a curved portion of the river, but outcrops are identified on both the right and left bank of the river.
- There are houses and a school building upstream of the diversion weir site, but the weir will not affect those buildings because a weir with a height of 15 m is relatively low.

Photo 5-9 Diversion Weir Site of Nyera Amari II

■ Headrace

<Nyera Amari I>

- According to the Pre-feasibility Report, the headrace tunnel is located on the left bank of Nyera Amari with a length of 13.22 km. The headrace tunnel is 4.50 m in diameter, modified horse shoe shaped and concrete lined. The slope considered for the headrace tunnel is 1:400 to meet the topographical requirement. The alignment of the tunnel has been chosen to have an adequate vertical and horizontal rock cover. Based on the length of tunnel, three intermediate adits and one side adit have been proposed. The intermediate adits are D-shaped with a 5.0 m diameter.

<Nyera Amari II>

- According to the Pre-feasibility Report, the water from the tail race tunnel of Nyera Amari I is diverted into the headrace tunnel of Nyera Amari II through a connection tunnel of length 215 m having a dia. of 4.50 m. The headrace tunnel of Nyera Amari II from the desilting chamber until the Surge Shaft is 13.29 km long with a 5.50 m diameter, modified horse shoe shaped and concrete lined. The design discharge of 53.47 m^3/s is carried through the headrace tunnel of Nyera Amari II until the junction of the connection tunnel from a secondary intake to the headrace tunnel. The discharge through the headrace tunnel after the junction is 68.09 m^3/s, which includes the flow from the Secondary Intake. The slope considered for the headrace tunnel is 1:400 to meet the topographical requirement. The alignment of the tunnel has been chosen to have an adequate vertical and horizontal rock cover. Based on the length of tunnel, three intermediate adits and one side adit have been proposed. The intermediate adits are D-shaped with a 5.5 m diameter.

■ Power house

<Nyera Amari I>

- According to the Pre-feasibility Report, the underground power house has a rock cover of about 295 m. The dimensions of the main power house cavern are 85 m (L) x 20 m (W) x 45 m (H) and 54 m (L) x 20 m (W) x 20 m (H) for transformer cum GIS cavern.
- However, judging from the observed topographical conditions, an open type power house, which is generally more cost efficient than an underground type, can be constructed near the diversion weir site for Nyera Amari II. It is, therefore, recommended to conduct a detailed comparative review of underground and open type power houses.

<Nyera Amari II>

- According to the Pre-feasibility Report, the underground power house has a rock cover of about 303 m. The dimensions of the main power house cavern are 105 m (L) x 20 m (W) x 51 m (H) and 75 m (L) x 20 m (W) x 20 m (H) for transformer cum GIS cavern. Nyera Amari-II has a long tailrace tunnel of 5,246 m to redirect the water into the main river course from the power house. The length of tailrace tunnel has been planned based on the gain in the head for generation of power. After the water is utilized for generation by the three units, it is diverted through the three unit tailrace tunnel, which converges into one main tailrace tunnel of 6.0 m diameter - slightly larger than the headrace diameter. The flow in the tailrace tunnel is free flow. One adit is provided in the tailrace tunnel for easier construction of the tailrace tunnel.
- However, judging from the observed topographical conditions, an open type power house, which is generally more cost efficient than an underground type, can be constructed on the ground next to the Nyera Amari River. It is, therefore, recommended to conduct a detailed comparative review of underground and open type power houses.

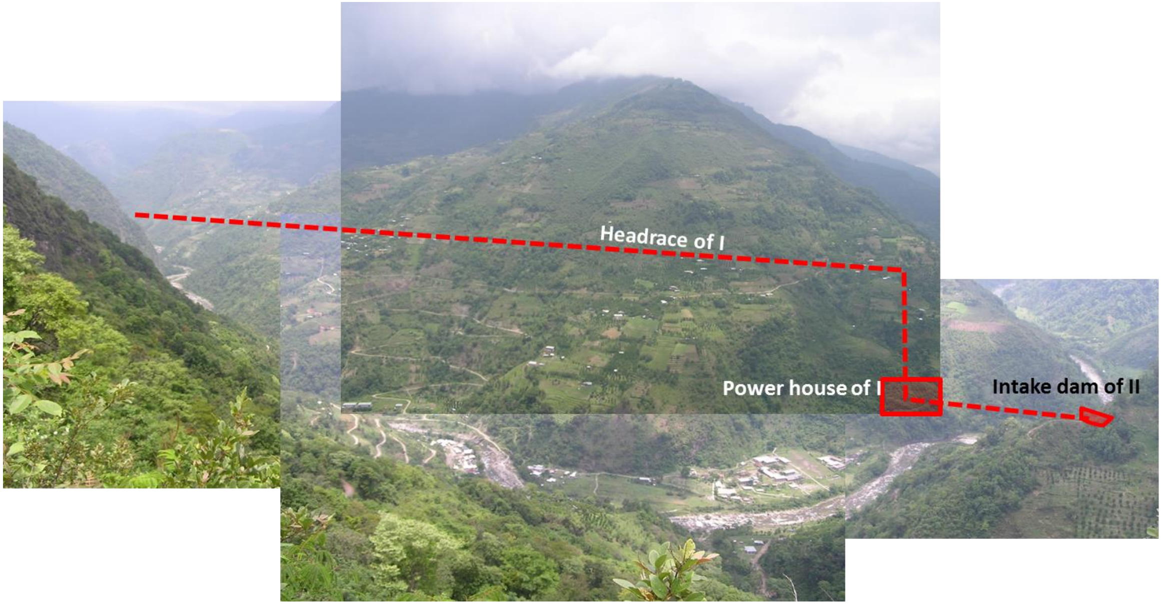


Photo 5-10 Power house of Nyera Amari I and Intake dam of Nyera Amari II

Photo 5-11 Power house of Nyera Amari II

- Accessibility of the Project Site
  - Both the dam sites of Nyera Amari I and II are accessible by 14 km of farm roads branching off from the Samdrup Jongkhar-Trashigang highway, while the power house site and the secondary diversion site of Nyera Amari II are also accessible by a 50 km road branching from the Samdrup Jongkhar-Trashigang highway at Deothang and an additional 13 km Martshala farm road. However, there are no available roads directly connecting to each other for the sites of project components, and access roads towards the construction adits of headrace tunnels are required.

5.1.2 Meghalaya in India

(1) General Topographical Conditions

Meghalaya is one of the Seven Sister States of northeast India and mountainous, with stretches of valley and highland plateaus. It is located in between Bangladesh in the south and the Brahmaputra valley in the north, in the north-eastern portion of India. The area of Meghalaya is 22,429 km^2.

Meghalaya is geographically termed the Shillong Plateau or the Meghalaya Plateau. An important aspect of the geography in Meghalaya is its rock formations - some of which are the oldest in India. Meghalaya includes the Khasi, the Garo, the Jaintia hills and the Assam ranges at its border. Meghalaya represents the extension of peninsular India towards the north-east. The height of the dissected Meghalaya Plateau is EL. 150 m – EL. 1,961 m (Shillong Peak).

The main rivers of the eastern and central regions of the Meghalaya plateau that flow towards the north are the Umiam, Umkhri and Digaru and some major rivers of the eastern and central regions of the Meghalaya plateau that flow towards the south are the Barapani or Umiew, Mawpa, Kynchiang (Jadukata), Myntdu and Umngot.

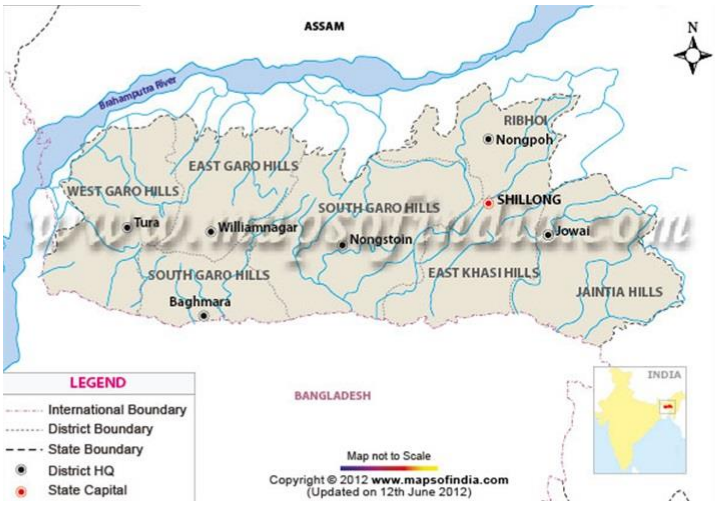
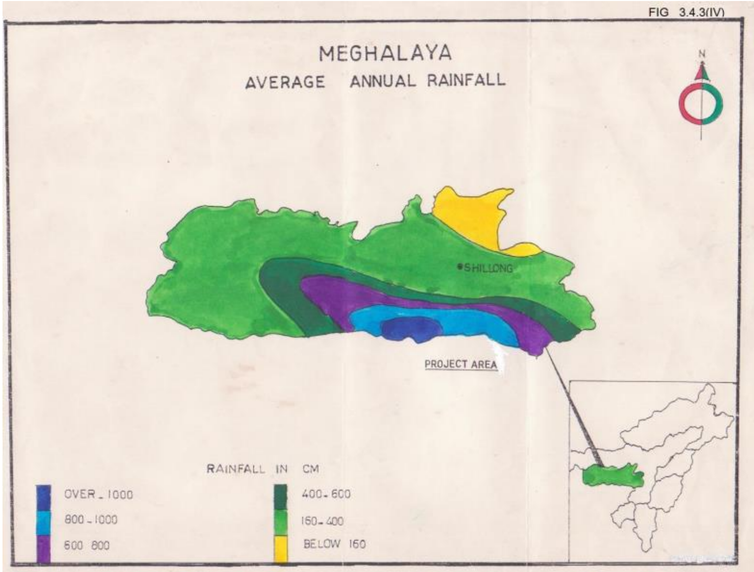


Figure 5-9 River Map of Meghalaya

The distribution of the average annual rainfall in Meghalaya is shown in Figure 5-10. Distribution of rainfall depends upon the topography and relief of the land. The windward side records the maximum amount of precipitation whereas the leeward side lies in the rain-shadow region, where rainfall diminishes uniformly at the adiabatic rate. Thus, rainfall decreases from south to north. This is evident from the rainfall recorded at Cherrapunji and at Shillong (about 45 km away), which receive 12,000 mm and 2,500 mm of rainfall annually respectively.



(Source: MePGCL)

Figure 5-10 Average Annual Rainfall in Meghalaya

(2) Candidate Hydropower Project Sites

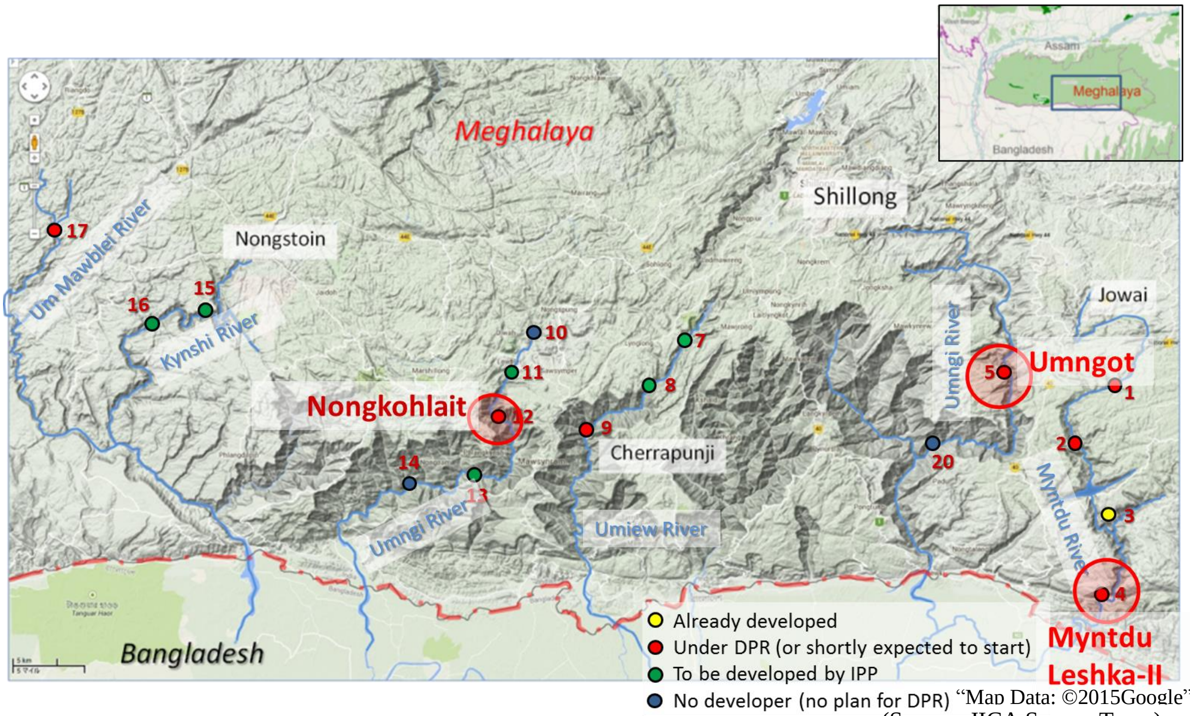
Site reconnaissance for the following hydropower projects located in the southern part of Meghalaya was carried out for a selection of promising sites.

Table 5-2 Main Features of Candidate Hydropower Project Sites in Meghalaya

	Myntdu Leshka II	Umngot	Nongkohlait
Installed capacity Unit size ×Units	280MW (70MW×4)	240 MW (80MWx3)	120 MW
Design annual energy	895.29 Gwh	838.73 Gwh	379.34 Gwh
Net head	259m	762.5m	463m
Discharge	119.79m3/s	35.17m3/s	36.70m3/s
Length of head race	6.0km	5.6 km	5.3 km
Dam height	65m	111m	43m
Reservoir volume	n.a.	41.34 million m3	0.46 million m3
Catchment area	480 km2	304 km2	229 km2
Construction cost	INR 29,400.0 million USD 460.5million*[1]	INR 15,646.2 million USD 245million*[1]	INR 3,262.2 million USD 51.1million*[1]
Unit construction cost per annual energy	USD 514 /MWh	USD 292 /MWh	USD 135 /MWh
Status	under DPR (to be completed in March 2016)	DPR completed	under DPR
Note	Cost: @Rs. 10.5crores/MW		Data from Pre-F/S in 2004

*[1] : 1 INR = 0.015663 USD

(Source: JICA Survey Team prepared based on MePGCL Data)



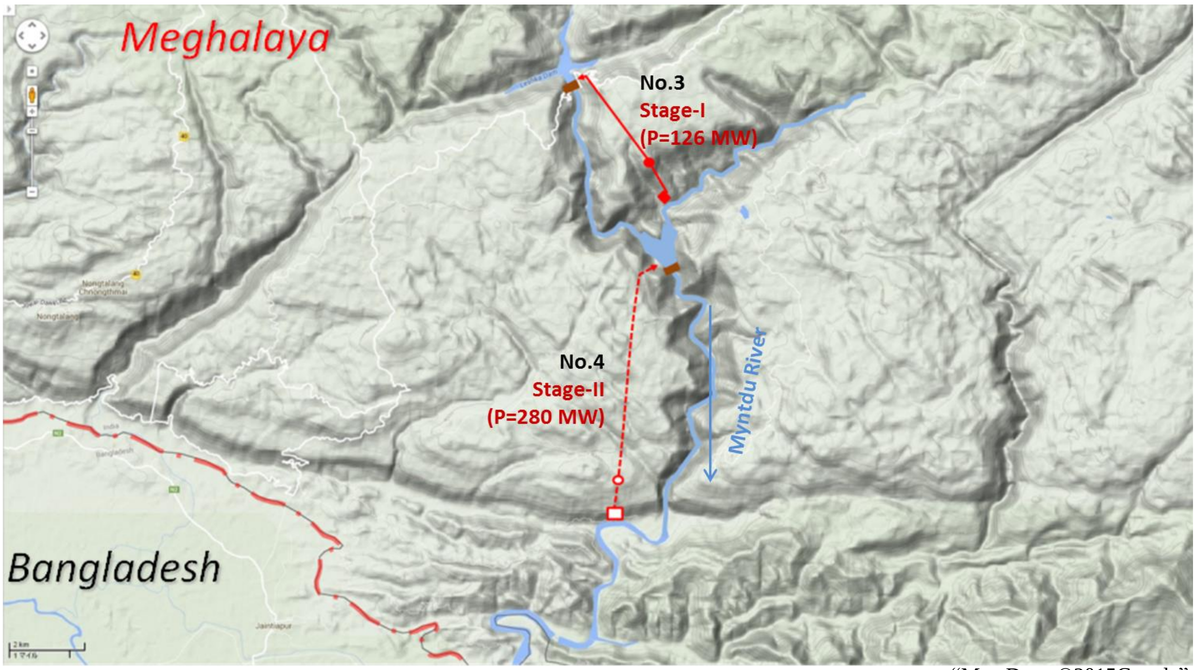
"Map Data: ©2015Google"
(Source: JICA Survey Team)

Figure 5-11 Location Map of Hydropower Projects in Southern Part of Meghalaya

(a) Myntdu Leshka II

Myntdu Leshka II (stage-II) hydropower project is planned and designed as a run-of-river hydropower scheme located just downstream of the existing Myntdu Leshka I hydropower plant (commissioned in 2011-2013) on Myntdu River, which flows north to south in the southeast area of Shillong, the capital city of Meghalaya.

The general layout of the Myntdu Leshka I and II Projects is shown in Figure 5-12.



"Map Data: ©2015Google"
(Source: JICA Survey Team)

Figure 5-12 General Layout of Myntdu Leshka I and II Projects

The results of the site reconnaissance are shown below.

- General Layout
  - The indicator showing the ratio between waterway length and head (difference in height): L/H is 23 (= slope 1/23), which is a good ratio for a large scale run-of-river type hydropower plant.
- Intake and reservoir site
  - The intake dam is planned to be constructed at a narrow steep-sided valley 130 m downstream of the confluence of Myntdu River and its left tributary. The site is basically considered a topographically suitable site for a concrete gravity dam with a height of 65 m.
  - The design flood at the dam site is more than 10,000 m^3/s.
  - There is no access road towards the dam site.

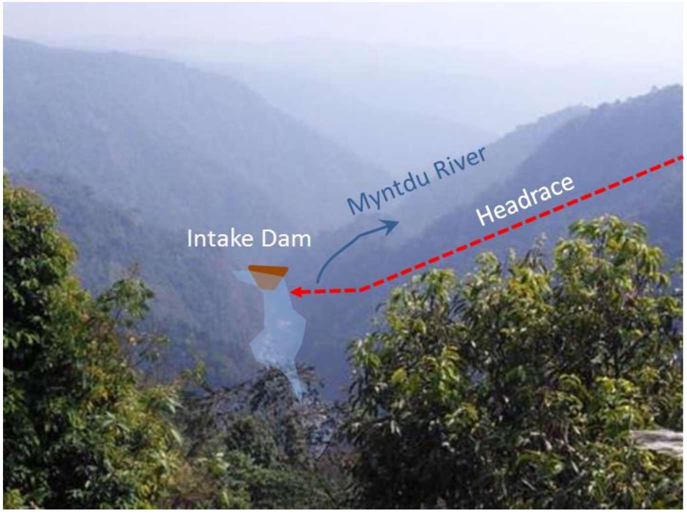


Photo 5-12 Intake Dam Site of Myntdu Leshka II

- Headrace
  - According to MePGCL, a 6 km long headrace tunnel, which is designed as a pressured tunnel, will be excavated by conventional drilling method.
  - The headrace tunnel will not cross major tributaries and depressions, and its slope is 1:293. However, a 1:293 slope is deemed too steep as a headrace tunnel.
  - The penstock with a length of about 1,000 m and a slope of 1:40 is planned to be underground. However, judging from the observed topographical conditions, an open type (exposed) penstock, which is generally more cost efficient than an underground type, can be constructed.
- Power house
  - An open type power house is planned near Amtara Village.

Photo 5-13 Power House Site of Myntdu Leshka II

- Accessibility of the Project Site
  - There is no access road towards the intake dam site, while the power house site is accessible through a farm road, which needs to be enlarged for the construction work.
  - There is no road connecting the dam site with the power house site along the river.

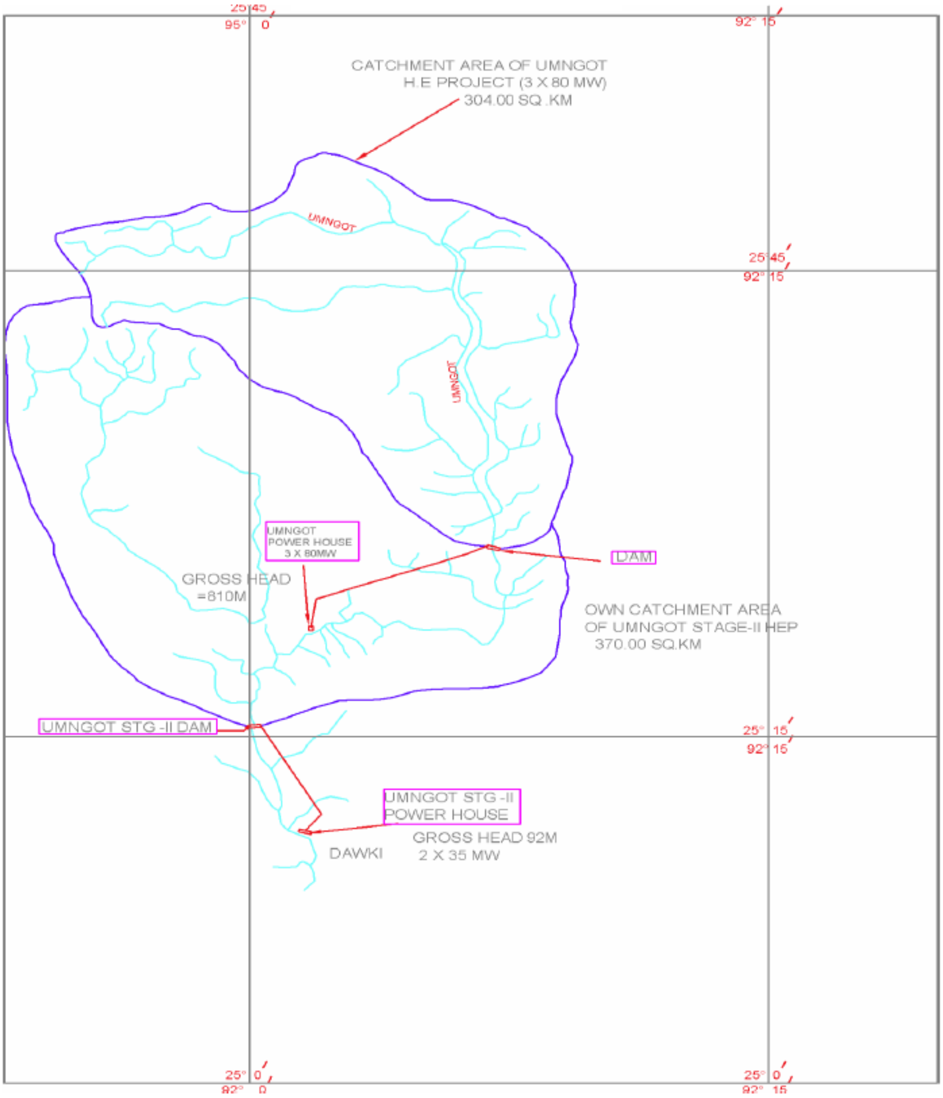
(b) Umngot

Umngot hydropower project is planned as a storage scheme (within the year storage) for generation of peak power with the setting up of a 3x80 MW power station on Umngot River, a south flowing river which flows into Bangladesh.

The project consists of a 111 m high concrete gravity dam with a length of 362 m across Umngot River. A 3.60m diameter headrace tunnel of length 5.59 km and a 2.75m diameter steel lined pressure shaft of length 2.20 km carry the water to three Pelton turbines of 80 MW capacity each in an open type power house of length 107.5m and width 22m for generation of 240 MW. The water, after discharging from the turbines, will be led through three tail race channels of cross sectional dimension 4.40 m x 2.80 m each, which will join the main tailrace channel of cross-section 6.60 m x 2.80 m, which discharges the tail water into Umngot River again. A restricted orifice surge shaft of 10 m diameter and 79.90 m height at the junction of the headrace tunnel and pressure shaft opens into the atmosphere at the top.

The Umngot Project is located on the border of East Khasi Hills District and Jaintia Hills District of Meghalaya. It is located in the southern part of the central plateau known as the Shillong plateau. The aerial distance of the project from the Bangladesh border is about 18 km. The Project site is located at a distance of about 70 km from the state capital, Shillong.

The Umngot basin development plan is shown in Figure 5-13.



(Source: Detailed Project Report, Umngot Hydro Electric Project, October 2010)

Figure 5-13 Umngot Basin Development Plan

The results of the site reconnaissance are shown below.

- General Layout
  - The indicator showing the ratio between waterway length and head (difference in height): L/H is 7 (= slope 1/7), which is a reasonably good ratio for a large scale hydropower plant.
- Intake and reservoir site
  - The intake dam is planned to be constructed at a narrow steep-sided valley.
  - The design flood at the dam site is about 9,000 m^3/s.
  - There is no access road towards the dam site.
- Headrace
  - According to MePGCL, a 5.6 km long headrace tunnel, which is designed as a pressured tunnel, will be excavated by conventional drilling method.
- Power house
  - An open type (surface) power house is planned.
- Accessibility of the Project Site
  - There is no access road towards any component of the project. Several access roads running down from the top of the plateau to the river levels are required.

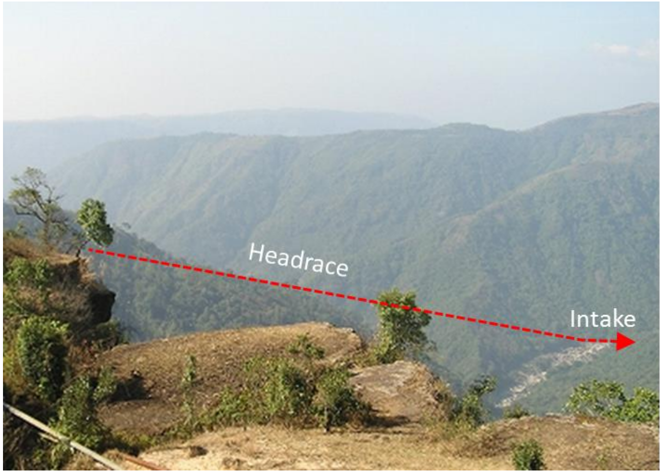
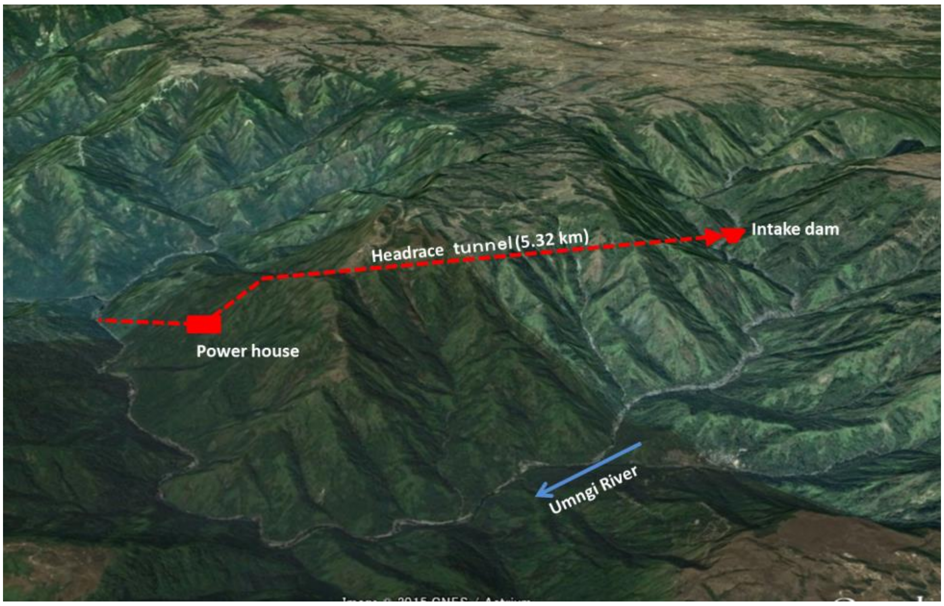


Photo 5-14 Intake Dam Site of Umngot Project

(c) Nongkohlait

The Nongkohlait project is planned as the third upstream hydropower project of the cascade hydropower projects on Umngi River, which flows north to south in a valley next to Mawsynram Village, known as the wettest place on Earth.

The project site is located downstream of "Umngi Storage" project, which is designed to improve flow duration of Umngi River. The Nongkohlait project is planned and designed on the assumption that flow duration of Umngi River will be improved by the operation of "Umngi Storage" Project. However, "Umngi Storage" Project itself is not economically viable at this moment, and is unlikely to be realized in the near future. Therefore, the Nongkohlait project will not be selected as a promising project in the Study.



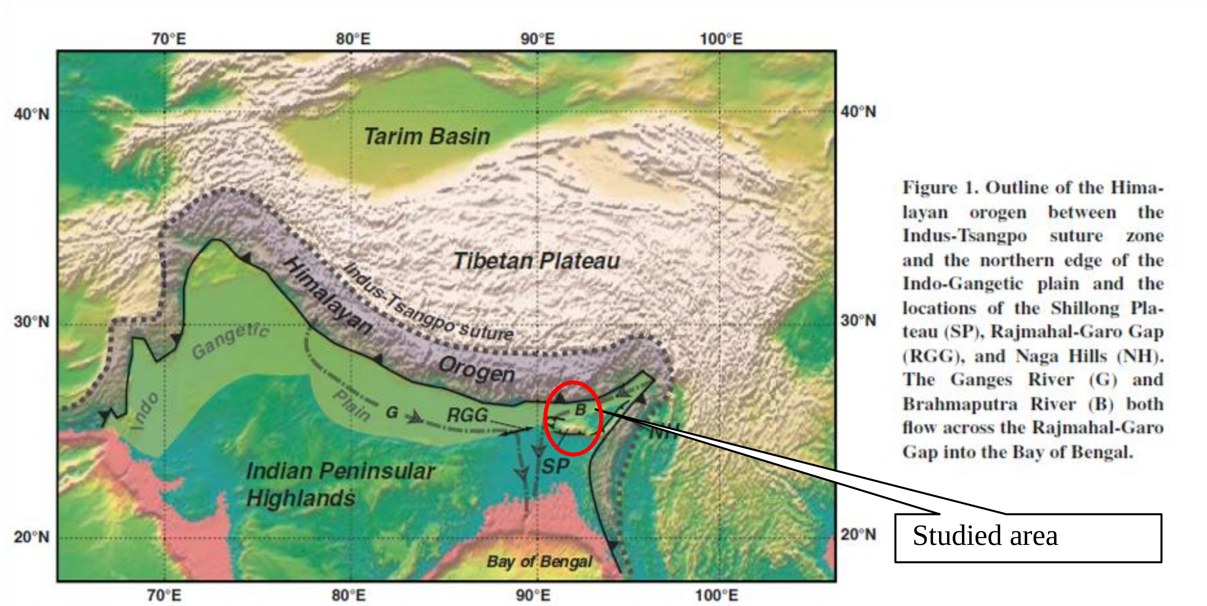
"Image©2015DegitalGlobe, Image©2015CNES/Astrium, Image Landsat©2015Google"

(Source: JICA Survey Team)

Figure 5-14 Bird's Eye View of Nyera Amari I and II Project

5.2 Structural Geology and Topographic feature of the Study Area

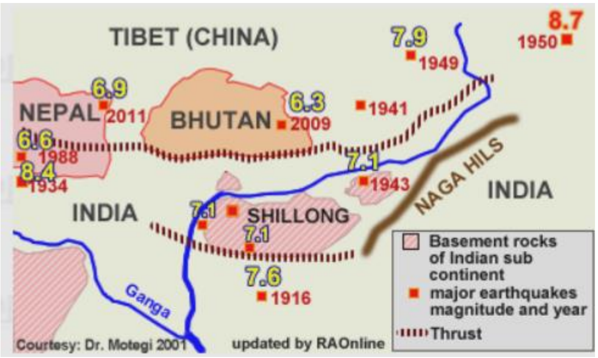
Structural geology of the study area is illustrated in Figure 5-15[3], which covers Nepal and Bhutan in the Himalayan orogen and Meghalaya state in India, in the Shillong Plateau.
This figure suggests that potential hydropower resources in the study area are limited to the above mentioned 'Himalayan orogen' and 'Shillong Plateau' areas, with Nepal and Bhutan in the former and Meghalaya state in India in the latter.



(Source: An Yin et al., 2010; 122; pp.337)

Figure 5-15 Structural Geological Outline of the study area

Upon such tectonic features, earthquakes have frequently occurred surrounding the tectonic region. There were 'great' earthquakes (over 8 on Richter) in Shillong (1897; 8.7), northwestern Himalayas (1905; 8.6), Nepal (1934; 8.4) and eastern Arunachal Pradesh (1950; 8.7) but Bhutan has not been affected. Large earthquakes with a Magnitude of over 6.3 have been recorded surrounding the studied area (see Figure 5-16).



(Source: RAOnline originated from Motegi, 2001)

Figure 5-16 Major Earthquakes, Magnitude and Year

No major earthquake had hit the landlocked Kingdom for over a century as the seismic active zone moved away by about 180 kilometers from the Himalayan foothills to the Shillong plateau, now the

3 cited from "Geologic correlation of the Himalayan orogen and Indian craton: Part 1. Structural geology, U-Pb zircon geochronology, and tectonic evolution of the Shillong Plateau and its neighboring regions in North-East India" (An Yin et al., 2010)

new boundary between the Asian and the Indian sub-continent plates, Dr. Motegi noted in 2001. (Referred from Asian Tribune).

According to the geological map shown in Figure 5-17, most of Bhutan belongs completely in GHC (Greater Himalayan Crystalline Complex, consisting of high-grade paragneiss, orthogneiss, and abundant Tertiary leucogranites and migmatite) in Himalayan units. On the other hand, the geological components of Meghalaya Plateau are complex, as shown in Figure 5-18. As seen on the cross section shown in Figure 5-18, there is an obvious tectonic boundary between Meghalaya and Bhutan, which the base rocks consist of undifferentiated Granites; former and the Greater Himalayan Crystalline Complex; latter.

