Nepal Electricity Authority
Nepal

Nationwide Master Plan Study on Storage-type Hydroelectric Power Development in Nepal

Final Report Appendix (1/2)

February 2014

Japan International Cooperation Agency

Electric Power Development Co., Ltd.

Appendix

Appendix 1	**Final Long List of the Potential Sites of Storage Projects**
Appendix 2	**Selected Promising Projects**
Appendix 3	**Strategic Environmental Assessment Report**
Appendix 4	**Power Development Plan and Development Plan of Storage-type Hydroelectric Power Projects taking into consideration Candidate Projects proposed by NEA**
Appendix 5	**Annex of SEA Report**

Appendix-1 Final Long List of the Potential Sites of Storage Projects

1.1 Final long list of potential sites of storage projects

1.2 Final long list of the potential sites of storage projects (additional)

Nepal Electricity Authority

(Government of Nepal Undertaking)

Phone: 4153054
4153055
4153007

Fax : 00977-1- 4153013
E-mail: neamd@mos.com.np
webpage: www.nea.org.np

Head Office
Durbar Marg
Kathmandu, Nepal
PB No.: 10020

Our Ref. No.: 066/067 MDS/D.N. 414

Date : December 17, 2009

To,

Mr. Yusuke TSUMORI
Representative
JICA Nepal Office
P.O.Box. 459, Kathmandu, Nepal
Karmachari Sanchaya Kosh Building
Hariharbhawan, Lalitpur, Nepal.

Subject : Final long list of the potential sites of storage projects.

Dear Mr. TSUMORI,

With reference to your letter No. JICA (NP)//-24001 dated November 23rd, 2009 and as per clause 2 of the Minutes of Meeting signed on November 19th, 2009, please find attached the summary of final long list of the potential sites with location maps. The list is based on the previous study reports for the different basins as mentioned below and as suggested by JICA expert in Nepal for your needful action.

1. Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA.
2. Master Plan of Hydroelectric Development in Nepal, 1974, JICA.
3. Gandaki River basin Power Study, Basin Study, Basin Master Plan, 1979, UNDP;
4. Master Plan Study on the Kosi River Water Resources Development, 1985, JICA;
5. Master Plan Study for Water Resources Development of the Upper Karnali River and Mahakali River Basins, 1993, JICA;
6. Medium Hydropower Study Project, Power Sector Efficiency Project, 1997, World Bank; CIWEC; and
7. Identification and feasibility Study of Storage Proejct, 2000-2004, NEA.

Your cooperation in this regard is highly appreciated.

Thanking you

Yours Sincerely

.....

Dr.Jivendra Jha
Managing Director

CC :
Engineering Services, NEA.
Mr. Y. Ozaki, JICA Expert NEA.

NEPAL ELECTRICITY AUTHORITY

Long List for Inventory of Potential Sites

Details of Storage Project in Eastern River Basin

No.	Project Name	Location/ River	MW	GWh	Dam Height (m)	Geology information	Enviromenatal information	Environmenatal Index	Grid connection	Study level	Donor Agency	Program year of commision	Remarks
1	Dudh Koshi	Okhaaldhunga / Khotang dist. Dudh koshi to Baiku Khola	300	1806	180	Augen Gneiss, Phyllite and quarzite	EIA Report Available	(0)	92 km (Lahan sub station),132KV	FS by CIWEC 1998			
2	Dudh Kosi-2	Solukhumbu / Dudh Koshi	456.6	2113	212	Phyllite, Quartizite	No. of Families: 75 Ag. Land: 2.8 km^2 Forest Cover:2.19Km2	(0)	92 km (Lahan sub station),132KV	Desk study			
3	Dudh Koshi-3	Solukhumbu / Dudhkoshi	1048.6	6006	357	Phyllite, Quartizite	No. of Families: 65 Ag. Land: 1.4 km^2 Forest Cover:5.5Km^2	(0)	94 km (Lahan Sub Station),132kV	Desk study			
4	Dudh Koshi-4	Solukhumbu / Dudhkoshi	1603	4664	425	Phyllite, Quartizite	No. of Families: 60 Ag. Land: 2.16 km2, Forest Cover:6.05Km^2	(0)	100 km (Lahan Sub Station),132kV	Desk study			
5	Khimti	Ramechhap, Dolakha / Khimti	128.1	621.5	194	Schist , Gneiss	No. of Families: 25 Ag. Land: 0.38 km2, Forest Cover:1.32Km^2	(0)	13.5 km (Khimti Sub Station),132kV	Desk study			

Note:

a) Geological Information

The basis for the level of the geological information is as follows:

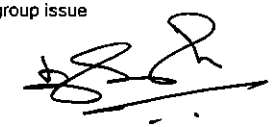
Desk Study: Based on regional maps and other relevant information without a site visit.

Prefeasibility Study: Geological mapping with site visit.

Feasibility Study: With drilling and Seismic and Construction material survey.

b) Environmental Information

Index	Description
(0)	No information available
(1)	The project area/reservoir area lies within the boundaries of a National Park or protected area
(2)	The impounding of the reservoir will involve large resettlements
(3)	The construction of project will involve ethnic minority group issue



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Long List for Inventory of Potential Sites

No.	Project Name	Location/ River	MW	GWh	Dam Height (m)	Geology information	Enviromenatal information	Environmenatal Index	Grid connection	Study level	Donor Agency	Program year of commision	Remarks
6	Kokhajor - 1	Sinchuli. Sindhupalchowk/Kokhajor	11.5	322.7	107	Sandstone with conglomerate	No. of Families: 25 Ag. Land: 0.53km2, Forest Cover:3.17Km^2	(0)	69 km (Dhalkebar Sub Station),132kV	Desk study			
7	Likhu - 1	Ramechhap / Likhu	91.2	425.7	139	Phyllite, Schist	No. of Families: 172 Ag. Land: 3.36km2, Forest Cover:0.65Km^2	(0)	55 km (Dhalkebar Sub Station),132kV	Desk study			
8	Mulghat	Dhankuta / Tamor	2647.7	7638	292	Sandstone, Mudstone, Shale	No. of Families: 227 Ag. Land: 17.15km2, Forest Cover:24.04Km^2	(0)	45 km (Duhabi Sub Station),132kV	Desk study			
9	Piluwa - 2	Sankhuwasabha/ Piluwa	107.3	312.6	119	Quartzite, Phyllite, Augen gneiss and schist	No. of Families: 20 Ag. Land: 2.03km2, Forest Cover:2.54Km^2	(0)	90 km (Duhabi Sub Station),132kV	Desk study			
10	Rosi - 2	Kavrepalanchowk / Roshi	106.5	399.9	124	Phyllite and Quartzite	No. of Families: 130 Ag. Land: 0.29km2, Forest Cover:0.39Km^2	(0)	32 km (Panchkhal Sub Station),132kV	Desk study			

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Prefeasibility Study: Geological mapping with site visit.

Feasibility Study: With drilling and Seismic and Construction material survey.

b) Environmental Information

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(0)	No information available
(1)	The project area/reservoir area lies within the boundaries of a National Park or protected area
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Long List for Inventory of Potential Sites

No.	Project Name	Location/ River	MW	GWh	Dam Height (m)	Geology information	Enviromenatal information	Environ enatal Index	Grid connection	Study level	Donor Agency	Program year of commision	Remarks
11	Sankhuwa - 1	Sankhuwasabha/ Sankhuwa	176	667.6	156	Biotite schist with quartzite	No. of Families: 32 Ag. Land: 0.68km2, Forest Cover:0.63Km^2	(1)	114 km (Duhabi Sub Station),132kV	Desk study			
12	Tama Kosi -3	Dolakha/ Tamakosi	330		160	Gneiss and Schist		(0)	85 km	FS by NEA in 2002			
13	Tamor No. 1	Dhankuta / Tamor	696		153	Phyllite, Quartizite, Schist		(0)		Desk Study			
14	Tamor (Terahathum)	Terathum / Tamor	380		170	Phyllite, Quartizite, Schist		(0)		Desk Study			
15	Sunkosi No 1	Khotang, Udayapur/ Sun Kosi	1357		147	Phyllite, Quartizite, Schist		(0)		Desk Study			

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Prefeasibility Study: Geological mapping with site visit.

Feasibility Study: With drilling and Seismic and Construction material survey.

b) Environmental Information

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(0)	No information available
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Long List for Inventory of Potential Sites

No.	Project Name	Location/ River	MW	GWh	Dam Height (m)	Geology information	Enviromenatal information	Environmenatal Index	Grid connection	Study level	Donor Agency	Program year of commision	Remarks
16	Sunkosi No 2	Ramechhap, Sindhuli/ Sun Kosi	1110		166			(0)		Desk Study in Master Plan			
17	Sunkosi No 3, Kosi M/P (Multipurpose)	Ramechhap / Sunkosi	536		140			(0)		Desk Study in Master Plan			
18	Sunkosi No 3, Kosi M/P	Ramechhap / Sunkosi	432		110.5			(0)		Desk Study in Master Plan			
19	Sunkosi No 3	Ramechhap / Sunkosi	190		144			(0)		Desk Study in Master Plan			
20	Indrawati	Sindhupalchowk / Indrawati	91.2		111	Lesser Himalaya greenish grey phyllite and quartizite	Settlement 455, Agricultural Land 810 Km2	(0)	29 km	Desk study			
21	Kankai	Ilam / Kankai	90		90		11700 families to be relocated	(2)	5 km	Feasibility Study by NEA			

Note:

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Prefeasibility Study: Geological mapping with site visit.

Feasibility Study: With drilling and Seismic and Construction material survey.

b) Environmental Information

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(0)	No information available
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Long List for Inventory of Potential Sites

Details of Storage Project in Central River Basin

No.	Project Name	Location/ River	MW	GWh	Dam Height (m)	Geology information	Enviromenatal information	Environmenatal Index	Grid connection	Study level	Donor Agency	Program year of commision	Remarks
1	Kaligandaki-Modi	Baglung,Parbar/Kaligandaki, Modi Confluence	816.4	3097	189	Quartzite, Phyllite	No. of Families: 235 Ag. Land: 16.73km2, Forest Cover:13Km^2	(0)	12 km (Modi Khola Sub Station),132kV	Desk study			
2	Lower Badigad	Gulmi / Badigad	380.3	1559	191	Phyllite, Schist, Quartzite	No. of Families: 240 Ag. Land: 10.22km2, Forest Cover:2.92Km^2	(0)	12 km (Kali Gandaki ASub Station),132kV	Desk study			
3	Lower Daraudi	Gorkha / Daraudi	120.2	347.9	111	Phyllite Quartizite and Gritty Phyllite	No. of Families: 500 Ag. Land: 9km2, Forest Cover:3.27Km^2	(0)	9 km (Marsyangdi Sub Station),132kV	Desk study			
4	Seti -Trisuli	Tanahun / Seti	128			Phyllite and Slaty Phyllite		(0)	10 km (Marsyangdi Sub Station),132kV	Feasibility			
5	Upper Daraudi	Gorkha / Daraudi	111.4	325.6	153	Phyllite Quartizite and Gritty Phyllite Schist	No. of Families: 50 Ag. Land: 1.88km2, Forest Cover:1.61Km^2	(0)	29 km (Marsyangdi Sub Station),132kV	Desk study			

Note

a) Geological Information

The basis for the level of the geological information is as follows:

Desk Study: Based on regional maps and other relevant information without a site visit.

Prefeasibility Study: Geological mapping with site visit.

Feasibility Study: With drilling and Seismic and Construction material survey.

b) Environmental Information

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No.	Project Name	Location/ River	MW	GWh	Dam Height (m)	Geology information	Enviromenatal information	Environmenatal Index	Grid connection	Study level	Donor Agency	Program year of commision	Remarks
6	Kaligandaki-2	Tanahun. Nawalparasi/ Kaligandaki	660		177	Phyllite Quartizite	Relocation of 7000 houses	(0)	40 km	Pre FS by NEA (1985)			
7	Burhi Gandaki	Dhading / Burhi Gandaki	600		225	Dolomitic Quartizite, Slate, Lime Stone		(0)		Pre FS by ED, MOWR, Technical assistance from CIDA			
8	Andhi Khola	Syangja / Andhi Khola	180	693	157	Lime Stone, Slate, Quartizite		(0)	44 km	FS study by NEA in 1998/1999			
9	Langtang Khola	Rasuwa / Langtang Khola	218		93	Gneiss and Quartizitic Schist	Relocate 33 families	(0)	27 km	Phase II Fine Screeening and Ranking Study by NEA .2000			
10	Uttar Ganga	Baglung / Uttar Ganga	300		200	Phyllite, Schist, Dolomite, Quartzite	Relocation of 625 families	(0)	90 km upto Butwal	Desk and Reconaissance Study			

Note

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Prefeasibility Study: Geological mapping with site visit.

Feasibility Study: With drilling and Seismic and Construction material survey.

b) Environmental Information

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No.	Project Name	Location/ River	MW	GWh	Dam Height (m)	Geology information	Enviromenatal information	Environmenatal Index	Grid connection	Study level	Donor Agency	Program year of commision	Remarks
11	Madi- Ishaneshor	Kaski, Lamjung	86(120)		138	Phyllite, Quartizite		(0)	26 km	Feasibility			Licence with Private Sector
12	Kali Gandaki No. 1	Kali Gandaki	1600		260			(0)		Desk Study in Master Plan			
13	Marsyangdi	Marsyangdi	510	3190	140			(0)		Desk Study in Master Plan			
14	Seti (Gandaki)	Seti	230	1340	140			(0)		Desk Study in Master Plan			
15	Dev Ghat	Narayani / Chitawan	150	1193	40			(0)		Desk Study in Master Plan			

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Prefeasibility Study: Geological mapping with site visit.

Feasibility Study: With drilling and Seismic and Construction material survey.

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Long List for Inventory of Potential Sites

No.	Project Name	Location/ River	MW	GWh	Dam Height (m)	Geology information	Enviromenatal information	Environmenatal Index	Grid connection	Study level	Donor Agency	Program year of commision	Remarks
16	Bhomichok	Buri Gandaki	200	956	80			(0)		Desk Study in Master Plan			
17	Trishulganga Storage (Alternative to Marsyangdi Storage, Burhi Gandaki and Mugling Schemes)		1500					(0)		Desk Study in Master Plan			

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Prefeasibility Study: Geological mapping with site visit.

Feasibility Study: With drilling and Seismic and Construction material survey.

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Long List for Inventory of Potential Sites

Details of Storage Project in Western River Basin

No.	Project Name	Location/ River	MW	GWh	Dam Height (m)	Geology information	Enviromenatal information	Environ enatal Index	Grid connection	Study level	Donor Agency	Program year of commision	Remarks
1	Barbung Khola	Dolpa / Barbung	122.9	484.3	66	Himalayan Crystalline Roc, Granitic gneiss, Gneiss and Schist	No. of Families: 0 Ag. Land: 0.1km2, Forest Cover:0.02Km2	(0)	170km (kholapur s/s) 132 kv	Desk study			
2	Chera - 1	Jajarkot / Chera	148.7	606.4	186	Phyllite Quartzite and Slate	No. of Families: 80 Ag. Land: 1.23km2, Forest Cover:1.93Km2	(0)	70.4km (kholapur) 132 kv	Desk study			
3	Chera - 2	Jajarkot / Chera	104.3	425.8	153	Phyllite Quartzite and Slate	No. of Families: 140 Ag. Land: 0.94km2, Forest Cover:4.4Km2	(0)	68.2km (kholapur), 132 kv	Desk study			
4	Humla-Karnali	Humla / Huma-Karnali	467.1	1841	271	Gneiss and Granitic Gneiss	No. of Families: 0 Ag. Land: 0.62km2, Forest Cover:3.4Km2	(0)	168km (lumki SS), 132 kv	Desk study			
5	Lower Jhimruk	Arghakachi, Pyuthan / Jhimruk	142.5	460.1	167	Lime Stone, Shale, Quartzite and Schist	No. of Families: 225 Ag. Land: 3.61km2, Forest Cover:2.88Km2	(0)	52km nearest point, 132 kV	Desk study			

Note

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The basis for the level of the geological information is as follows:

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Prefeasibility Study: Geological mapping with site visit.