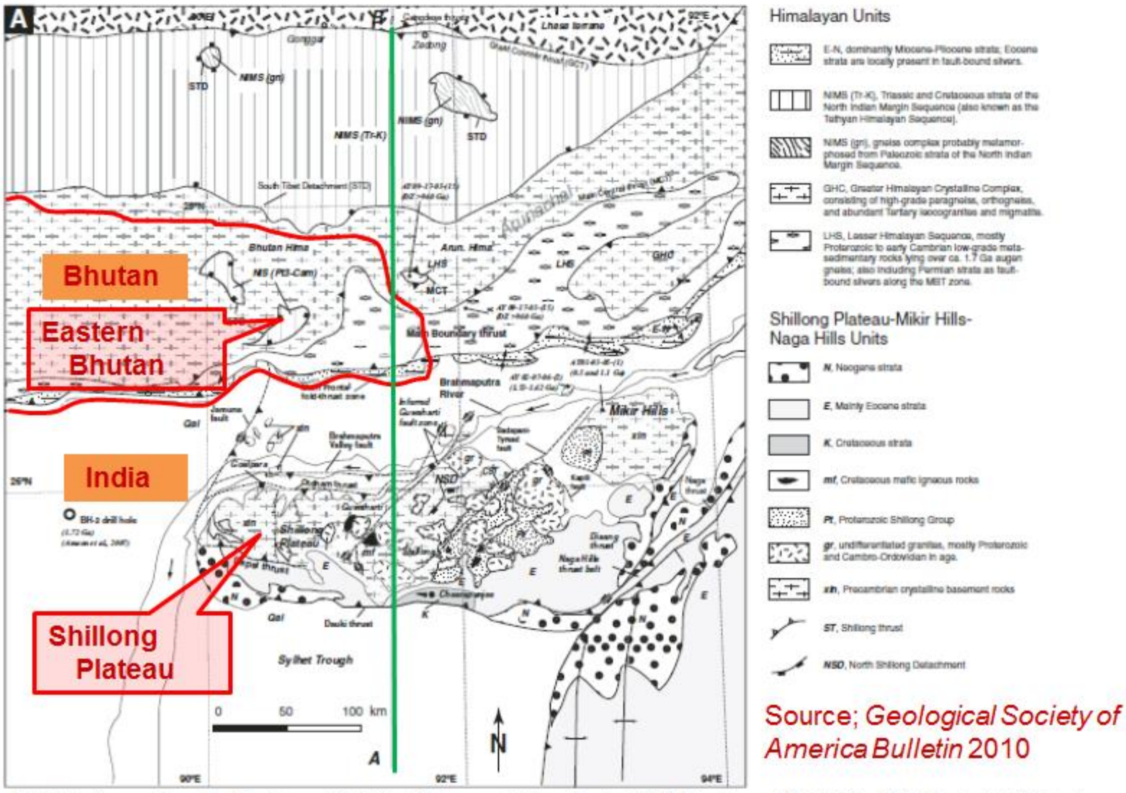


Figure 5-17 Tectonic map of the eastern Himalayas and the Shillong Plateau

(compiled from Pan et al. (2004), Srivastava and Sinha (2004a, 2004b), Ghosh et al. (2005))

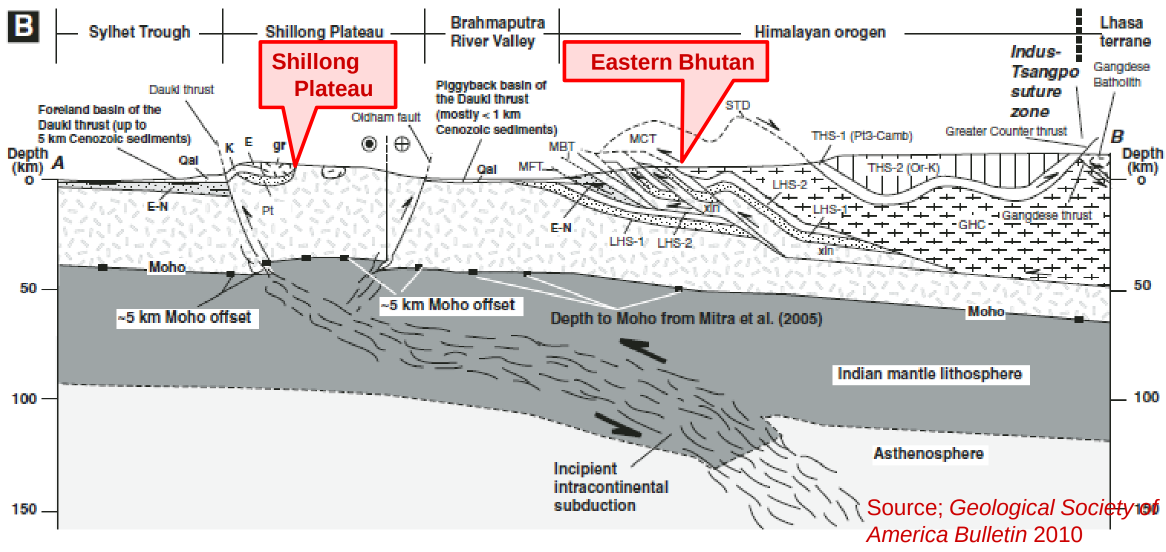
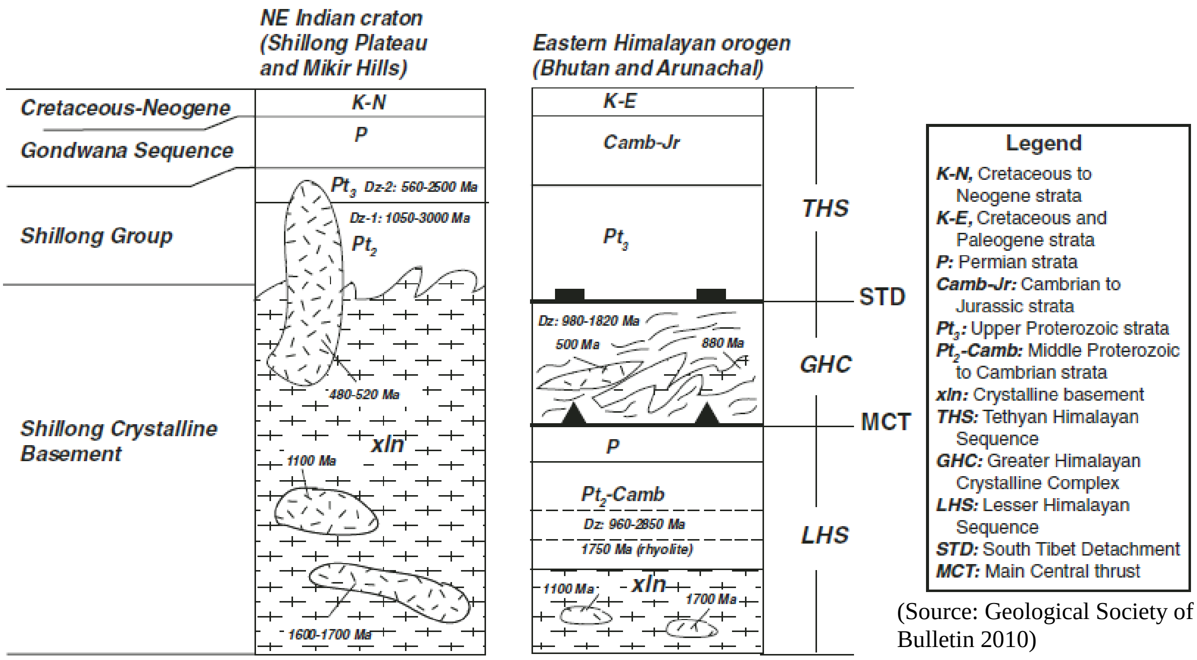


Figure 5-18 Schematic cross section across the A-B line on Figure 5-17

Figure 5-19 shows the schematic logs of both Shillong plateau and Bhutan. Foundation rock of the Shillong plateau is undifferentiated granite, mostly in the Proterozoic and Cambro-Ordovician era. Proterozoic Shillong Group, Cretaceous strata, and Eocene strata are overlaid on the foundation rock.



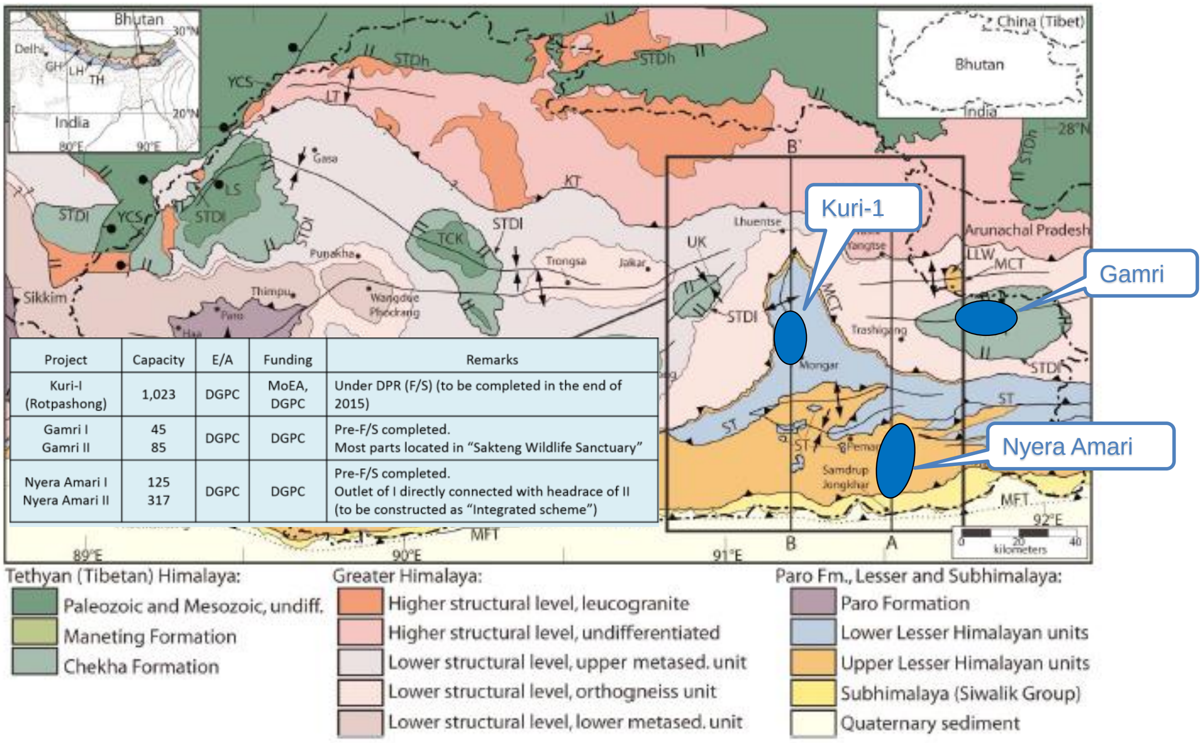
(Source: Geological Society of America Bulletin 2010)

Figure 5-19 Correlation of lithostratigraphic units between the Himalayas and northern India

The topographic features of Bhutan and the Shillong plateau are very contrasting. Bhutan forms the E-W trend mountainous terrain caused by continuous compression from the southern continent; however, the major river systems flow from north to south in comparison with it. On the other hand, the Shillong plateau is characterized by a wide flat summit and SW-NE trend fracture zones which cut the plateau.

5.2.1 Geology and Geotechnical Conditions of the visited sites in Bhutan

The geology of Bhutan is seen in Figure 5-20. It is very complex, but basically it is categorized into three major groups: Lesser and Subhimalaya, Greater Himalaya, and Tethyan (Tibetan) Himalaya in order of age. The Kuri-I site is in the Lower Lesser Himalayan unit, which belongs to the oldest Group, and the Nyera Amari site spreads from Upper Lesser Himalayan to Subhimalaya (Siwalik Group). The Gamri project site belongs to Chekha Formation of late Pre-Cambrian age.



Project	Capacity	E/A	Funding	Remarks
Kuri-I (Rotpashong)	1,023	DGPC	MoEA, DGPC	Under DPR (F/S) (to be completed in the end of 2015)
Gamri I Gamri II	45 85	DGPC	DGPC	Pre-F/S completed. Most parts located in "Sakteng Wildlife Sanctuary"
Nyera Amari I Nyera Amari II	125 317	DGPC	DGPC	Pre-F/S completed. Outlet of I directly connected with headrace of II (to be constructed as "Integrated scheme")

(Source: modified from Long et al. 2011)

Figure 5-20 General Geology of Bhutan and location of visited Sites

(1) Kuri-I

(a) Project Location and scheme (cited from the Pre-feasibility Study Report issued by NORPLAN, 2011)

The Kuri I hydropower plant utilizes the head over a 18 km long reach of Kurichhu, from Autsho to downstream of Kurizampa, near the confluence of Shongarchhu, in Mongar Dzongkhag. The intake dam is located at Rewan, 5 km downstream of Autsho, and creates a reservoir that reaches upstream to Autsho. The tailrace outlet is located some 3.5 km upstream of the existing Kurichhu HPP. A head of around 14 m remains between the tailrace and intake reservoir water level at Kurichhu.

(b) Site Geology

Geological map and schematic profile along the HRT route are shown in Figure 5-21

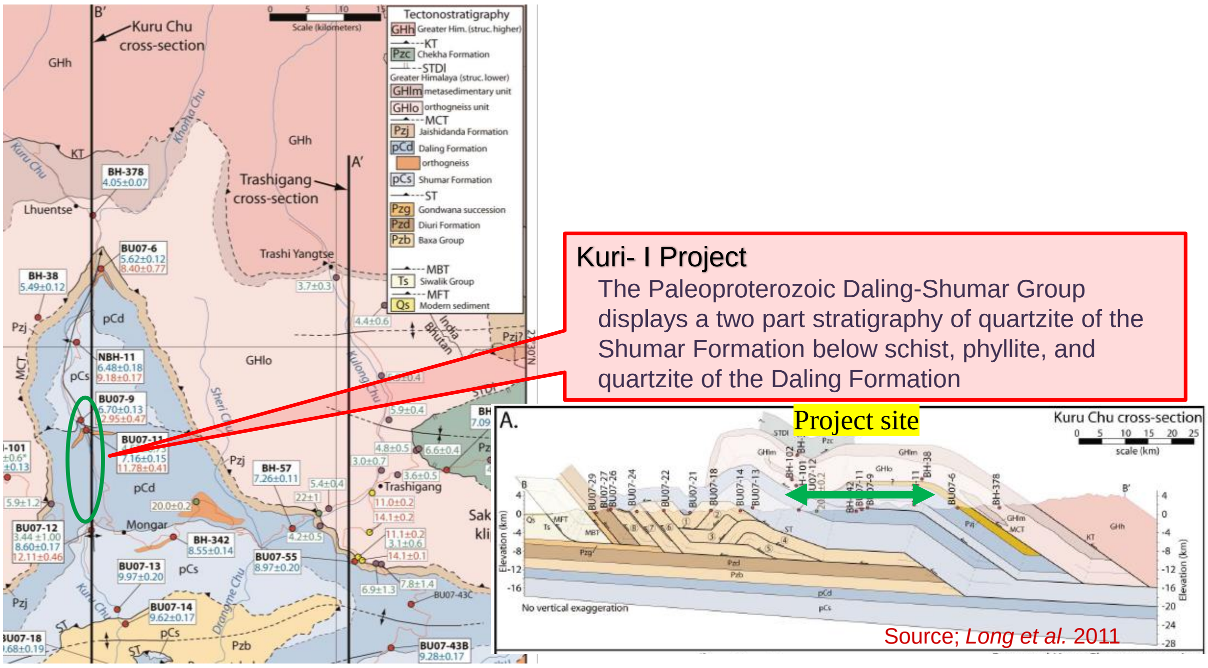


Figure 5-21 Geological Map and the Schematic Section along the HRT Route of Kuri I Project

The studied area falls under the Daling-Shumar Group (Gansser, 1983), also called the Shumar Formation (Bhargava, 1995) of Precambrian age. This litho-package occurs along the upper tectonic level of the Lesser Himalayan metasedimentary belt south of the crystalline thrust sheet of the Thimphu Formation. The stratigraphy of this area has been prepared by Konagaya and Gyenden (2003), see Table 5-3.

Table 5-3 Lithological Succession of the Shumar & Thimphu Group in the project area

Geologic province	Lithofacies
Shumar Formation	- Thickly bedded quartzite with narrow band of phyllite/phyllitic schist and basic rock at places. - Medium to coarse grained marble bands (5-10m thick) - Graphitic Schist (2-10 m thick)
----------------------------Main Central Thrust---------------------------	
Thimphu Group Quartz	-mica schists and biotite granitic gneiss

(Source: Druk Green, April 2014)

The main rock types in the area are low-grade meta-sediments of Lesser Himalayan Sequence, mainly consisting of sericite-schist, phyllite and quartzite belonging to different members of Shumar sequence.

The Shumar Formation consists of alternating sequences of quartzite and phyllite/mica schist with impersistent bands of carbonate and lenses of gypsum. Phyllite/mica schist, which forms the main bulk of the sequence, is fine grained, commonly grey to greenish colored and well foliated. The quartzite of this formation is commonly fine grained, white to greyish white, thin to medium bedded and well jointed. The carbonate unit is represented by fine grained, thinly bedded grey to greyish white colored limestone. Basic sills are common in the upper part of the sequence whereas concordant sheet-like bodies of mylonitised granite gneiss are present at different areas within the sequence (Bhargava, 1995).

The thickest section of this formation is found along Kurichhu. Here, it forms a complicated antiform with strikes to the North and is cut, particularly towards the South, by West to East directed fault and thrust zones.
Several thin, concordant, sheet-like bodies of mylonitised granitic gneiss are found in the Kurichhu valley within the mica schist of the Shumar Formation at different levels (Gansser, 1928 & Bhargava, 1965, 1968). Table 5-4 shows the lithological succession of the Shumar Formation in the Kuri Chu valley, compiled by Bhargava.

Table 5-4 Lithological Succession in the Kurichhu Valley at Autsho

AUTSHO	Phyllite, schist, limestone and flaggy quartzite with granitic gneiss
	Quartzite
	---------------- Chhimung Ri fault-----------------
	Phyllite, flaggy quartzite, limestone, dark grey slate, gypsum bed, basic sill and Chhimung Ri gneiss
	Quartzite, thick, massive, locally gritty and sericitic

(Source: Druk Green, April 2014)

(c) Engineering Geology

1) Dam and Intake site

It is easily accessible from the existing trunk road since the scheme is planned to extend over the road.

Photo 5-15 Overview of right bank of dam, where intake is also planned

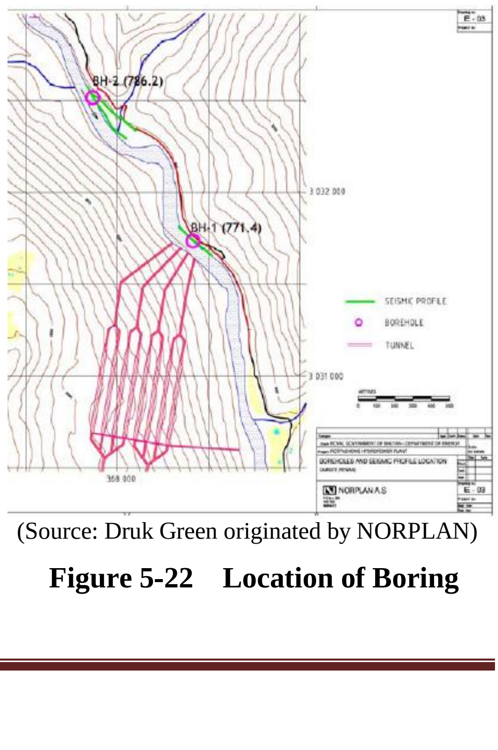
The rock which is observed at the left bank of the dam site is gneissose mica schist, as seen in the right photo. The rock is slightly foliated but massive.
Numerous trends of joints and cracks are seen on the rock surface on both the right and left river side (see the photos below). Crushed rocks are observed in some parts of the cracks, and the left bank's is fractured into smaller sizes.
Since it is assumed that this fracturing might be caused by gravitational sliding, detailed investigation and examination for these cracks on the right bank should be conducted in the FS stage.

Photo 5-16 The rock at the left bank of the dam site

Photo 5-17 Enlarged above dip-slope crack on the right abutment, where some parts are crushed

Photo 5-18 A crushed dip-slope crack on the left bank along the main road

The proposed dam is approximately 60 m in height from the river bed with a crest length of approximately 200 m and the crest level is 825 masl.
According to the results of BH-1 boring, which was carried out on the riverbed (see the right figure), the thickness of riverbed deposit is 33.6m. Furthermore, there is a weak zone at approximately 40 m - 48.5 m. This issue might also be made clear on the FS, and the result reflected in the design of the dam. Jet-grouting for the thick riverbed materials will also be considerable. However, there may be no crucial geotechnical problems except for the above-mentioned cracks on the right bank of the dam.



(Source: Druk Green originated by NORPLAN)

Figure 5-22 Location of Boring

2) Headrace tunnel route

It is estimated that the rock hardness grade along the tunnel route based on observation of the dam site rock conditions may be "R4; strong rock" following the table at the end of this chapter, and the estimated RMR value is 63 (refer to the right table) at most parts of the tunnel route. It may be categorized in "class II; Good rock" on the RMR classification.

According to the Pre-feasibility Study Report, TBM tunneling is recommended for the HRT tunnels. Due to the length of the tunnels, the possibilities for access tunnels and the geological conditions with very heavily fractured quartzite and schist layers it is assumed that TBM with segment lining will be the best solution.

Table 5-5 Assumed RMR Value of Kuri I Scheme

PARAMETER			RATING
1	Strength	σ c	7
2	Drill core	RQD	17
3	Spacing of Discontinuities		15
4	Condition of discontinuities	length	6
		separation	5
		roughness	5
		infilling	6
		weathering	5
5	Ground water		7
Rating adjustment			10
Total			63

(Source: JICA Survey Team)

3) Powerhouse and Sedimentation Cavern

The powerhouse is designed for deep underground. Since the stability of the underground cavern depends on the rock characteristics, a detailed stability design should be examined in the next stage.

(2) Gamri (cited from the Pre-feasibility Study Report issued by Druk Green, June 2011)

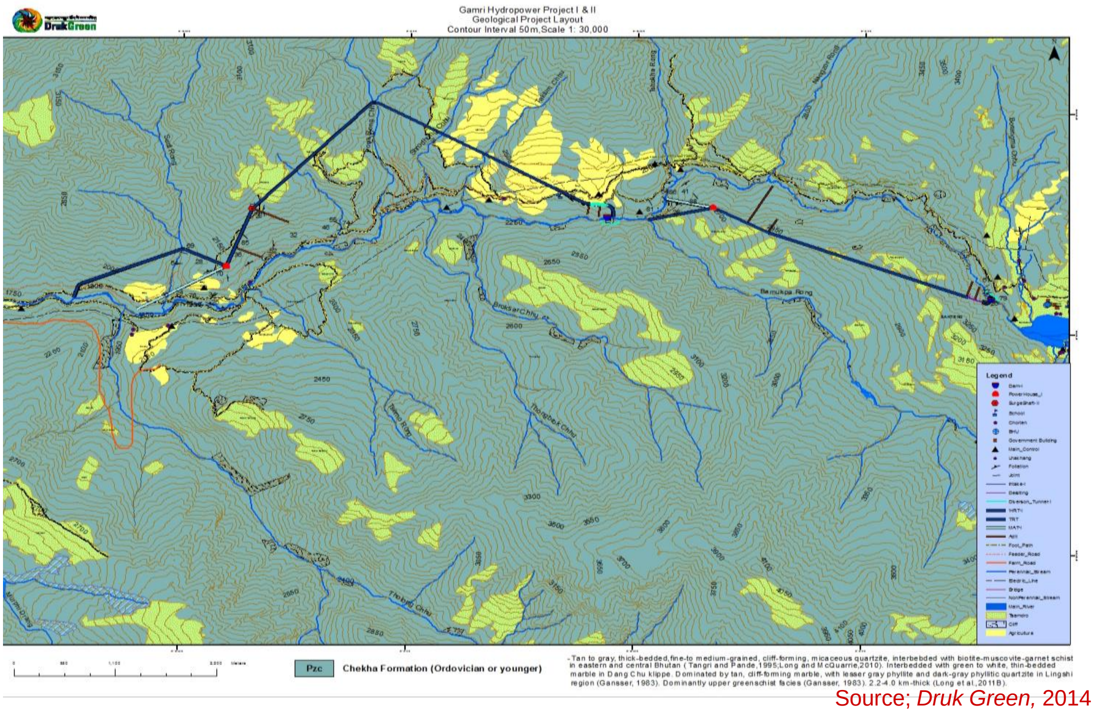
(a) Project Location and scheme

The Gamri–I has an intake located approximately 700 m downstream of Sakteng Village under Trashigang Dzongkhag at El. 2905 m, while an underground Power House is located at Tsebchinang under Trashigang Dzongkhag.

(b) Site Geology

The geological map shown in Figure 5-23 is cited from the Pre-feasibility Study Report issued by Druk Green, July 2014.

The whole project alignment falls within Chekha formation, comprising schist, Quartzite, and Limestone and basic sills. The lowermost unit of Chekha Formation comprises highly puckered and crumpled garnetiferous sericite schist, as reported to occur near Ramjar and in the southern limb of syncline near Bartsam and Bedung Village. Biotite – chlorite-garnet schist – is exposed along the paths between Wange La (Bedung) and Wangse La (Bartsam), where it is reported to be resting over the sericite schist unit. A thin lenticular occurrence of white crystalline limestone is intercalated in the sericite schist in Bedung and also on the right bank of Bamukparong towards the north of Sakteng. Exposures of grayish white, fine grained garnet bearing quartzite associated with schist were observed between Sonapang and Thrakthi.



(Source: Druk Green, April 2014)

Figure 5-23　Geological map of Gamri-I and II project

The Tectono-stratigraphic succession in the region is presented in Table 5-6 as compiled by O.N. Bhargava et al. 1995.

Table 5-6　Tectono-Stratigraphic succession of the region.

Intrusive		Tourmaline granite, pegmatite and quartz veins	Tertiary
Tethyan Sequence	Chekha Formation	Schist, Quartzite and limestone with basic sills	Late Precambrian
--------------Contact concealed due to granite intrusion-----------			
Thimphu Group		Granite, gneiss, schist, quartzite and basic sills.	Precambrian
--------------Main Central Thrust------------			

(Source: Druk Green, April 2014)

(c)　Engineering Geology

1)　Dam and Intake site

According to the Pre-feasibility Study Report, the permeability of the rock mass at both Gamri-I and II Dam Sites indicates moderate permeability; therefore, grouting is necessary but this presents no difficulties. The bedrock might have sufficient strength for the small dam, the height of which is less than 30m.

As a result, it seems there are no special issues regarding the bedrock of either dam site.

2)　Headrace tunnel route

The rocks encountered in the area are of Chekha formation comprising schist, quartzite, limestone and basic sills, with intrusions of granite, pegmatite and quartz veins. According to the Pre-feasibility Study Report, the rock mass will be classified on prima facie to be around 2% in class I, 20% as class II, 50% class III and 28% as class IV and below.

The rock mass is observed to be of sufficient quality and strength to be self-supporting in tunnels and other underground openings.

Weakness zones in the form of shears and lineaments will affect the rock stability and would call for rock support. The necessary rock support measures should be studied and incorporated, such as rock bolting in combination with steel fiber reinforced sprayed concrete, and with heavier structural support, e.g. steel reinforced sprayed concrete arches or cast concrete lining, in case of weakness zones of poor quality. Leakage zones encountered during tunneling may need to be sealed by use of cement grouting, which is generally considered as sufficient.
Judging by the above comments, it is estimated that the rock hardness grade along the tunnel route may be "R4; strong rock" but it might be worse than the Kuri I site.
According to the impression of the DGPC personnel conducting the PFS, the bedrock is suitable for tunnel construction, and the rock mass has sufficient quality and strength to be self-supporting in tunnels and other underground openings.

3) Powerhouse

The powerhouse site is designed for under the ground.
The right photo, which was taken by the JICA Survey Team, shows alternation of quartzite and schist on a cutting slope of a newly constructed village road over the proposed powerhouse-I.
Since the bedrock of the underground cavern might have anisotropy as seen in the photo, the most suitable cavern direction should be examined to maintain mechanical stability on the FS.

Photo 5-19 The rock on a cutting Slope

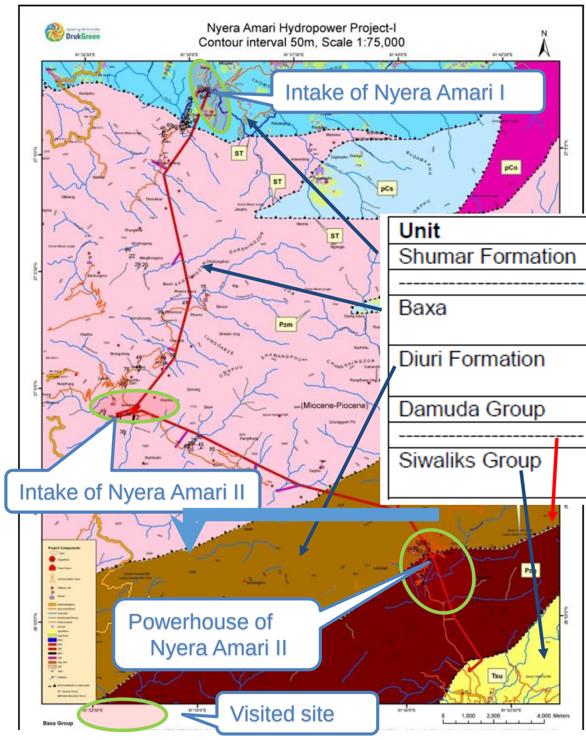
(3) Nyera Amari (cited from the Pre-feasibility Study Report issued by Druk Green, July 2014)

(a) Project Location and scheme

The Nyera Amari originates at an elevation of more than 4000masl and its headwaters drain the southern part of the Merak-Sakten massif. The Nyera Amari is a tributary of the Brahmaputra River. The Bhutanese part of the basin covers an area of about 1000 km^2 and it borders the Gamrichhu basin to the west, with the Gamrichhu sub-basin to the north and the Dhansiri/Jhomori basin to the north-east and east.
The Nyera Amari-I has its intake near Ramchongma village in Trashigang Dzongkhag, while the power station and the whole of Nyera Amari-II are in the Samdrup Jongkhar Dzongkhag.
The Nyera Amari II project is located between Tsangchilu zam- Amshing, where the access tunnel to Nyera Amari-I underground powerhouse is, and almost down to Phuentshothang. The tailrace tunnel outlet to Nyera Amari will be approximately 1km North of Phuentshothang Bridge. The powerhouse will be underground not far from the village of Martshala, around 5km to the south.

(b) Site Geology

The study area falls within the Lower Bhutan Himalaya and has a complex geology.
The southern border is defined by Main Boundary Thrust and the northern limit is difficult to trace. The main boundary thrust is northward dipping and seems to flatten with depth. It is also reported that the youngest part of the Siwalik section is bordering the MBT. It is also found that the various units are divided by more interior thrusts as shown in the Figure below. In this area, the older in the North is worth than the younger in the South. Stratigraphically, Baxa Group is dominant in the North. There are two major thrusts, which are the Shumar thrust and MBT in the South.



<u>Southern part is worse than northern part, because of its geotechnical characteristics, especially, distribution of Fracture zones (Main Boundary Thrust)</u>

Unit	Lithology	Age
Shumar Formation	Phyllite, Quartzite, Schist	Late Precambrian
------------------------	Shumar Thrust	--
Baxa	Dolomite, Quartzite , Slate	Lower Paleozoic to Precambrian?
Diuri Formation	Pebbly Phyllite, Phyllite, Slate	Permean
Damuda Group	Sandstone, Shale , Coal	Permo-Carboniferous
------------------------	MBT (main Boundary thrust)	--
Siwaliks Group	Sandstone, Shale, Pebble beds, Conglomerate	Mid-Miocene to Pliocene

- **Northern part of the project is in Baxa Group** which belongs Upper Lesser Himalayan units
- MBT , which run through near the powerhouse site, forms remarkable trough along the boundary of Upper Lesser Himalayan units and sub-Himalaya

(Source: originated from Druk Green, April 2014)

Figure 5-24 Geological map of Nyera Amari-I and II Project

(c) Engineering Geology

1) Dam and Intake site of Nyera Amari-I (cited from the Pre-feasibility Study Report issued by Druk Green, July 2014)

The dam is proposed as a massive concrete gravity dam and the bedrock of the dam site consists of Quartzite. According to the records of drill holes (DH-2), bedrock condition below riverbed material having thickness of 15m is low quality. Based on the refraction seismic survey at the dam site, it is expected that the depth to bedrock at the alternative dam site D-1A is around 10-20m. Careful examination should be made based on the study results of the next stage.

2) Dam and Intake site of Nyera Amari-II (cited from the Pre-feasibility Study Report issued by Druk Green, July 2014)

The dam site (alternative D-2C) has been considered to be the favorable dam site. The river width is the narrowest and it increases as the river moves further downstream; in-situ bedrock has been exposed on both the abutments. Quartzitic phyllite on the right banks is observed. On the left bank, the rock exposed is mostly slate and pebbly quartzite which are fine to medium grained, massive to moderately bedded, slightly weathered to moderately weathered, medium strong to strong. The following photograph shows an overall view of the dam site and an illustration of the dam.

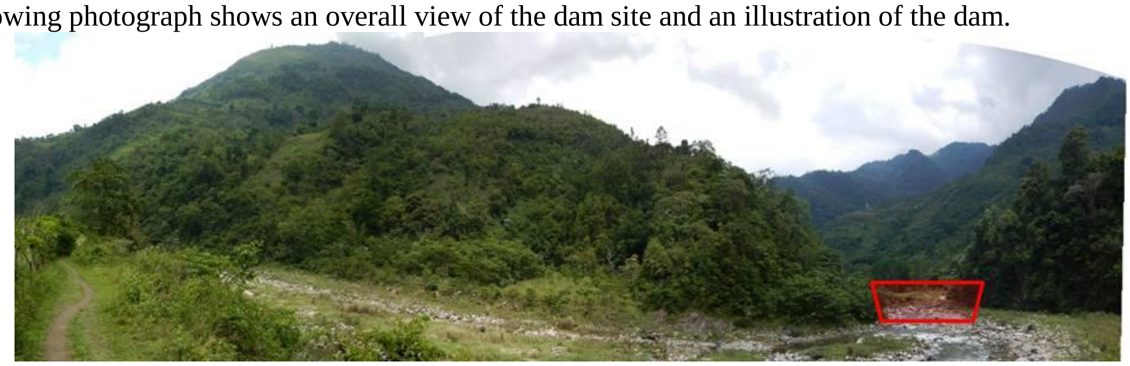


Photo 5-20 Overall View of the Dam Site (Nyera Amari-II Site)

3) Powerhouse and Penstock (cited from the Pre-feasibility Study Report issued by Druk Green, July 2014)

The underground power house (PH-2B) is located below Thrizor village. DH-3 borehole has been drilled and it was observed that the rock types were slate, coal and carb-shale, with the presence of highly fractured rock and shear zone.

The following photograph shows the western side view of the powerhouse site. There is a collapse on the huge cutting slope which was an abandoned old coal mine.

Photo 5-21 Western Side View of the Powerhouse Site

From the drilling results, it is found that the geological condition is unfavorable for locating the power house.

Given such conditions, the powerhouse site is not recommended for under the ground. An alternative design should be examined based on the detailed investigation during the DPR stage.

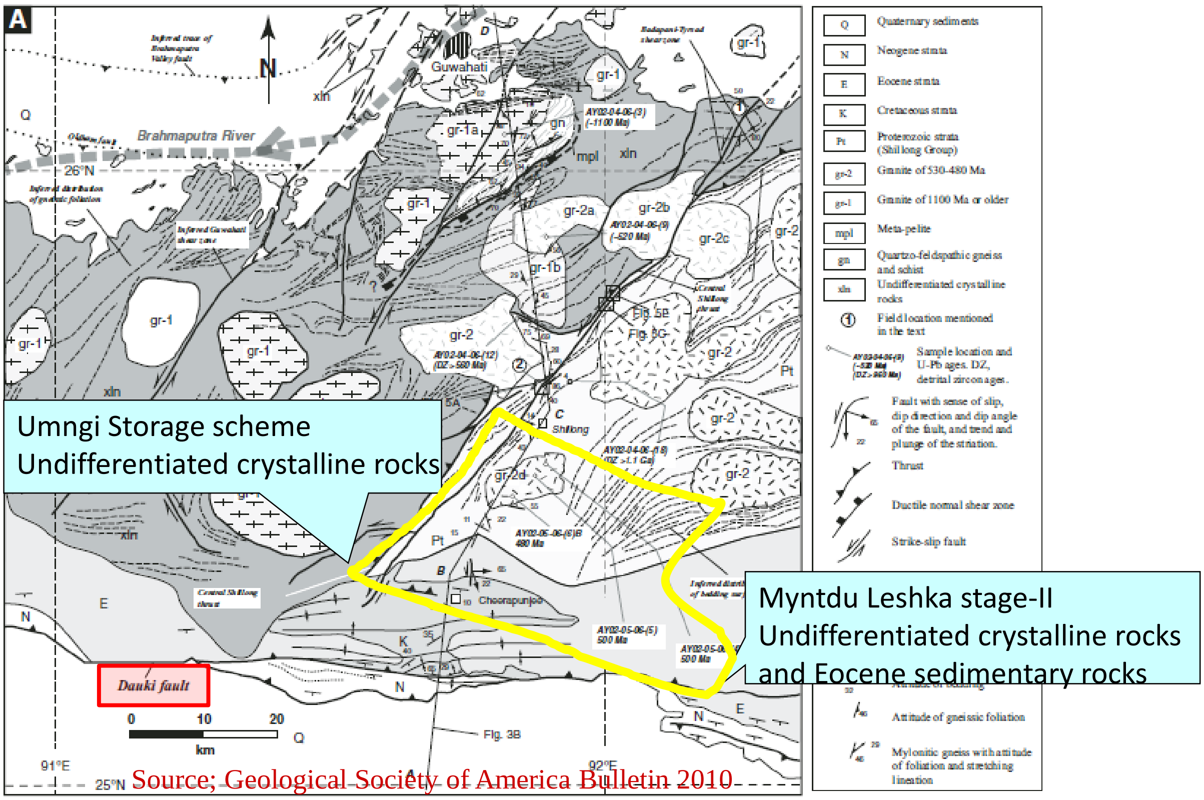
5.2.2 Geology and Geotechnical Conditions of the visited sites in Meghalaya

The surveyed area in Meghalaya is shown in the general geological map of Figure 5-25. As well as Figure 5-19, the undifferentiated crystalline rock is overlain by a younger strata which consists of Cretaceous and Eocene sedimentary rocks.

The JICA Survey Team tried to investigate several hydropower scheme sites, but only two - Myntdu Leshka stage II and Umngi storage site - were successfully carried out due to weather conditions.

The undifferentiated crystalline rock exposes at the dam site of the Umngi storage scheme and, on the Myntdu Leshka stage II site, both the older bedrock exposes at the dam site and the younger Eocene sedimentary rocks are seen in the southern part of the headrace tunnel and the powerhouse site.

Furthermore, the well-known Dauki fault runs almost along the national boundary between India and Bangladesh. The fault is close to the Myntdu Leshka stage II site.



(Source: Geological Society of America Bulletin 2010)

Figure 5-25 General Geological Map of Meghalaya and surveyed area

(1) Myntdu Leshka stage II

The Myntdu Leshka stage II project is located just downstream of the existing Myntdu Leshka I hydropower plant on Myntdu River, which is in the southernmost area of the Shillong plateau as shown in Figure 5-12 and Photo 5-12.

The geology of the dam site and most parts of the headrace tunnel may be Granite. And the Eocene sedimentary rocks may overlie the granite at some downstream part of the headrace tunnel. Furthermore, the Dauki fault, having an E-W direction, runs close to the power house site.

The dam is proposed as a concrete gravity dam with a height of 65 m. According to the bed rock conditions near the powerhouse of Myntdu Leshka stage I which is located on the upstream of several hundred meters from the planned dam site of Myntdu Leshka stage II, the site is basically considered both topographically and geotechnically suitable site for the dam and headrace tunnel (see Photo 5-22 and Photo 5-23).

On the other hand, the geological conditions between the lower part of the headrace tunnel and the powerhouse may not be suitable because of the earthquake risk caused by the Dauki fault (see Figure 5-26) and weathered bedrock (see Photo 5-24). Careful interpretation of such risk and geotechnical conditions is required in the subsequent study stage.