Feasibility Study: With drilling and Seismic and Construction material survey.

b) Environmental Information

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Long List for Inventory of Potential Sites

No.	Project Name	Location/ River	MW	GWh	Dam Height (m)	Geology information	Enviromenatal information	Environmenatal Index	Grid connection	Study level	Donor Agency	Program year of commision	Remarks
6	Madi	Rolpa/Madi	199.8	585.1	190	Phyllite Limestone and Quartzite	No. of Families: 79 Ag. Land: 1.79km2, Forest Cover:3.29Km2	(0)	55km from lamahi SS & 40 km from Jhimruk, 132 kv	Desk study			
7	Mugu Karnali	Bajura, Mugu, Humla / Mugu Karnali	3843.8	11193	694	Phyllite, Schist, Dolomite and Limestone	No. of Families: 150 Ag. Land: 6.38km2, Forest Cover:22.32Km2	(0)	132km from lamki, 132 kv	Desk study			
8	Sani Bhari - 1	Rukum / Sani Bheri	763.5	2185	417	Phyllite, Limestone, Dolomite and Quartzite	No. of Families: 170 Ag. Land: 2.63km2, Forest Cover:5.25Km2	(0)	126km from kholpur, 132 kv	Desk study			
9	Sani Bhari - 2	Rukum / Sani Bheri	646.9	1851	330	Phyllite, Limestone, Dolomite and Quatzite	No. of Families: 400 Ag. Land: 7.2km2, Forest Cover:3.6Km2	(0)	92km from kholpur ss,132 kv	Desk study			
10	Sharada - 2	Salyan / Sharada	96.8	282.7	118	Sandstone, Mudstone., Siltstone	No. of Families: 173 Ag. Land: 3.49km2, Forest Cover:2.58Km2	(0)	27.5km from kholpur SS, 132 kv	Desk study			

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11	Thuligi Gad - 2	Doti / Thuligad	119.7	435.4	115	Sandstone, Mudstone, Dolomite, Shale and Limestone	No. of Families: 220 Ag. Land: 2.21km2, Forest Cover:1.11Km2	(0)	39 km , 132 kv	Desk study			
12	Tila - 1	Kalikot / Tila	617.2	2451	269	Gneiss, Schist, Phyllite		(0)	92 km from Lamki, 132 kv	Desk study			
13	Tila - 3	Kalikot / Tila	481.9	2135	338			(0)	76km from lamki, 132 kv	Desk study			
14	Thuli Gad	Doti / Thuligad	120		115	Sandstone, Mudstone, Shale,Dolomite, Limestone		(0)	39 km	Desk study			
15	LR-1	Surkhet / Lohore	98					(0)		Desk Study in Master Plan			

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16	BR3B	Bheri	801					(0)		Desk Study in Master Plan			
17	BR 4	Bheri	667					(0)		Desk Study in Master Plan			
18	Surkhet	Bheri	600	3570				(0)		Desk Study in Master Plan			
19	Lakarpata	Karnali	1200	7110	197			(0)		Desk Study in Master Plan			
20	Bhanakot	Karnali	810	4800	200			(0)		Desk Study in Master Plan			

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No.	Project Name	Location/ River	MW	GWh	Dam Height (m)	Geology information	Enviromenatal information	Enviromenatal Index	Grid connection	Study level	Donor Agency	Program year of commision	Remarks
21	Thapna	Bheri	500	2980				(0)		Desk Study in Master Plan			
22	SR6	Seti (West)	642					(0)		Desk Study in Master Plan			
23	Nalsyagu Gad	Jajarkot / Nalsyagu	400		189	Dolomite, Slate and Phyllite	150 house to be relocated	(0)		Feasibility on Progress			Tentaive Plans for application to the Chinese Government

Note

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Nepal Electricity Authority

(Nepal Government Undertaking)

Engineering Services

Ref No. : 2066/67 Cha No 459 *Date:- December 23, 2009*

To,

Mr. Yusuke TSUMORI
Representative
JICA Nepal Office
P.O.Box. 459, Kathmandu, Nepal
Karmachari Sanchaya Kosh Building
Hariharbhawan, Lalitpur, Nepal.

Subject : Final long list of the potential sites of storage projects.

Dear Mr. TSUMORI,

With reference to our letter No 066/067 MOS/D.N. 414 dated December 17, 2009, we request you to incorporate the following additional projects in the long list for you needful action as suggested by JICA Expert in Nepal.

- Ridhi Khola 97 MW, Central River Basin
- Sarada Babai 75 MW Western River Basin
- Naumure (W.Rapti) 245 MW, Western River Basin
- Lohare Khola 67 MW, Western River Basin

Your cooperation in this regard will be highly appreciated.

Thanking you

Yours Sincerely

S. C. Jha
General Manager

CC :
Mr. Y. Ozaki, JICA Expert NEA.

P.O.No.3794, DURBAR MARG, KATHMANDU, NEPAL, Ph. No. 4-153025
Fax No. : 00977-1-4153026

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Additional Project to Long List for Inventory of Potential Sites

In Central River Basin

No.	Project Name	Location/ River	MW	GWh	Dam Height (m)	Geology information	Enviromenatal information	Environmental Index	Grid connection	Study level	Donor Agency	Program year of commision	Remarks
1	Ridi Khola	Palpa, Arghakhanchi/Ridi	97					(0)					

In Western River Basin

No.	Project Name	Location/ River	MW	GWh	Dam Height (m)	Geology information	Enviromenatal information	Environmental Index	Grid connection	Study level	Donor Agency	Program year of commision	Remarks
1	Sarada Babai	Salyan	75	484.3	90	Sandstone, Siltstone, Mudstone, Shale		(0)	40 km	Desk Study in MHSP			
2	Naumure(W. Rapti)	Argakhanchi, Puythan/ Rapti	245	979	190	Sandstone, Mudstone, Shale		(0)		Pre FS by NEA in 1990			Interest shown by Indian Government
3	Lohare Khola	Dailekh/Lohare	67		120	Phyllite, Gneiss, Quartzite		(0)					

Note:

a) Geological Information

The basis for the level of the geological information is as follows:

Desk Study: Based on regional maps and other relevant information without a site visit.
Prefeasibility Study: Geological mapping with site visit.
Feasibility Study: With drilling and Seismic and Construction material survey.

b) Environmental Information

Index	Description
(0)	No information available
(1)	The project area/reservoir area lies within the boundaries of a National Park or protected area
(2)	The impounding of the reservoir will involve large resettlements
(3)	The construction of project will involve ethnic minority group issue

A.1.2 - 2

Appendix 2 Selected Promising Projects

A.2 Selected Promising Projects

The 10 projects selected as promising projects are listed below. Out of total 75 districts, the development ranking of district where each project located at is shown in parentheses for reference.

Table A.2-1 Promising Projects

No.	Project Name	(MW)	District (Ranking)*	River (Major River Basin)
E-01	Dudh Koshi	300.0	Okhaldhunga (50/75), Khotang (48/75), Solukhumbu (44/75)	Dudh Koshi to Baiku Khola (Koshi)
E-06	Kokhajor-1	111.5	Sinduli (51/75), Kabhrepalanchok (6/75)	Kokhajor to Bagmati (Bagmati)
E-17	Sun Koshi No.3	536.0	Ramechhap (56/75), Kabhrepalanchok (6/75), Sindhupalchok (43/75)	Sun Koshi (Koshi)
C-02	Lower Badigad	380.3	Gulmi (33/75)	Badigad (Gandaki)
C-08	Andhi Khola	180.0	Syangja (9/75)	Andhi Khola to Kali Gandaki (Gandaki)
W-02	Chera-1	148.7	Jajarkot (62/75)	Chera (Karnali)
W-05	Lower Jhimruk	142.5	Arghakhanchi (27/75), Pyuthan (54/75)	Jhimruk (Karnali)
W-06	Madi	199.8	Rolpa (66/75)	Madi (Karnali)
W-23	Nalsyau Gad	410.0	Jajarkot (62/75)	Nalsyau Gad (Karnali)
W-25	Naumure (W. Rapti)	245.0	Arghakhanchi (27/75), Pyuthan (54/75)	West Rapti (Karnali)

*): Development ranking based on Composite Index (Source: Central Bureau of Statistics. 2003. District level indicators of Nepal for monitoring overall development. Kathmandu, Nepal.)

The locations of the promising projects are shown below in Figure A.2-1.