Photo 5-22 Rock Condition along the riverbed downstream of the Myntdu Leshka I powerhouse

Photo 5-23 Hard and Fresh Granite in the backyard of the Myntdu Leshka I powerhouse

(Source: JICA Survey Team)

Figure 5-26 Planned Myntdu Leshka II powerhouse (star symbol) and Dauki fault (broken line)

Photo 5-24 Hard and Fresh Granite in the backyard of the Myntdu Leshka I powerhouse

(2) Umngi Storage site

The bedrock of Umngi storage dam site is Granite, as seen in the right photograph. Huge boulders are scattered on the fresh granite bedrock. The following photograph shows an overview of the dam site with the proposed dam illustrated as a triangle shape on it. This is considered to be the favorable dam site.

Photo 5-25 Overview of the Dam Site (Umngi Storage Site)

(3) Other recommendable scheme

Shillong plateau has many candidates for a pumped storage scheme, from the viewpoint of not only topography and geology, but also of less compensation.
The following items should be considered as criteria for PSPP site selection.

- Elongation from active faults should be more than 10km
- Without large fractured zones around dam site
- Without large landslides in and around reservoir
- Without high pervious zones such as limestone cave in and around reservoir

The following conditions are preferable from the viewpoint of geopolitics:

- Upper pond: Close to the existing trunk road
- Lower pond: no or less compensation
- Waterway: shorter is better
- Construction materials: on the riverbed of the lower reservoir

To confirm the geographical conditions, the following investigations shall be carried out on PFS.

- Gathering the lithologic literature regarding distribution of limestone and coal mining surrounding the area
- Wide range subsurface reconnaissance surrounding the candidate scheme area,
- Seismic and electric prosecting along the aimed waterway line and main civil structures,
- Several bore hole drillings at the upper reservoir, lower dam site, intake shaft, underground power house, surge tank, construction material site and along the waterway.

5.2.3 General Geological Risks to be considered for the Scheme in Bhutan and Meghalaya

To develop the hydropower scheme, the following risks should be examined.

(1) Bhutan

- Collapse of glaciers and unstable slopes caused by earthquakes and floods,
- Stability of the mountain slope reflecting weathering and overburden conditions, especially in civil structure construction sites,
- Permeability of the bedrock surrounding the pond,
- Fractured zones hidden in the river bottom

(2) Meghalaya

- Lack of construction materials,
- Permeability of the bedrock surrounding the pond

Criteria for Engineering Geological Assessment

The following criteria are applied for the engineering assessment.

Rock hardness and weathering shown in the table-A and B below are applied in the field. RMR system shown in the table-C is applied only for tunnel assessment.

Table-A Field Estimation of Rock Hardness (after ISRM 1981)

Grade	Description	Field Identification	Approx. Range of Uniaxial Compressive Strength (MPa)
R0	Extremely weak rock	Indented by thumbnail.	0.25 -1
R1	Very weak rock	Material can be shaped with a pocket knife or can be peeled by a pocket knife. Crumbles under firm blows of pick (or point) of geological hammer.	1.0 – 5.0
R2	Weak rock	Knife cuts material but too hard to shape into triaxial specimens or material can be peeled by a pocket knife with difficulty. Shallow indentations (< 5mm) made by firm blow with pick (or point) of geological hammer.	5.0 - 25
R3	Medium strong rock	Cannot be scraped or peeled with a pocket knife. Hand held specimens can be fractured with single firm blow of geological hammer.	25 - 50
R4	Strong rock	Hand held specimens requires more than one blow of geological hammer to fracture it.	50 - 100
R5	Very strong rock	Specimen requires many blows of geological hammer to break intact rock specimens (or to fracture it).	100 - 250
R6	Extremely strong rock	Specimen can only be chipped under repeated hammer blows, rings when hit.	> 250

Table-B Weathering Classification (after ISRM 1981)

Term	Symbol	Description	Discoloration Extent	Fracture Condition	Surface Characteristics
Residual Soil	W6	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	Throughout	N/A	Resembles soil
Completely Weathered	W5	100% of rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	Throughout	Filled with alteration minerals	Resembles soil
Highly Weathered	W4	More than 50% of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.	Throughout	Filled with alteration minerals	Friable and possibly pitted
Moderately Weathered	W3	Less than 50% of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones. Visible texture of the host rock still preserved. Surface planes are weathered (oxidized or carbonate filling) even when breaking the "intact rock".	>20% of fracture spacing on both sides of fracture	Discoloured, may contain thick filling	Partial to complete discoloration, not friable except poorly cemented rocks
Slightly Weathered	W2	Discoloration indicates weathering of rock material on discontinuity surfaces (usually oxidized). Less than 5% of rock mass altered.	<20% of fracture spacing on both sides of fracture	Discoloured, may contain thin filling	Partial discoloration
Fresh	W1	No visible sign of rock material weathering.	None	Closed or Discoloured	Unchanged

Table-C Rock Mass Rating System (after Bieniawski 1989)

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

	Parameter		Range of values						
1	Strength of intact rock material	Point-load strength index	>10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range - uniaxial compressive test is preferred		
		Uniaxial comp. strength	>250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5 - 25 MPa	1 - 5 MPa	< 1 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core Quality *RQD*		90% - 100%	75% - 90%	50% - 75%	25% - 50%	< 25%		
	Rating		20	17	13	8	3		
3	Spacing of discontinuities		> 2 m	0.6 - 2 . m	200 - 600 mm	60 - 200 mm	< 60 mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities (See E)		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slickensided surfaces or Gouge < 5 mm thick or Separation 1-5 mm Continuous	Soft gouge >5 mm thick or Separation > 5 mm Continuous		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10 m tunnel length (l/m)	None	< 10	10 - 25	25 - 125	> 125		
		(Joint water press)/ (Major principal σ)	0	< 0.1	0.1, - 0.2	0.2 - 0.5	> 0.5		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	7	4	0		

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)

Strike and dip orientations		Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable
Ratings	Tunnels & mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Rating	100 ← 81	80 ← 61	60 ← 41	40 ← 21	< 21
Class number	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING OF ROCK CLASSES

Class number	I	II	III	IV	V
Average stand-up time	20 yrs for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hrs for 2.5 m span	30 min for 1 m span
Cohesion of rock mass (kPa)	> 400	300 - 400	200 - 300	100 - 200	< 100
Friction angle of rock mass (deg)	> 45	35 - 45	25 - 35	15 - 25	< 15

E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions

Discontinuity length (persistence)	< 1 m	1 - 3 m	3 - 10 m	10 - 20 m	> 20 m
Rating	6	4	2	1	0
Separation (aperture)	None	< 0.1 mm	0.1 - 1.0 mm	1 - 5 mm	> 5 mm
Rating	6	5	4	1	0
Roughness	Very rough	Rough	Slightly rough	Smooth	Slickensided
Rating	6	5	3	1	0
Infilling (gouge)	None	Hard filling < 5 mm	Hard filling > 5 mm	Soft filling < 5 mm	Soft filling > 5 mm
Rating	6	4	2	2	0
Weathering	Unweathered	Slightly weathered	Moderately weathered	Highly weathered	Decomposed
Ratings	6	5	3	1	0

F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING**

Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip - Dip 45 - 90°	Drive with dip - Dip 20 - 45°	Dip 45 - 90°	Dip 20 - 45°
Very favourable	Favourable	Very favourable	Fair
Drive against dip - Dip 45-90°	Drive against dip - Dip 20-45°	Dip 0-20 - Irrespective of strike°	
Fair	Unfavourable	Fair	

* Some conditions are mutually exclusive . For example, if infilling is present, the roughness of the surface will be overshadowed by the influence of the gouge. In such cases use A.4 directly.
** Modified after Wickham et al (1972).

Source: Bieniawski, Z. T. (1989). Engineering rock mass classifications: a complete manual for engineers and geologists in mining, civil, and petroleum engineering. Wiley-Interscience.

5.3 Transmission Line Route

5.3.1 Bhutan

The construction of transmission lines in the National Protected Area shown in Figure 6-4 should be avoided as much as possible. It is reasonable to select the transmission line route drawn in NTGMP, shown in Figure 2-12. Photo 5-26 shows sample pictures of the expected transmission line route in Bhutan.

Power House of Kuri-I (plan)

Biological Corridor

Lokhaitora River

Photo 5-26 Transmission Line Route in Bhutan

According to BPC, the challenges of the 400kV transmission line from Punatsangchhu hydro power plan are as follows:

1) Transportation of materials and equipment to the remote construction site of the hydropower plant
2) Ensuring a stable workforce
3) Procurement of materials (most of them are transported from West Bengal in India to Bhutan)

The transmission line is constructed in a mountainous area, and the materials are transported to the construction sites by manpower and/or ropeway without a construction road, considering environmental and cost impacts. The tower construction and excavation work is also done by humans.

Most of the materials are transported from West Bengal state in India all the way down to Bhutan on poor condition roads by truck. Approximately 10-15% of the total material is stolen or broken on the way, and the contractor must consider these losses.

BPC prefers to construct transmission lines along the river, but in most cases, the lines must be constructed in mountain areas due to existing households and animal trails along the river.

In general, it is recommended to construct transmission lines near existing roads, but it is feasible to construct the transmission lines in other areas avoiding troublesome arrangements with local residents and stakeholders.

Ropeway

400kV T/L Under Construction

Photo 5-27 Transmission Erection Work in Bhutan

5.3.2 India

The transmission line in India is necessary to export electricity from Bhutan and Nepal to Bangladesh due to the geographical locations of each country. There are several existing West-East transmission lines to send electricity from Arunachal Pradesh state and Bhutan to the western region of India, and the chicken neck area is known as the most congested area of transmission lines. Photo 5-28 shows the high voltage transmission lines in India around the area. In order to send electricity directly from the power station to Bangladesh, new transmission lines need to cross the existing West-East transmission lines, and this increases the construction and maintenance risks.

Meghalaya state of India has a border with Bangladesh, and the power generation line does not cross the West-East transmission lines in India. However, the hydro potential sites in Meghalaya state are located in steeply-inclined areas, and careful consideration is necessary to select the transmission line route.

±800kVDC T/L Under Construction

Existing 400kV AC T/L

Photo 5-28 High Voltage Transmission Lines in India

Chapter 6 Environmental and Social Considerations

6.1 Overview of Legal Framework in Target Countries

For the target power system international interconnection project, comprising hydropower plant and transmission construction, legislation and governmental organizations in charge of environmental clearance in each country are listed in the Table below. Bangladesh and Nepal established rules for Environment Impact Assessment during the 1990s, while India and Bhutan established them after 2000. As of July 2015, Myanmar has not enacted rules/regulations on EIA. This is still ongoing, based on the Environmental Conservation Law in 2012, although the government drafted a set of Environmental Impact Assessment Rules in 2001.

Table 6-1 Legislation and Organizations in charge of Environmental Clearance in Target Countries

Target Countries	Legislation	Policies and Strategies	Organization in Charge
Bangladesh	・Environmental Conservation Act, 1995 ・Environmental Conservation Rules, 1997	・National Conservation Strategy 1992 ・Environmental Policy, 1992	Department of Environment (DOE), The Ministry of Environment and Forests (MOEF)
Bhutan	・Environmental Assessment Act, 2000 ・Regulation for Environmental Clearance of Projects and Regulation in Strategic Environmental Assessment, 2002 ・National Environmental Act, 2007	・Conservation in Bhutan, 1994 ・The Middle Path, National Environment Strategy for Bhutan, 1998 ・Biodiversity Action Plan for Bhutan, 2002 ・Vision and Strategy for the Nature Conservation Division, 2003	National Environment Commission (NEC)
India	・The Environment (Protection) Act,1986 ・The Environment (Protection) Rules,1986 ・The Environment Impact Assessment Notification, 2006	・National Conservation Strategy and Policy statement on Environment and development, 1992 ・National Environment Policy, 2006	<Central Government> The Ministry of Environment, Forest and Climate Change <State Government> The State Level Environmental Impact Assessment Authority (SEIAA)
Myanmar	・Environmental Conservation Law, 2012 ・Environmental Conservation Rules,2014 ・Environmental Impact Assessment Rules (Draft)	・National Environment Policy, 1994 ・Forest Policy, 1995	Ministry of Environmental Conservation and Forestry (MOECAF)
Nepal	・Environment Protection Act, 1996 ・Environment Protection Rules, 1997	・National Conservation Strategy for Nepal, 1988 ・National Environmental Policy and Action Plan, 1993	Ministry of Environment, Science, and Technology (MOEST)

(Source: JICA Survey Team)

6.2 Environmental Clearance for Hydropower and Transmission Lines in Bhutan, India, and Bangladesh

This section briefly describes the policy, legal and regulatory requirements for implementing a new Hydropower Plant and Transmission Line project in the selected countries.

6.2.1 Bhutan

(1) Outline of Major Laws related to Natural and Social Environment Considerations

The following are the important laws or regulations applied for promoting environment protection directly or indirectly on the implementation of a Hydropower Plant and its related facilities in Bhutan.

(a) National Environment Act (2007)

This act was promulgated after "Environmental Assessment Act (2000)" and "Regulation for Environmental Clearance (2002)" were enacted, and as the higher ranking law, it stipulates that "The provisions of all existing laws relating to environment, which are inconsistent with this Act, are hereby repealed" (Chapter I. 2).

Under this act, the National Environment Commission was established as the highest decision making entity on all issues of the environment. The purpose of the act is "to provide for the establishment of an effective system to conserve and protect the environment through the National Environment Commission or its successors, designation of competent authorities and constitution of other advisory committees, so as to independently regulate and promote sustainable development in an equitable manner" (Chapter II. 3).

(b) Environmental Assessment Act (2000) and Regulation for the Environmental Clearance of Projects (2002)

With respect to development projects, "Environmental Assessment Act (2000)" establishes procedures for the assessment of potential effects on the environment by them and makes Environment Clearance (EC) mandatory for any project or activity that may have an environmental impact. "Regulation for Environmental Clearance (2002)" was adopted under this act with the purpose of defining the responsibilities and procedures for the implementation of the act, concerning the issuance and enforcement of EC.

(c) Forest and Nature Conservation Act (1995) and Forest and Nature Conservation Rules (2006)

The purpose of this act is "to provide for the protection and sustainable use of forests, wildlife and related natural resources of Bhutan for the benefit of present and future generations". Under this act, "Forest and Nature Conservation Rules (2006)" was established to refer specifically to the conservation of forests, wildlife, and plants. These rules stipulate the restriction of activities in protected areas such as national parks, wildlife sanctuaries, and biological corridors. According to the rules, if a transmission line or water channel may go through government reserved forest, it is necessary to obtain forest clearance from the Department of Forest and National Park Services, Ministry of Agriculture.

(d) Water Act of Bhutan 2011 and Water Regulation of Bhutan (2014)

One of the objectives of this act is "to ensure that the water resources are protected, conserved and/or managed in an economically efficient, socially equitable and environmentally sustainable manner" (Chapter II.4). In relation to Hydropower development projects, the Water Regulation of Bhutan (2014)" that was adopted for the effective enforcement of "The Water Act of Bhutan (2011)" states "the minimum environmental flow to be maintained in a water course to sustain its water ecology and environment will be based on the Environmental Impact Assessment (EIA) report "(Chapter IV.64). In the case that scientific study reports are unable to determine this, "at least 30% of lean season flow shall be maintained" (Chapter IV.64).

(e) The Land Act of Bhutan 2007 and The Land Rules and Regulations (2007)
In respect to land acquisition issues caused by the development project, Chapter 7 in this act stipulates the acquisition of registered land. Chapter 7 in "The Land Rules and Regulations (2007)" discusses further details on restrictions on acquisition of and substitute land, mode of compensation, institutional arrangements, and acquisition procedure.

(f) Electricity Act of Bhutan (2001)
In terms of environmental and social considerations, one of the objectives of this act is "to take environmental considerations into account when developing the electricity supply industry" (3.1 (vi)) and the Bhutan Electricity Authority (BEA) shall "ensure the protection of the natural resources, the environment and other public interests affected by the development of electricity supply" (11.2 (vi)). Subsequently, the licensee for electricity development and supply is required to observe the environmental guidelines.

Right of Way (ROW) for transmission lines in Bhutan usually follows the Indian Standard (the Indian Standards (IS) 5613 (Part-II; Section 2)).

(2) Legal Framework for Environmental Impact Assessment (EIA)

(a) Organizations responsible for Environmental Clearance
Annex 2 of "Regulation for Environmental Clearance (issued in 2002)" (hereinafter referred to as "EC Regulation") stipulates for what kind of project it is necessary/unnecessary to obtain Environmental Clearance and from which government organizations (Department in charge of ministry, public company, local administration authority, etc.) EC should be obtained. In the case of projects listed under the jurisdiction of the Competent Authority (hereinafter "CA") in Annex 2 of EC regulation, CA can issue EC. Applicants submit a document containing Environmental Information for the planned project to the CA. EC Regulation requires the establishment of an Environmental Unit within CA.

NEC is a high decision-making and coordinating body, which establishes environmental policies or laws and regulations, institutionalizes and examines Environmental Clearance, and governs the conservation/preservation/improvement of the natural environment, such as water resources and climate change. NEC is composed of the Prime Minister of RGoB as a chairman and 8 members: Ministers of related ministries, representatives of NGOs, a member of Parliament, the Secretary of NEC and a Special Advisor.

Under the Secretary, there are 4 divisions: Environment Services, Environment Monitoring, Water Resource Coordination, and Climate Change. Environmental Clearance is managed under the Environmental Service Division. At the local administration level (Dzongkhag), NEC assigns one environmental officer, "Dzongkhag Environment Officer (DEO)", to each Dzongkhag, who is in charge of environmental conservation for that Dzongkhag.

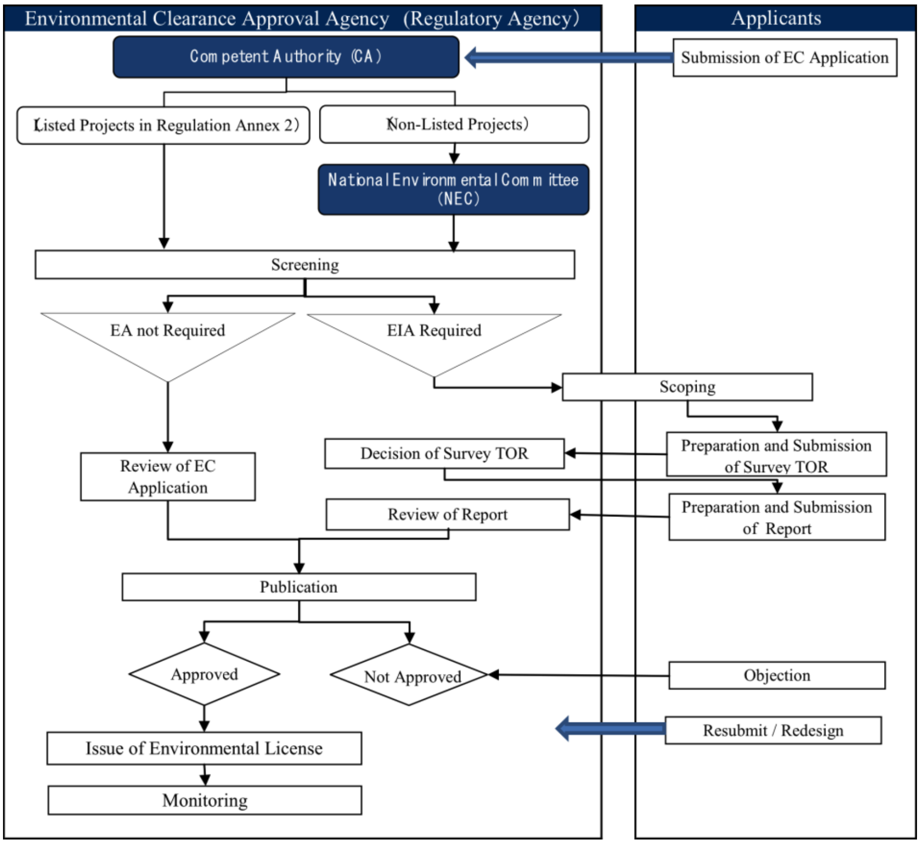
(b) Environmental Clearance Process
For hydropower and power transmission line projects, an environmental impact assessment (EIA) is necessary for EC from NEC. There are environment assessment guidelines by NEC on these projects for the applicants to follow during the preparation of EIA. According to NEC, it is necessary to implement an EIA for all hydropower projects, regardless of the installed capacity of the power plant. Transmission line projects are also required to conduct EIA in line with the guideline.

The procedure of EC for hydropower and transmission line projects is shown in the figure below. The applicant submits the EC application form to the Competent Authority (CA) (in the case of these projects, CA is the Ministry of Economic Affairs) or directly to NEC. As EIA is required for all hydropower projects, through a scoping process, the applicants must submit Terms of Reference (TOR) for the EIA to NEC and obtain their approval prior to the commencement of the EIA study.

During the EIA process, public consultation is mandatory under the EA Act and EC regulation in order to obtain the opinions of project affected people and gain their consent for the project. After the submission of the EIA study report to NEC, NEC reviews it and also makes it public. After the publication, NEC finally approves the study and then issues EC. In the case that NEC does not approve the EIA study, the applicants can appeal on the decision or redesign the EIA study and resubmit it for approval.

According to NEC, the requirement for EIA transmission line projects depends on the case, as follows:

- If the transmission line is less than or equal to 33 kV and if the transmission line falls only in one dzongkhag (district), the clearance is delegated to the Dzongkhag Environment Committee and there is no need for EIA.
- If the transmission line is less than or equal to 33 kV and if the transmission line falls in more than one dzongkhag, then the clearance is obtained from NEC but does not require EIA.
- In the case that the transmission line does not fall under a protected area, there is no need for EIA
- In the case that the transmission line falls under a protected area, even a buffer zone, then an EIA study report is necessary.



(Source: JICA Survey Team based on NEC "Regulation for the Environmental Clearance of Projects" (2012), "Environmental Assessment Guideline for Hydropower Projects" (2002), "Environmental Assessment Guideline for Power Transmission Line Projects" (2013), and NEC Website (as of June 2015))

Figure 6-1 Environmental Clearance Process for Hydropower and Transmission line projects

(3) Legal Framework for Land Acquisition and Resettlement

Under the Land Act (the latest version was issued in 2007), the National Land Commission (hereafter NLC) has the responsibility for registration of land possession and management, approval of the application for development projects, and procedures on land acquisition. According to NLC, if land acquisition is required, the project implementation authority sends a letter to NLC, and NLC proceeds with the arrangements for land acquisition, with consultation by the land record officer in the district.

At the outset, the committee is formed, comprising Gup, who is the representative at the block level, the forestry officer of MOAF in the block, and Tshogpa, who is the representative of the villages. This committee investigates the land ownership and current situation of the land and also reviews the content of compensation and discusses it. After the investigation at the block level, the district officer in charge submits the approval on the land acquisition to NLC and then the Chief or Director of the Land Registration Division in NLC will finally approve it.

With regard to compensation for land acquisition, there are two methods: 1) provide alternative land and 2) provide cash compensation. According the Land Act (2007), in case of the land acquired in rural area, the land owner shall have the discretion to opt for either of two methods, whereas in case of the land acquired in Thromde (= the third administration level, urban area in Bhutan) the land owner shall be provided cash compensation except for the case of small-scale land.

Substitute land in rural area will be determined with the following priority in terms of the location; at first in the same village, second in the same Gewog, and then in the same Dzongkhag. The act also states that "if the value of substitute land in Thromde is not inadequate, additional cash compensation shall be provided subject to the value of land" (Chapter 7 148). According to NLC, it is usual to provide alternative land for landless farmers, and to provide cash compensation in the case of small-scale land owners.

For cash compensation for the acquired land, it is necessary to refer to the Land Compensation Rate, established by the Property Assessment & Valuation Agency (PAVA), under the Department of National Properties, the Ministry of Finance. Compensation rates for the land are categorized by the class depending on the conditions, in case of urban or rural area respectively. Dzongkhag land officer judges the classification of the land for compensation. Buildings and crops in the acquired land are also targets for compensation, and the value is calculated into cash based on the public standard Compensation Rate. According the Land Act, PAVA shall revise an assessment of the compensation rates after 3 years. According to PAVA, people generally prefer the provision of alternative land than cash compensation.

Apart from these acts and regulations, for mobilizing the fund for social consideration in case of hydropower project, "Sustainable Hydropower Development Policy (2008)" by Ministry of Economic Affairs states that the Developer of the Hydropower Project shall provide an amount of 1 % and less of the project cost for the rehabilitation and resettlement of the displaced persons from the project area and other local development activities. In addition, the necessary infrastructure for the construction/development of the project and local area development is also described as part of the project under the responsibility of the Developer.

6.2.2 India

(1) Outline of Major Laws related to Natural and Social Environment Considerations

The important major laws or regulations, which promote environment protection directly or indirectly for the implementation of a Hydropower Plant and its related facilities in India, are the following:

(a) Environment (Protection) Act (1986).

The Environment (Protection) Act, 1986 (EPA-1986) provides a holistic framework for the protection and improvement of the environment and specifies that the State shall protect and improve the environment (article 48A).

Concerning Environmental and Social Considerations, in 1994, new articles were added which promulgated the EIA notification making environmental clearance mandatory for expansion or modernization of any activity or for setting up new projects.

(b) Forest (Conservation) Act (1980).
The Forest (Conservation) Act, 1980 provides for the conservation of forests and regulating diversion of forestlands for non-forestry purposes. When Hydropower or Transmission projects fall within forestlands, prior Forest Clearance (FC) is required from the relevant authorities under the Forest (Conservation) Act 1980.

In 2012, Guidelines[4] for the maximum allowable width of Right of Way for transmission lines in forest areas were stated with respect to the width of Right of Way (ROW) to determine the area of forest land for diversion under Forest (Conservation) Act (1980) as given below:

Table 6-2 Maximum width of ROW for various voltage levels

	Transmission Voltage (kV)	Width of Right of Way (Meters)
1	400 kV SIC	52
2	400 kV DIC	46
3	765 kV SIC (with delta configuration)	64
4	765 kV DIC	67
5	±800kV HVDC	69
6	1200 kV AC	89

(Source: Guidelines for ROW (2012, MOEFCC))

The proposals for environmental clearance will not be linked with the clearances from Forestry and wildlife even if they involve forestland and/or wildlife habitats, as these clearances are independent of each other.
Therefore, Forest Clearance or Wildlife Clearance should be obtained as applicable to such projects before starting any activity in Forest or Wildlife Habitat sites.

(c) The Wildlife Protection Act (1972).
The Wildlife (Protection) Act (1972), was enacted in 1972 to promote the objectives of effectively protecting the wildlife of the country and to control poaching, smuggling and illegal trade in wildlife and its derivatives. In the case that the project site is located within an eco-sensitive zone or within 10 km in the absence of delineation of such a zone from the boundaries of National Parks or Wildlife Sanctuaries, or is an Elephant Reserve/Tiger Reserve and/or important corridor of wildlife movement, the Project Proponent should seek prior Wildlife Clearance from the Standing Committee of the National Board for Wildlife before seeking Environmental Clearance and the procedure (Office Memorandum 2009, No.3-11013/2006).

(d) Water (Prevention and Control of Pollution) Act (1974).
This act makes provisions for the establishment of the Central and State level Pollution Control Boards, whose responsibilities include the managing of water quality and effluent standards and issuing licenses for construction of any facility. However, definitive articles on environmental flow requirements in various water resource development projects have yet to be added into the existing Water Act.

[4] F. No. 8-44/2002-FC (pt) Dated: 24th January, 2012

But some conditions on the volume of environmental flows are commonly required by the Environmental Appraisal Committee for River valley Projects at the planning phase or issuing phase of Environmental Clearance.

(e) National Resettlement and Rehabilitation Policy (NRRP) 2007

This policy aims to strike a balance between the need for land for development activities and protecting the interests of the land owners, and others such as the tenants, the landless, the agricultural and non-agricultural laborers, artisans, and others whose livelihoods depend on the land involved.
This policy also requires a Social Impact Assessment Study and an SIA Clearance for all new projects or expansions of existing projects involving involuntary displacement of 400 or more families in plain areas, or 200 or more families in tribal or hilly areas.

(f) Electricity Act (2003).

The Electricity Act, 2003, is an act to consolidate the laws relating to the generation, transmission, distribution, trading and use of electricity in India. The act does not explicitly deal with the environmental implications of activities related to Hydropower or Transmission. However, as part of the process of receiving authorization under Section 164 of the Electricity Act, 2003, public notification of the projects with details of the schemes, including the locations of the projects, is mandatory and environmental protection should be integrated into the project activities.

(2) Legal Framework for Environmental Impact Assessment (EIA) Procedures

(a) Organizations responsible for Environmental Clearance

The Ministry of Environment Forests and Climate Change (MOEFCC) is the nodal agency in the administrative structure of the Central Government for promotion, co-ordination and overseeing of the implementation of environmental and social considerations in India. However, some parts of the actual implementation of these policies have been transferred to State Government (which comprises 29 states) and have mainly been implemented at the Environment Department of each State.

At the central level, there are 40 divisions under MOEFCC dealing with implementation of environmental issues, in which the Environment Research Division (RE), Impact Assessment Division (IA), Conservation and Survey Division, Forest Policy Division and Forest Services Division are the main divisions responsible for executing environmental and social considerations.

(b) Environmental Clearance Process

The Government of India promulgated the "Environment Impact Assessment (EIA) Notification of 14th September 2006", under the provisions of the Environment (Protection) Act (1986), which not only directed the entire process of obtaining environmental clearance (EC) from the MOEFCC/the State Environment Impact Assessment Authority (SEIAA) but also introduced a number of new projects or activities, or expansion or modernization of existing projects or activities, which would require prior environmental clearance.

Hence, The EIA Notification 2006 notes a list of 39 developmental sectors in the schedule as EIA mandatory projects, which have been further categorized as A or B based on their capacity and likely environmental impacts. Category B projects have been further categorized as B1 and B2.

Table 6-3 Category Types of Projects defined in Schedule of Notification 2006

Category Type	Definition
Category A	If it is likely to have significant negative impacts and is thus one of the types of project listed in this category in the EIA Notification. Such projects require EIA, plus Environmental Clearance (EC) from MOEFCC
Category B	If it is likely to have fewer negative impacts and is listed in this category in the EIA Notification. These projects require EC from the State Environment Impact Assessment Authority (SEIAA), who classify the project as B1 (requiring EIA) or B2 (not requiring EIA), depending on the level of potential impacts. Projects classified as B2 require no further study.

(Source: Notification of 2006, MOEFCC)

Hydropower Projects are listed as River Valley Projects in the Schedule, which require the compiling of an EIA and obtaining of Environmental Clearance (EC) from MOEFCC, but Transmission Line Projects are not listed in the Schedule so they are not only exempted from obtaining Environmental Clearance but they are also not required to prepare an EIA.

In terms of the notification of 2006, Hydropower projects are to be categorized as "River Valley Projects" and divided into two categories as per the below Table:

Table 6-4 Categories with threshold limit on Hydropower Activity

Project or Activity	Category with threshold limit		Conditions if any
	A	B	
River Valley Project	i) $\geq$ 50 MW hydroelectric power generation; ii) $\geq$ 10,000 ha. of culturable command area	i) < 50 MW $\geq$ 25 MW hydroelectric power generation; ii) < 10,000 ha. of culturable command area	General Condition shall apply*
* General Condition	General Condition (GC): Any project or activity specified in Category 'B' will be treated as Category A if located in whole or in part within 10 km from the boundary of: i) Protected areas notified under the Wildlife (Protection) Act, 1972, ii) Critically polluted areas as notified by the Central Pollution Control Board from time to time, iii) Notified Eco-sensitive areas, iv) Inter-state boundaries and international boundaries.		

(Source: Notification of 2006, MOEFCC)

Environment (Protection) Act (1986) and Notification of 2006 have explicitly mentioned the need to undertake an Environmental Impact Assessment (EIA) for 39 prescribed projects as well as the process of approving an EIA report.

Based on this Act and Notification, Hydropower projects of more than 25 MW in capacity are made mandatory to be considered for the application of an Environmental Assessment, which will be undertaken through the four stages of Screening, Scoping, Public Consultation and Appraisal, described below and shown in the Figure below.

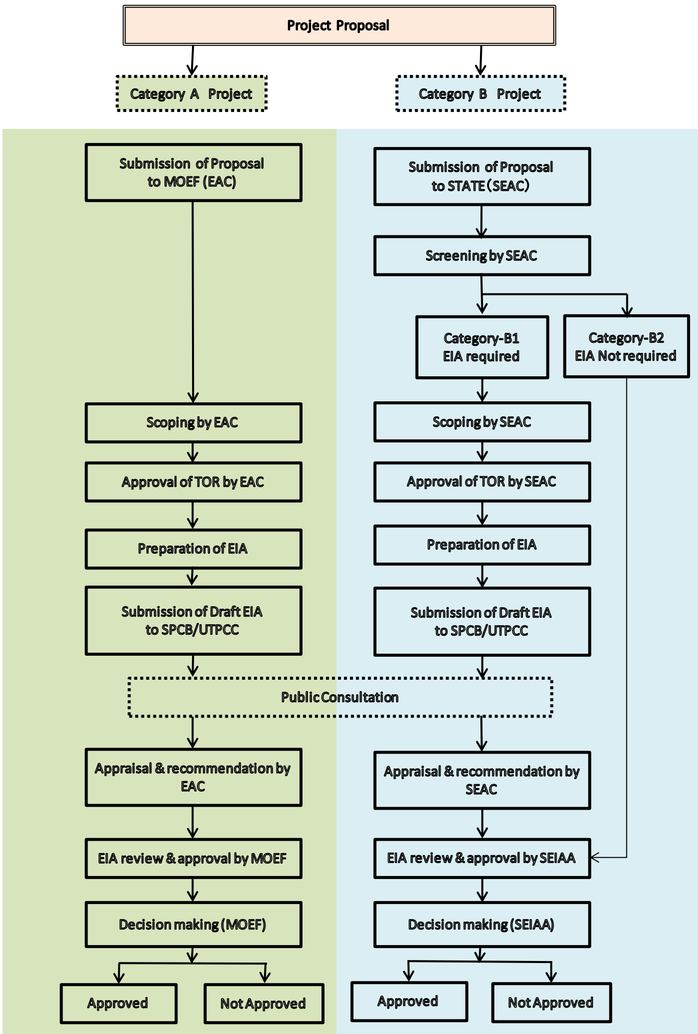
(Screening Stage)
This stage is applicable only for Category 'B' developmental activity, i.e., if general conditions are applicable for a Category B project, then it will be treated as Category A project. Besides, screening also refers to the classification of Category B projects into either Category B1 or Category B2. Category B1 projects must follow all stages applicable for a Category A project, but are processed at the State Level Environmental Impact Assessment Authority (SEIAA). Category B2 projects, on the other hand, do not require either EIA or public consultation.

(Scoping Stage)
Scoping refers to the process by which the Expert Appraisal Committee (EAC), in the case of Category 'A' projects or activities, and State Level Expert Appraisal Committee (SEAC), in the case

of Category 'B1' projects, including applications for expansion and/or modernization of existing projects, determines TOR for EIA studies addressing all relevant environmental concerns for preparation of an EIA Report.

(Public Consultation)
Public consultation refers to the process by which the concerns of local affected people and others who have a plausible stake in the environmental impacts of the project or activity are ascertained. All Category A and Category B1 projects require a public hearing. Public consultation involves two components: one is the public hearing, and the other is inviting written responses/objections through the Internet/by post, etc., by placing the summary of the EIA report on the website. The public hearing shall be carried out at the site or in close proximity to it, district-wise, to ascertain the concerns of local affected people.

(Appraisal Stage)
Appraisal means the detailed scrutiny by the EAC or SEAC of the application and the other documents like the final EIA report, and the outcome of the public consultation including public hearing proceedings submitted by the applicant for the granting of environmental clearance. The appraisal shall be made by EAC to the Central Government or by SEAC to SEIAA.



SPCB:State Pollution Control Board
UTPCC: The Union territory Pollution Control Committee

(Source: JICA Survey Team based on Notification of 2006, MOEFCC)

Figure 6-2 Environmental Clearance Process for Category A/B projects

(3) Legal Framework for Land Acquisition and Resettlement

Under the Land Acquisition Act (1894), "The Right to Fair Compensation and Transparency in Land Acquisition Rehabilitation and Resettlement Act (RFCTLARRA, 2014)" has been enforced. The new act, i.e. RFCTLARRA, 2013, authorizes State Govt. (i.e. GoMe) or its authorized Government agency to complete the whole process of acquisition of private land including Social Impact Assessment (SIA), and Action Plan for R&R (i.e. Rehabilitation and Resettlement) & its implementation.

The act also provides for transparent process and fair compensation to land owners and those affected by land acquisition, for land acquired for public purpose. In determining the market price, land owners in urban areas will get twice the amount, due to the 100% solatium, and in rural areas, the multiplying factor is between 1 to 2 depending on distance from the nearest urban center, to be notified of by the appropriate government body, and then 100% solatium.

The procedure for acquisition and R&R is included in the Social Impact Assessment (SIA), which will cover the investigation of the public purpose and the minimum extent of land required, and the estimation of displacement and social impact on affected families apart from the overall cost versus benefit analysis for the proposed project.

6.2.3 Bangladesh

(1) Outline of Major Laws related to Natural and Social Environment

The important major laws or regulations, which promote environment protection directly or indirectly for the implementation of a Hydropower Plant and its related facilities in Bangladesh, are the following:

(a) Environment Conservation Act (1995).