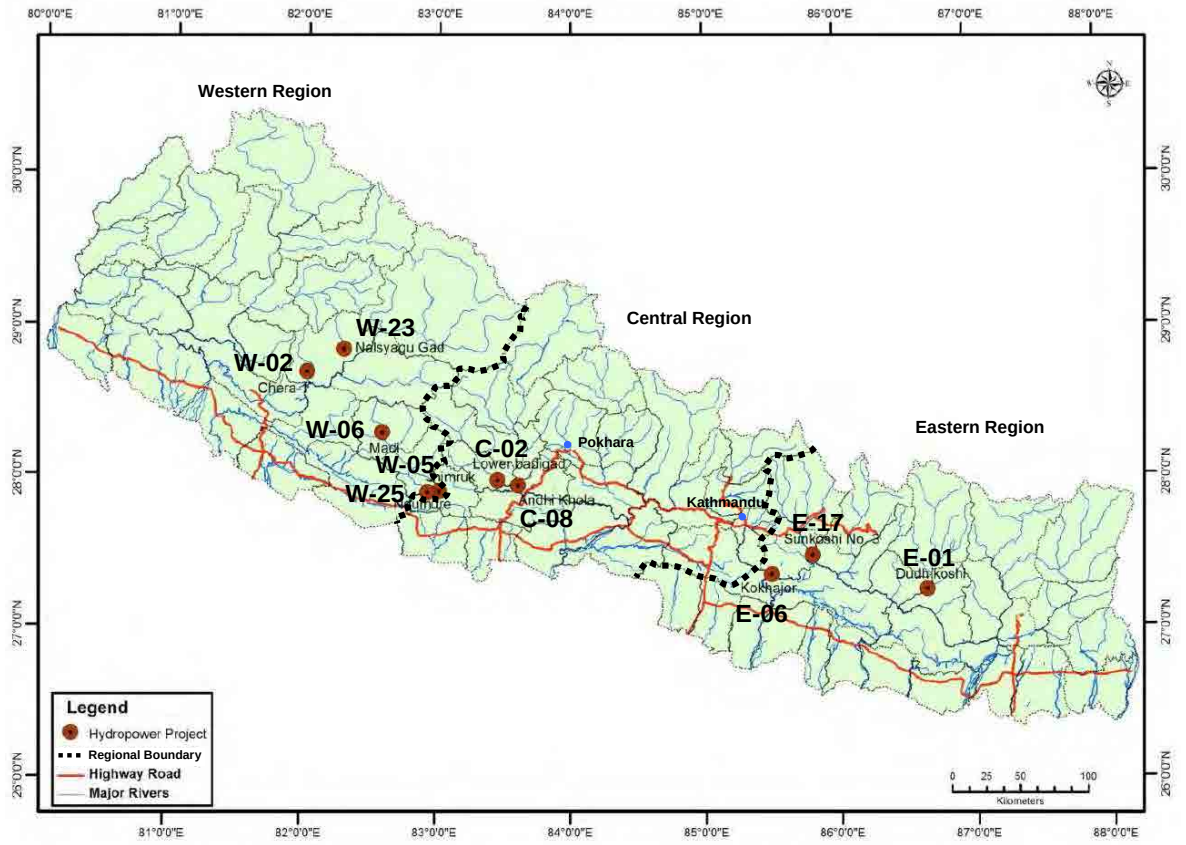

Figure A.2-1 Locations of Promising Projects

The salient features of the promising projects are summarized in Table A.2-2.

Table A.2-2 Salient Features of Promising Projects

No.	Unit	E-01	E-06	E-17	C-02	C-08	W-02	W-05	W-06	W-23	W-25
Project Name		Dudh Koshi	Kokhajor-1	Sun Koshi No.3	Lower Badigad	Andhi Khola	Chera-1	Lower Jhimruk	Madi	Nalsyau Gad	Naumure (W. Rapti)
Installed Capacity	MW	300.0	111.5	536.0	380.3	180.0	148.7	142.5	199.8	410.0	245.0
Catchment Area	km^2	4,100.0	281.0	5,520.0	2,050.0	475.0	809.0	995.0	674.0	571.5	3,430.0
Dam Height	m	180.0	107.0	140.0	191.0	157.0	186.0	167.0	190.0	200.0	190.0
Total Storage Volume	MCM	687.4	218.7	1,220.0	995.9	336.5	254.9	386.0	359.5	419.6	1,021.0
Effective Storage Volume	MCM	442.1	166.1	555.0	505.5	238.7	141.1	211.6	235.1	296.3	580.0
Reservoir Area	km^2	11.1	4.6	30.1	13.7	5.5	4.0	6.0	7.7	6.3	19.8
Full Supply Level	m	580.0	437.0	700.0	688.0	675.0	866.0	597.0	1,090.0	1,570.0	517.0
Minimum Operating Level	m	530.0	390.0	674.0	654.0	626.7	814.0	557.0	1,030.0	1,498.0	474.2
Tail Water Level	m	303.4	200.0	575.0	475.0	368.5	640.0	390.0	800.0	872.0	358.0
Rated Gross Head	m	275.0	226.3	116.3	196.0	307.0	220.0	194.6	280.8	649.3	162.6
Rated Net Head	m	249.3	205.6	109.3	192.5	286.3	217.6	190.4	277.0	635.5	154.5
Rated Power Discharge	m^3/sec	136.0	63.9	570.0	232.6	81.4	80.5	88.1	84.9	75.0	185.6
Total Energy	GWh	1,909.6	278.9	1,883.6	1,366.0	648.7	563.2	454.7	621.1	1,406.1	1,157.5
Dry Energy	GWh	523.3	94.1	335.9	354.7	137.1	120.6	94.4	170.7	581.8	309.9
Length of Access Road	km	65.0	22.0	20.0	0	8.0	5.5	18.0	15.0	25.0	34.0
Length of Transmission Line	km	43.0	62.0	35.0	49.0	49.0	66.0	75.0	62.0	112.0	79.0
Project Cost	MUS$	1,144.0	476.5	1,690.5	1,209.8	665.8	576.9	520.9	637.3	966.9	954.5
Unit Generation Cost	¢ /kWh	6.0	17.1	9.0	8.9	10.3	10.2	11.5	10.3	6.9	8.2
EIRR (8% of Interest Rate, 12NRs/kWh)	%	17.6	7.6	13.1	13.2	13.0	12.6	10.9	12.3	15.6	15.2
FIRR (8% of Interest Rate, 12NRs/kWh)	%	30.0	n.a.	19.4	19.8	19.1	17.8	11.5	16.8	25.8	25.3
Forest Land to be submerged	km^2	4.1	2.9	8.2	3.3	1.5	1.5	1.9	1.6	0.8	7.9
Downstream Protected Area	nos	2	1	2	3	3	3	2	2	3	2
Protected Species in the Project Area	nos	20	11	18	17	15	16	19	15	8	20
Dewatering Area	km	60	21	1	4	60	7	8	10	11	1
Reported Fish species	nos	24	7	21	12	6	11	11	8	8	16
Resettlement (Household)	nos	63	92	1,599	1,606	542	566	229	336	263	456
Cultivated land to be submerged	km^2	3.3	1.7	9.4	5.9	1.7	1.1	2.0	1.9	2.5	6.1
Fishermen	nos	154	-	712	217	156	25	254	100	115	43
Road to be submerged	km	5	-	39	26	3	4	3	11	-	2

The source reports of the promising projects are shown in Table A.2-3..

Table A.2-3 Source Reports of Promising Projects

No.	Project Name	Source Report
E-01	Dudh Koshi	Dudh Koshi Hydroelectric Project Feasibility Study, 1998, CIWEC (Canadian International Water and Energy Consultants)
E-06	Kokhajor-1	Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA
E-17	Sun Koshi No.3	Master Plan Study on the Koshi River Water Resources Development, 1985, JICA
C-02	Lower Badigad	Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA
C-08	Andhi Khola	Feasibility Study on Andhi Khola Hydroelectric Project, 1998, NEA
W-02	Chera-1	Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA
W-05	Lower Jhimruk	Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA
W-06	Madi	Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA
W-23	Nalsyau Gad	Nalsyau Gad Storage Hydroelctric Project Feasibility Study, Executive Summary, 2012, NEA
W-25	Naumure (W.Rapti)	Naumure (W.Rapti) Hydroelectric Project Pre-Feasibility Study, 1990, NEA

Information of the each selected project in terms of the following items is included in Appendix 2.

1) Outline of Project
2) Meteorology and Hydrology
3) Geology
4) Power Development Plan
5) Electrical/Mechanical Equipment and Transmission Line

Furthermore, information related to natural and social environment is summarized in Strategic Environmental Assessment Report (Appendix 3).

2.1 Dudh Koshi Project (E-01)

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A.2.1 Dudh Koshi (E-01)

(1) Project Summary

The Dudh Koshi Project is a 300 MW storage-type hydroelectric power project located in the Okhaldhunga, Khotang and Solukhumbu Districts in the eastern region. The intake is located at the Dudh Koshi river and the outlet is located at the Baiku Khola river. This project was originally discovered in the "Master Plan Study on the Koshi River Water Resources Development, 1985" carried out by JICA. After that, the "Dudh Koshi Hydroelectric Project Feasibility Study" was carried out by CIWEC (Canadian International Water and Energy Consultants) and the study results were summarized in the report in 1998.

Further, the JICA Study Team conducted a site reconnaissance at the Dudh Koshi project site in June 2012. The findings attained through site reconnaissance are also summarized in this clause.