The Environment Conservation Act (1995) provides for the conservation of the environment, improvement of environmental standards and control and mitigation of environmental pollution. Concerning Environmental and Social Considerations, any proponent planning to set up or operate an industrial project is required to obtain an "Environmental Clearance Certificate (ECC)" from the Department of Environment (DOE), under the Environment Conservation Act 1995.

(b) Forest Act (1927).

The Forest Act, 1927 provides for reserving forests over which the Government has an acquired property right. The Government (Forest Department) can prohibit certain activities in the declared Reserved Forest/Forest areas such as the activities described below:

a. To kindle, keep or carry any fire except at such seasons as the Forest-Officer may notify in this behalf;
b. To trespass or pasture cattle, or permit cattle to trespass,
c. To cause any damage by negligence in felling any tree or cutting or dragging any timber,
d. To quarry stone, burn lime or charcoal, or collect, subject to any manufacturing process, or remove any forest produce other than timber; or enter a reserved forest with firearms without prior permission from the Divisional Forest Officer concerned.

When Hydropower or Transmission projects fall within forestlands, a "No Objection Certificate (NOC)" from the Department of Forest is required. Therefore, a No Objection Certificate (NOC) which represents Forest Clearance should be obtained as applicable to such projects before starting any activity in Forests.

(c) Bangladesh Water Act (2008).

This act makes provision for the establishment of the Central and State level Pollution Control Boards, whose responsibilities include the managing of water quality an effluent standards and issuing licenses for construction of any facility.

Concerning the environmental issues associated with Hydropower, the following requirements are specified in the articles:

a. No construction of roads, dams, bridges and other structures which may seriously interfere with the flow of navigable waterways shall take place without having an approved plan and Planning Proforma approved by the Planning Commission after a clearance from The Water Resources Planning Organizations (WARPO).
b. Water of a stream may not be stored in a reservoir by an individual in such amounts that may prejudice the right of any other user. Any who operates the reservoir with the necessary authorization shall, when required, release water for the minimum of stream flow.

However, definitive articles on environmental flow requirements in various water resource development projects have yet to be added into the existing Water Act.

But some conditions on the volume of environmental flows at the phase of issuing an "Environmental Clearance Certificate" are commonly required by the Department of Environment (DOE).

(d) Bangladesh Electricity Act (1910).
This act provides the permission to the National Electricity Board (at present, BPDB) or any licensee of the Government to lay down or place electricity supply lines within the area of supply. The Act provides such permission subject to payment of compensation to the affected person due to removal of structures, standing trees or any other objects for extending aerial lines. Provision under this law requires that this authority shall be subject to intimation to the local authority or to the owner.

Regarding the Right of Way (ROW), Power Grid Company of Bangladesh Limited (PGCB) published a guideline for minimum clearance standard, as below:

Table 6-5 Minimum Clearance Standard

Description of Clearance	Minimum Clearance (m)		
	132kV	230kV	400kV
Ground (see note d)	7	8	9
Roads	8	9	14
Buildings, structures, walls or other objects on which a person can stand or against which he can lean a ladder (see note b)	5	6	7
Trees (see note c)	3.5	4.5	5.5
Shrubs	3	4	5.5
Railways (measured from railway track)	9	10	18
River Crossing	23	25	-

Notes:
(a) Clearances are measured to the nearest projection of an object.
(b) These clearances also apply to earthed metal clad buildings.
(c) Clearances applicable to trees under the transmission line and to trees adjacent to the line. Clearances also applicable to trees falling towards the line with conductors hanging in a vertical plane.
(d) The clearance shall be measured from the highest flood level.

(Source: PGCB)

(e) The Acquisition and Requisition of Immovable Property Ordinance (1982).
This ordinance is the principal legal instrument governing land acquisition in Bangladesh. This ordinance requires, whenever it appears to the Government of Bangladesh that any property in any locality is needed or is likely to be needed for any public purpose or in the public interest, that the Government can acquire the land, "provided that no property used by the public for the purpose of religious worship, graveyard and cremation ground shall be acquired" (Part II 3). This ordinance also requires that compensation be paid for

(i) land and assets permanently acquired (including standing crops, trees, houses)
(ii) any other damage caused by such acquisition.

(2) Legal Framework for Environmental Impact Assessment (EIA) Procedures
(a) Organizations responsible for Environmental Clearance
The Government of Bangladesh promulgated the "Environment Conservation Rules 1997" and "EIA Guidelines for Industries" for the formal documents providing guidance for conducting an Environmental Assessment based on "The Environmental Conservation Act" (1995). Under these regulations, any proponent planning to set up or operate an industrial project is required to obtain an "Environmental Clearance Certificate (EC)" from the Department of Environment (DOE).

The Regulations denote a list of industries that need an "Environmental Clearance Certificate (EC)" and classify these projects to be assessed (by the DOE) into the four categories of "Green", "Amber-A", "Amber-B" and "Red".
Power development projects and Transmission Line Projects are allocated to the red category, as No-6 and No-64 in the list respectively, and trigger an automatic requirement for an Initial Environmental Examination (IEE) followed by a full Environmental Impact Assessment (EIA).

Table 6-6 Category Types of Projects defined in lists of industries

Category Type	Definition
Green	Green listed industries are considered relatively pollution-free, and therefore do not require an EIA.
Amber-A	Amber-A listed industries require a location clearance certificate, followed by issuance of Environmental Clearance upon the satisfactory submission of the required documents. IEE/EIA is not required.
Amber-B	Amber-B listed industries require a location clearance certificate, followed by issuance of Environmental Clearance upon the satisfactory submission of the required documents. IEE is required but EIA is not required.
Red	Red listed industries require a location clearance certificate, followed by issuance of Environmental Clearance upon the satisfactory submission of the required documents. Both IEE and EIA are required

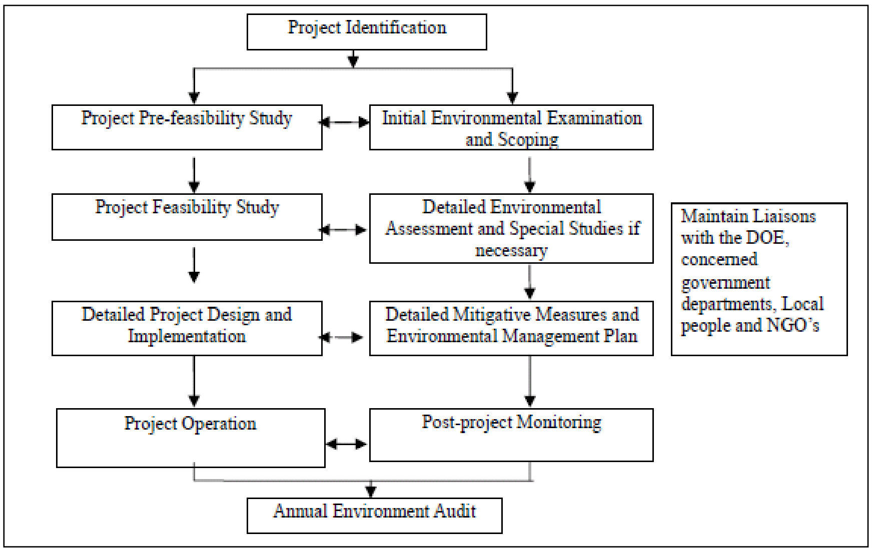
(Source: EIA Guidelines for Industries, 1997, DOE)

(b) Environmental Clearance Process

The "Environment Conservation Rules 1997" and "EIA Guidelines for Industries" explicitly mention the need to undertake an Environmental Impact Assessment (EIA) for projects categorized as Red, as well as the process of approving an EIA report.

Based on these regulations, Hydropower projects and Transmission line projects are made mandatory to be considered for the application of an Environmental Assessment.

The flow for environmental assessment, consultation and monitoring is shown in the figure below.



(Source: Department of Environment, Ministry of Environment and Forest, "EIA Guidelines for Industries", 1997)

Figure 6-3 Project Planning, Implementation and EIA Process

(3) Legal Framework for Land Acquisition and Resettlement

Under the Acquisition and Requisition of Immovable Property Ordinance of 1982 (amendments in 1993, 1994, 2004), Deputy Commissioner (DC) who is an executive head of the district in Bangladesh will take responsibility for procedure of the land acquisition and compensation. The Land Acquisition Officer (LAO) of Deputy Commissioner's Office, with a support by Land Officer of Upazila (subdistrict) Office, conduct field level verification on the target land with respect to the category of the land, feature, size, nature of structure, the value of crops and trees and so on.

According to the Ordinance, the land price is calculated based on the market value of the property at the date of publication of the notice of the land acquisition. Upon determining the market price, DC shall consider average value of one year prior to the date of publication, damages on any standing crops and trees on which may be on the property, influence to other property, diminution of the profits of the property during the acquisition process period, etc. DC also shall consider the award of a sum of fifty percent on such market value because of the compulsory nature of the acquisition.

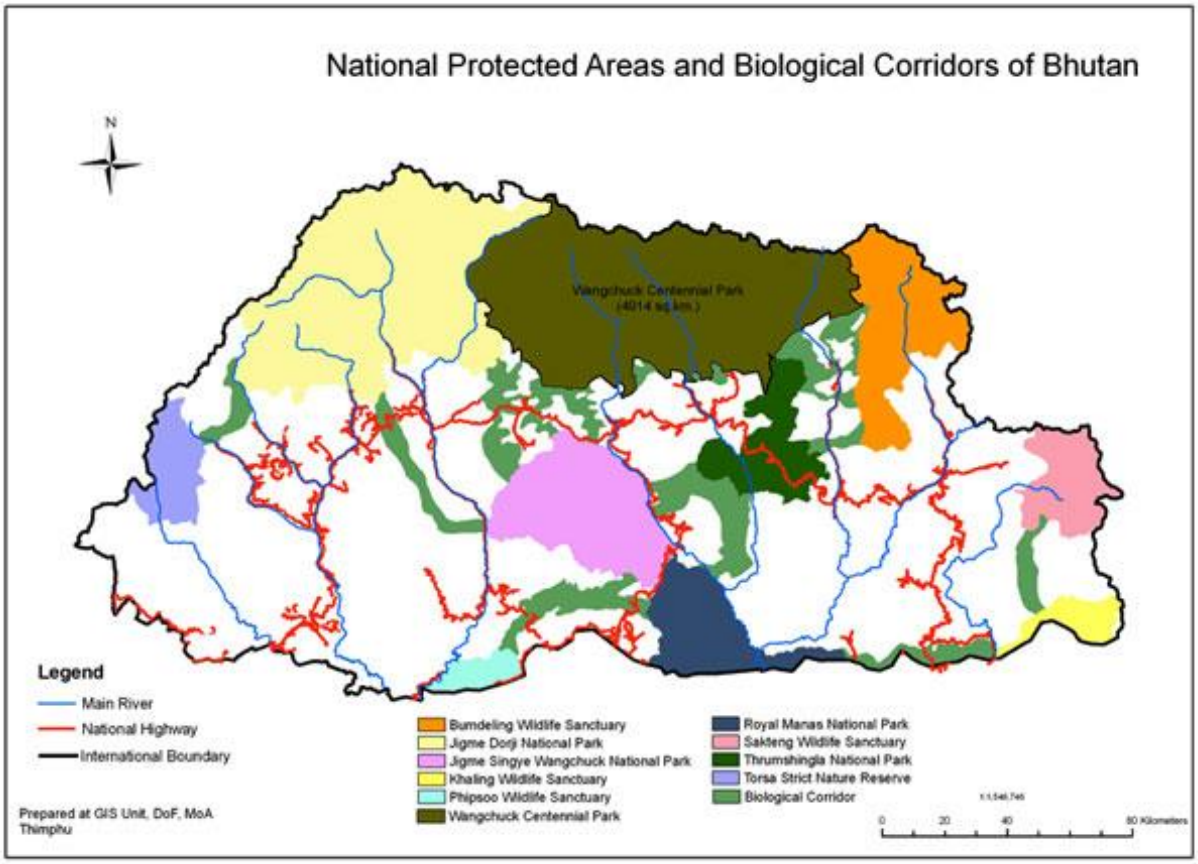
6.3 Situation in Project Sites

6.3.1 Bhutan

(1) Overview of Natural and Social Environment

As of 2015, the forestry coverage ratio is 80.89% of the total land in Bhutan. As shown in Figure 6-4, protected area in Bhutan is composed of a total of 12 areas, with 5 national parks, 4 wildlife sanctuaries, 1 nature reserve, 1 biological corridor and 1 royal botanical park. Total protected areas account for approximately 50% of the national land.

According to the National Statistics Bureau (NSB), the current population of Bhutan is approximately 762 thousand. In Bhutan, ethnic minorities exist: for example, there are nomads who wear particular ethnic clothes in Laya and Lunana in the north and also one called "Brokpa" in the east. However, officially there is no group designated as an ethnic minority to be protected or taken into legal consideration.



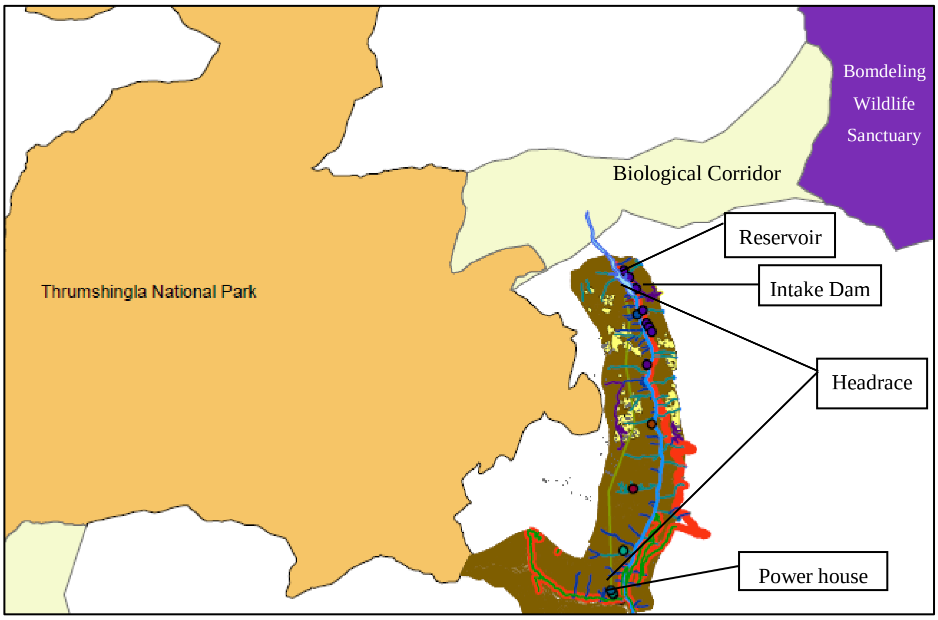
(Source: Department of Forest & Park Services (DoFPS), MOFA)

Figure 6-4 National Protected Areas and Biological Corridors of Bhutan

(2) Kuri-I Hydropower Project

(a) Location

Project components of Kuri-I are located in Mongar Dzongkhag, except the reservoir, for which the plan is extended to Luentse Dzongkhag, beyond the border of Mongar Dzongkhag (District). Project Site and Pictures of the Kuri-I are shown in the Figure and Photo below.



(Source: DGPC "DPR Study of Rotpashong Hydropower Project (STATUS REPORT)", July 2014)

Figure 6-5 Protected Areas and Kuri I Hydropower Project Site

Forestry and plants in Intake Dam area
(the right bank of the river)

Three permanent houses, possibly requiring resettlement, on the right bank of the river in Autsho Village, Tsenkhar Geog, Lhuntse Dzongkhag

Photo 6-1 Vegetation and Houses in Kuri I Hydropower Project Site

(b) Potential Environmental Impacts caused by the Project

The main environmental and social impacts that may arise due to the Project are as per the Tables below:

Table 6-7 Main Potential Impacts on Environment due to Kuri I Project

Natural Environment	
Protected Area	Project Location does not fall in any Protected Area. Nearest protected area is Thrumshingla National Park that is located in the west, in the direction of the right bank of the Kuri river. Biological Corridor is located upstream of the reservoir area.
Hydrology	Reservoir with about 1.6 to 1.7 km^2 will lead to loss of natural forest.
	Reduced water flow of 15 km in Kuri river from the dam site to the tailrace may affect population of fish and the regular breeding or feeding cycle of migrated fish. Snowtrout (Schizothorax progastus), Maheer (Tor Putitoria), and River Cat/Baynya (Glyptothorax) are observed in the river.
Ecosystem	(Wild Flora) Loss of vegetation and forest will occur due to access roads, reservoir, and other project components; however, the vegetation consists of common species as follows, with limited conservation value. -Chirispine (*Pinus Roxbughii*) observed all along the river, Karnikara (*Pteropemum Acerifolium*), Indian orak (*Quercus Griffithli*), etc. (Wild Fauna) It is necessary to conduct a further survey to ascertain exact status. Pre-FS reported that totally protected wild animals may occur in the project area, out of an existing 17 mammal species; however, these species likely use the project area just for sheltering but not for breeding or main feeding activities. -Endangered species in the IUCN Red List: Tiger (*Panthera tigris*), Fishing Cat (*Prionailurus viverrinus*), Leopard (*Panthera pardus*), Dhole/Wild Dog (*Cuon Alpiines*). -Others are Leopard Cat (*Felis bengalensis*) and Himalayan Serow (*Capricornis symatraensis*). Pre-feasibility study describes that Black-necked crane (*Grus nigricollis*), categorized as "vulnerable" in the IUCN red list, was reported; however, it seems to be observed rarely according to the site survey observation.
Social Environment	
Land Ownership and Main Use	Acquisition of small private agricultural land will likely occur in dam area. The road will be relocated to governmental land on the hill top on the left bank of the river. General features of the project area are: -Ownership: private / government -Main use by people: agriculture and grazing.
Involuntary Resettlement	Due to the backwater of the reservoir, resettlement of 3 permanent houses and other small facilities in Autsho village may occur.
Ethnic Minorities/ Indigenous People	No ethnic minorities in project site.
Use of River by Local People	No use of river water for irrigation or drinking. Fishing in the river is allowed only for licensed persons.
Infrastructure, Cultural Heritage and Remains	• 1.5km of the road will be submerged; realignment is necessary. • Small bridge in Autsho village may be submerged and need to be relocated. • No registered cultural heritage. Relocation of small chorten may occur depending on influence of water level.

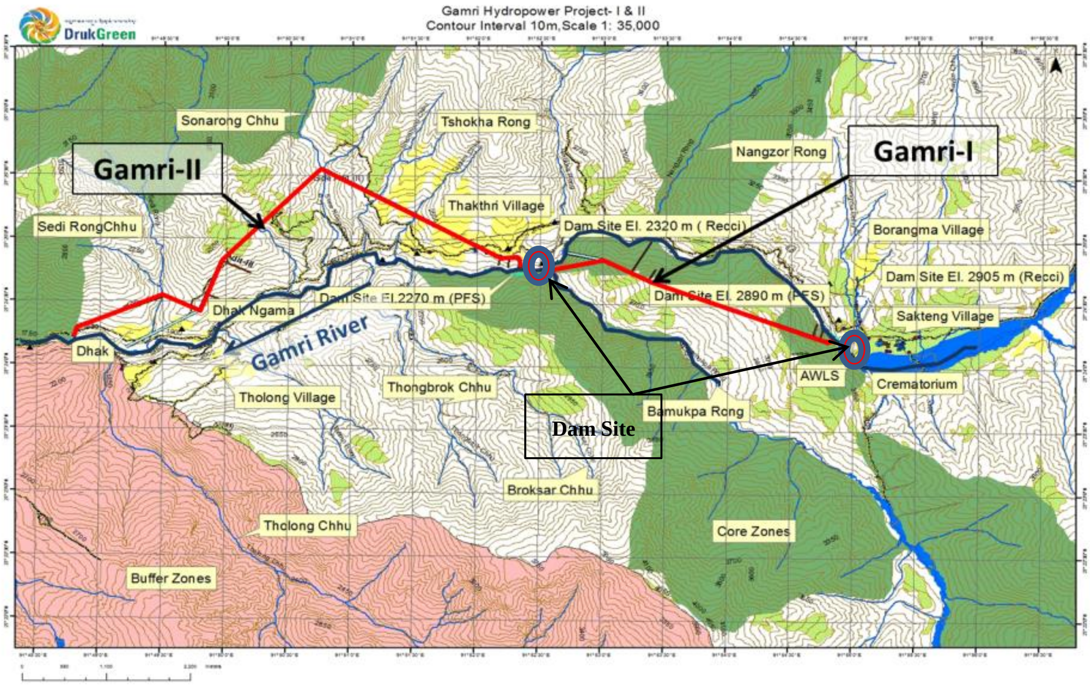
(Source: "Volume 5 Initial Environmental and Social Impact Assessment in Pre-feasibility study Report Rotpashong Hydropower Project" and DGPC head office officer and project site manager)

(3) Gamri I & II Hydropower Projects

(a) Location

All project components of Gamri HP Project-I & II fall in and around the protected areas (core zones) of Sakteng Wildlife Sanctuary (SWS), in Sakteng Dungkhag (sub-district), Trashigang Dzongkhag. The general layout and pictures of the Gamri I & II project site are shown in the （Source: DGPC "Pre-Feasibility Study Report Gamri Hydropower Projects (I & II)", 2011）

Figure 6-6 and Photo 5-6. Gamri II intake dam site is located near Thakthri Village. From Gamri I intake dam, the headrace tunnel will be extended underground beneath Thakthri Village toward the Power house site near Dhak Village. Gamri II intake dam site is located near Sakteng Village and the headrace tunnel will be extended to beneath part of the core zone of SWS towards the Gamri I powerhouse and Gamri II intake dam site.



（Source: DGPC "Pre-Feasibility Study Report Gamri Hydropower Projects (I & II)", 2011）

Figure 6-6 Each Zoning Area for Wildlife Protection and Gamri-I & II Project Site

Traditional Clothes of "Brokpa"
(Thakthri Village)

Houses in Thakthri Village

Photo 6-2 View of Thakthri Village in Gamri II Site

(b) Potential Environmental Impacts caused by the Project

The main environmental and social impacts that may arise due to the Project are as per the Tables below:

Table 6-8 Main Potential Impacts on Environment due to Gamri I & II Project

Natural Environment		
Project Site	Gamri-I	Gamri-II
Protected Areas	Located in “Sakteng Wildlife Sanctuary”*	
	The left abutment of the Dam abuts the **core zone**, and other facilities will be constructed in the ***core zone***, where any kind of construction, including motor roads, buildings, or any physical structures, are strictly prohibited, but these facilities will possibly be permitted as long as they are constructed underground.	The left abutment of the Dam abuts the ***core zone,*** but facilities will mostly be located in the ***multiple-use zone***, where sustainable utilization of natural resources by its residents is permitted including pasture, without negative impact on the core zone.
Hydrology	Reservoir of 0.027km^2 will lead to loss of natural forest in ***core zone.***	Reservoir of 0.026km^2 will lead to partial loss of natural forest in ***core zone***.
	Reduced water flow of 5.36km in Gamri River will impact on the regular breeding or feeding cycle of migrated fish.	Reduced water flow of 7.69km in Gamri River will impact on the regular breeding or feeding cycle of migrated fish.
Ecosystem	Core zones are wilderness areas and undisturbed habitats of wild flora and fauna, which should strictly be exclusively protected, but knowledge of their status is insufficient and they have not been assessed. The following endemic/rare wild flora and fauna have been recorded and may be affected: (Wild Flora) -Biotic community of Rhododendrons (*Rhododendron bhutanense*), Bearded Coelogyne (*Coelogyne barbata)* (Wild Fauna) -Endangered in the IUNC Red List: Red Panda (*Ailurus fulgens*), Bengal Tiger (*Panthera tigris tigris),* Golden Langur (*Trachypithecus geel*) -Vulnerable in the IUNC Red List: Himalayan Black Bear (*Ursus thibetanus laniger*) -Bird: Himalayan monal *(Lophophorus impejanus)*.	
Social Environment		
Land Ownership and Main Use	3.8 Acres of private land might have to be acquired. The following are the general characteristics: Ownership: Private/Government Main Use: Mainly Grazing (cows and yaks) and agriculture (maize, barley, potatoes and vegetables)	
Involuntary Resettlement	There are some villages of approximately 30 to 50 households around project sites; however, resettlement is not required.	
Ethnic Minorities/ Indigenous People	An indigenous group of people termed “Brokpas” live around project sites. They are traditionally a nomad people. Currently, more people tend to settle in one place.	
Use of River By local people	• No main use for drinking, irrigation or livestock • In the traditional Brokpa funeral rites, they cut the dead body into 108 pieces and put them into the river. Currently, this is officially prohibited; however, the local officials reported that some cases had still been observed.	
Infrastructure, Cultural Heritage and Remains	No registered cultural heritage	

Note: *wildlife sanctuary area is divided into the following 4 zones:

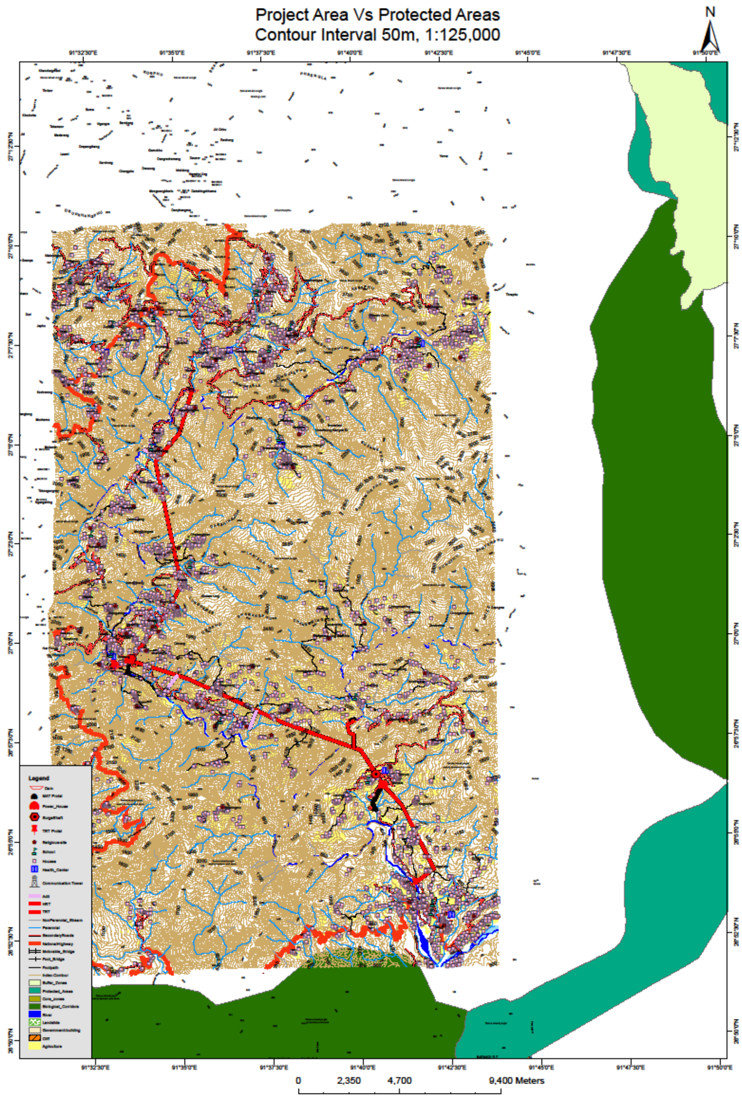
- Core Zone: total protection
- Multiple-use Zone: sustainable utilization of natural resources
- Buffer Zone: extra layer of protection for the Sanctuary
- Recreational (overlapping) Zones: potential tourist areas in multiple-use zones and low impact trails and sites in core zones

(Source: "Volume 5 Initial Environmental and Social Impact Assessment in Pre-feasibility Study Report Rotpashong Hydropower Project" and DGPC head office officers and Trashigang District officers)

(4) Nyera Amari I & II Hydropower Projects

(a) Location

Project components of Nyera Amari I and II encompass Trashigang and Samdrup Jongkhar Dzongkhag; part of Nyera Amari I is located in Trashigang and the rest of Nyera Amari I and the entire Nyera Amari II lie in Samdrup Jongkhar. Project Site and Pictures of the Nyera Amari I & II are shown in the Figures below. The dam site of Nyera Amari I is located near Pangzam Village in Thrimshing Geog, Trashigang Dzongkhag. The headrace tunnel from the intake dam will be extended to the powerhouse in Sawong Village in Gomdar Gewog, Samdrup Jongkhar.



(Source: "Pre-Feasibility Study Report Nyera Amari Hydropower Project -I & II", 2014)

Figure 6-7 Protected Area and Nyera Amari I & II Project Layout

Forestry and plants around the intake dam site in the river (NA- I)

School and Basic Health Unit in Sawang Village, on left bank of the river (below the power house No.I and near the reservoir NA-II)

Forestry and plants around Power House (NA- II)

Orange tree plantation on right bank of the river (NA-II)

*NA= Nyera Amari

Photo 6-3 Vegetation and Social Facilities in Nyera Amari I & II Project Site

(b) Potential Environmental Impacts caused by the Project

The main environmental and social impacts that may arise due to the Project are as per the Tables below:

Table 6-9 Main Potential Impacts on Environment due to Nyera Amari I & II Project

Natural Environment	
Protected Area	Project site does not fall under any Protected Area or Biological Corridor.
Hydrology	Following reservoir areas will lead to loss of natural forest. -NA-I: submergence area of 0.133 km^2 in dam site and the backwater of 0.806km towards Phegpari stream and 1.264km toward Nyera Amari -NA-II: submergence area of 0.032 km^2 with backwater stretch of 0.418km
	Distance of the river with reduced water flow is quite long, approx. 52.5km. This may affect the population of fish and the regular breeding or feeding cycle of migrated fish. This can be reconsidered with a change in design in the detailed study. Karla/Mahseer (*Neolissochelius spp*), Snow trout (*Schzothorax spp*) etc. are observed in the river.
Ecosystem	(Wild Flora) Loss of vegetation and forest will occur mainly due to access roads and reservoir. Rich forest species diversity is observed due to the elevation difference, such as:

	- Chirispine (*Pinus Roxbughii*), Walnut (*Juglans regia*), etc. (Wild Fauna) In the surroundings of the project area the below wildlife in the IUCN Red List may be observed; however, these species likely use the project area just for sheltering but not for breeding or main feeding activities. -Endangered species in the IUCN Red List: Tiger (*Panthera tigris*), Asiatic elephant (*Elephas maximus*), etc. -Vulnerable species in the IUCN Red List: Himalayan Black Bear (*Selenarctos thibetanus*), Capped langur (*Trachypithecus pileatus*), Leopard Cat (*Felis bengalensis*), etc. Regarding birds, Rufous-necked Hornbill (*Aceros nipalensis*) is often observed in NA II project. It was found during the site survey.
Social Environment	
Land Ownership and Main Use	Out of a total of 340 Acres for land requirement for the project, 30.31 Acres of private land might have to be acquired. The following are the general characteristics in the project area: -Ownership: Private/Government -Main Use: Agriculture (Crops such as potato, chili, vegetables, and orange tree plantations), Grazing (cattle, cows, and horses), etc.
Involuntary Resettlement	Not required for resettlement of permanent houses; however, there is a possibility of compensation for a few temporary houses in the reservoir area of NA-II.
Ethnic Minorities/ Indigenous People	No ethnic minorities or indigenous population in the project site
Use of River by Local People	No use of river water for irrigation or drinking. Fishing in the river is allowed only for licensed persons.
Infrastructure, Cultural Heritage and Remains	• School and Basic Health Unit that are located under the NA-I Power House and along the river (approx. 500 m from intake dam) are not expected to be affected in the design. • No registered cultural heritage

(Source: "Volume V Initial Environmental and Social Impact Assessment in Pre-feasibility Study Report Nyera Amari I & II Hydropower Project" and DGPC head office officers and Trashigang and Samdrup Jongkhar District officers)

6.3.2 India (Meghalaya State)

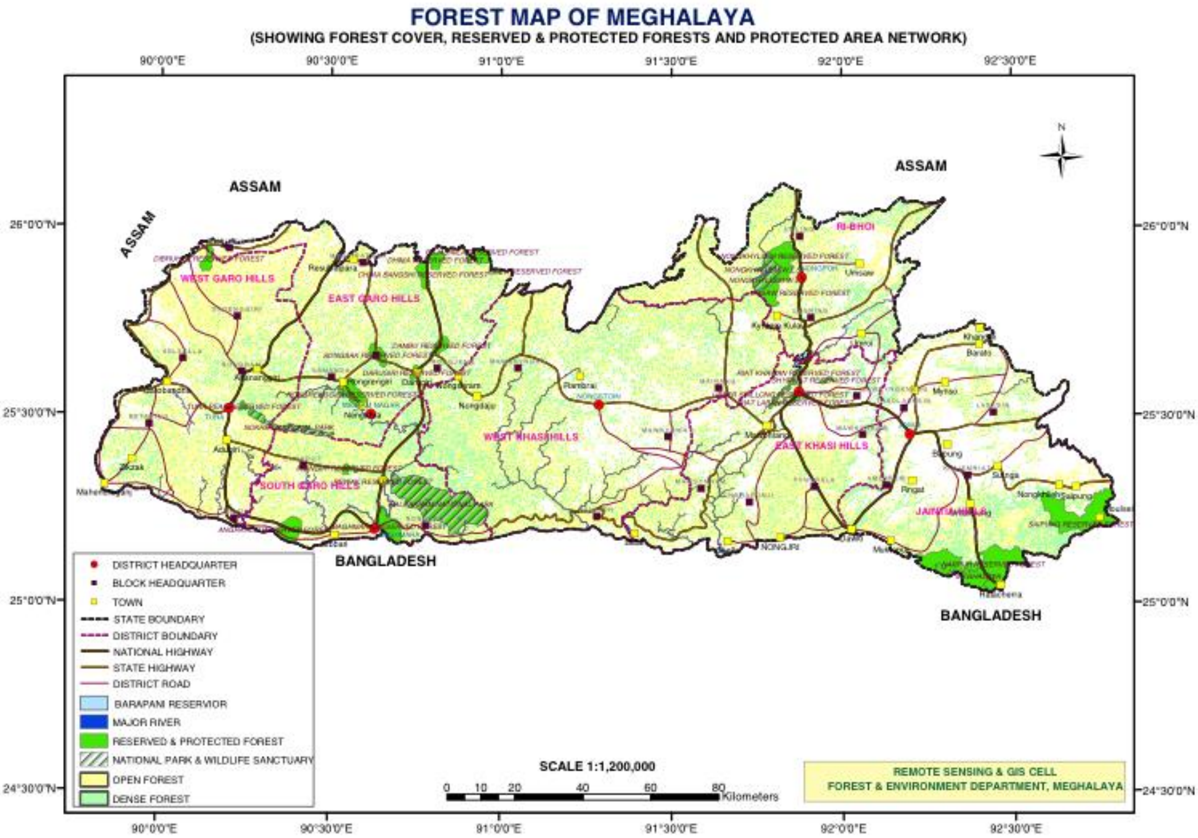
(1) Overview of Natural and Social Environment in Meghalaya State

The State is located in the bio-geographic zone of the North-East hills and possesses an extremely rich bio-diversity. About 77.08% of the area is classified as forests, in which there are five protected areas, consisting of 2 National Parks, 2 Wildlife Sanctuaries and 1 Plant Sanctuary, as shown in the Figure below. All these protected areas are located in the South Garo Hills, Ri-Bhoi, East Garo Hills and West Garo Hills districts. These protected areas are an abode to a diverse range of flora and fauna.

The whole of Meghalaya except for the Shillong Municipal area is covered under Schedule Six of the Constitution. This schedule provides for administration of tribal areas as autonomous areas and these areas are endowed with legislative, judicial executive and financial powers.

The population of Meghalaya as per the census in 2011 was 2,966,889. In Meghalaya State, the Scheduled Tribe population is the majority caste group. There are three main tribal groups in Meghalaya State: Garos, Khasis and Pnars (or Jaintias), and the Khasis, Jaintias and Garos are the main tribes, constituting 85.5% of the total population.

Landownership in Meghalaya state is predominantly private land, at approx. 96% of total, with the remaining 4% being governmental land.



(Source：Forest & Environment Department, Government of Meghalaya)

Figure 6-8 Map of Reserved Forests and Protected Areas of Meghalaya State

(2) Myntdu Leshka Hydropower Project-Stage II

(a) Location

Project components of Myntdu Leshka Hydropower Project-Stage II are located in Jantia Hills District, Meghalaya State. The nearest villages to the dam sites are Satpator and Trangblang on the right bank and Bataw on the left bank of the Myntdu River. In the powerhouse site, Kharkana village on the right bank is the nearest and the surge shaft is located in Amtra Village. The figure below shows a view of the area around the project site.

Amtra village

Bitter nuts (left) and crops of house yard (right)

Photo 6-4 View around Myntdu Leshka II Hydropower Project Site

(b) Potential Environmental Impacts caused by the Project

The main environmental and social impacts that may arise due to the Project are as per the Tables below:

Table 6-10 Main Potential Impacts on Environment due to Myntdu Leshka II Project

Natural Environment	
Protected Area	Project site does not fall under any Reserved Forest or Protected Area
Hydrology	Submergence area of the reservoir of 51 ha will lead to loss of the forest. Reduction of river flow from dam site to tailrace of power house may have some minor impact on aquatic ecology.
Ecosystem	Further survey will be required for potential impacts on flora and fauna; however, impacts may not be minor due to limited scale of submergence area. The secondary information of the existing study describes as follows: (Wild Flora) -The major vegetation type in the project area is lower mixed forest, which consists of deciduous forest, sub-tropical forests and Sal forests. Major species are Arjun, sal, Nakha, Oak, etc. (Wild Fauna) -Major faunal species in the project area are Clouded Leopard, Leopard cat, Rhesus Macaque, etc.
Social Environment	
Land Ownership and Main Use	Submergence area of 51 ha comprises mainly mixed forest. No private land or homesteads are likely to be acquired.
Involuntary Resettlement	Not required
Ethnic Minorities/ Indigenous Population	In terms of ethnicity, "Khasis" and "Jantias", major tribe of Meghalaya State, are living around the project site.
Use of River by Local People	No main use for drinking water, irrigation or livestock
Infrastructure, Cultural Heritage and Remains	No identified cultural heritage

(Source: "Interim Report on Survey and Investigations of Myntdu (Leshka) Hydro Electric Project Stage-II" (2009) and interview with MePGCL officers in charge of the project)

(3) Umngot Hydropower Project

(a) Location

The Umngot is one of the major southwardly flowing rivers of Meghalaya, originating at an altitude of 1840 m from the junction of Nongkrem road and NH-44, which is at a distance of 11 km from Shillong, situated in the Khasi Hills district of Meghalaya. The Umngot Hydropower Project is located near Siangkhanai village of the East Khasi Hills district. The catchment area and pondage lies in the districts of East Khasi hills and Jaintia hills.

Photo 6-5 River Basin and surrounding Vegetation of Umngot Dam Site (Dam-1)

(b) Potential Environmental Impacts caused by the Project

The main environmental and social impacts that may arise due to the Project are as per the Tables below:

Table 6-11 Main Potential Impacts on Environment due to Umngot Project

Natural Environment	
Protected Area	There is no reserve forest area in the project area and hence no National Parks or wild life sanctuaries are affected due to the project. Biosphere reserves and Bird Sanctuaries are also not in the project area.
Hydrology	Reduced water flow of 20 km in Umngot river from the dam site to the tailrace may affect the population of fish and the regular breeding or feeding cycle of migrated fish. Spotted snakehead (Channa punctatus), One-stripe spinyeel (Macrognatha aral), and Zig-zag eel (Mastacembelus armatus) are observed in the river.
Ecosystem	There are no Endangered flora or fauna species designated by IUCN and no rare species designated at a local level within the project area.
Social Environment	
Land Ownership and Main Use	The total area proposed for acquisition towards the submersion of private cultivated lands and other appurtenances is 420ha. The land area mainly comprises shrub land (15%), forest (64%) and water bodies (19%) besides arable land (2%). Some cultivated lands pertaining to some of the villages are likely to be affected. Land ownership of the forest lands, which occupy about 64% of the project area, are community and other lands owned by private individuals.
Involuntary Resettlement	The creation of storage by the construction of a huge dam 111 m high involves moderate submersion of land; 12 villages where there is only land are to be acquired and no houses are to be acquired.
Ethnic Minorities/ Indigenous population	This project site is occupied by aboriginal tribes called "Khasis".
Use of River by Local People	There are no uses of the river by local people as most of the project area falls in a deep gorge area with a steep slope. The water, after generating the required power, will be let 20 km downstream through a tunnel; thus, there will be no impact on the downstream water utilization.
Infrastructure, Cultural Heritage and Remains	There are no significant monuments, or places of archeological, historical or cultural importance in the project area There are, however, a number of falls lying in a stretch of about 20km between the proposed dam site and the power house site.

(Source: "Umngot Hydro Electric Project (3 x 80 MW) Meghalaya Detailed Project Report" (2010) and interview with MePGCL officers in charge of the project)

(4) Umngi Storage Development (for Nongkohlait Hydropower Project)

Development of Umngi Storage is the premise of the Nongkohlait Hydropower Project. Therefore, in terms of environmental impact, the component of Umngi storage development is examined in this section.

(a) Location

Umngi Storage site is located near the village of Laitmowsiang, East Khasi Hills District, Meghalaya State. A view of the site is shown in the Figure below.

Forestry and plants along the Umngi river

Agricultural field in the reservoir area of Umngi Storage

Photo 6-6 Vegetation and Agriculture Land in Umngi Storage Site

(b) Potential Environmental Impacts caused by the Project

The main environmental and social impacts that may arise due to the Project are as per the Tables below:

Table 6-12 Main Potential Impacts on Environment due to Umngi Storage Development

Natural Environment	
Protected Area	Project site does not fall in any Reserved Forest or Protected Area.
Hydrology	Submergence area of the reservoir of 495 ha will lead to loss of natural forest and agricultural field.
	Some minor impacts on fish and other aquatic life will occur due to reduced water flow; however, it is not expected to be serious. Snow trout, a migratory fish, can be present in the river.
Ecosystem	Only secondary forests are observed in intake dam and reservoir areas. Rare Species of wildlife and plants are not likely found inside the area. Primary data and information from the field survey is not available; however, the secondary information from the existing study is as follows: (Wild Flora) -Dense mixed forests of mainly pine (*pinus wallichiana*) are observed; however, density of forests in areas close to the settlements is degraded. (Wild Fauna) - Leopard Cat (*Felis bengalensis*), Rhesus Macque (*Macaca mulata*),etc.
Social Environment	
Land Ownership and Main Use	Submergence area of the reservoir of 475ha requires large scale land acquisition. - Ownership: Mainly private land - Main Use: Agriculture (rice field, vegetables), grazing, etc.

Involuntary Resettlement	Relocation of some homesteads may occur.
Ethnic Minorities/ Indigenous Population	In terms of ethnicity, "Khasis", one of the major tribes of Meghalaya State, are living around the project site.
Use of River by Local People	No main use for irrigation or livestock. A few fishing activities were observed during the site survey.
Infrastructure, Cultural Heritage and Remains	No identified cultural heritage

(Source: "Preliminary Feasibility Report 54 MW Umngi H.E. Project" (2004) and interview with MePGCL officers in charge of the project)

(5) Potential Site Area of Pumped-storage Hydropower Plant

The potential site area is located in the south west of Shillong, in the East Khasi Hills District, Meghalaya State. Primary data and information on the potential project site are not available and further detailed survey is required to identify precise issues and risks. From examination of a landscape photo of the potential site area, the general natural and social environment conditions are as follows:

(a) Upper dam area

The area does not fall under any reserved forest or protected area. It is a Flat and Mainly Grazing area. No settlements are observed nearby.

(b) Lower dam area

From the bottom of the valley is a steep slope covered with forest. No settlements are observed nearby.

6.4 Issues and Risks in Environmental and Social Considerations

As a result of preliminary analysis through a review of existing documents and the site visit in 6.3, the issues and risks for the candidate hydropower projects are summarized in the Table below.

Table 6-13 Issues and Risks for the Candidate Projects

Target Country	Project Title	Rating Score			Main Issues and Risks
		N	S	Total	
Bhutan	Kuri-I Hydropower Project	3	3	3	● Protected Area: Thrimshingla park and Biological Corridor is located near Project site; therefore, endangered/vulnerable mammal species may be observerd; however, not for breeding or main feeding activities in project site. ● Distance of the river with reduced flow is relatively long; thus, this may cause impact on acquatic ecology. ● Involuntary Resettlement of a few households may occur. ● Land acquisition of private land and relocation of existing small infrastrucure are necessary, since the reservoir area is adjacent to a village.
	Gamri I & II Hydropower Projects	1	3	2	● Protected Area: Part of the location of the project site is inside the core zone of Sakten Wild Sanctuary, where endangered/vulnerable fauna and flora species exist. ● Consideration for Indigenous People: Culture and lifestyle of Brokpa people in relation to project development should be paid attention to in order to mitigate/avoid negative impacts.
	Nyera Amari I&II Hydropower Projects	3	4	3.5	● Protected Area: Khaling Wildlife Sanctuary is located near Project site; thus, vulnerable avifauna "Rufous-necked Hornbill" is observed in project site. ● Distance of the river with reduced flow is relatively long; thus, this may cause impact on acquatic ecology.
India	Myntdu Leshka II Hydropower Project	4	4	4	● Relatively limited scale of land acquisition and potential impact on fauna and flora are not expected to be large-scale.
	Umngot Hydropower project	3	3	3	● Submergence area of the reservoir is large-scale, which requires acquisition of private land.
	Umngi Storage (for Nongkohlait Hydropower Project)	3	2	2.5	● Submergence area of the reservoir is large-scale, which requires acquisition of private land and maybe some homesteads.

N: Impact on Natural Environment S: Impact on Social Environment
Total is the average score of natural and social environment impact scores.

Note: For the purpose of first screening at this phase, scale of negative impact is mainly considered.
Rating Criteria for Natural Environment:
1: Serious Negative Impact (Unrecoverable Scientifically, International Standard)

2: Serious Negative Impact but it can be alleviated by mitigation measures (International Standard)
3: Negative Impact to some extent (Unrecoverable, Local Standard)
4: Negative Impact to some extent but it can be alleviated by mitigation measures
5: No negative impact

Rating Criteria for Social Environment:
1: Serious Negative Impact (Large-scale resettlement is required, and there are areas of ethnic minority/Indigenous people that require special consideration. Alternative land can only be compensated in a distant area)
2: Serious Negative Impact but it can be alleviated by mitigation measures (Large-scale resettlement is required. Alternative land can be compensated in neighborhood. Ethnic minority/Indigenous people live around the Project site)
3: Negative Impact to some extent (in case of either or both the following situations: 1) Relatively limited scale of resettlement and/or land acquisition are required, but alternative land can be compensated only in a distant area. 2) Ethnic minority/indigenous people exist in Project site and special consideration is necessary for them.)
4: Negative Impact to some extent but it can be alleviated by mitigation measures (Relatively limited scale of land acquisition. Alternative land can be compensated in neighborhood)
5: No negative impact

*Large-scale land is tentatively defined here as 100 ha and more

Chapter 7 Draft for Interconnection Project

7.1 Selection of Hydropower Development Candidate Sites

Chapter 4 confirms two areas, namely East Bhutan and the Indian State of Meghalaya, as the most prioritized areas for hydropower development for Bangladesh. In those two areas, the JICA Survey Team undertook fieldwork on specific potential hydropower development sites. The results of the fieldwork are shown in Chapter 5 for terrestrial and geological features and Chapter 6 for natural and social environmental features.

7.1.1 Evaluation Criteria Setting

The following table shows a set of evaluation criteria to score potential hydropower sites and select development candidate sites.

Table 7-1 Evaluation Criteria for Hydropower Development Candidate Sites

	Items to be evaluated	Evaluation Viewpoint	Weight
1	Preference of the Government of Bangladesh	Larger generation capacity is preferable	5
2	Economy of the potential site	Evaluated by unit construction cost (USD/MWh) based on computation of construction cost and annual generation volume	5
3	Required construction cost of dedicated transmission lines for energy evacuation	Unit transmission cost (USD/MWh) being calculated with construction cost estimate based on transmission line length and voltage level	2
4	Environmental issues	Evaluated on whether there is an existence of environmentally protected areas, endangered species or indigenous population nearby	4
5	Geological issues	Evaluated on whether there is a possibility of landslide during construction and sedimentation during operation	4
6	Issues for power export to Bangladesh	Evaluated by possibility of utilization of related transmission lines for power transmission to Bangladesh and energy output volume	3
7	Ease of construction and implementation	Status for construction access road, and availability of utilities/infrastructure such as electricity for construction	2
8	Operational flexibility	Evaluated by water storage capacity – the point is higher in the case of seasonal output adjustment	1
9	Project status	Evaluated by credibility of project feasibility based on progress of project preparation	1
10	Prospects for future JICA assistance	Evaluated on whether there is another sponsor for development funding and on total project cost (size)	3

(Source: JICA Survey Team)

Each of the potential sites is evaluated and scored alongside each of the above evaluation criteria with the highest score being five points. However, any potential sites with their scores in 4) Environmental issues and 5) Geological issues being two points or below will not be selected as candidates due to serious risk exposure, even if the total scores are relatively larger than others.

7.1.2 Comparison and Screening of Hydropower Development Sites alongside the Evaluation Criteria

(1) East Bhutan

In the eastern part of Bhutan, there are three sites and five power plants, Kuri-I (formerly known as Rotpashong), Gamri-I, Gamri-II, Nyera Amari-I and Nyera Amari-II for which pre-feasibility studies (Pre-F/Ss) have been conducted. The following table summarizes the techno-economic comparison among these five proposed power plants.

Table 7-2 Hydropower Development Potential Candidate Sites in East Bhutan

	Kuri-I	Gamri I	Gamri II	Nyera Amari I	Nyera Amari II
Installed capacity Unit size × Units	1,230MW (205MW×6)	45MW (22.5MW×2)	85MW (42.5MW×2)	125MW (62.5MW×2)	317MW (105.67MW×3)
Design annual energy	5,265GWh	215.69GWh	399.90GWh	614GWh	1,556GWh
Reservoir volume	10.4 million m^3	0.11 million m^3	0.22 million m^3	0.62 million m^3	0.2 million m^3
Construction cost (million)	USD 1,686.5	BTN 3,620 (USD 56.6)	BTN 5,587 (USD 87.3)	BTN 12,490 (USD 195.2)	BTN 22,291 (USD 348.4)
Unit construction cost per annual energy	USD 320/MWh	USD 262/MWh	USD 218/MWh	USD 318/MWh	USD 224/MWh
Length of T/L	400kV 140km	132kV 8km	132kV 36km	220kV 16km	220kV 66km
Construction cost of T/L	USD 70 million	USD 11 million		USD 22 million	
Unit construction cost	USD 13.3/MWh	USD 17.9/MWh		USD 10.1/MWh	

(Source: JICA Survey Team)

The following observations have been made.

- Kuri-I has the most expensive unit construction cost at USD 320/MWh
- Looking at design annual energy (GWh), each site expects between 4,300 and 5,000 hours in operation annually and it is confirmed that the maximum output is rated rationally against estimated river flow
- As for the size of reservoirs, all the sites have very limited volume with water resource requirement for three to five hours of peaking operation, making all the potential sites pure run-of-the-river power plants that generate energy solely based on water flow from upstream

Table 7-3 Evaluation Results for Potential Hydropower Sites in East Bhutan

	Evaluated items	Weight	Kuri-I	Gamri I, II	Nyera Amari I, II	Notes
1	Preference of the Government of Bangladesh	5	5	1	3	GOB prefers potential sites with larger output capacity
2	Economy of the potential site	5	3	4	4	Kuri-I has slightly inferior unit construction cost per MWh
3	Required construction cost of dedicated transmission lines for energy evacuation	2	4	4	4	No significant differences among potentials
4	Environmental issues	4	3	2	3.5	Gamri-I and –II are located within a national park
5	Geological issues	4	4	3	2	Based on the geological expert's evaluation
6	Issues for power export to Bangladesh	3	3	2	3	Gamri-I &-II to utilize T/L shared with Kholongchhu HPP
7	Ease of construction and implementation	2	4	2	3	Kuri-I to be constructed adjacent to an existing road and required infrastructure around the site is well prepared
8	Operational flexibility	1	2	2	2	While daily operation/ adjustment is possible during the dry season, seasonal operation is impossible in all the potentials
9	Project status	1	4	3	3	Pre-FSs have been completed for all. FS is underway only for Kuri-I
10	Prospects for future JICA assistance	3	2	4	3	Taking account of the total project cost, Gamri-I & -II seem to be most comfortable for JICA
	Total (weighted)		105	80	94	

(Source: JICA Survey Team)

Kuri-I records the highest total score, followed by Nyera Amari and, in turn, Gamri. Kuri-I fits the expectation of the GOB in terms of its larger scale of development. Because there seem to be no significant impediments to development, the JICA Survey Team selects Kuri-I as the most prioritized development candidate.

(2) The Indian State of Meghalaya

(a) Conventional hydropower plant

In the State of Meghalaya, there are three potential sites for conventional hydropower development with sizable capacity and considerable progress in project preparation, namely Myntdu Leshka-II, Umngot and Nongkohlait. The following table summarizes the techno-economic comparison among the three proposed power plants.

Table 7-4 Hydropower Development Potential Candidate Sites in Meghalaya

	Myntdu Leshka II	Umngot	Nongkohlait
Installed capacity Unit size × Units	280MW (70MW x 4)	240MW (80MW x 3)	120MW
Design annual energy	895.29 GWh	838.73 GWh	379.34 GWh
Reservoir volume	n.a.	41.34 million m^3	0.46 million m^3
Construction cost	INR 29,400 million (USD 460.5 million)	INR 15,646 million (USD 245 million)	INR 3,262 million*1) (USD 51.1 million)
Construction cost per annual energy	USD 514/MWh	USD 292/MWh	USD 135/MWh*1)
Length of T/L	220kV 98km	220kV 111km	220kV 95km
Construction cost of T/L	USD 27 million	USD 31 million	USD 27 million
Unit construction cost	USD 30.2/MWh	USD 37.0/MWh	USD 71.2/MWh

*1): Data from Pre-F/S in 2004

(Source: JICA Survey Team)

The following observations have been made.

- Looking at design annual energy (GWh), each site expects between 3,200 and 3,500 hours of operation annually and it is confirmed that the maximum output is rated to be relatively larger against estimated river flow
- Myntdu Leshka-II has a unit construction cost of USD 514/MWh, being a little more expensive than any other site
- Umngot has a relatively larger reservoir volume with a water resource requirement of 330 hours at its peaking operation
- Nongkholait's construction cost comes from one in the pre-F/S, conducted in 2004, so the current price is expected to be much higher.

Table 7-5 Evaluation Results for Potential Hydropower Sites in Meghalaya

	Evaluated items	Weight	Myntdu Leshka II	Umngot	Nongkohlait	Notes
1	Preference of the Government of Bangladesh	5	3	3	2	GOB prefers potential sites with larger output capacity
2	Economy of the potential site	5	2	3	4	ML-II has slightly inferior unit construction cost per MWh
3	Required construction cost of dedicated transmission lines for energy evacuation	2	4	3	2	No significant differences in transmission lengths
4	Environmental issues	4	4	3	2.5	Umngot and Umngi Storage (upstream of Nongkohlait) has a larger submersion area
5	Geological issues	4	2	4	4	Myntdu Leshka II is located near a seismic fault
6	Issues for power export to Bangladesh	3	4	4	4	Each HPP to be directly connected with the Bangladeshi grid
7	Ease of construction and implementation	2	4	3	3	New access roads required for Umngot and Nongkohlait
8	Operational flexibility	1	2	4	2	With its reservoir, Umngot can be operated seasonally
9	Project status	1	4	4	3	Pre-FS has been done for all the sites
10	Prospects for future JICA assistance	3	4	4	4	The size of the projects is taken into consideration
	Total (weighted)		95	102	95	

(Source: JICA Survey Team)

There are only small differences among the total scores of all three potential sites. Myntdu Leshka-II is not advantageous because a seismic fault has been confirmed near the site, in addition to its extremely high construction cost. Nongkohlait is one of the Umngi cascade hydropower developments and thus its economy solely depends on regulated water flow by Umngi Storage HPP with a reservoir. However, Umngi HPP development requires a considerable amount of compensation for the submersion of a large number of quality rice paddy fields, eroding the economy of the project. Therefore, development activities have stalled over the years. Umngot has no critical issues. After one of the IPP developers had undertaken a technical survey for investment, the developer gave up for some reason. Then, MePGCL proceeded with the development of the site.

As a result of the above-mentioned issues, it is thought that Umngot is the most promising site for conventional hydropower development in Meghalaya state.

(b) Pumped storage power plant (PSPP)

The southern part of Meghalaya state has very steep geographical features, and has a lot of appropriate site of PSPP. Moreover, it is assumed that the optimal scale of the power plant will be 1,500MW class because it can expect a high head that exceeds 600m. However, a concrete site survey has not been done for the PSPP of Meghalaya state up to now.

Based on the above-mentioned geographical features, many candidate sites with a high head by a shorter waterway length, compared with other PSPP sites across the world, exist. Moreover, because it is undeveloped now, it is thought that an economically excellent site can be selected from among the candidate sites. Due to the geographical features of this area, no access road currently exists because the candidate area for the lower reservoir will be a deep valley section of the river, though the area that is a candidate for the upper reservoir is in an easily-accessible plain.

Though a concrete site cannot be specified, an evaluation of the development candidate site executed with the items similar to conventional hydropower is as follows. A very high score for the pumped storage hydropower plant can be expected compared with conventional hydropower.

Table 7-6 Evaluation Results for Potential PSPP Sites in Meghalaya

	Evaluated items	Weight	PSPP	Notes
1	Preference of the Government of Bangladesh	5	5	GOB prefers potential sites with larger output capacity
2	Economy of the potential site	5	4	Comparatively cheap from the relation between the head and the waterway length.
3	Required construction cost of dedicated transmission lines for energy evacuation	2	4	Transmission distance is almost the same as the conventional hydropower site.
4	Environmental issues	4	4	A site without serious issues can be selected.
5	Geological issues	4	4	A site without serious issues can be selected.
6	Issues for power export to Bangladesh	3	4	Direct connection to Bangladesh system
7	Ease of construction and implementation	2	3	Construction of access road is necessary at the construction of lower reservoir.
8	Operational flexibility	1	5	PSPP can carry out frequency control operation
9	Project status	1	1	Study not yet started
10	Prospects for future JICA assistance	3	3	The size of the projects taken into considerations
	Total (weighted)		118	

(Source: JICA Survey Team)

(c) Overall evaluation

Because the supply capacity is insufficient in Meghalaya state and the states in its vicinity, it is necessary to supply part of the electric power from the hydropower that will be developed in Meghalaya state to these regions.

When the hydropower of Meghalaya state is developed, it will be difficult for Bangladesh to import the whole quantity of power in order to transmit part of it to Meghalaya state and states in the vicinity. In short, because Bangladesh can only receive almost half of the amount of development, the development of a larger scale site is more preferable. Conventional hydropower is a development scale of about 200MW, so the amount of receipt in Bangladesh is only about 100MW. On the other hand, because the PSPP is a development scale of 1,500MW class, almost 1,000MW can be expected for receipt in Bangladesh.

Based on the above-mentioned view, the JICA Survey Team selects PSPP as a development priority site in Meghalaya state.

7.2 Kuri I Hydropower Project

7.2.1 Hydro Power Plant

(1) Outline of the Project

Project features of Kuri-I project are indicated in Table 7-7.

Table 7-7 Project Features of Kuri-I Project

Items		Unit	Feature	Remarks
Name of River		-	Kurichhu River	
Location		-	from Autsho to Kurizampa in Mongar Dzongkhag	
Coordinates	Dam Intake	-	27°23'27"N, 91°11'54"E	
	Powerhouse	-	27°16'32"N, 91°10'49"E	
Generation Plan	Catchment Area	km^2	8,808	
	Reservoir Volume	Million m^3	10.4	
	Intake Water Level	EL.m	798.5	
	Tailrace Water Level	EL.m	545.0	
	Gross Head	m	268	
	Plant Discharge	m^3/s	540	
	Installed Capacity	MW	1230	205MW x 6
	Annual Power Generation	GWh	5,265	
	Plant Factor	%	49.0	
Civil Structures	Dam Height	m	65	Concrete gravity
	Headrace Length	km	10.5	TBM method
	Type of Powerhouse	-	Underground	
Electric Mechanical Equip.	Type of Turbine	-	Francis	6 units
	Generator Capacity	MVA	241	
	Transmission Line	km	33.9	400kV
Development Cost		Million US$	1,686.5	
Unit Construction Cost	Const. Cost per kW	US$/kW	1,371	
	Const. Cost per kWh	Nu/kWh	2.57	
FIRR		%	10.1	
EIRR		%	12.2	

(Source: Pre-Feasibility Report)

As an indication of the hydropower facilities' layout, if L/H (crest length of dam divided by gross head) is less than 50, the project plan will be feasible. In the Pre-F/S report for the Kuri-I project, L is 345 (m) and H is 268 (m); therefore, L/H for the project is 1.28 and judged to be feasible.

Regarding the construction method for the headrace tunnel, it is planned to be excavated by Tunnel Boring Machine (TBM). Although there are risks such as collapse of the tunnel and machine constraint by ground lateral pressure in the case of soft layers appearing, it is possible to avoid machine excavation risks by preparation of countermeasures and a thorough understanding of the ground characteristics of the proposed tunnel site in advance, via an additional boring survey. Therefore, the JICA Survey Team has agreed to apply TBM method to headrace tunnel excavation in this project. However, at the detailed design stage, excavation method is an essential study point.

According to the Pre-F/S report, the Powerhouse is set as underground type, but ground type has not been compared with underground type and the possibility of ground type is not mentioned.

Based on a site survey of topographical and geological conditions in the project site, there is a flat area where the powerhouse can be arranged at the Shongarchhu riverside and the slope of Shongarchhu riverside is a gradual slope against Kurichhu riverside, so construction work can be facilitated. Therefore, the JICA Survey Team considered that a ground or semi-underground type powerhouse would be possible, so placement position of the powerhouse is also an essential study point at the detailed design stage.

(2) Construction Cost

Construction costs for the Kuri-I project in Pre-F/S are indicated in Table 7-8.

Table 7-8 Summary of Construction Cost

	Item	Total Cost (1,000 US$)	Remark
1	Infrastructure	21,699	
2	Reservoir	716	
3	Dam	176,124	Concrete gravity dam
4	Intake	47,785	
5	Settling Basin	156,415	
6	Waterway	531,123	Excavated by TBM
7	Transfer Tunnel	53,209	
8	Power station	90,111	Underground type
9	Power station Equipment	419,621	Francis turbine, 6 units
10	Transmission, Local Power Supply	34,379	400kV, 33.9km
11	Environmental Cost	2,000	
12	Engineering, Supervision, and Administration	153,318	(Item 1-11)*10%
	Total Project Cost	1,686,500	

(Source: Pre-Feasibility Report)

The unit prices for estimating construction costs in the Pre-F/S are based on international projects' performance, and these prices are adjusted by taking into account the construction cost of the under-construction projects in Bhutan.

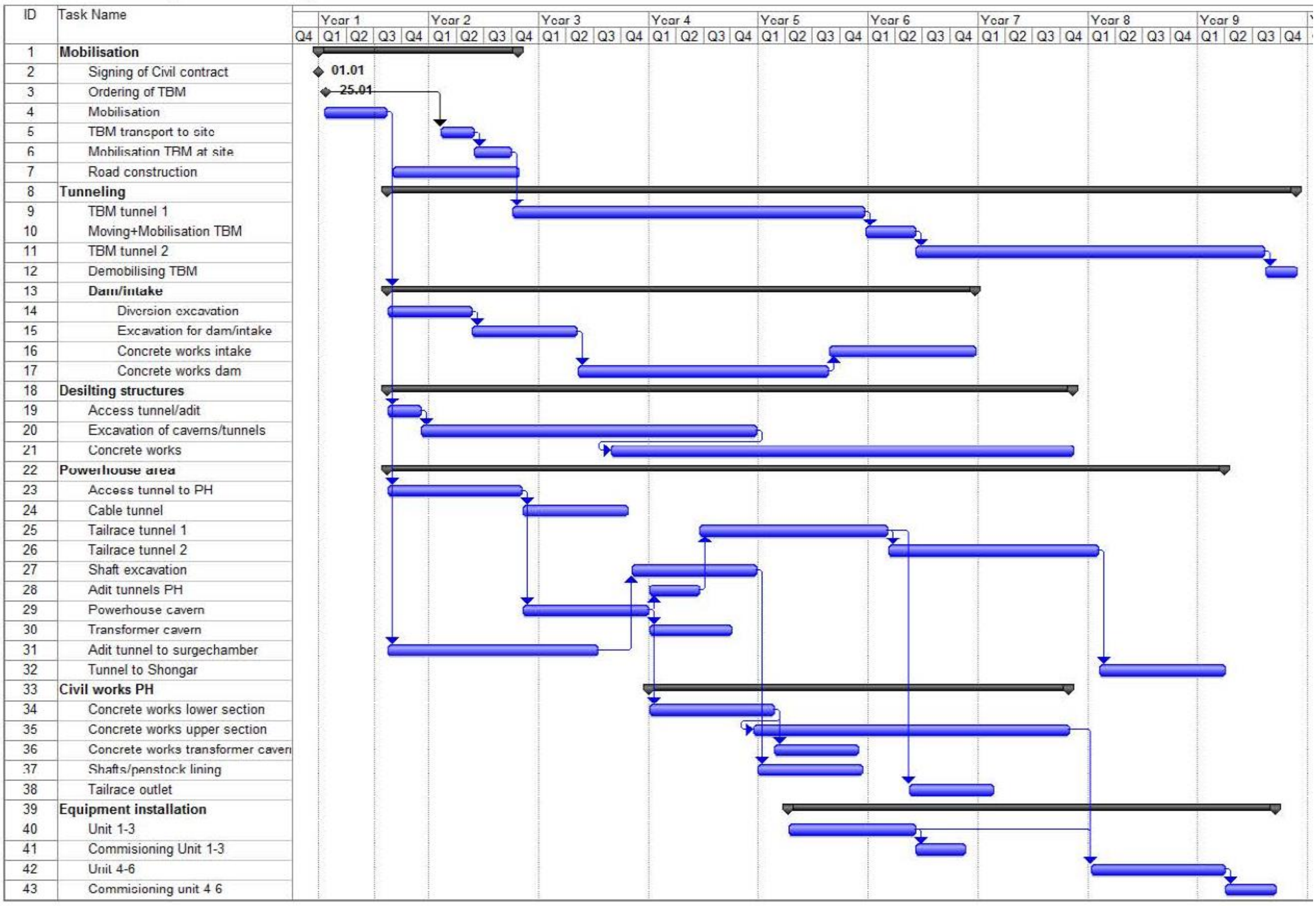
The unit price of headrace tunnel excavation by TBM method is US$14,400/m, lower than Japanese standards for estimation. However, the unit price is reasonable because it is an accumulated value of past international projects.

Underground type is adopted as the powerhouse structure and the cost is also reasonable. However, if ground or semi-underground type is possible for the project site, the construction cost will be reduced.

(3) Construction Planning

Implementation schedule for the Kuri-I project in Pre-F/S is indicated in Table 7-9.

Table 7-9 Implementation Schedule



(Source: Pre-Feasibility Report)

The critical work for whole schedule of the project is the Headrace Tunnel work. It takes 9 years including the preparatory work period.

Two headrace tunnels extending 10.5km in length will be excavated by TBM method, taking 36 months for each, and the average progress of excavation is approximately 300 meters per month. Penetration rate of TBM method is 400 meters per month in Europe and 700 meters per month in the USA, but at the same time, it is only 220 meters per month in Japan. Long-distance excavation in homogenous and stable layers is often encountered in overseas projects, but passing through the fracture zone in complex geological layers is often encountered in Japan. Therefore, penetration rate in Japan is lower. Progress of the Headrace Tunnel work should be reasonable if the ground layers in the project site are good stable layers. However, if the fracture zone appears in the project site and the penetration rate is the same as in Japanese project cases, the construction period for the Headrace Tunnel work will be extended to 48 months. Penetration rate by TBM method is an essential study point at the detailed design stage.

7.2.2 Electromechanical Facilities

(1) Main electromechanical features

In the pre-feasibility study for the Kuri I project, the main electromechanical features are shown in Table 7-10.

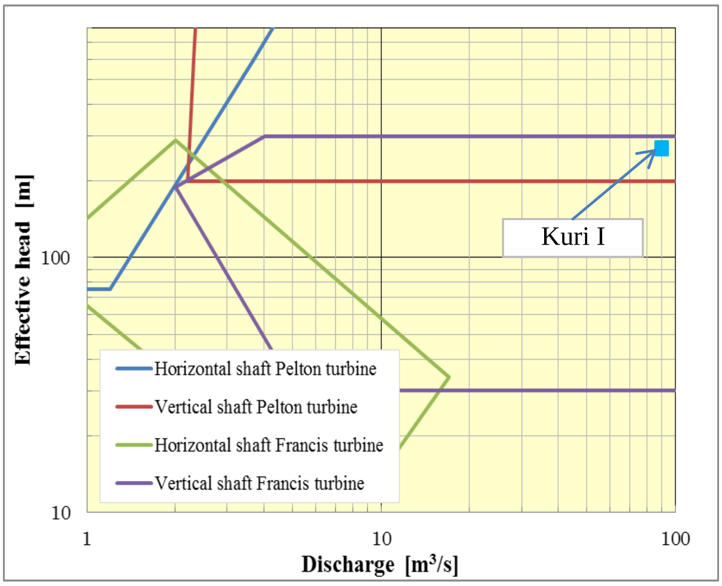
Table 7-10 Main Electromechanical Features of Turbines and Generators

Item		Feature
Turbine	Type	Vertical shaft Francis turbine
	Number of units	6
	Design net head	268 m
	Rated discharge per turbine	90 m^3/s
	Synchronous speed	214 min^{-1}
	Runner submergence	-5 m
Generator	Nominal effective power	205 MW
	Rated capacity	241MW
	Power factor	0.85
	Frequency	50 Hz

(Source: Pre-Feasibility Report)

(2) Selection of turbine type

A selection chart of turbine type is shown in Figure 7-1.



(Source: JICA Survey Team)

Figure 7-1 Selection Chart of Turbine Type

The Features of the Kuri I project are located in the areas of vertical shaft Francis turbine and vertical shaft Pelton turbine on this chart. If vertical Pelton turbine is selected, the turbine will have many nozzles because discharge for one unit will be high. As a result, the structure of the turbine would be complicated. Therefore, it is correct that a vertical Francis turbine was selected.

(3) Synchronous speed

Specific speed is defined as the following formula.

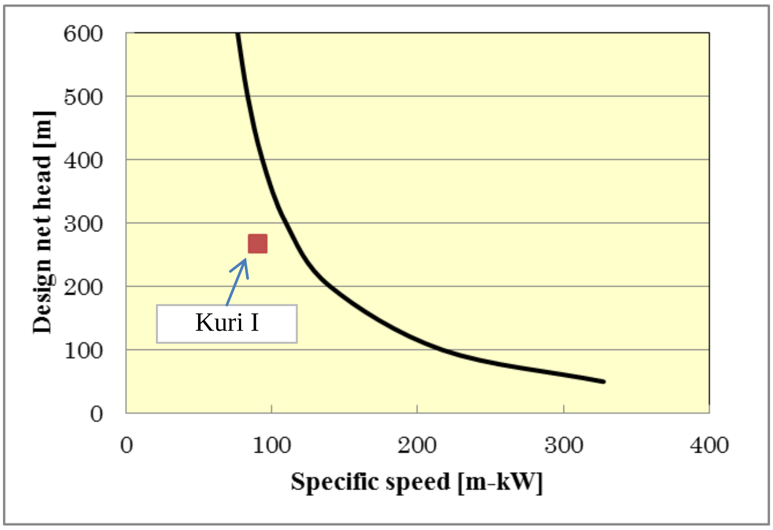
$$n_s = n \cdot \frac{\sqrt{P}}{H_t^{5/4}} = 214 \cdot \frac{\sqrt{210{,}000}}{268^{5/4}} = 90.4\,(\text{m - kW})$$

where, n_s: Specific speed (m-kW)
n : Synchronous speed (min^{-1})
P : Rated turbine output (210,000kW = 205,000 / 0.975)
H_t: design net head (m).

According to JEC 4001-2006 (Japanese Electromechanical Committee), the following formula is applied to calculate the limit of specific speed for Francis turbine.

$$n_s \le \frac{23{,}000}{H_t + 30} + 40.$$

The limit of specific speed for Francis turbine is shown in Figure 7-2.



(Source: JICA Survey Team)

Figure 7-2 Limit of Specific Speed for Francis Turbine

The specific speed of turbine for the Kuri I project is located at the lower left of the limit line. Because the specific speed is smaller than the limit, the synchronous speed of turbine for the Kuri I project is adequate.

(4) Suction head

According to the Guidebook of Hydropower Generation (New Energy Foundation), the following formula is applied to calculate suction head.

$$H_s = 9.7 - 0.048 \cdot \left(\frac{n_s}{100}\right)^{1.5} \cdot H_{max}$$

where, H_s : Suction head (m)
n_s : Specific speed (m-kW)
H_{max}: Maximum net head (m).

The maximum net head of the Kuri I project is calculated as the following formula.

$$H_{max} = HWL - H_{OUT} = 825 - 545 = 280\,(m)$$

where, HWL: Full supply level of the reservoir = 825 (m)
H_{OUT} : Elevation of tailrace outlet sill = 545 (m).