As hydrological characteristics, the annual rainfall at the Okhaldhunga gauging station nearest to the project site is 1,774 mm and the average river discharge at the dam site is significant, 224 m^3/s. The catchment area is 4,100 km^2, and the specific sediment volume is estimated to be 2,540 $t/km^2/year$. This is smaller than the 3,300 $t/km^2/year$ value adopted by the NEA as an average specific sedimentation volume in the eastern region. It has to be noted that three glacier lakes having a high risk of a GLOF are identified in the drainage basin.

From a geological view point, the project area lies in the Lesser Himalaya Zone and is composed mainly of phyllite, quartzite, schist and gneiss. The reservoir area is underlain mainly by phyllite. This area is water tight and slopes in its surrounding area are stable. The dam site is underlain by quartzite and phyllite, which form relatively permeable rock. The headrace tunnel route passes phyllite, quartzite, schist, gneiss and three major local faults. The portions of overburden of more than about 1,000 m and crossing faults would need strong tunnel support. The underground power house is located in hard and compact gneiss rock. The project area is located in the area where a large acceleration of 240 mgal is shown on the seismic hazard map. However, it is away from large tectonic thrusts at a long distance of 26 km and from epicenters of larger than M4 at a relatively long distance of 10 km.

From the view point of the natural and social environment, the impact on the Natural Environment is relatively high and impact on the Social Environment is average. The Dudh Koshi Project is located in the Koshi river basin and the reservoir area is 11.1 km^2. The number of recorded plants is 67, which is the highest next to the Madi Project. The number of recorded fauna is relatively high, with numbers such as 24 mammals, 51 birds, and 17 Herpetofauna. The number of fish species is the highest, which is 24. The length of the dewatering area is 60km, which is the longest together with the Andhi Khola Project. The length of the Transmission Line is 43km, which is relatively short. The number of resettlements is the lowest, which is 63, and the number of resettlements per unit of generation power is also the lowest, around 0.21 HH/MW. The affected irrigation scheme is one which is relatively low. Rafting activities are found in the reservoir area. There is no development plan in the reservoir area. The Indigenous groups in the reservoir area are Newar (Advanced), Magar (Disadvantaged), Tamang (Disadvantaged) and Majhi (Marginalised).

From the view point of hydropower planning, two alternatives are compared in terms of layout in FS. One is a layout that has a rockfill dam and headrace tunnel of 13.3 km conducting water

to the powerhouse with 127.35 m of a water head. The other is a layout that has a concrete gravity dam and powerhouse located at the left bank immediately downstream of the dam site. FS concludes that the layout of the rockfill dam and headrace tunnel is more economical. Although inflow into the Kurule dam, which diverts river water from the Sun Koshi river to the Kamala river for irrigation and hydropower projects in Sun Koshi Multipurpose Scheme (Phase I) would decrease since the Kurule dam is located upstream of the outlet of the Dudh Koshi project, it is concluded that there would be no adverse effect because the necessary water volume could be secured for the projects. Further, FS also concludes that the flood volume of a GLOF is less than that of a PMF and can be controlled to flow down safely by installing an emergency spillway, assuming the case that the main spillway gates are out of order. However, a sand flushing facility such as that adopted in the Tanahu project, which enables flushing out the sediment produced by a GLOF has to be studied, since several glacier lakes having potential risk of a GLOF exist upstream of the Dudh Koshi project. The dam type that enables installation of such a sand flushing facility in the dam also has to be studied.

The location, basic layout and salient features of the project are shown below.

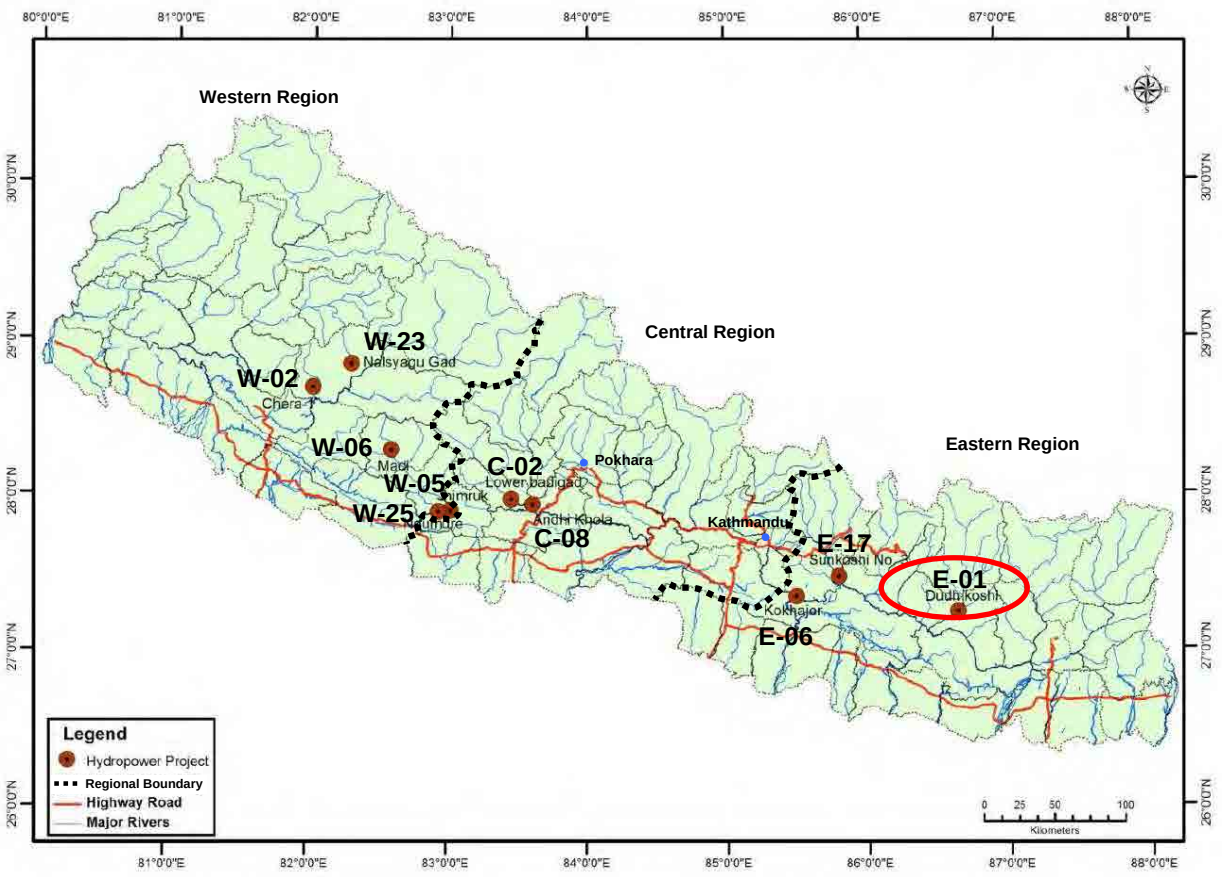


Figure A.2.1-1 Location of the Dudh Koshi Project (E-01)