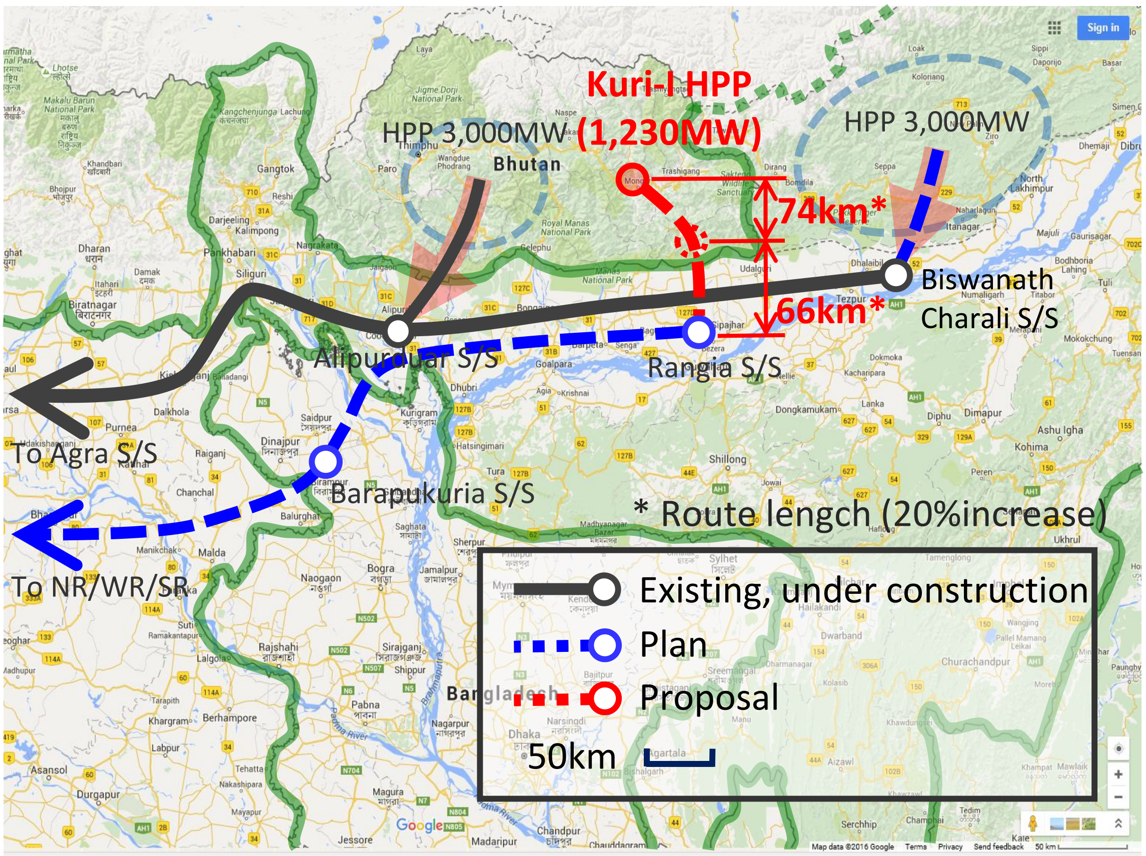
Thus, the suction head required for the turbine is estimated as follows.

$$H_s = 9.7 - 0.048 \cdot \left(\frac{90.4}{100}\right)^{1.5} \cdot 280 = -1.85\,(m)$$

The runner submergence of the pre-feasibility is slightly deeper than the estimated suction head. The suction head will be studied at the next stage.

7.2.3 Transmission Line Development Plan

The power evacuation plan from Kuri I HPP to Bangladesh is illustrated in the following figure.



(Source: JICA Survey Team)

Figure 7-3 Power Evacuation Plan for Kuri I HPP

A 400kV double-circuit transmission line with a length of 140km, from Kuri I via Nyera Amari P/S to Rangia S/S in the State of Assam, will be constructed. The construction cost for the section is estimated at approximately JPY 10 billion. From Rangia S/S to Barapukuria S/S, the receiving point in Bangladesh, the proposed ±800kV HVDC interconnection line (Case 2) will be utilized. The biggest issue here is the construction of the ±800kV HVDC line. India envisages that this interconnection line will primarily evacuate energy out of the hydropower in Bhutan and the State of Arunachal Pradesh to the huge load centers in North, West and Central India.

Currently, in the region, construction of the ±800kV HVDC transmission line colored black in the above figure is underway, and its commissioning is expected in 2016. This HVDC line is designed to receive 3,000 MW at Biswanath S/S from hydropower plants in Arunachal Pradesh and receive another 3,000MW at Alipurduar S/S from hydropower plants in Bhutan, then to evacuate the combined 6,000MW more than 1,000km away to Agra S/S near Delhi.

Regarding hydropower in Bhutan, the summation of Punatsangchhu-I (1,200MW), Punatsangchhu-II (1,020MW) and Mangdechhu (720MW), all under construction, reaches almost 3,000MW. On the other hand, in Arunachal Pradesh there are three development candidate sites with a total capacity of 1,710MW in the 12th Five Year Plan (FYP) (2016-17) and there are 12 sites with a total capacity of 7,550MW in the 13th FYP 2021-22 already identified. However, development of almost all the candidate sites has stagnated. For instance, Lower Subansiri (2,000MW) started its construction in 2005, but has faced harsh protests from the population nearby and construction has stopped for the time being.

Unless hydropower development gets on the right track in the State of Arunachal Pradesh, coming closer to the aggregated capacity of 3,000MW, India will hardly recognize the need for the additional ±800kV HVDC transmission route (blue dotted line in the above figure) out of Rangia S/S to the West of India via Barapukuria S/S (Bangladesh). Therefore, construction timing for the blue dotted route will largely hinge on future hydropower development in Arunachal Pradesh and it is expected that the line will not be able to be commissioned in 2022 as scheduled.

Before the Indian needs are known, it is technically possible to proceed with the construction of the section from Rangia S/S to Barapukuria S/S only. However, it is likely that India will not approve the plan for partial commissioning. If India does approve the plan, Bangladesh has to mobilize most of the funds for construction (with an estimated budget of JPY 60 billion) because there is no reason for India to share in the investment cost at that moment.

7.2.4 Issues and Risks

(1) Environmental Considerations

The following are the main points regarding environmental considerations for mitigation measures or the environmental management plan.

- Protected Area: Thrimshingla park and Biological Corridor is located near the Project site; therefore, endangered/vulnerable mammal species may be observed.
- Distance of the river with reduced flow is relatively long; thus, this may cause impact on aquatic ecology.
- Involuntary Resettlement of a few households may occur.
- Land acquisition of private land and relocation of existing small infrastrucure are necessary, since the reservoir area is adjacent to a village.

(2) Hydro Power

Issues and risks of hydro power facility design are the validity of TBM method and placement position of the powerhouse.

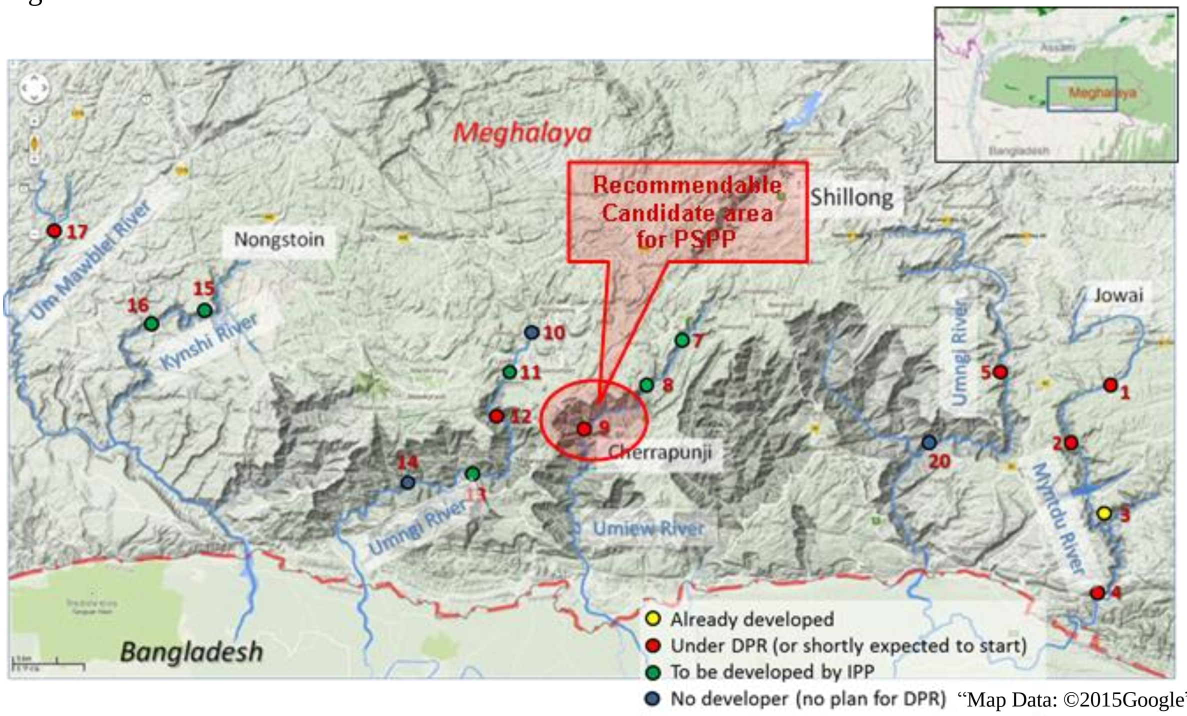
Regarding the introduction of TBM method, whether the method will be possible or not is determined by the expected geological conditions; the schedule plan will then be set up during the following detailed design stage. If TBM is not adopted as the tunnel excavation method, an alternative plan should be proposed and rescheduling will be necessary.

Rather than underground type as the only powerhouse option, the possibility of ground type or semi-underground type powerhouse should be considered to reduce construction cost.

7.3 Meghalaya Pumped Storage Hydropower Project

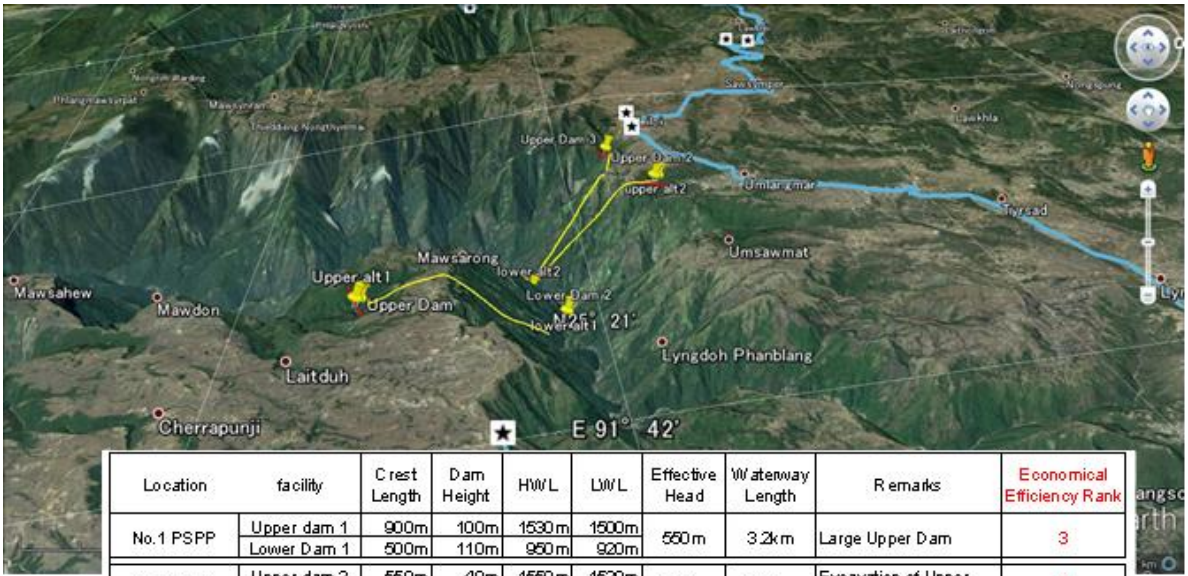
7.3.1 Pumped Hydro Power Plant

The potential site for the Pumped Storage Power Plant in Meghalaya is indicated in Figure 7-4 and Figure 7-5.



"Map Data: ©2015Google"
(Source:JICA Survey Team)

Figure 7-4 Potential Sites in Meghalaya



Location	facility	Crest Length	Dam Height	HWL	LWL	Effective Head	Waterway Length	Remarks	Economical Efficiency Rank
No.1 PSPP	Upper dam 1 Lower Dam 1	900m 500m	100m 110m	1530m 950m	1500m 920m	550m	3.2km	Large Upper Dam	3
No.2 PSPP	Upper dam 2 Lower Dam 2	550m 300m	40m 140m	1550m 830m	1520m 800m	690m	3.2km	Excavation of Upper pond is Needed	2
No.3 PSPP	Upper dam 3 Lower Dam 2	450m 300m	100m 140m	1500m 830m	1470m 800m	640m	4.1km	Kannagawa Class	1

"Image©2015DegitalGlobe, Image©2015CNES/Astrium, Image Landsat©2015Google"
(Source: JICA Survey Team)

Figure 7-5 Three Candidate Sites for PSPP in Meghalaya

Topography near the Bangladesh border in Meghalaya is mainly composed of flat plateaus and steep valleys, and it is very suitable for a Pumped Storage Power Plant. Depending on the need for the Pumped Storage Power Plant in India, 1,000 MW class powerhouses can be sufficiently developed and, while planning to secure the peak supply capacity in Bangladesh, it is possible to improve the electric power quality in Bangladesh.

The JICA Survey Team has conducted site surveys of candidate pumped storage power plant sites, and the three potential sites in Figure 7-5 are proposed as suitable sites for a pumped storage power plant site in Meghalaya. However, this proposal is based on visiting and watching from the road on the plateau and desk study.

7.3.2 Electromechanical facilities

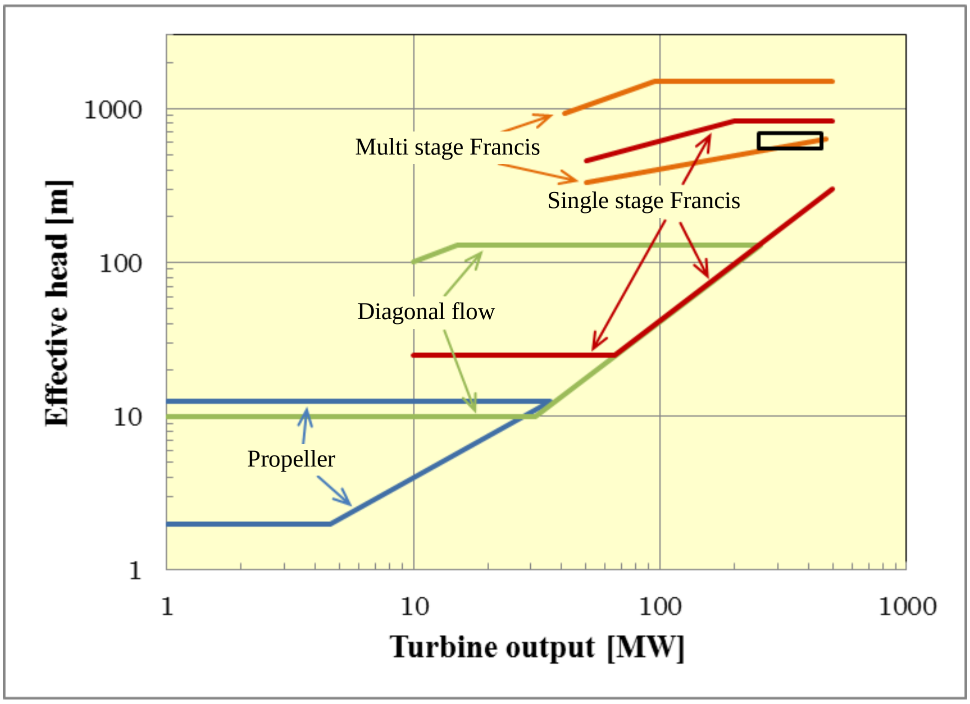
(1) Selection of pump-turbine type

Three sites in Meghalaya were selected for pumped storage power plants. Their design net head is shown in Table 7-11. A selection chart of pump-turbine types is shown in Figure 7-6.

Table 7-11 Design Net Head of Candidate Sites

Site	Design net head	Remarks
No.1 PSPP	550 m	
No.2 PSPP	690 m	
No.3 PSPP	640 m	Kannagawa PSPP class

(Source: JICA Survey Team)



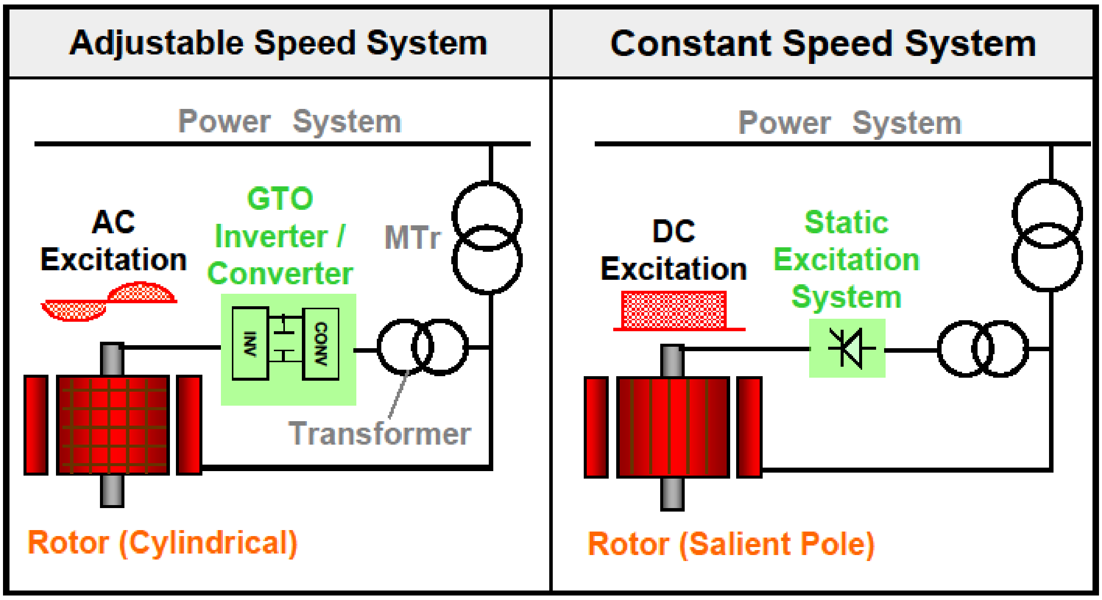
(Source: JICA Survey Team)

Figure 7-6 Selection Chart of Pump-Turbine Type

When the rated power output of a pump-turbine is changed from 250MW to 450MW, the design net head of their sites is located in the black rectangle on the chart. The pump-turbines of the three sites are included in both areas of a single-stage Francis pump-turbine and multi-stage Francis pump-turbine. However, the mechanism of a multi-stage pump-turbine is complicated, so it is correct that single-stage pump-turbines are selected.

(2) Adjustable speed pumped storage power system

The main feature of this system is control of the rotating speed of the rotor during generating and pumping operations in line with adjusting slip with stator by exciting the cylindrical rotor's three-winding with variable-frequency three-phase AC.

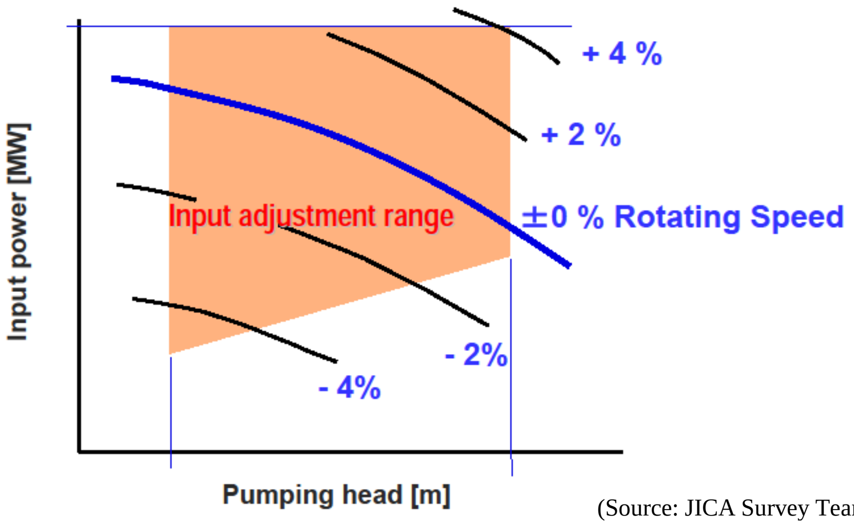


(Source: JICA Survey Team)

Figure 7-7 Configuration of Adjustable Speed System

The merits of using this technology are as follows:

- Input power to motor during pumping operation can be adjusted because axial input power changes in proportion to the cube of the rotating speed of the rotor, which can be adjusted within a certain range. As a result of this, frequency adjustment capacity of the power system during low demand at night is expanded.



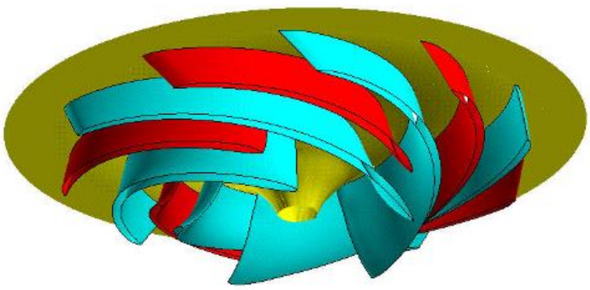
(Source: JICA Survey Team)

Figure 7-8 Input Adjustment Range during Pumping Operation

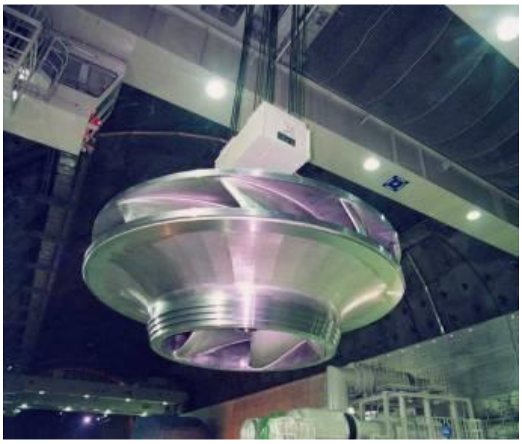
- High-efficiency operation during generating operation can be performed by setting rotating speed to the most efficient point according to head and discharge, and consequently output adjustable range; in other words, frequency adjustment capacity during generating operation in the daytime is expanded by suppressing turbine oscillation and cavitation during low-head and low-load operation.

(3) Splitter runner

A splitter runner has some main blades and some splitter blades that are shorter than the main blades. The structure of the splitter runner is shown in Figure 7-9.



Blue: Main blade (Long blade)
Red: Splitter blade (Short blade)



(Source: JICA Survey Team)

Figure 7-9 Structure of Splitter Runner

The splitter runner has more blades than a conventional runner to regulate the flow in the runner. However, the splitter runner has enough flow channels for the outlet of the runner.
The splitter runner has some advantages in comparison with a conventional runner. The advantages of the splitter runner are shown in Table 7-12.

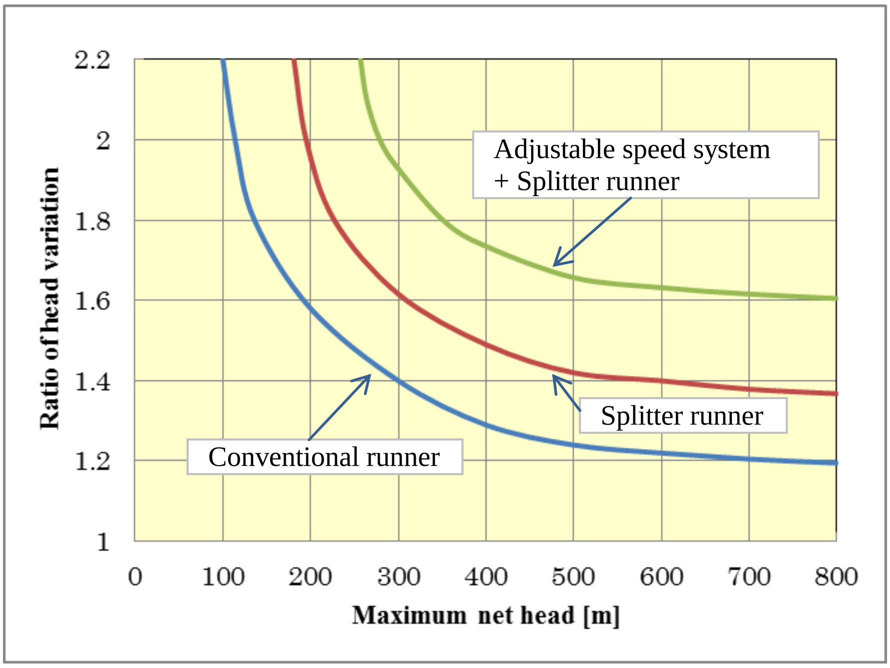
Table 7-12 Advantages of Splitter Runner

Item		Conventional runner	Splitter runner
Improvement in efficiency	Turbine operation (at rated output) (at 50 % output)	 85.3 % 81.5 %	 89.2 % 84.6 %
	pumping operation (at minimum pumping head)	88.0 %	91.8 %
Expansion of turbine operation range		50 ~ 100 %	40 ~ 100 %
Reduction in pressure fluctuation	at inlet of runner (at 50 % output)	7.0 %	4.7 %
Improvement in reliability of runner	Stress fluctuation of runner	11.8MPa	8.9MPa
Improvement in ratio of head variation*	(at rated net head)	1.21	1.37

*Ratio of head variation: (Maximum pumping head) / (Minimum turbine head)

In the case of a large ratio of head variation, if a vertex doesn't occur on the intake, the reservoir can have a deeper usable water depth than for a small ratio of head variation. As a result, the height of the dam will become lower.

For the ratio of head variation, the difference of the splitter runner and the conventional runner is shown in Figure 7-10.



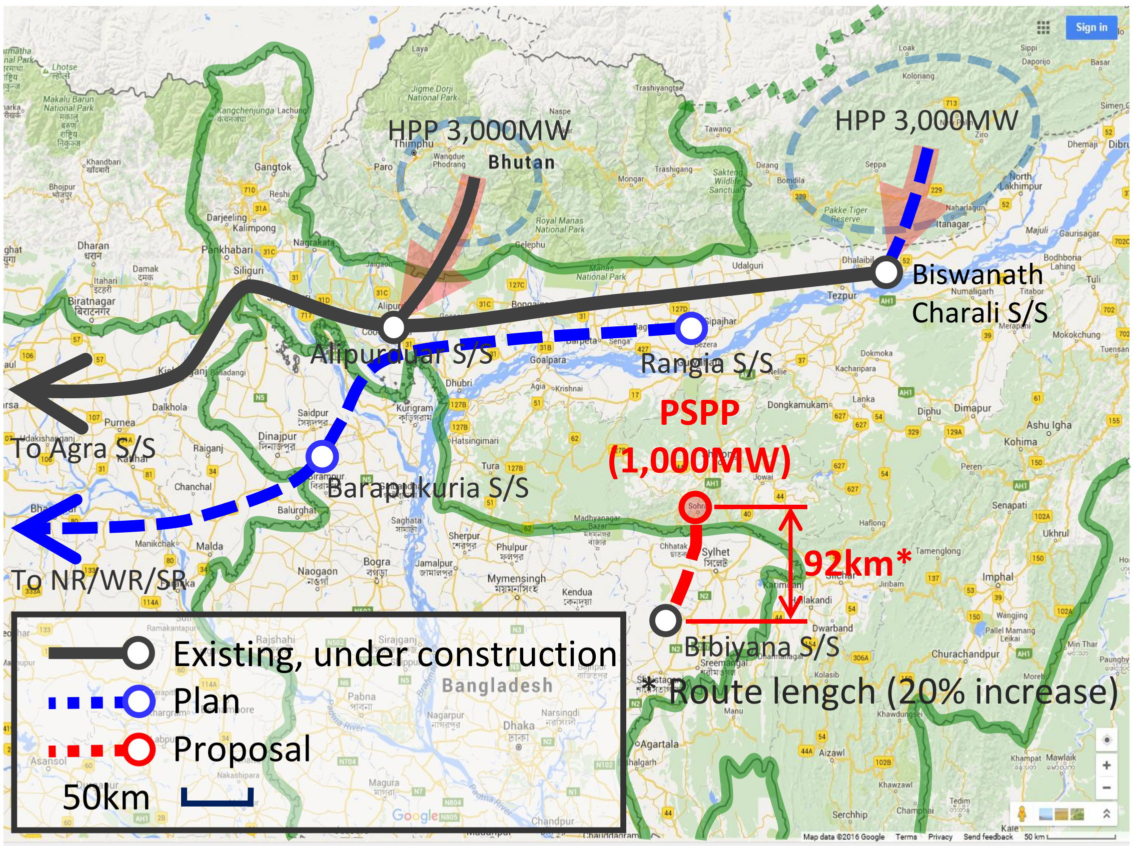
(Source: JICA Survey Team)

Figure 7-10 Difference of Ratio of Head Variation

When the splitter runner and the adjustable speed system are put together, the ratio of head variation becomes larger.

7.3.3 Transmission Line Development Plan

The power evacuation plan from PSHP to Bangladesh is illustrated in the following figure. A 400kV double-circuit transmission line with a length of 90km from the power plant to Bibiyana S/S in Bangladesh will be constructed. The construction cost is estimated at approximately JPY 6 billion. The line is linked to a 400kV double-circuit transmission line between Bibiyana and Kaliakoir substations, which are under construction. The contractor for the 400kV Bibiyana–Kaliakoir is GS Engineering & Construction Corp., South Korea, and the line will be commissioned in 2017.
If the line is connected to the India system, it is an option to extend it to Killing substation in India by constructing an additional 100 km transmission line in a northerly direction.



(Source: JICA Survey Team)

Figure 7-11 Power Evacuation Plan for PSPP in Meghalaya State

7.3.4 Issues and Risks

(1) Environmental Considerations

An inventory of forestry species and land ownership, and local people's usage, should be critically examined during the detailed environmental impact survey.

7.4 Effectiveness of the project

7.4.1 Economic Analysis

The JICA Survey Team estimated Financial Internal Rate of Return (FIRR) and Economic Internal Rate of Return (EIRR) for Kuri-I as the highest-prioritized hydro power station development candidate in East Bhutan.
In estimating IRR, the cost includes both construction cost and O&M cost of potential hydro power station sites and exclusive transmission lines. The benefit includes power purchasing price at the cross border point taking into consideration wheeling tariff from the potential site to the cross border point.

(1) Estimated Cases
The JICA Survey Team estimated the following 4 cases at each potential site.
<FIRR>
Case 1: case scenario of purchasing price is 3.11 BTN/kWh at Barapukuria S/S (equivalent to 4USC/kWh)
Case 2: case scenario of purchasing price is 3.89 BTN/kWh at Barapukuria S/S (equivalent to 5USC/kWh)
Case 3: case scenario of purchasing price is 4.66 BTN/kWh at Bheramara S/S (equivalent to 6USC/kWh)
<EIRR>
Case 4: case scenario of purchasing price is 7.20 BTN/kWh which is the average generation cost in Bangladesh
In estimating EIRR, if the purchasing price of the power is lower than the average generation cost, there is some possibility for the potential Hydro site to sell the power to Bangladesh. Therefore, the gap between the purchasing price and average generation cost should be included in the EIRR's benefit.

(2) Estimated Conditions
The estimated conditions of the construction period and O&M price of the hydro power station are assumed by the scale of the construction site.

Table 7-13 Calculation Conditions for Economic Analysis

Country	Site name	Hydro Power Station		Exclusive Transmission Line	
		Construction Period	O&M cost	Construction Period	O&M cost
Bhutan	Kuri-I	9 years	1.5%/year	2 years	0.3%/year

(Source: JICA Survey Team)

(3) Estimated Result of IRR

Table 7-14 Estimated Results of FIRR and EIRR

		Case 1 (FIRR)	Case 2 (FIRR)	Case 3 (FIRR)	Case 4 (EIRR)
Bhutan	Kuri-I	6.4	8.2	9.8	13.9

(Source: JICA Survey Team)

(4) Internal Rate of Return for Kuri I
The calculation of IRR is as follows. Because only Benefit for each Case is different, only Case 3 and Case 4 are described.

(a) Case 3

Table 7-15 FIRR (Case 3)

FIRR（Case 3）	**9.8%**
NPV	**-2,652.9**
B/C	**1.0**

million BTN

Year	Activities	Cost(C)						Financial Benefit (B)	
		Hydro Power	Transmission Line	Hydro O&M	Transmission O&M	Wheeling and other	Total Cost ①	Benefit ②	Net ③=②−①
-8		14,582					14,582	0	-14,582
-7		14,582					14,582	0	-14,582
-6		14,582					14,582	0	-14,582
-5		14,582					14,582	0	-14,582
-4	Construction	14,582					14,582	0	-14,582
-3		14,582					14,582	0	-14,582
-2		14,582					14,582	0	-14,582
-1		14,582	2,724				17,305	0	-17,305
0		14,582	2,724				17,305	0	-17,305
1				1,969	16	2,633	4,617	24,535	19,918
2				1,969	16	2,633	4,617	24,535	19,918
3				1,969	16	2,633	4,617	24,535	19,918
4				1,969	16	2,633	4,617	24,535	19,918
5				1,969	16	2,633	4,617	24,535	19,918
6				1,969	16	2,633	4,617	24,535	19,918
7				1,969	16	2,633	4,617	24,535	19,918
8				1,969	16	2,633	4,617	24,535	19,918
9				1,969	16	2,633	4,617	24,535	19,918
10				1,969	16	2,633	4,617	24,535	19,918
11				1,969	16	2,633	4,617	24,535	19,918
12				1,969	16	2,633	4,617	24,535	19,918
13				1,969	16	2,633	4,617	24,535	19,918
14				1,969	16	2,633	4,617	24,535	19,918
15				1,969	16	2,633	4,617	24,535	19,918
16				1,969	16	2,633	4,617	24,535	19,918
17				1,969	16	2,633	4,617	24,535	19,918
18				1,969	16	2,633	4,617	24,535	19,918
19				1,969	16	2,633	4,617	24,535	19,918
20				1,969	16	2,633	4,617	24,535	19,918
21				1,969	16	2,633	4,617	24,535	19,918
22				1,969	16	2,633	4,617	24,535	19,918
23				1,969	16	2,633	4,617	24,535	19,918
24				1,969	16	2,633	4,617	24,535	19,918
25	Operation			1,969	16	2,633	4,617	24,535	19,918
26				1,969	16	2,633	4,617	24,535	19,918
27				1,969	16	2,633	4,617	24,535	19,918
28				1,969	16	2,633	4,617	24,535	19,918
29				1,969	16	2,633	4,617	24,535	19,918
30				1,969	16	2,633	4,617	24,535	19,918
31				1,969	16	2,633	4,617	24,535	19,918
32				1,969	16	2,633	4,617	24,535	19,918
33				1,969	16	2,633	4,617	24,535	19,918
34				1,969	16	2,633	4,617	24,535	19,918
35				1,969	16	2,633	4,617	24,535	19,918
36				1,969	16	2,633	4,617	24,535	19,918
37				1,969	16	2,633	4,617	24,535	19,918
38				1,969	16	2,633	4,617	24,535	19,918
39				1,969	16	2,633	4,617	24,535	19,918
40				1,969	16	2,633	4,617	24,535	19,918
41				1,969	16	2,633	4,617	24,535	19,918
42				1,969	16	2,633	4,617	24,535	19,918
43				1,969	16	2,633	4,617	24,535	19,918
44				1,969	16	2,633	4,617	24,535	19,918
45				1,969	16	2,633	4,617	24,535	19,918
46				1,969	16	2,633	4,617	24,535	19,918
47				1,969	16	2,633	4,617	24,535	19,918
48				1,969	16	2,633	4,617	24,535	19,918
49				1,969	16	2,633	4,617	24,535	19,918
50				1,969	16	2,633	4,617	24,535	19,918
				NPV (at 10% Discount Rate)			105,818	103,166	-2,653

(Source: JICA Survey Team)

(b) Case 4

Table 7-16 EIRR (Case 4)

EIRR（Case 4）	**13.9%**
NPV	**53,578.9**
B/C	**1.5**

million BTN

Year	Activities	Cost(C)						Financial Benefit (B)	
		Hydro Power	Transmission Line	Hydro O&M	Transmission O&M	Wheeling and other	Total Cost ①	Benefit ②	Net ③=②−①
-8		14,582					14,582	0	-14,582
-7		14,582					14,582	0	-14,582
-6		14,582					14,582	0	-14,582
-5		14,582					14,582	0	-14,582
-4	Construction	14,582					14,582	0	-14,582
-3		14,582					14,582	0	-14,582
-2		14,582					14,582	0	-14,582
-1		14,582	2,724				17,305	0	-17,305
0		14,582	2,724				17,305	0	-17,305
1				1,969	16	2,633	4,617	37,908	33,291
2				1,969	16	2,633	4,617	37,908	33,291
3				1,969	16	2,633	4,617	37,908	33,291
4				1,969	16	2,633	4,617	37,908	33,291
5				1,969	16	2,633	4,617	37,908	33,291
6				1,969	16	2,633	4,617	37,908	33,291
7				1,969	16	2,633	4,617	37,908	33,291
8				1,969	16	2,633	4,617	37,908	33,291
9				1,969	16	2,633	4,617	37,908	33,291
10				1,969	16	2,633	4,617	37,908	33,291
11				1,969	16	2,633	4,617	37,908	33,291
12				1,969	16	2,633	4,617	37,908	33,291
13				1,969	16	2,633	4,617	37,908	33,291
14				1,969	16	2,633	4,617	37,908	33,291
15				1,969	16	2,633	4,617	37,908	33,291
16				1,969	16	2,633	4,617	37,908	33,291
17				1,969	16	2,633	4,617	37,908	33,291
18				1,969	16	2,633	4,617	37,908	33,291
19				1,969	16	2,633	4,617	37,908	33,291
20				1,969	16	2,633	4,617	37,908	33,291
21				1,969	16	2,633	4,617	37,908	33,291
22				1,969	16	2,633	4,617	37,908	33,291
23				1,969	16	2,633	4,617	37,908	33,291
24				1,969	16	2,633	4,617	37,908	33,291
25	Operation			1,969	16	2,633	4,617	37,908	33,291
26				1,969	16	2,633	4,617	37,908	33,291
27				1,969	16	2,633	4,617	37,908	33,291
28				1,969	16	2,633	4,617	37,908	33,291
29				1,969	16	2,633	4,617	37,908	33,291
30				1,969	16	2,633	4,617	37,908	33,291
31				1,969	16	2,633	4,617	37,908	33,291
32				1,969	16	2,633	4,617	37,908	33,291
33				1,969	16	2,633	4,617	37,908	33,291
34				1,969	16	2,633	4,617	37,908	33,291
35				1,969	16	2,633	4,617	37,908	33,291
36				1,969	16	2,633	4,617	37,908	33,291
37				1,969	16	2,633	4,617	37,908	33,291
38				1,969	16	2,633	4,617	37,908	33,291
39				1,969	16	2,633	4,617	37,908	33,291
40				1,969	16	2,633	4,617	37,908	33,291
41				1,969	16	2,633	4,617	37,908	33,291
42				1,969	16	2,633	4,617	37,908	33,291
43				1,969	16	2,633	4,617	37,908	33,291
44				1,969	16	2,633	4,617	37,908	33,291
45				1,969	16	2,633	4,617	37,908	33,291
46				1,969	16	2,633	4,617	37,908	33,291
47				1,969	16	2,633	4,617	37,908	33,291
48				1,969	16	2,633	4,617	37,908	33,291
49				1,969	16	2,633	4,617	37,908	33,291
50				1,969	16	2,633	4,617	37,908	33,291
				NPV (at 10% Discount Rate)			105,818	159,397	53,579

(Source: JICA Survey Team)

7.4.2 Estimation of the GHG Emission Reductions from the Project

The GHG emission reduction calculations are conducted as in the case of distributing 100% of the electricity to Bangladesh from Kuri-I. The values used for calculations are annual energy production of 5,265,000 MWh, emission factor of Bangladesh of 0.6407 tCO2/MWh[5] and emission factor of Kuri-I of 0 tCO2/MWh[6]. Transmission losses are assumed to remain at approximately 3%. Thus, GHG emission reductions from the project are calculated as follows:

PEy = (Ely × 0.97) × (EFbangladesh,y - EFkuri-I,y)

Table 7-17 Values of GHG Emission Reduction Calculation (Base Case)

Parameters	Description	Unit	Value
PEy	Project emissions in year y	tCO_2e	
Ely	Electricity transmitted from Kuri-I in year y	MWh	5,265,000
EFbangladesh,y	Emission Factor of Bangladesh	tCO_2/MWh	0.6407
EFkuri-I,y	Emission Factor of Kuri-I	tCO_2/MWh	0
TLy	Transmission loss in year y	%	3

(Source: JICA Survey Team)

The result of the GHG emission reduction is approximately 3,272,000 tCO_2e.