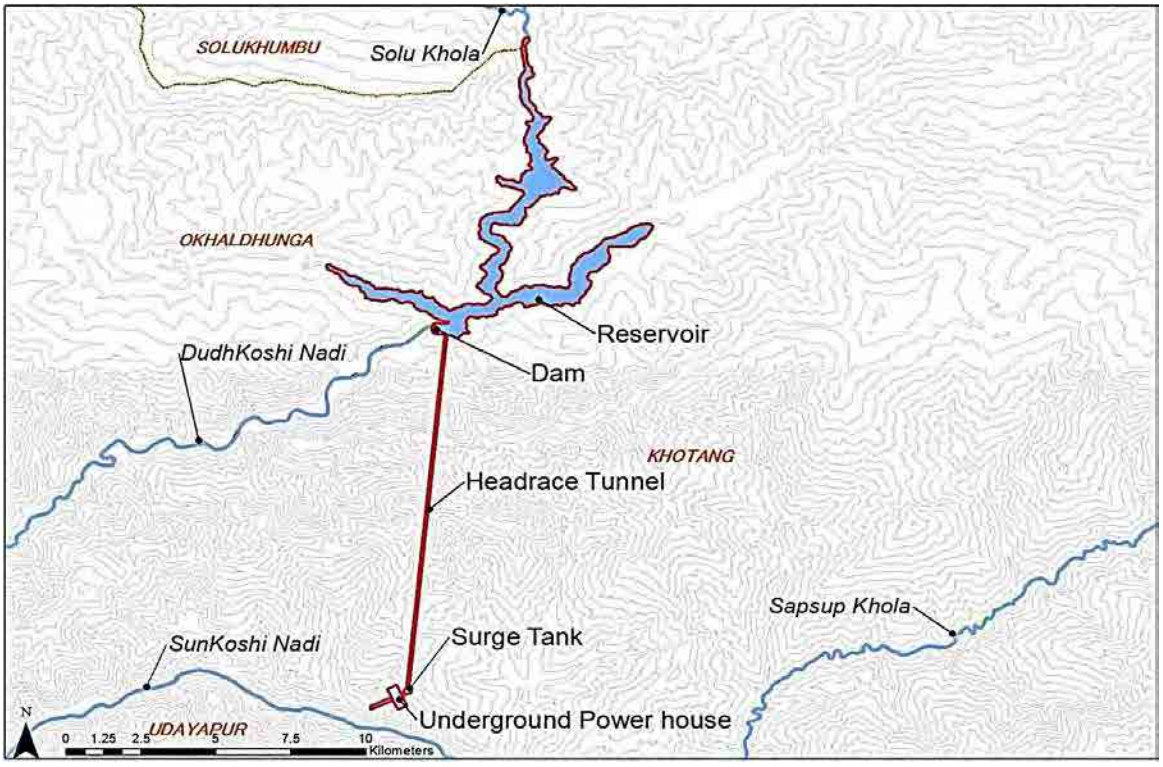


Figure A.2.1-2 General Layout of the Dudh Koshi Project (E-01)

Table A.2.1-1 Project Description

Item	Unit	Dudh Koshi	Remarks
Location	(District)	Okhaldhunga, Khotang, Solukhumbu	
Name of the River	(River)	Dudh Koshi to Baiku Khola	
Installed Capacity	MW	300	
Catchment Area	km^2	4,100	
Location of Dam Site	Longitude/ Latitude	86° 39' 17.3" 27° 15' 47.2"	
Dam Height	m	180	
Total Storage Volume	MCM	687.4	
Effective Storage Volume	MCM	442.1	
Regulating Capability Factor	%	6.3	
Reservoir Area at FSL	km^2	11.1	
Full Supply Level	m	580.0	
Minimum Operation Level	m	530.0	
Tail Water Level	m	303.4	
Rated Gross Head	m	275.0	
Rated Net Head	m	249.3	
Rated Power Discharge	m^3/s	136.0	
Total Energy	GWh	1,909.6	Estimated by the Study Team.
Dry Energy (December-April)	GWh	523.3	Estimated by the Study Team.
Length of Access Road	km	65	
Length of Transmission Line	km	43	Estimated by the Study Team.
Number of Household	nos	63	Surveyed by the Study Team in 2012.
Project Cost	MUS$	1,144.0	Estimated by the Study Team at 2013 price level.
Unit Generation Cost	cent/kWh	6.0	Estimated by the Study Team.
EIRR (8% of Interest Rate, 12NRs/kWh)	%	17.6	Estimated by the Study Team.
FIRR (8% of Interest Rate, 12NRs/kWh)	%	30.0	Estimated by the Study Team

Source: Dudh Koshi Hydroelectric Project Feasibility Study, 1998, CIWEC (except remarked items)

In addition, the summary of natural and social environmental investigation result and its evaluation are shown below. The detailed information is summarized in Appendix 3 and 5.

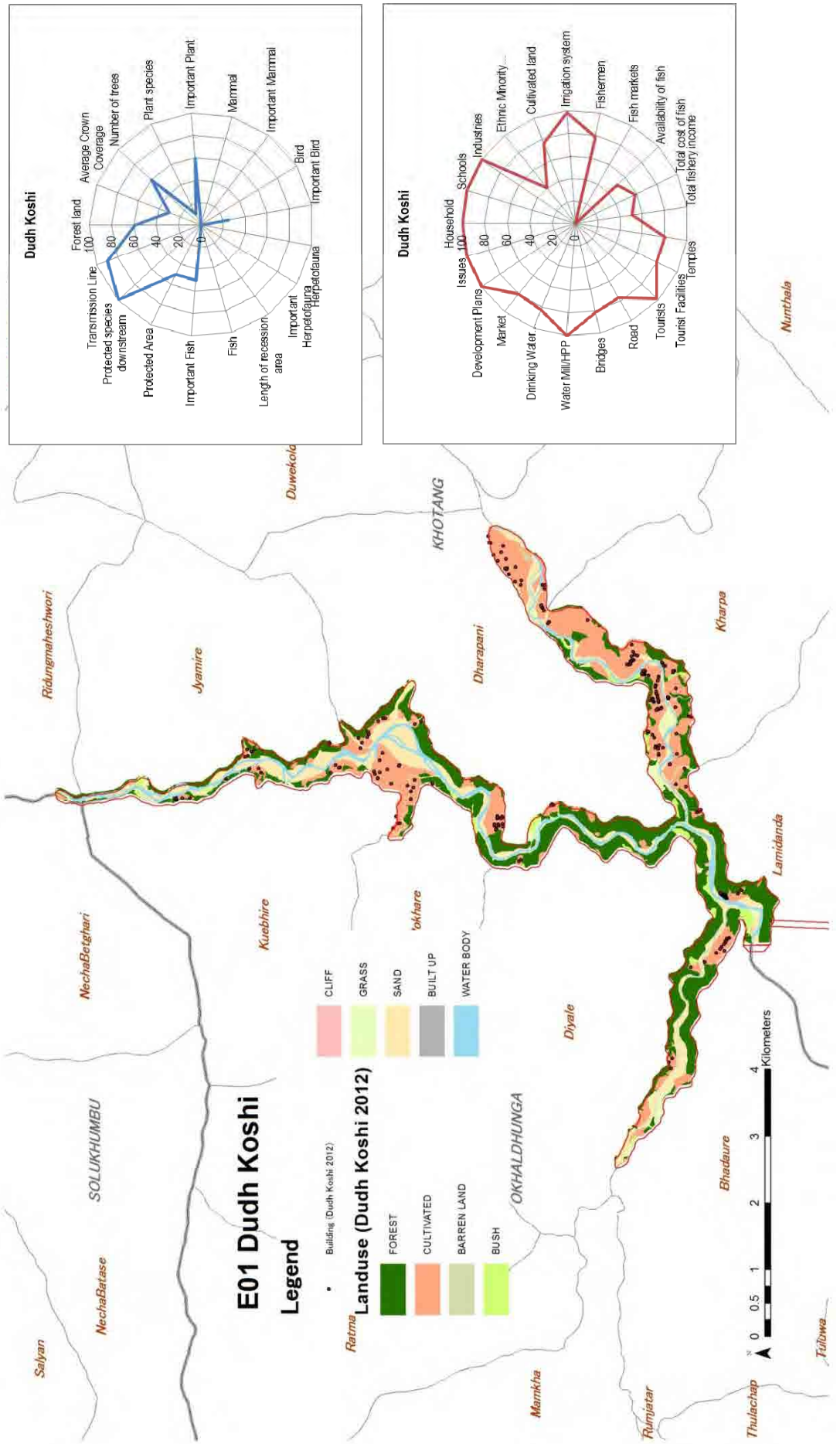


Figure A.2.1-3 Land Use and Buildings in the Reservoir Area of the Dudh Koshi Project

(2) Meteorology & Hydrology

With regard to the Dudh Koshi project, the meteorological characteristics and the criteria for hydrological evaluation, namely reliability of flow data, risk of a GLOF and sediment impact are mentioned below.

1) Meteorology

The Dudh Koshi project site is located at the Dudh Koshi river and the Baiku river. The districts where the project site is located at are the Okhaldhunga, Khotang and Solukhumbu.

The synoptic station (1206) is located in the Okhaldhunga district. The precipitation station (1211) is located in the Khotang district. Table A.2.1-2 shows the monthly rainfall of the Okhaldhunga station. Table A.2.1-3 shows the monthly rainfall of the Khotang station.

Table A.2.1-2 Monthly Rainfall at the Okhaldhunga Station

Name	Index	District	Type of Station	Start to Record	Location		Elevation
					Latitude	Longitude	(m)
OKHALDHUNGA	1206	Okhaldhunga	SYNOPTIC	Jan, 56	27.32	86.50	1,720

Precipitation (mm)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
14.2	14.4	27.9	59.8	145.8	316.2	461.1	402.4	241.1	71.4	10.2	9.9	1,774.4

Source: Department of Hydrology and Meteorology: DHM

Table A.2.1-3 Monthly Rainfall at the Khotang Station

Name	Index	District	Type of Station	Start to Record	Location		Elevation
					Latitude	Longitude	(m)
KHOTANG BAZAR	1211	Khotang	PRECIPITATION	Jan, 59	27.03	86.83	1,295

Precipitation (mm)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
16.6	12.3	29.1	42.6	111.6	201.8	332.2	237.6	159.3	49.4	6.4	9.1	1,208.0

Source: Department of Hydrology and Meteorology: DHM

2) Reliability of Flow Data

As the gauging station (670) is located at 1.5 km upstream of the dam axis, the reliability of flow data of the Dudh Koshi project is relatively high.