In another case, the electricity is assumed to be distributed at a rate of 80% Bangladesh/20% India from Kuri-I. The values for calculations are annual energy production of 5,265,000 MWh, emission factor of Bangladesh of 0.6407 tCO_2/MWh[5], emission factor of India of 0.895 tCO_2/MWh[5] and emission factor of Kuri-I of 0 tCO_2/MWh[6]. Transmission losses are assumed to remain at approximately 3%. Then,

PEy = (Ely × 0.97 × 0.8) × (EFbangladesh,y - EFkuri-I,y)
+ (Ely × 0.97 × 0.2) × (EFindia,y - EFkuri-I,y)

Table 7-18 Values of GHG Emission Reduction Calculation (Another Case)

Parameters	Description	Unit	Value
PEy	Project emissions in year y	tCO_2e	
Ely	Electricity transmitted from Kuri-I in year y	MWh	5,265,000
EFbangladesh,y	Emission Factor of Bangladesh	tCO_2/MWh	0.6407
EFindia,y	Emission Factor of India	tCO_2/MWh	0.895
EFkuri-I,y	Emission Factor of Kuri-I	tCO_2/MWh	0
TLy	Transmission loss in year y	%	3

(Source: JICA Survey Team)

The result of the GHG emission reduction is approximately 3,532,000tCO_2e. (2,618,000tCO_2e in Bangladesh and 914,000tCO_2e in India)

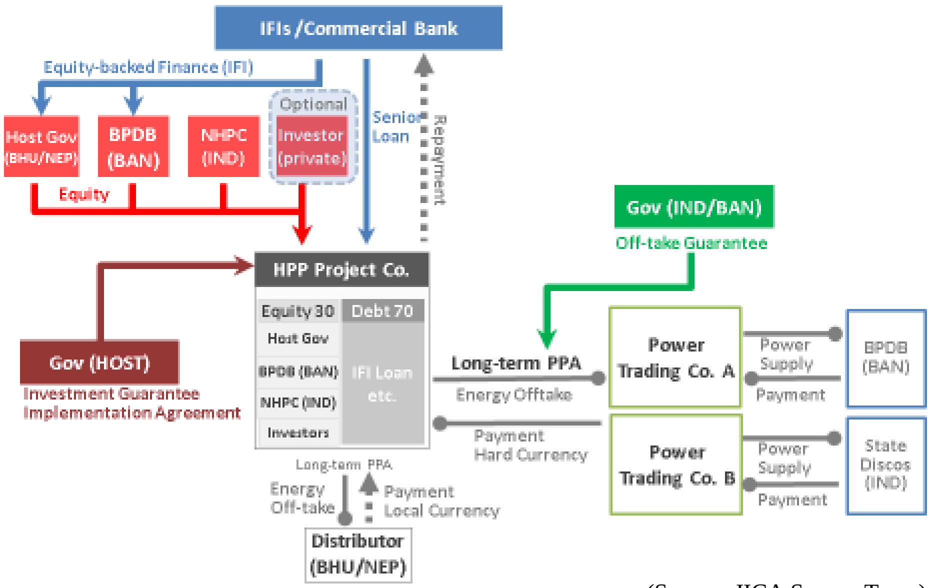
5 JICA Climate-FIT Version 2.0, 03/2014
6 CDM Project 2746: Dagachhu Hydropower Project, Bhutan

7.5 Implementation Framework for Sub-regional Hydropower Development

BBIN countries have agreed to promote and identify sub-regional hydropower projects to be undertaken by at least three BBIN countries on an equitable basis. For small- and medium-sized projects of less than USD 100 million equivalent, it may be relatively easy to mobilize Indian funds such as grants and EXIM bank loans/credit. However, as project size becomes larger, alternative financing from IFIs such as JICA, ADB and the World Bank is required.

Assuming a large hydropower project in Bhutan or Nepal, where Bangladesh and India jointly develop together with the host country, it may be better to invite private investors to equity shareholding through a Public-Private Partnership (PPP) scheme than to leave the investment to a pure public joint venture (JV). In general, large-scale hydropower development involves complex technical, geological, socio-environmental, institutional and commercial risks. Usually, the risk perception of a public investor is different from a private one. Therefore, whenever significant problems, whether technical or institutional, become patent, construction tends to be halted for many years. In addition to governmental commitment, the presence of private (non-governmental) investors with huge experience in large-scale hydropower development would make the project's IFI lenders more comfortable.

The following figure illustrates HPP development framework and equity shareholding in a special purpose company (SPC) for implementation of a large-scale hydropower project in the sub-region. In the following chapter, the JICA Survey Team will present more project-specific ideas for the detailed project implementation arrangement.



(Source: JICA Survey Team)

Figure 7-12 Illustration of the Sub-regional HPP Development Framework

There are a number of variations in the combination of the share of participating parties and the share of rights to the off-take of energy from the HPP. The following exhibit shows just four examples. The share in stake does not necessarily match the share in energy off-take. In a country with a power surplus like Bhutan, the HPP may be solely export-oriented (Options 2 and 4). On the other hand, the host country can claim its right to tap the energy output in proportion with its equity shareholding (Options 1 and 3). In an actual situation, these shares shall be negotiated and reflected in the shareholders' agreement.

Option 1	Share	Off-take
Host (BHU/NEP)	34%	34%
BPDB (BAN)	33%	33%
NHPC (IND)	33%	33%
	100%	100%

Option 2	Share	Off-take
Host (BHU/NEP)	34%	
BPDB (BAN)	33%	50%
NHPC (IND)	33%	50%
	100%	100%

Option 3	Share	Off-take
Host (BHU/NEP)	30%	30%
BPDB (BAN)	30%	30%
NHPC (IND)	30%	30%
Investor (Private)	10%	10%
	100%	100%

Option 4	Share	Off-take
Host (BHU/NEP)	30%	
BPDB (BAN)	30%	50%
NHPC (IND)	30%	50%
Investor (Private)	10%	
	100%	100%

(Source: JICA Survey Team)

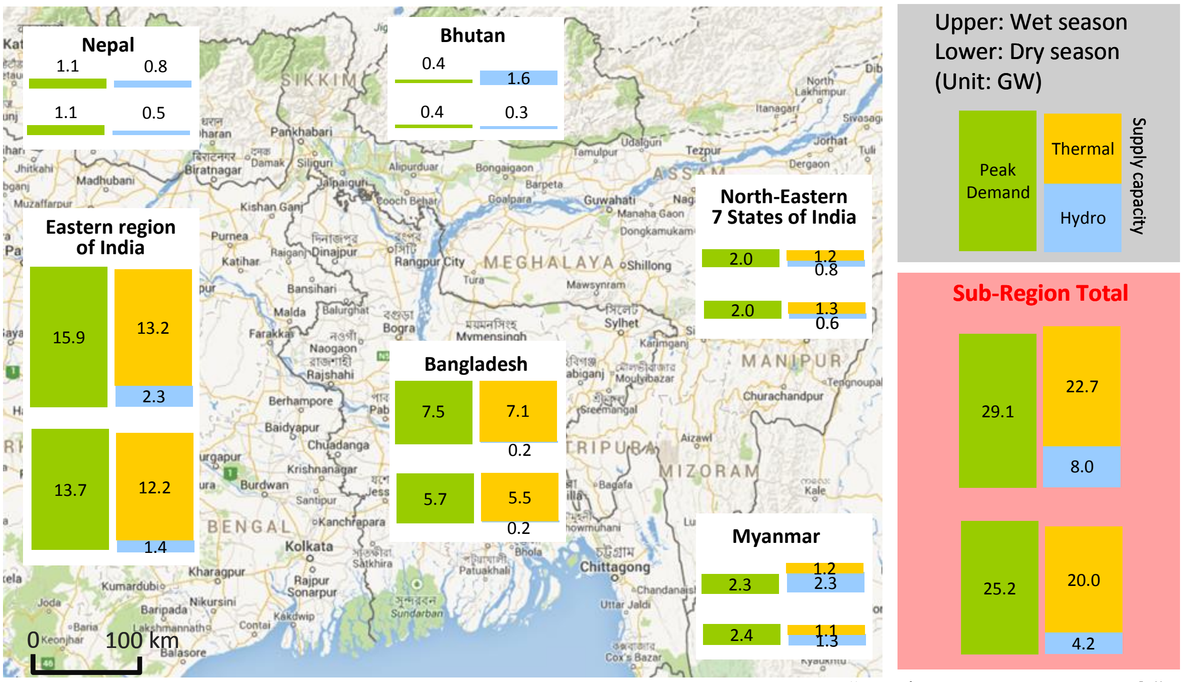
Figure 7-13 Illustration of Equity Shareholding and Off-Take Rights

Chapter 8 Recommendations on Regional Power Interconnection to Make It Happen

The key purposes of power Import through regional transmission interconnection are to diversify sources of electricity, to procure generally affordable electricity, and to improve quality of power supply to the extent possible. To this end, it is desirable that Bangladesh develops hydropower potential in neighboring countries and connects them directly to its national grid. However, crossing Indian territory is inevitable whenever Bangladesh taps energy from Bhutan and Nepal. Therefore, it is very challenging to directly synchronize those power plants with the Bangladeshi power system. Based on this fact, the Survey Team proposes directions for the future development of regional hydropower potential.

8.1 Electric Power Supply and Demand Situation in the Neighboring Countries of Bangladesh

The neighboring countries of Bangladesh have rich hydropower potential. However, the amount of development at present is small, and a great amount of development can be expected in the future.
The electric power supply and demand situations in the rainy season and dry season in 2014 in the neighbouring countries (Eastern region and Northeastern states in India) of Bangladesh are shown as follows.



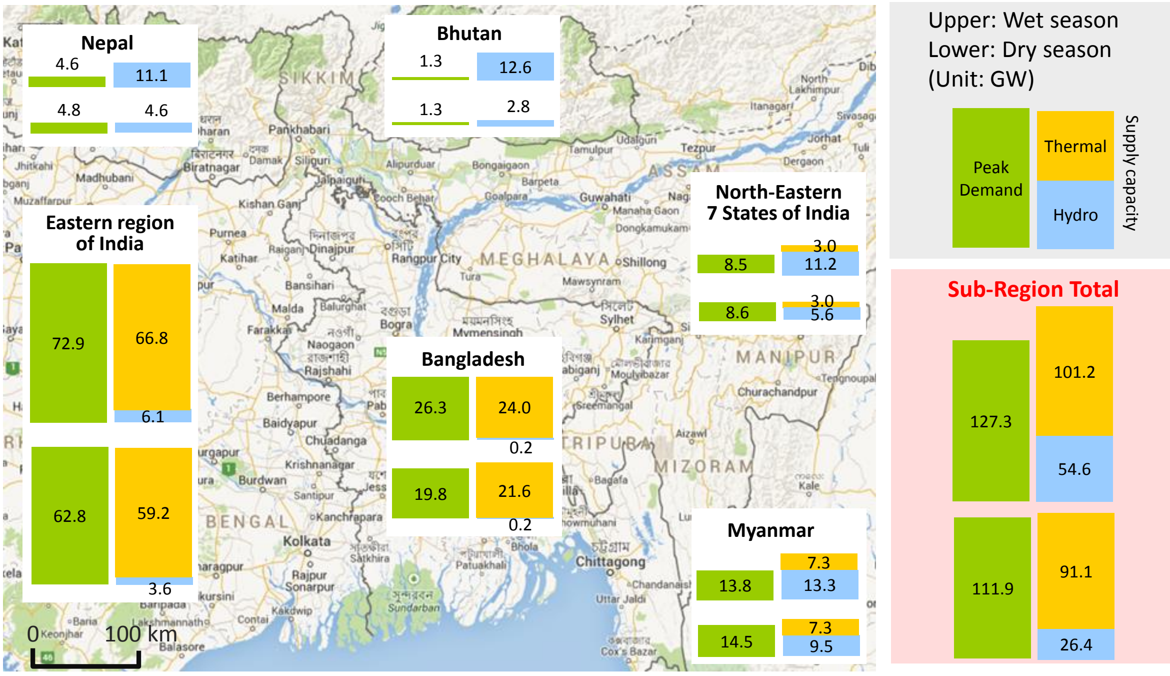
"Map data©2014 AutoNavi Google"

(Source: JICA Survey Team)

Figure 8-1 Electric Power Supply and Demand Situation in the Neighboring Countries of Bangladesh (2014)

The supply capacity from hydropower is about 25% of the whole supply capacity in this area at present because there is not a lot of hydropower development yet. Because a lot of hydroelectric power plants in these regions are the run-of-river type, the amount of power generation decreases below half in the dry season, though a lot of power generation can be expected in the rainy season. Therefore, the supply capacity is slightly insufficient in the dry season because the supply capacity from hydropower decreases remarkably, though power demands also decrease a little.

The electric power supply and demand situation forecast in 2030 is shown below in addition to that mentioned above.



"Map data©2014 AutoNavi Google"

(Source: JICA Survey Team)

Figure 8-2 Electric Power Supply and Demand Situation in the Neighbouring Countries of Bangladesh (2030)

Hydropower development can be actively executed in Nepal, Bhutan, India's northeastern states, and Myanmar, and the capacity of the hydropower plants is expected to increase approximately by 10GW in each. As a result, the supply capacity from hydropower will increase to about 35% of the whole supply capacity in the rainy season. On the other hand, the supply capacity of hydropower in the dry season decreases below half, and a lack of supply capacity is feared in Nepal, which mainly supplies electricity by hydropower. However, because demand decreases greatly and the reserve capacity of thermal power can be secured in Bangladesh, which mainly supplies electricity by thermal power, enough supply capacity can be secured in the region as a whole.

8.2 Power Import Planning in Bangladesh

8.2.1 BPDB's Ideas and the Issues it Faces

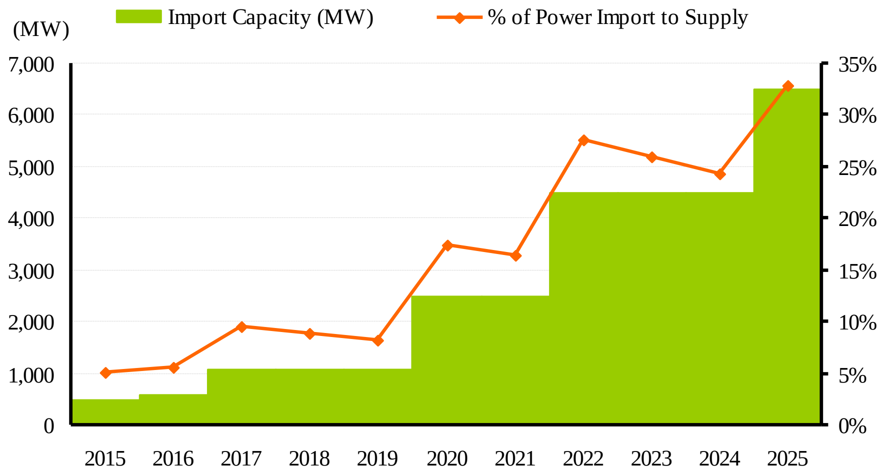
It is confirmed that BPDB will maintain the following power import plan.

Table 8-1 Power Import Plan by BPDB

		MW	Year	Remarks
1	Bheramara - Baharampur	500	2013	Existing
2	Tripura - Comilla	100	2016	Some load (100MW) in Comilla (N) S/S will be connected to Indian system.
3	Bheramara - Baharampur	500	2017	Extension of Bheramara HVDC.
4	Bheramara - Baharampur	1,000	2020	Additional extension of Bheramara HVDC
5	Tripura - Comilla	400	2020	Construction of HVDC (500MW) in Comilla (N) S/S. Some load (100MW) in Comilla (N) S/S will be disconnected from Indian system.
6	Rangia/Rowta - Barapukuria	2,000	2022	Power import using Case 2 T/L (±800kV DC)
7	From Nepal (including GMR)	2,000	2025	Power import using Case 3 T/L (765kV AC)
	Total	6,500		

(Source: Hearing from BPDB)

The following figure shows power import volume and share of power import against the whole supply capacity.



(Source: JICA Survey Team)

Figure 8-3 Future Power Import Volume and its Share (BPDB Plan)

Power Import will surge after 2020 and reach 6,500MW in 2025, making its share against the whole supply capacity more than 30%.

8.2.2 Challenges and Countermeasures of Power Imports

The challenges arising from importing power and their countermeasures are as follows.

(1) Energy Security

In the case of importing power from other countries, the risk of supply interruption caused by adverse relationships between the two countries needs to be considered. Electric power, which is different from other types of supply, is technically easy to shut down even in minutes. So it is necessary to avoid excessive reliance on other countries in order not to place oneself in a serious situation. Specifically, the capacity of imported power from one country should be within the limit of generating reserve margin and also 10% of all supply capacity in order to continue the supply in the event of supply interruption. In the case of Bangladesh, imported power from Bhutan and Nepal has to be transmitted through India. Therefore, imported power from Bhutan and Nepal should be within 10% of all supply capacity.

In general, demand equivalent to the peak load, more than 95% of the maximum load, occurs for approximately 100 hours on 25 days, assuming 4 hours of daily peak hours. Hence, only if the system tolerates 5% of load shedding during such peak hours it is considered that power import through the Indian grid may increase to 15% of the total supply capacity in Bangladesh. These interconnection lines shall be constructed in close cooperation with India after fully understanding and confirming India's needs.

(2) Compliance with Commissioning Timing of the Transmission Lines in India

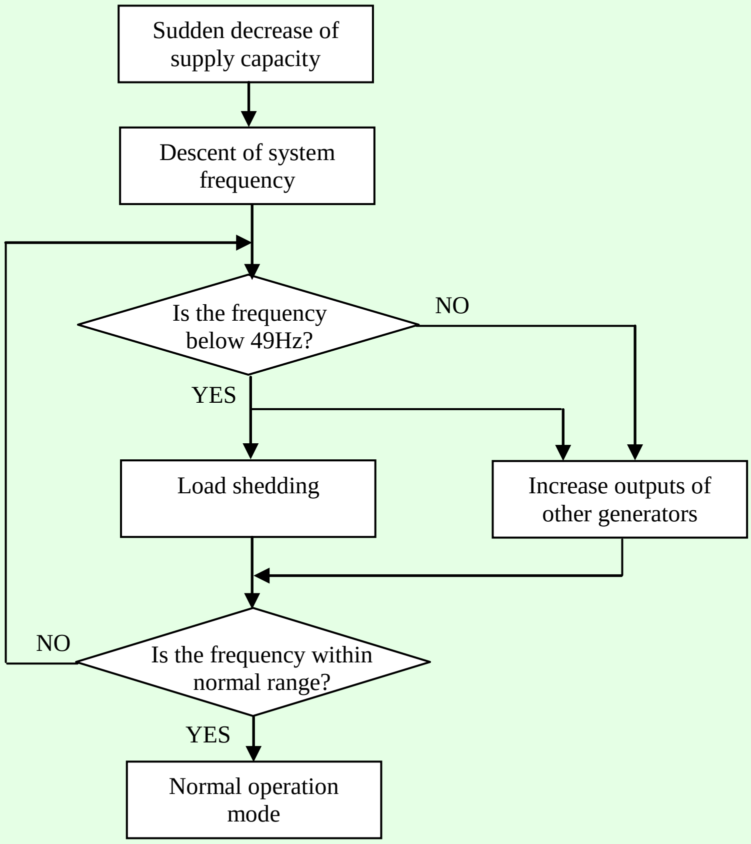
The aforementioned plan hinges on commercial operation of the Case 2 HVDC (±800kV) interconnection line by 2022 and the Case 3 HVAC (765kV) interconnection line by 2025. When hydropower capacity exceeds 3,000MW in Arunachal Pradesh, the ±800kV inter-state transmission line currently under construction reaches its full transmission capacity, giving rise to a need for the construction of the Case 2 interconnection line. On the other hand, there seems to be no reason for India to realize the needs for the Case 3 line for the time being.

(3) Massive blackout due to large scale power loss of supply

It is desirable to import as much power as possible through one connecting point from the viewpoint of economic efficiency. However, if a huge amount of power is transmitted through one connecting point, it can lead to the risk of massive blackout, such as blackout across the entire country during the shutdown of the connecting line. Massive blackout occurred on 1st November 2014, triggered by 500MW power loss of the BTB break down on the inter-connection line from India. In order to avoid this risk, the limit of the power loss level needs to be worked out, by checking sufficiently continuous power generators' operation during frequency drop and the load shedding scheme during large scale power supply loss. Based on this result, the maximum level of import capacity in one inter-connection point has to be decided.

In the Case 2 interconnection line shown in Table 8-1, Bangladesh will tap 2,000 MW at Barapukuria S/S (Conversion Station) at the middle of the whole length of the transmission line. If any fault occurs in the Case 2 interconnection line, Bangladesh loses 2,000 MW supply capacity instantly. The forecasted maximum peak load in 2025 is 18,000 MW. Even if the sudden loss of 2,000MW takes place, a large-scale blackout is not expected at the peak load, but merely a frequency drop of approximately 1 Hz. However, if the loss of 2,000MW takes place during off peak time, frequency will drop more than 1.5 Hz, increasing the probability of a large-scale blackout in the country. Therefore, it is required to regulate the received volume of power during the off-peak time.

<Large-scale blackout that occurred on November 1, 2014>
A large-scale blackout that occurred at about 11:30 Saturday, November 1, 2014 was triggered by a sudden 470MW decrease in the supply capacity received from India due to trouble with an HVDC which was an interconnecting point between Bangladesh and India. Though an official report of this trouble describing the cause analysis and countermeasures has not been submitted, the Survey Team briefly analyzes this event.
In the case of a sudden decrease in the supply capacity due to an accident etc., the process of restoring to normal condition in a general system is shown below.



(Source: JICA Survey Team)

Figure 8-4 Restoring Process to Normal Condition

When the supply capacity decreases due to an accident and supply capacity shortage versus demand occurs, the frequency in the system descends. It relates generally to the demand scale and the amount of the sudden decrease in supply capacity. It is said that the frequency decreases by 1Hz when supply capacity that corresponds to 5%-10% of the demand scale decreases suddenly, though the amount of the decrease differs depending upon the system. The output of other healthy generators is increased when the descending amount of the frequency is small, and this provides additional supply capacity to make up the shortfall. However, in order to decrease the demand, load shedding is executed in addition to an output increase of generators when the descending amount of the frequency is large (49Hz or less), and the frequency is returned to regulated value (50Hz). Because these operations are too late to perform via instructions from the load dispatching center, the function to do a series of operations automatically according to the descending amount of the frequency is built into the system.
On the other hand, power generating machines are designed to operate stably at the rotational speed based on a regulated frequency. When the frequency drops from the regulated value greatly (48.5Hz or less),

events such as vibration, which negatively affects the equipment as the rotational speed changes, occur in the power generating machine. Therefore, if the descending amount of the frequency is large and the duration becomes long, the machine automatically stops to protect the equipment.

<Analysis of the event on November 1, 2014>

1. The frequency decreased to 48.6Hz immediately after occurrence of the accident, though the frequency before the accident was 50.3Hz.
   ➔ The demand scale at that time was about 4,500MW, and the frequency decreased by 1.7Hz because of a supply capacity decrease in about 10% of demand scale. It is understood that the frequency decreases by 1Hz when the supply capacity that corresponds to 6% of the demand scale decreases in the present system.
2. It recovered to 49.0Hz or more once afterwards.
   ➔ It is thought that the function of load shedding automatically operated normally.
3. However, the frequency decreased gradually afterwards, and the frequency decreased suddenly to about 44Hz about one minute after the accident.
   ➔ It is thought that thermal power plants in the system stopped automatically under the pretext of equipment protection though the frequency had not decreased too much.
4. The frequency repeated violent fluctuations on the cycle of a few seconds afterwards, and finally, all systems collapsed.
   ➔ There is a possibility that the amount of load shedding corresponding to the descending amount of the frequency was not appropriate and the load shedding was executed more than the necessary amount when the descending amount of the frequency was very large.

<Actions based on the lessons from the accident on November 1, 2014>

This accident was not caused by interconnection with another country, though the accident at the HVDC equipment was a direct trigger. There is a risk that the same event will occur when a sudden decrease in large supply capacity occurs due to an accident involving equipment other than HVDC. It is thought that the system collapse could have been prevented if an automatic restoration procedure were correctly maintained because there was not such a large amount of frequency decrease. Actions based on the lessons learnt from the accident are as follows.

- Setting the upper limit of the amount of decrease of supply capacity at a single contingency in order to keep the amount of descending of the frequency within a regulated value (especially in off-peak period when the demand decreases).
- Verification of confirmation of automatic restoration procedure (automatic load shedding scheme and automatic stop condition of thermal power plants) and their validities when frequency decreases
- Confirmation of frequency response performance of thermal power generation equipment and examination of the necessary frequency control amount according to the system scale

(4) Mutual Interference due to Grid Accidents

Conducting power trading means transmission lines are connected between two neighboring countries, which will lead to the threat of mutual interference due to grid accidents. But it is possible to minimize the influence by connecting DC lines. Current inter-connection lines between India and Bangladesh apply DC lines or non-connected lines by switching the load. There will be a few mutual interferences due to grid accidents in these two cases.

8.2.3 Proposals on Power Import Planning

Reflecting the aforementioned issues, the Survey Team proposes the following power import plan for Bangladesh.

Table 8-2 Proposal for Power Import Plan by JICA Survey Team

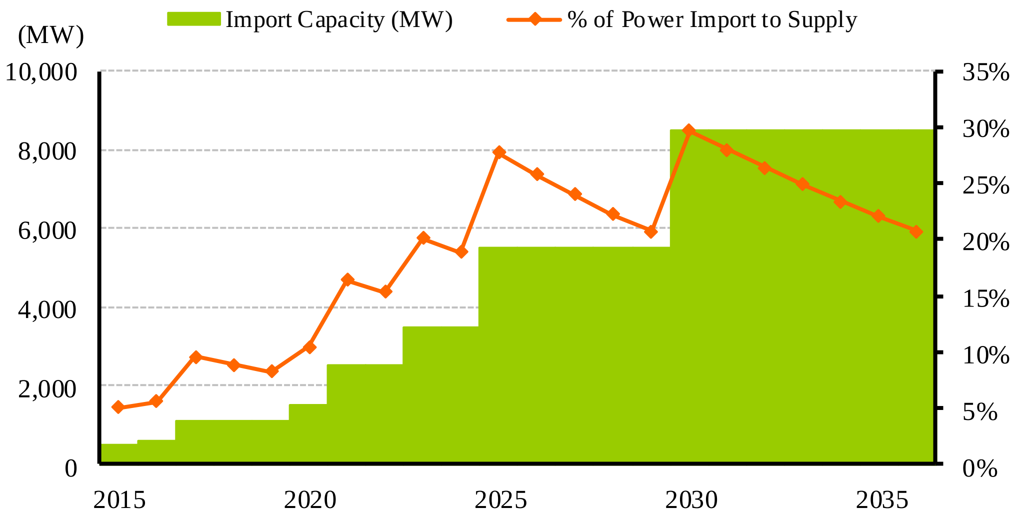
	Interconnection	MW	Year	Remarks
1	Bheramara - Baharampur	500	2013	Existing
2	Tripura - Comilla	100	2016	Some load (100MW) in Comilla (N) S/S will be connected to Indian system.
3	Bheramara - Baharampur	500	2017	Extension of Bheramara HVDC.
4	Bheramara - Baharampur	1,000	2021	Additional extension of Bheramara HVDC Power import from Nepal (including GMR)
5	Tripura - Comilla	400	2020	Construction of HVDC (500MW) in Comilla (N) S/S. Some load (100MW) in Comilla (N) S/S will be disconnected from Indian system.
6	Rangia/Rowta - Barapukuria	1,000	2023	Power import by using Case 2 T/L (±800kV DC)
7	Rangia/Rowta - Barapukuria	1,000	2025	Power import by using Case 2 T/L (±800kV DC)
8	From Nepal	1,000	2025	Power import by using Case 3 T/L (765kV AC)
9	Bongaigaon/Rangia - Jamarpur	1,000	2030	Power import from Bhutan
10	Bibiyana - Meghalaya (PSPP)	1,000	2030	PSPP in Meghalaya State
11	From Nepal	1,000	2030	Power import by using Case 3 T/L (upgrade to 765kV AC)
12	Cox's Bazar - Myanmar	500	2040	Power import from Myanmar
	Total	9,000		

(Source: JICA Survey Team)

Differences between the above plan and BPDB's plan are summarized as follows:

- Extension of Bheramara – Baharampur HVDC by 1,000MW to be commissioned in 2021, one year later than BPDB's plan. Power imports from Nepal will utilize this interconnection for the time being.
- Case 2 T/L (±800kV DC) to be commissioned in 2023, one year later than BPDB's plan, taking Indian needs into consideration. In the early years after commissioning, the receiving capacity shall be 1,000 MW, and then another 1,000 MW is to be added in 2025 in order to accommodate energy from hydropower plants in Arunachal Pradesh and Bhutan.
- Completion of the Pumea – Barapukuria of Case 3 T/L (765kV AC) is expected in 2025, with a receiving capacity of 1,000 MW, to receive energy from Neparl at Barapukuria HVDC, and then another 1,000 MW is to be added in 2030, with raising line voltage 400kV to 765kV.
- Completion of the Bongaigaon/Rangia – Jamarpur is expected in 2030, with a receiving capacity of 1,000 MW, to receive energy from Bhutan at Jamarpur HVDC.
- A pumped-storage power plant to be developed by 2030 and connected at Bibiyana S/S directly
- An interconnection line to be established in 2040 and import of hydropower from Myanmar started

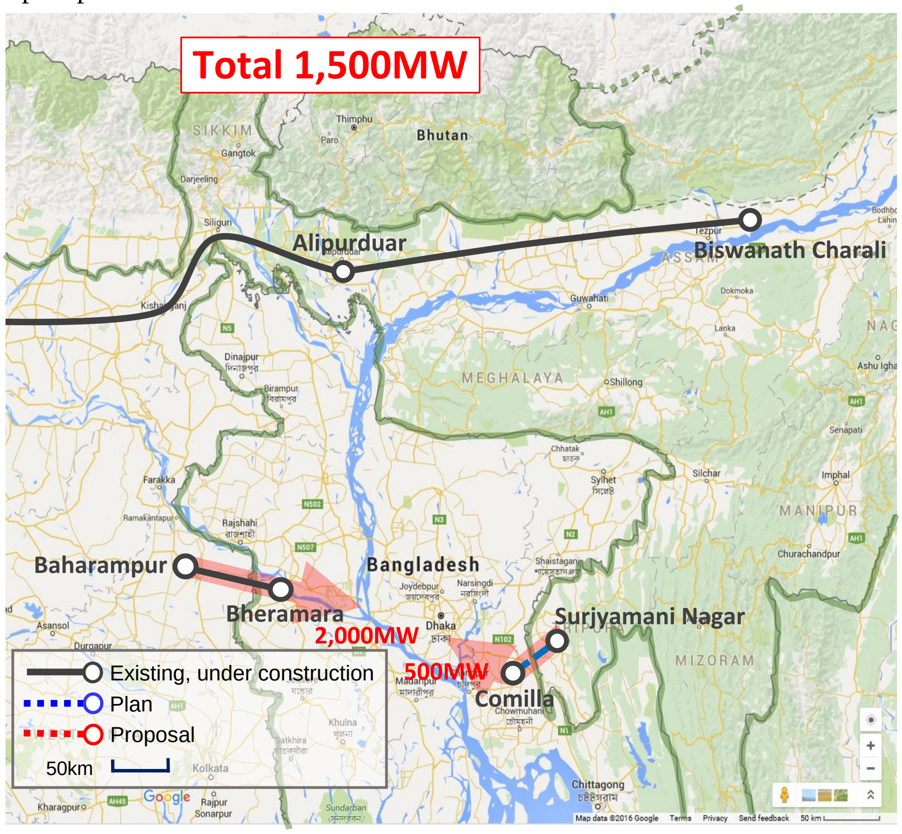
The following figure shows the import volume and its share against the total supply capacity in the power import plan proposed by the Survey Team.



(Source: JICA Survey Team)

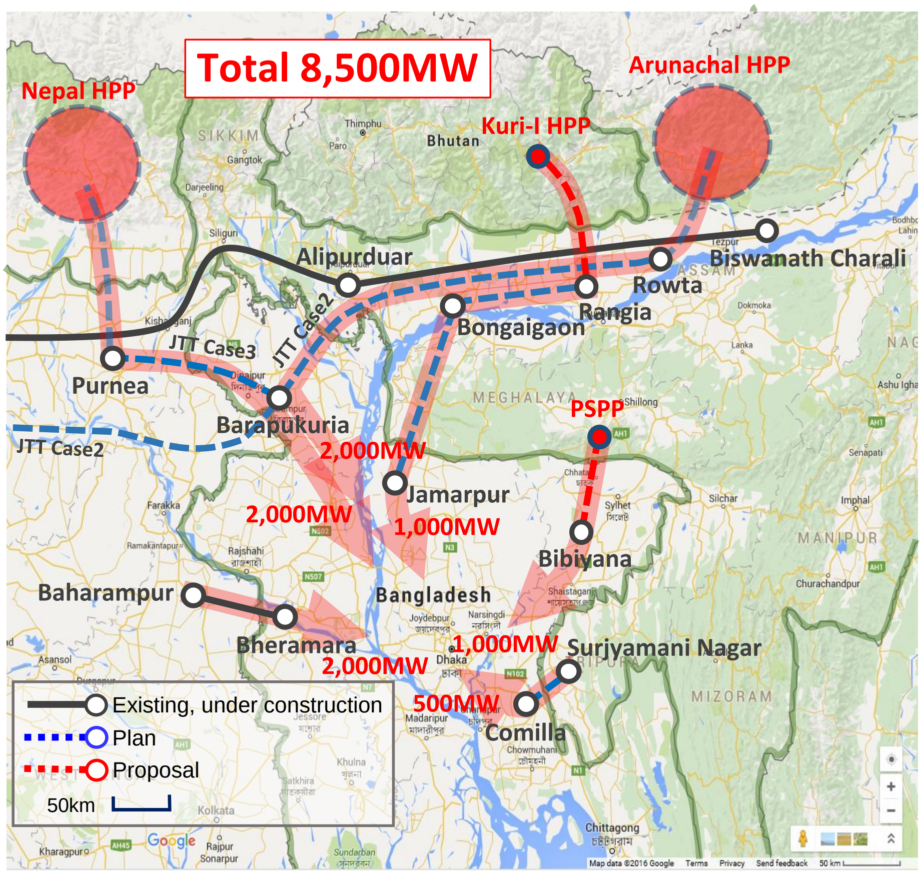
Figure 8-5 Future Power Import Volume and its Share (Proposal)

The share of power imports against the total supply capacity will be between 20% and 30% within the permissible range, albeit a little bit large.
The power import plan in 2020 and 2030 are shown below.