Table A.2.1-4 shows the monthly flow data used for energy calculation.

Table A.2.1-4 Flow Data of the Dudh Koshi Project

(m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
1997	51.00	47.10	45.20	48.40	66.30	167.00	423.00	598.00	393.00	148.00	72.50	55.30	176.23
1998	41.30	33.10	33.60	50.10	103.00	273.00	602.00	882.00	1370.00	254.00	100.00	63.70	317.15
1999	44.20	37.60	33.90	47.40	97.20	129.00	286.00	301.00	315.00	193.00	94.70	61.00	136.67
2000	46.90	35.30	28.30	43.00	74.00	192.00	383.00	455.00	423.00	171.00	96.60	58.20	167.19
2001	39.30	31.40	29.00	31.70	75.20	329.00	572.00	955.00	518.00	247.00	81.90	43.40	246.08
2002	31.10	24.70	17.30	20.20	56.90	303.00	1060.00	879.00	437.00	202.00	69.10	49.80	262.51
2003	36.00	28.00	28.90	66.20	60.70	467.00	1040.00	639.00	567.00	256.00	123.00	72.30	282.01
2004	55.10	38.50	37.70	53.20	136.00	357.00	978.00	736.00	585.00	163.00	117.00	87.30	278.65
2005	71.50	53.60	51.40	54.00	96.60	215.00	739.00	714.00	237.00	133.00	75.90	61.70	208.56
2006	39.70	28.50	32.70	42.80	74.40	393.00	433.00	364.00	350.00	120.00	64.20	46.70	165.75
Ave.	45.61	35.78	33.80	45.70	84.03	282.50	651.60	652.30	519.50	188.70	89.49	59.94	224.08

3) Risk of GLOF

The study results about a GLOF of the Dudh Koshi basin where the Dudh Koshi project is located are follows.

The Dudh Koshi basin is the largest glacierized in Nepal. The number of glaciers is 278 with a total area of 482 km^2 and an ice volume of 51 km^3. The glaciers are located in the high mountains and 40 glaciers, accounting for 70% of the glacierrized area, extend down into the valley. The Ngojumba, Khumbu, Bhote Koshi and Hungu glaciers are the principal glaciers in the Dudh Koshi basin.

Almost all of the glaciers are retreating at 10–59 m/year. The Imja Glacier retreated at 34 m/year from 1962 to 2000, a rate that increased to 74 m/year from 2000 to 2007. This fast and continuous retreat of glaciers has resulted in a proliferation of glacial lakes.

There are 243 glacial lakes more than 1,000 m^2 in an area situated above 3,500 m in the Dudh Koshi basin. The most important of these are the Lumding Tsho, Dig Tsho, Imja Tsho, Tam Pokhari, Dudh Pokhari, Hungu and Chamiang.

ICIMOD indicates the 12 potentially critical glacial lakes in the Dudh Koshi basin as of 2007. Table A.2.1-5 shows the specification of these glacial lakes.

Table A.2.1-5 List of Potentially Critical Glacial Lakes in Nepal as of 2007

Lake No.	Name	Location	Altitude	Average length in year			Average area in year			Remarks
				1960s	2000	2007	1960s	2000	2007	
			m a.s.l.	m	m	m	m^2	m^2	m^2	
28	Lumding Tsho	27°46.51' N, 86°37.53' E	4846	625	1952	2180	104944	836765	940077	Growing
55	Dig Tsho	27°52.41' N, 86°36.61' E	4364	605	1262	1263	143250	375681	403044	GLOF on 4 Aug. 1985, no danger
350	Imja Tsho	27°54.00' N, 86°55.40' E	5023	410	1822	2027	48811	848742	945662	Rapidly growing
399	Tam Pokhari	27°44.33' N, 86°50.76' E	4431	515	925	898	138846	265386	255495	GLOF on 3 Sep. 1998
422	Dudh Pokhari	27°41.21' N, 86°51.68' E	4760	1120	1095	1159	274297	297574	316767	No change in area
442	Unnamed	27°47.70' N, 86°54.81' E	5266	840	1082	1075	133753	194966	188559	No change in area
444	Unnamed	27°48.23' N, 86°56.61' E	5056	420	0	235	112398	0	25376	Dried/reappeared, no danger
449	Hungu	27°50.17' N, 86°56.26' E	5181	875	1054	1327	198905	232842	267720	Merged with lake 532
459	East Hungu 1	27°47.92' N, 86°57.95' E	5379	465	982	1105	78761	296886	222102	Merged with lake 460
462	East Hungu 2	27°48.30' N, 86°58.65' E	5483	640	448	459	211877	178317	164098	Area decreasing
464	Unnamed	27°46.86' N, 86°57.22' E	5205	1100	1918	2251	349397	783553	835131	Growing in size
466	W. Chamiang	27°45.24' N, 86°57.33' E	4983	125	1699	1698	6446	831427	852858	465–469 merged into one

Source: Glacial Lakes and Glacial Lake Outburst Floods in Nepal, March 2011, ICIMOD

As shown in Table 2.4.2-2, ICIMOD indicated the 21 potentially critical glacial lakes as of 2010. Out of them, the nine potentially critical glacial lakes are located in the Dudh Koshi basin. Table A.2.1-6 shows the list of them. There are three glacial lakes of category I in the Dudh Koshi basin.

Table A.2.1-6 List of Potentially Critical Glacial Lakes in the Dudh Koshi Bain as of 2010

Lake number	Lake name	Latitude	Longitude	Altitude (masl)	Length (m)	Area (m2)	Class	Category
kodud_gl_0184	Imja Tsho	27°53.9198'	86°55.3102'	5,012	1,879	873,000	M(e)	I
kodud_gl_0036	Lumding Tsho	27°46.7344'	86°36.8792'	4,833	2,357	943,000	M(e)	I
kodud_gl_0242	Chamlang Cho	27°45.3010'	86°57.5321'	4,985	1,695	791,000	M(e)	I
kodud_gl_0241	Hungu 2	27°46.9912'	86°57.4409'	5,204	1,982	743,000	M(e)	II
kodud_gl_0193	Tam Pokhari	27°44.5713'	86°50.6821'	4,423	827	229,000	M(e)	II
kodud_gl_0229	Hungu 1	27°50.2717'	86°56.1550'	5,206	1,075	224,000	M(e)	II
kodud_gl_0238	East Hungu 1	27°47.9575'	86°57.9895'	5,410	996	227,000	M(lg)	III
kodud_gl_0220	Mera	27°47.6672'	86°54.6675'	5,274	1,009	171,000	M(lg)	III
kodud_gl_0239	East Hungu 2	27°48.3344'	86°58.4511'	5,511	491	162,000	M(e)	III

Source: Glacial Lakes and Glacial Lake Outburst Floods in Nepal, March 2011, ICIMOD

Although the Dudh Pokhari is listed in Table A.2.1-5 which is the list as of 2007, it is not included in Table A.2.1-6 which is one as of 2010. However, as the Dig Tsho is located near the Dudh Koshi project site, it should be included to review the risk of a GLOF of the Dudh Koshi project. Table A.2.1-6 shows the potentially critical glacial lakes of the Dudh Koshi project. Figure A.2.1-2 shows the location of them.

As shown in Table A.2.1-7, there are 10 potentially critical glacial lakes upstream of the Dudh Koshi project. Out of 10, 3 glacial lakes are classified in category I which means high risk for a GLOF. Therefore, the risk of a GLOF of the Dudh Koshi project is relatively high. The Imja Tsho is the most at risk for a GLOF.