(Source: JICA Survey Team)

Figure 8-6 Power Import Plan in 2020



(Source: JICA Survey Team)

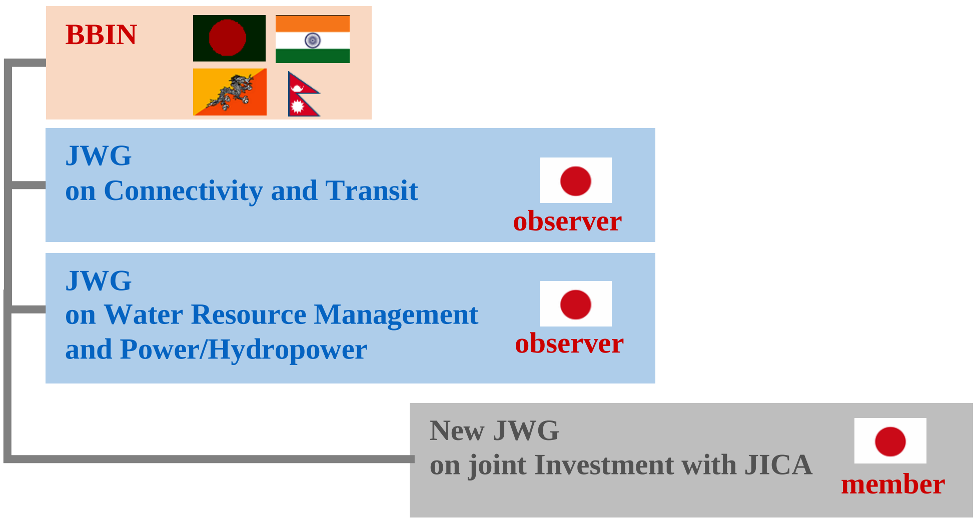
Figure 8-7 Power Import Plan in 2030

8.2.4 Implementation Arrangement

The existing communication channel suffices for discussions over bilateral power trades between Bangladesh and India. However, if power trades with Bhutan and Nepal are involved, the use of the Indian network is inevitable. Bilateral discussions between a seller (Bhutan or Nepal) and a buyer (Bangladesh) are not enough to facilitate such power trades. A multilateral framework that includes India is a prerequisite.

To provide a discussions platform of this kind, a group of countries comprising Bangladesh, Bhutan, India and Nepal (BBIN) has been formulated. BBIN holds Joint Working Groups (JWGs) twice a year. Therefore, it seems to be most effective to discuss regional power trades and interconnection in JWGs for the implementation of specific projects. An illustration of the possible implementation arrangement is summarized as follows:

- JICA may be invited as an observer to JWGs whenever BBIN reviews any proposals on regional hydropower development or power interconnection projects with financing arrangements with JICA.
- Otherwise, a new JWG on joint investment for formation/implementation of projects for JICA financing will be considered.



(Source: JICA Survey Team)

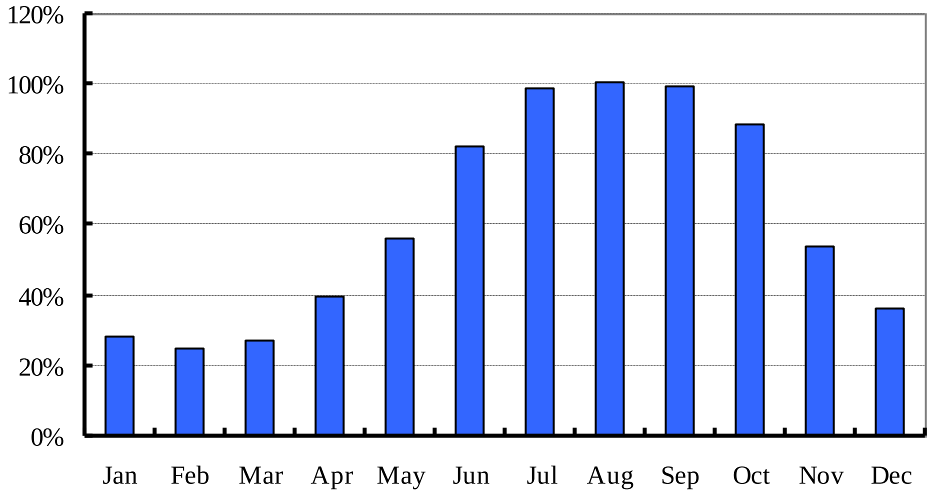
Figure 8-8 Illustration of Implementation Arrangement

8.3 Recommendations for Power Import from Bhutan

As is mentioned in Chapter 7.1, Rotpashong HPP (to be renamed as Kuri-I) is the most promising for export to Bangladesh.

(1) Estimation of Energy Price at the Reception Point in Bangladesh
According to a study, the total construction cost is estimated at USD 1,686.5 million and the expected annual generation volume is 5,265 GWh. Based on this investment cost and energy volume, the energy price at the reception point in Bangladesh, namely Barapukuria S/S, is estimated in US cent 4-5/kWh, taking into account royalty payments to the Royal Government of Bhutan, transmission services fees, and transmission losses.

(2) Receiving Energy
Due to the nature of Bhutan's hydrology, hydropower generation output drastically drops in the winter season. Although the tributary is not the same, average monthly operational records for the 20 years between 1991 and 2010 of the existing Chhukha HPP (336MW) are illustrated in the following figure.



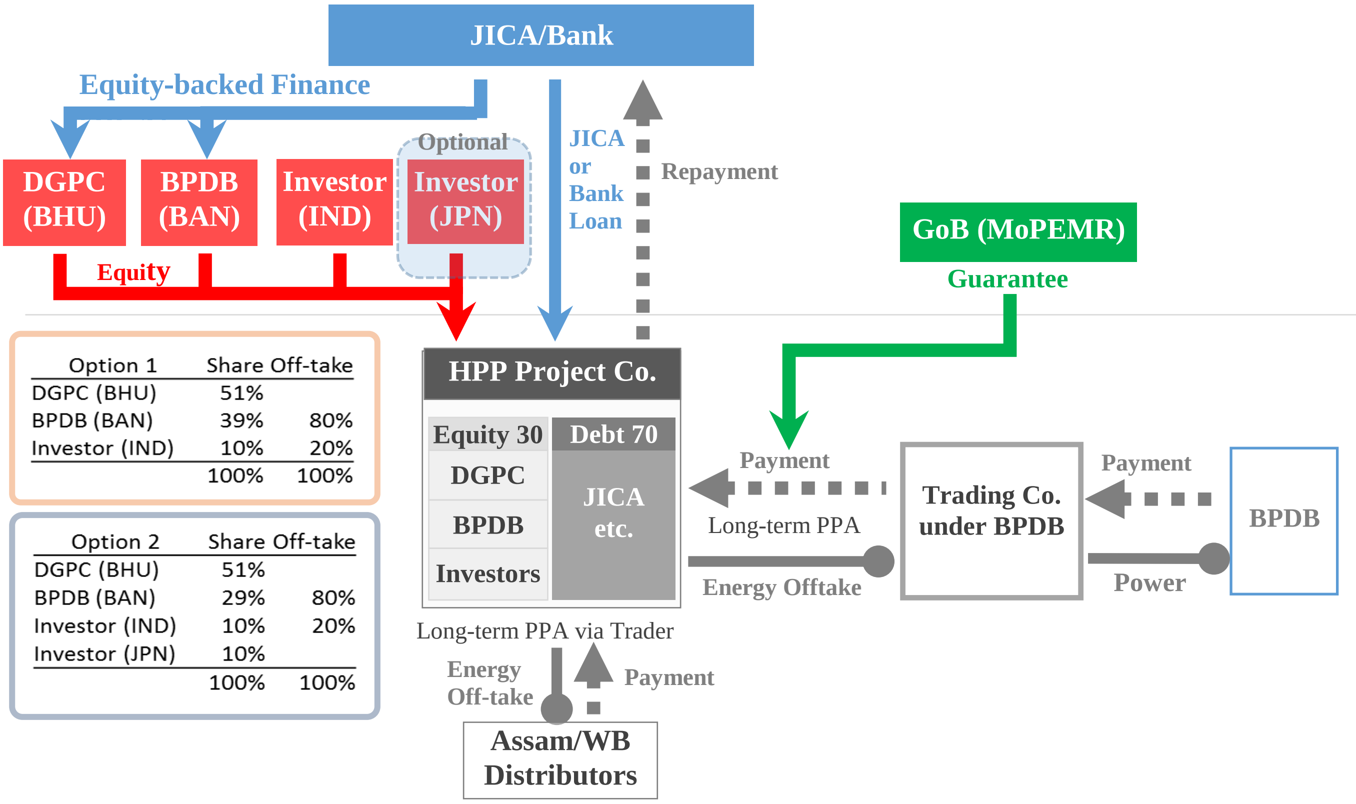
(Source: MOEA, arranged by JICA Survey Team)

Figure 8-9 Operation Records for Chhukha HPP (20-year average)

There are huge seasonal differences in output as average output for the three months between January and March decreases to approximately 25% of the maximum output (installation capacity). The above 20-year average includes non-operating hours due to facility faults and overhaul. This means that almost 100% output is recorded for the three months from July to September, assuming the HPP usually operates at more than the maximum capacity for these wet summer months.

(3) Implementation Arrangement
Conventionally in Bhutan, a special purpose company (SPC) on a pari passu basis (50/50) between the Governments of Bhutan and India is created whenever a large-scale hydropower development is undertaken. The SPC undertakes construction and operation of the HPP. This investment format is relevant only for projects developed by Bhutan. There is no single precedent for HPP development undertaken by any third party country in Bhutan.

When Bangladesh imports energy from Bhutan, it is inevitable that the Indian national power grid is used. Taking this into consideration and emulating the aforementioned investment platform, the Survey Team proposes the following implementation arrangement for Kuri I HPP development.



(Source: JICA Survey Team)

Figure 8-10 Implementation Arrangement for Kuri I HPP

(a) Equity Shareholding of SPC
It is assumed that the equity accounts for 30% of the total investment requirement, while the remaining amount is covered by debt financing. The equity shall be shared by the Government of Bhutan, the Government of Bangladesh, and private investors from India and Japan. The Royal Government of Bhutan may secure a controlling stake of 51%.

(b) Energy Off-Take Share
Although it may be ideal for Bangladesh to off-take all the energy from Kuri I, it is sensible to share the energy between Bangladesh and the Indian investors upon their request. The share of energy off-take may reflect the equity shareholding (Bangladesh+Japanese Investor : Indian Investor = 4:1) and thus Bangladesh is entitled to off-take 80% of the energy, while the Indian investor off-takes the remaining 20%. It should be noted that the firm supply capacity of hydropower in Bhutan decreases to 25% of the installed capacity in the dry season, and there is a capacity surplus in the dry months at the energy receiving point. Therefore, Bangladesh can procure supplemental energy through the Indian power pool or contracts with any Indian power trader.
There is an opinion that it should be the intent to import electric power through the Indian market instead of importing it from the specified power plant. However, in order to purchase stable electric power at a cheap price, it is necessary that Bangladesh should secure the right to receive power from some specified power plants and import part of its electric power according to a long-term contract.

(c) Other issues
It is less likely that BPDB will make a direct investment in SPC on behalf of the Government of Bangladesh. It is assumed that BPDB will newly establish a subsidiary company for power trading and investment in hydropower development in neighboring countries like Coal Power Generation Company Bangladesh Ltd (CPGCBL) for Matarbari CFTPP.

After commissioning of the HPP, the SPC owns and operates the power plants. O&M may be outsourced to DGPC's O&M subsidiary. Shareholders of the SPC are entitled to off-take energy on a pro rata basis.

Regarding transmission lines for the evacuation of energy, BPC (Bhutan), PGCIL (India), and PGCB (Bangladesh) construct their respective domestic sections on their own and receive wheeling charges for transmission services from the SPC.

8.4 Power Supply Quality Improvement with the Utilization of Interconnection

The permissible range of frequency level in Bangladesh is ±1Hz. Therefore, the quality of power supply in Bangladesh is quite low and, in turn, the quality of industrial products relying on the poor quality electricity is also mediocre. Hence, countermeasures to reduce the fluctuation of frequency and to supply quality electricity to the nation are very important for the national economy.

The most promising measure to stabilize the system frequency is to secure relevant supply capacity vis-à-vis power demand. However, even if the supply capacity is well secured, the system frequency does not automatically become stable. For a better quality of power supply, it is extremely important to keep balancing supply and demand all the time to catch up with fluctuations in the power demand and generation availability over time. This section presents a few options for such measures to improve the quality of the power supply in Bangladesh, focusing on the utilization of regional power interconnection.

8.4.1 Pumped-storage Power Plant (PSPP) Development in the State of Meghalaya

The Indian State of Meghalaya shares a border with Bangladesh and if the connection in the right figure is established, it will be possible to directly synchronize a generator located in Meghalaya with the Bangladesh system, clearly separating the generator with the Indian system.

In the case of a demand-supply emergency in either the Indian or Bangladesh system, by switching from one to the other, all the generation capacity can be served to the one experiencing the emergency.

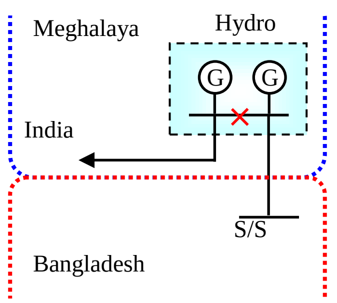


Figure 8-11 Connection Method

However, there seems to be only approximately 3,000MW of hydropower potential in Meghalaya at maximum and the size of each potential site is rather small (with the biggest being 200MW). Therefore, hydropower potential volume in Meghalaya is much smaller than in Arunachal Pradesh or in Bhutan. On the other hand, there are favorable geological endowments with very steep cliffs for pumped-storage near the border with Bangladesh.

Taking advantage of the geological features, it is possible to improve the quality of the power supply in Bangladesh by developing a pumped-storage power plant of 1,000MW class in Meghalaya and directly synchronizing the plant with the Bangladesh system. Energy to pump up water will come from Bangladesh and all the generated energy will go to the Bangladesh system.

(1) Economy of Peak Supply Capacity

Pumped-storage power is expected as peak supply capacity with its annual capacity utilization rate being approximately 10%. An evaluation of the economy of the peak supply is shown in the following table.

Table 8-3 Generating Cost for Various Power Sources

	Construction cost (USD/kW)	Annual fixed cost (USD/kW/yr)	Variable cost (USC/kWh)	Generating cost (USC/kWh)		
				L.F=10%	L.F=40%	L.F=80%
PSPP	800	101.0	7.2	18.8	---	---
Gas CC	900	125.0	13.1	27.4	16.7	14.9
Gas GT	700	98.2	18.9	30.1	21.7	20.3
Oil GT	700	99.2	30.1	41.4	32.9	31.5
Coal ST	1,500	193.2	5.1	27.1	10.6	7.8

It is assumed that coal power generation serves to pump energy during off-peak times and coal generation/fuel prices are used for evaluation. Pumped-storage losses are assumed to be 30% (with 70% of PSPP efficiency)

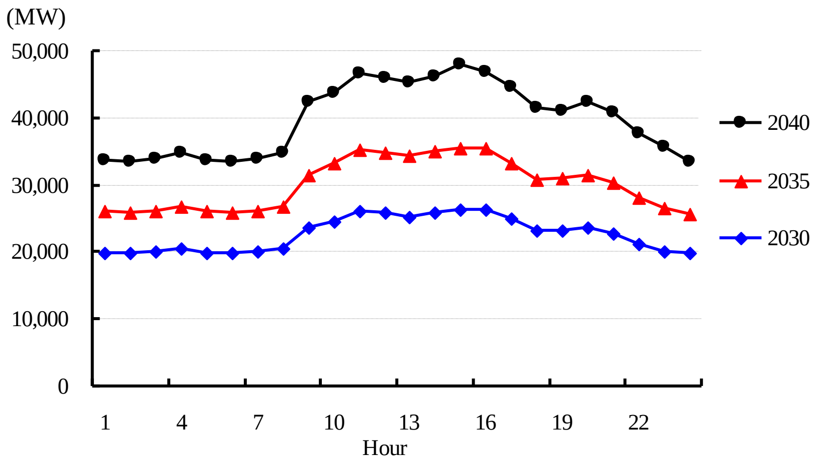
(Source: PSMP Team, arranged by JICA Survey Team)

As is shown in the table, PSPP is the most economical as peak supply capacity.

(2) PSPP Development Needs

To guard against the demand being volatile from moment to moment, it is a prerequisite to possess generation capacity for peak-time supply, operating only during peak demand hours, in addition to daily operating generation capacity. Peak supply requirement depends on demand curve. In general, 20% of the total capacity is considered to be relevant.

The following figure illustrates estimated demand curves on the annual peak days in 2030, 2035 and 2040 in Bangladesh.



(Source: PSMP Team)

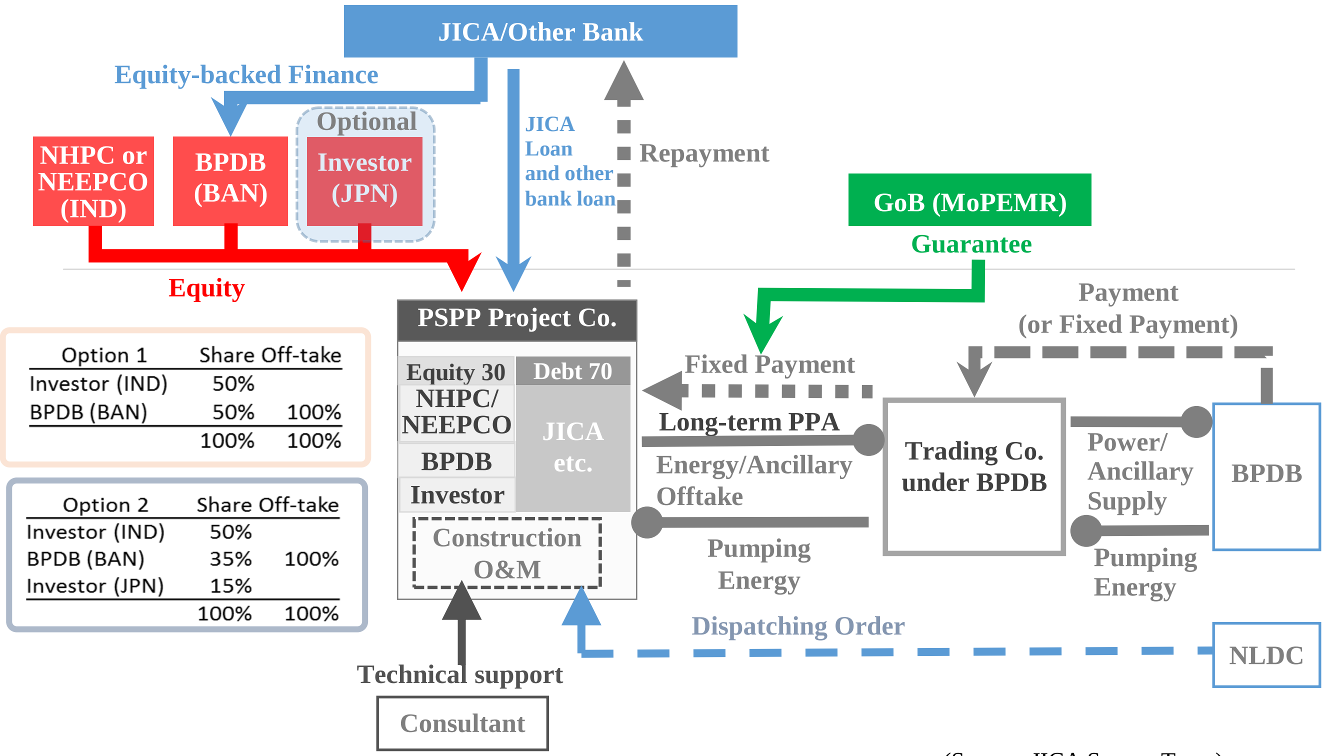
Figure 8-12 Daily Load Curve Estimation during the Annual Peak Demand

Differences between daytime and night-time demand are approximately 7,000MW in 2030, 10,000MW in 2035 and 13,000MW in 2040, gradually increasing. On the other hand, for the supply capacity mix, the share of thermal power generation with imported coal gradually increases, while that of domestic gas decreases due to the deletion of the domestic gas. As for peak hour supply capacity, the use of gas turbine generation with natural gas and/or diesel fuel and combined-cycle gas generation are expected in Bangladesh. However, PSPP is more economical than any of these generation technologies.

General pumped-storage equipment rapidly changes its generating capacity during generation and boasts a wide range of adjustable capacity. However, it cannot take on the function of frequency adjustment during pumping up due to its 100% pumping energy input. The adjustable speed pumped-storage system was developed in order to overcome such a disadvantage. An adjustable speed pumped-storage system can vary its energy input and thus serve the frequency adjustment function even during pumping up. In around 2030 in Bangladesh, coal power generation capacity accounts for a significant share during off-peak generation. In general, a CFPP is not good at frequency adjustment. Therefore, a lack of frequency adjustment function during off-peak hours is expected. Taking this point into account, the introduction of the adjustable speed pumped-storage system is highly desirable in Bangladesh.

On the other hand, any potential survey has not been undertaken in Meghalaya. However, the Indian government greatly changes the policy along with the promotion of the introduction of renewable energy, and has recently begun to promote the development of PSPP actively.

(3) Implementation Arrangement
Although there has been no such precedent in the world, the Survey Team proposes the following implementation arrangement to proceed with PSPP development in Meghalaya.



(Source: JICA Survey Team)

Figure 8-13 Implementation Arrangement for PSPP Development in Meghalaya

(a) Equity Shareholding of SPC
Although the PSPP is constructed based on the needs from Bangladesh, it is sensible to share the equity between public companies from Bangladesh and India on a pari passu basis due to the fact that the location of the PSPP is in Indian territory. However, if India has no interest in the shareholding of SPC, Bangladesh may hold all of the stake. The equity accounts for 30% of the total investment requirement and the rest relies on borrowing.

(b) O&M
The SPC shall take on operation and maintenance (O&M) after construction. Bangladesh shall establish a power trading company exclusively working on regional power trading, which, based on its

exclusive right to receive energy from the PSPP, procures pumping energy from BPDB, supplies it to the SPC and sells back the energy out of PSPP to BPDB, the Single Buyer. In addition, the SPC shall provide BPDB with ancillary services such as frequency adjustment. The power trading company shall contract out the operation and maintenance services to the SPC and make capacity (fixed) payment to the SPC for the services. The operation of the PSPP should comply with dispatching orders from NLDC of Bangladesh.

(c) Other Issues

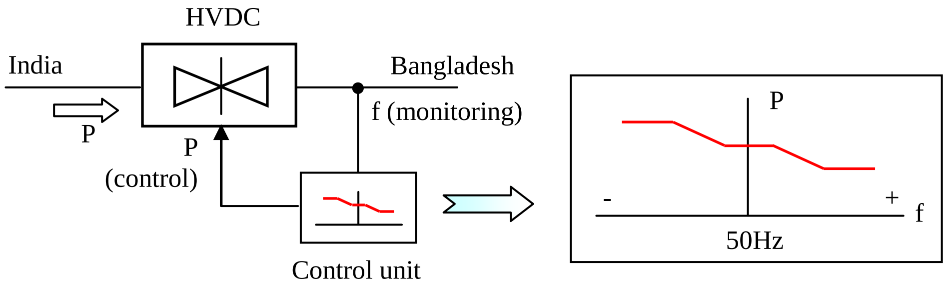
- Due to the lack of experience in construction and operation of PSPPs, especially in Bangladesh to some extent, it is required to hire an experienced technical advisor, or the Consultant. In this case, if any Japanese investment is involved, the Japanese investor may offer the owner's engineering services if relevant.
- A PSPP is expected to be peak supply capacity and therefore its annual operational hours are limited to approximately 2,000 hours. Its operation largely depends on the demand/supply balance. Hence, it is very risky to undertake a business owning the PSPP asset and solely depending on revenues only out of providing services. Taking this into consideration, power purchase agreements (PPAs) among parties, namely SPC, the Power Trading Company and BPDB have to be based on fixed capacity payment. The Power Trading Company may be endowed with the right to receive energy from other power plants.
- The policy has been greatly changed along with the promotion of the introduction of renewable energy, though India has not actively advanced the development of PSPP up to now. Therefore, it is thought that India will develop a PSPP in Meghalaya state at its own expense and according to its own needs. However, the unit capacity will be 400MW class because a high head of 600m or more can be expected for a PSPP in Meghalaya state, and the optimal scale is assumed to exceed 1,500MW with four units. Considering such a situation, the JICA Survey Team recommends the system configuration in the power plant indicated in Figure 8-11. Two units connect to the Indian system and two units connect to the Bangladesh system in the normal situation, and the number of connecting units can be varied depending on the request in emergency situations.

(4) Power Evacuation Plan

A 400kV transmission line from the PSPP to Bibiyana S/S with a length of approximately 90km shall be constructed. For connecting to the Indian grid, a 400kV transmission line to Killing S/S with a length of approximately 100km shall be constructed.

8.4.2 Frequency Adjustment with the Use of AC/DC Convertor

An AC/DC convertor easily and rapidly controls power flow. Thus, by monitoring frequency on one side of the grid and quickly adjusting the power flow according to the variance between the monitored frequency and the defined frequency standard, frequency stabilization can be very easily achieved. A specific illustration of control is given in the following figure.



(Source: JICA Survey Team)

Figure 8-14 An Illustration of Frequency Control with HVDC

When frequency rises in Bangladesh due to the surplus in supply capacity, the supply capacity from India shall be lowered. On the other hand, when the frequency drops due to the lack of supply capacity, the supply capacity from India shall be increased. To avoid fluctuation of the receiving capacity, as long as the monitored frequency stays within a certain dead band near the 50 Hz standard, the receiving capacity stays constant.

Because this is a very simple controlling module, only small additional investment is required. However, in order to accommodate this controlling module, the following points should be taken into consideration.

- Fluctuation in power flow at the AC/DC convertor induces frequency fluctuation in India. Therefore, Bangladesh needs India's consent for the controlling scheme. As applicable conditions, the size of the other network is sufficiently large and frequency fluctuation due to the fluctuation of power flow at the convertor would be rather small. In this case, the size of the Indian East grid is more than double that of the Bangladesh grid. As long as the upper limitation of fluctuation is clearly defined, it is possible to regulate the frequency fluctuation in relation to the power flow fluctuation at the convertor.
- Because it is not possible to receive more power than the HVDC capacity, the operational capacity has already got some margin for adjustment in the case of frequency drop to boost receiving capacity from India.
- When receiving capacity varies due to frequency fluctuation, the actual energy received faces deviation from the contracted capacity, hence incurring penalty. To avoid the penalty payment, within the contracted time zone (15 minutes), some manipulation to balance between actual and contracted capacity has to be required.

Specifically, this controlling scheme is technically applicable in the existing Bheramara HVDC convertor station (500MW). However, there are multiple contracts to utilize almost the full capacity. It is not sensible to modify the existing contracts to accommodate the frequency control. Bheramara HVDC has a plan to add to its capacity in the near future. The application of the frequency control modules shall be considered in the augmentation plan.

8.4.3 Direct Interconnection by AC

Interconnection by DC reduces interference caused by system faults in one of the interconnected systems. However, heavy investment in AC/DC convertor worsens investment efficiency. By 2040, the final year of PSMP2015, Bangladesh envisages direct AC interconnection with India, looking at the opportunity to get access to more affordable energy through the Indian power market. To this end, Bangladesh is required to improve the quality of electricity to the extent that it at least reaches or exceeds that of India.

8.5 The Possibility for Electricity Sales

8.5.1 The Possibility for Electricity Sales based on Bilateral Contract

As mentioned in 2.1.3 (2), since it is possible to be in a power surplus status from the late 2010s, depending on the trend of the future demand, it is important to investigate the possibility of power export via interconnections.

In order to obtain long-term stable revenue through electricity sales, continuous export based on the bilateral contract with India, where strong economic growth is expected in the future, is desirable. The JICA Survey Team will continue to investigate the future supply and demand situation and price trends of India, and, based on the results of this investigation, the JICA Survey Team will conduct an analysis of the feasibility of electric power sales.

In addition, from interviews with PGCB, power trading between India and Bangladesh is found to be intermediated by NTPC Vidyut Vyapar Nigam Limited (NVVN), which was established by government capital, in the position of Nodal Agency.
JICA Survey Team will add the investigation of this company to our plan.

8.5.2 The Possibility of Short-term Trading via the Electricity Wholesale Market

In India, there are two major markets for electricity wholesale - IEX (Indian Energy Exchange) and PXIL (Power Exchange India Limited). Table 8-4 shows a summary of each market regarding the eligibility to become a member or participant and products.

It is not clear whether entities relating to the electricity trade in Bangladesh can be eligible to become a member of the markets. However, according to interviews with PGCIL, NVVN has acquired membership. So, it is possible to trade electricity through this company.

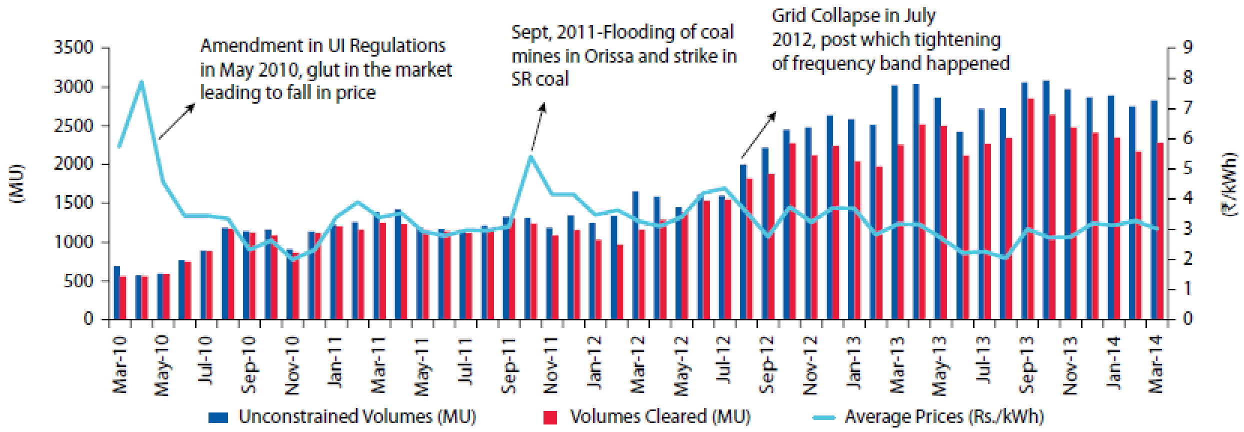
Table 8-4 Summary of Power Exchange Market in India

		Power Exchange India Ltd (PXIL)	Indian Energy Exchange Ltd (IEX)
Market Members	**Key Attributes**	- Electricity traders - Inter-State Generating Stations (ISGSs) - Distribution Licensees/Deemed Distribution Licensees - IPPs, connected on ISTS - CPPs & MPPs * - Open Access Customers* - State Generating Stations - Eligible and Obligated Entities (Applicable in case of REC) - Others** *: With a clearance to be obtained from the concerned SLDC **: Would be admitted only as Advisory Member, Independent Power Producers (IPPs), Captive Power Producers (CPPs), or Merchant Power Plants (MPPs)	The following entities are eligible to become a Member of IEX: - Proprietor Firm - Registered Partnership Firm - Private Limited Company - Public Limited Company - Government owned Entity - State Electricity Board
Market Participation	**General Eligibilities**	- Membership at PXIL - Even non-members of PXIL can trade through a member	- Only the **Exchange Members** - Persons who are not Exchange Members can participate as **Clients** through a registered Exchange Member Category of Client: **Grid-connected Client**: who is eligible to buy or sell electricity and is connected to the grid ex. Distribution Licensees, Generators, Consumers and Open Access Users **Trader Client**: who is eligible to trade in

		Power Exchange India Ltd (PXIL)	Indian Energy Exchange Ltd (IEX)
			electricity under the Electricity Act 2003 and has a legally valid power purchase/sale agreement
	Other Requirements	- Grid connectivity - State Load Dispatch Center (SLDC) concurrence required for application to nodal RLDC - Two Settlement Accounts for Settlement of Trade - Installation of Availability Based Tariff (ABT) Meter(*) (*) ABT Meter is programmed to record injection/withdrawal of energy, demand, voltage and average frequency at 15 min intervals, which is one time block as per the Indian Electricity Grid Code.	- Standing Clearance from State Load Dispatch Center (SLDC) of State/UT (Union Territory) - Presence of ABT (Availability based Tariff) Meter - Member must open settlement account in the following designated Clearing Banks. ➢ HDFC Bank Limited ➢ Indusind Bank Limited ➢ State Bank of India
Market Products	**Day Ahead**	1. Day Ahead Spot Contract (DAS) 2. Day Ahead Contingency Contract (DAC)	1.**Day-Ahead Market (DAM)** -electricity on 15-minute block basis -a day prior to the delivery of electricity - both buyers and sellers submit their anonymous bid electronically
	Weekly	3. Week Ahead Contract	2**. Term-Ahead Market (TAM)** - TAM covers a range of buying/selling electricity for durations up to 11 days. - Participants can purchase electricity for *the same day through intra-day contracts *the next day through day-ahead contingency *on a daily basis for rolling seven days through daily contracts *on weekly basis through weekly contracts
	Daily	4. Intra Day Contract 5. Any Day Contract	
	CO2 Free (Renewable Energy) Options	6. Renewable Energy Certificates (REC)	3.**Renewable Energy Certificates (REC)** - this market facilitates transactions in green attributes - The Renewable Energy (RE) generator can opt to get RECs against green attributes of their generation, and can sell RECs through the Exchange.
	Energy Saving Options	None	4.**Energy Saving Certificates (ESCerts)** : in the near future - the tradable certificates under the Perform, Achieve, Trade (PAT) Scheme of Bureau of Energy Efficiency (BEE) - a market-based mechanism to incentivise energy efficiency in large energy-intensive industries

(Source: IEX and PXIL Websites)

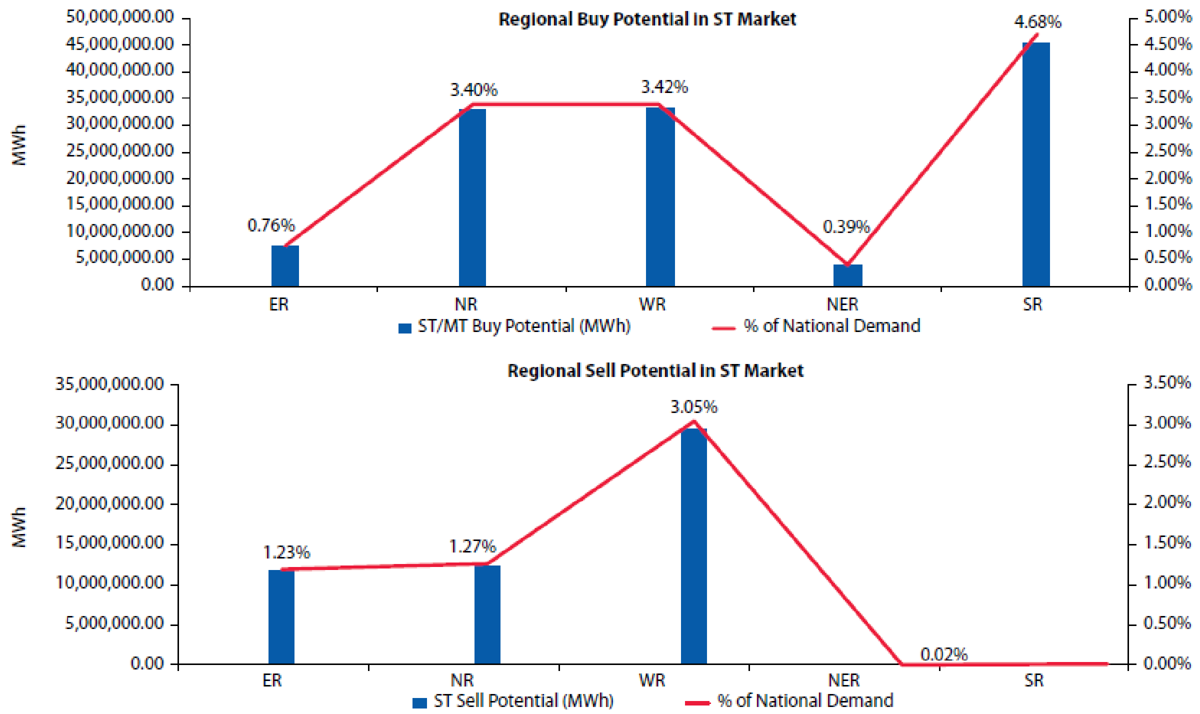
According to the "Indian Power Market: Journey so far and way forward (June 2014)", published by IEX, trading volume remained at about 3% of the overall domestic power procurement amount at the time in July 2013. But, as shown in Figure 8-15, due to an increase in trading volume and the number of participants, the price has been relatively stable.



(Source: Indian Power Market: Journey so far and way forward (IEX, June 2014))

Figure 8-15 Trends in Prices and Volumes on IEX from 2010 through 2014

Figure 8-16 illustrates the regional short-term buy and sell potential limits at inter-state level due to co-skewness of the demand curves of various states, based on the data for 2012-13.
According to this, except for the East Region (ER), each area seems not to be in a self-sufficient status because of higher Buy Potential than Sell Potential. In particular, the South Region (SR) is in a status of higher Buy Potential and no Sell Potential.
Although it depends on the future of Indian domestic power development trends, it can be estimated that there is sufficient possibility of selling electricity to this country.



(Source: Indian Power Market: Journey so far and way forward (IEX, June 2014))

Figure 8-16 Regional Buying and Selling Potential Limits at Inter-State Level due to Co-skewness