Table A.2.1-7 List of Potentially Critical Glacial Lakes for the Dudh Koshi Project

Lake number	Lake name	Latitude	Longitude	Altitude	Length	Area	Class	Category	Distance from GL to site	Remarks
				(masl)	(m)	(m2)			(km)	
kodud_gl_0184	Imja Tsho	27°53.9198'	86°55.3102'	5,012	1,879	873,000	M(e)	I	89	S. No. 3
kodud_gl_0036	Lumding Tsho	27°46.7344'	86°36.8792'	4,833	2,357	943,000	M(e)	I	66	S. No. 4
kodud_gl_0242	Chamlang Cho	27°45.3010'	86°57.5321'	4,985	1,695	791,000	M(e)	I	70	S. No. 5
kodud_gl_0241	Hungu 2	27°46.9912'	86°57.4409'	5,204	1,982	743,000	M(e)	II	71	S. No. 8
kodud_gl_0193	Tam Pokhari	27°44.5713'	86°50.6821'	4,423	827	229,000	M(e)	II	58	S. No. 9
kodud_gl_0229	Hungu 1	27°50.2717'	86°56.1550'	5,206	1,075	224,000	M(e)	II	78	S. No. 10
kodud_gl_0238	East Hungu 1	27°47.9575'	86°57.9895'	5,410	996	227,000	M(lg)	III	75	S. No. 14
kodud_gl_0220	Mera	27°47.6672'	86°54.6675'	5,274	1,009	171,000	M(lg)	III	74	S. No. 16
kodud_gl_0239	East Hungu 2	27°48.3344'	86°58.4511'	5,511	491	162,000	M(e)	III	76	S. No. 20
kodud_gl_0205	Dudh Pokhari	27°41.2474'	86°51.5263'	4,764	1,125	298,000	M(e)	II	54	

Source: Glacial Lakes and Glacial Lake Outburst Floods in Nepal, March 2011, ICIMOD

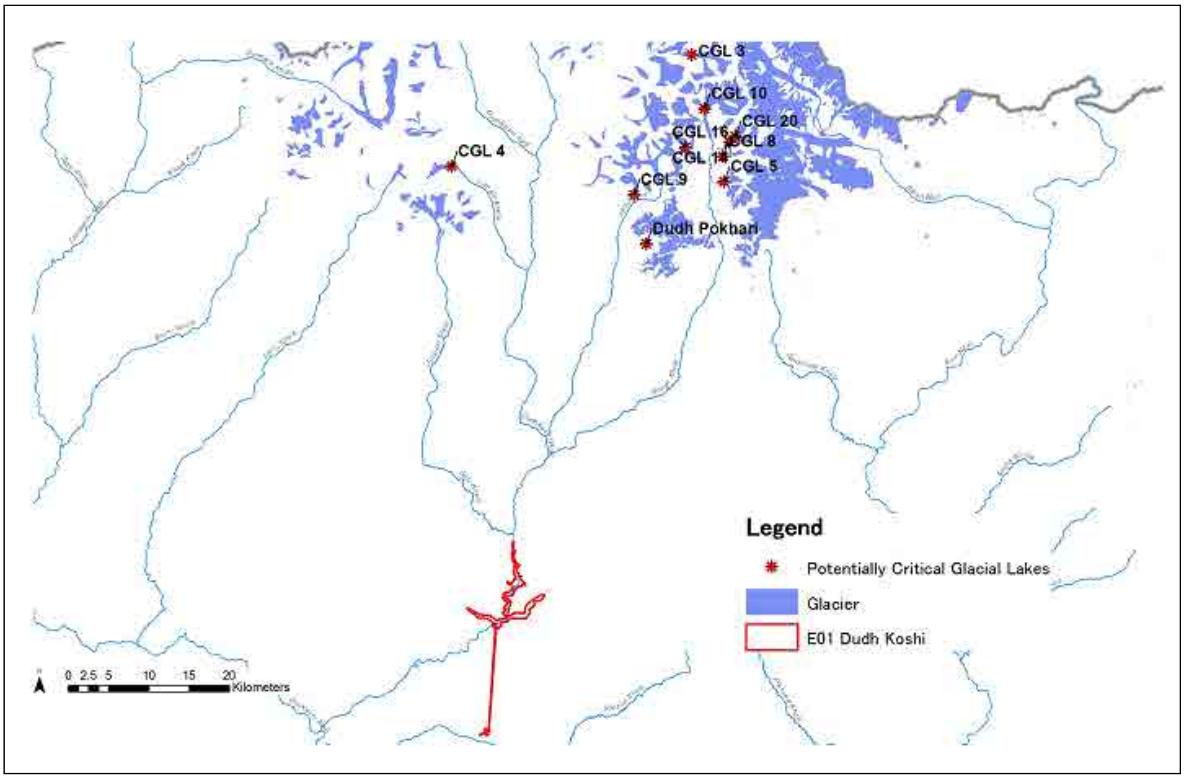


Figure A.2.1-4 Location of potentially critical glacial lakes in the Dudh Koshi project

NEA has conducted the feasibility study of the Dudh Koshi project in 1998. In the study it is considered how a GLOF impacts to the Dudh Koshi project in the case a GLOF occurs from the Imja Tsho.

The volume of Imja Tsho is assumed as 31.05 million m^3 based on the glacial lake area. The peak flow at the dam site was calculated assumed that the moraine dam of the Imja Tsho was collapsed. As a result of analysis, FS concludes that flood volume of the GLOF is less than that of PMF and can be controllable to flow down safely by installing emergency spillway assuming the case that the main spillway gates are out of order.

As a result of the latest study by ICIMOD, the volume of Imja Tsho is 35.5 million m^3. When

the feasibility study for the Dudh Koshi project is conducted in future, the latest information should be considered to comprehend the impact of a GLOF on the Dudh Koshi project quantitatively.

4) Sediment Impact

According to the FS report, the specific sediment yield of the Dudh Koshi project site is estimated to be 2,540 t/km^2/year. By using this yield, the life of the reservoir is estimated. The life of reservoir is an index to evaluate the sediment impact to reservoir and calculated dividing total storage volume by mean annual sediment yield.

Table A.2.1-8 shows the calculation result of the life of reservoir. The life of reservoir of the Dudh Koshi project is estimated to be 100 years.

However, a sand flushing facility such as adopted in the Tanahu project, which enables to flush out the sediment produced by a GLOF has to be studied, since several glacier lakes having potential risk of a GLOF exist at the upstream of Dudh Koshi project. The dam type that enables to install such sand flushing facilities in the dam has also to be studied.

Table A.2.1-8 Life of Reservoir

a) Specific Sediment Yield	2,540 t/km^2/yr
b) Sediment Yield (Catchment Area × Specific Sediment Yield / Sediment Density)	6.9×10^6 m^3/yr (4,100 km^2 × 2,540 t/km^2/yr / 1.5 t/m^3)
c) Total Storage Volume	687.4×10^6 m^3
d) Life time of Storage (Total Storage Volume / Sediment Yield)	100 years (687.4×10^6 m^3 / 6.9×10^6 m^3/yr)

(3) Geology

1) Site Geology

The Dudh Koshi project area belongs to the Okhaldhunga district and the Khotang district, east in Nepal. The dam site is located on the Dudh Koshi river. The powerhouse site is located on the left bank of the Sun Koshi river. According to the FS report (1998), the geology and engineering geology of the project area are summarized as follows.

The project area lies in the Lesser Himalayan Zone, and is underlain by phyllite, quartzite, limestone, schist and gneiss. The geological map of the project area is shown in Figure A.2.1-3.

The reservoir and its surrounding area are underlain by phyllite and subordinate quartzite. Thotane fault, which is shown as Vichalo Faulr in Figure A.2.1-3, crosses the reservoir near the dam site. The reservoir area is watertight because of the lack of permeable rocks such as limestone. No major instability is observed in the reservoir area.

At the dam site, quartzite is distributed on the left bank, and phyllite on the right bank.

Bedding planes incline 10 to 30 degrees toward west or northwest, i.e. toward downstream or right bank. The geological section of the dam site is shown in Figure A.2.1-4. The rocks are permeable as indicated by many test sections of more than 10 Lu. Quartzite is more permeable than phyllite. The groundwater level of the left bank is slightly higher than river level. But, it is expected that permeability of bed rock decrease as the depth increase. The depth of river deposits was confirmed to be 19.2 m by a boring.

The headrace tunnel route passes the mountains between the Dudh Koshi river and the Sun Koshi river. The length of the tunnel is about 13 km. A geological section along the tunnel route is shown in Figure A.2.1-5. The route passes, from the intake to the surge tank, the section composed of phyllite and quartzite, the section of phyllite and limestone, and the section of schist and gneiss. This tunnel route encounters 3 major faults. The strike of bedding plane or foliation is NE-SW and at an angle of about 60 degrees to the tunnel direction. They incline toward intake in about 3 km long section from the intake to the Dudh Koshi Fault, and toward the surge tank in the remaining section. The overburden of this tunnel is up to 1,250 m.

The powerhouse is of underground type and its site is located on the left bank of the Baiku Khola river, a tributary on the left bank of the Sun Koshi river. This site is composed of schistose gneiss, which is strong. The RQD of this rock is 72%. Foliation of the gneiss inclines at angles of 20 to 50 degrees toward northwest.

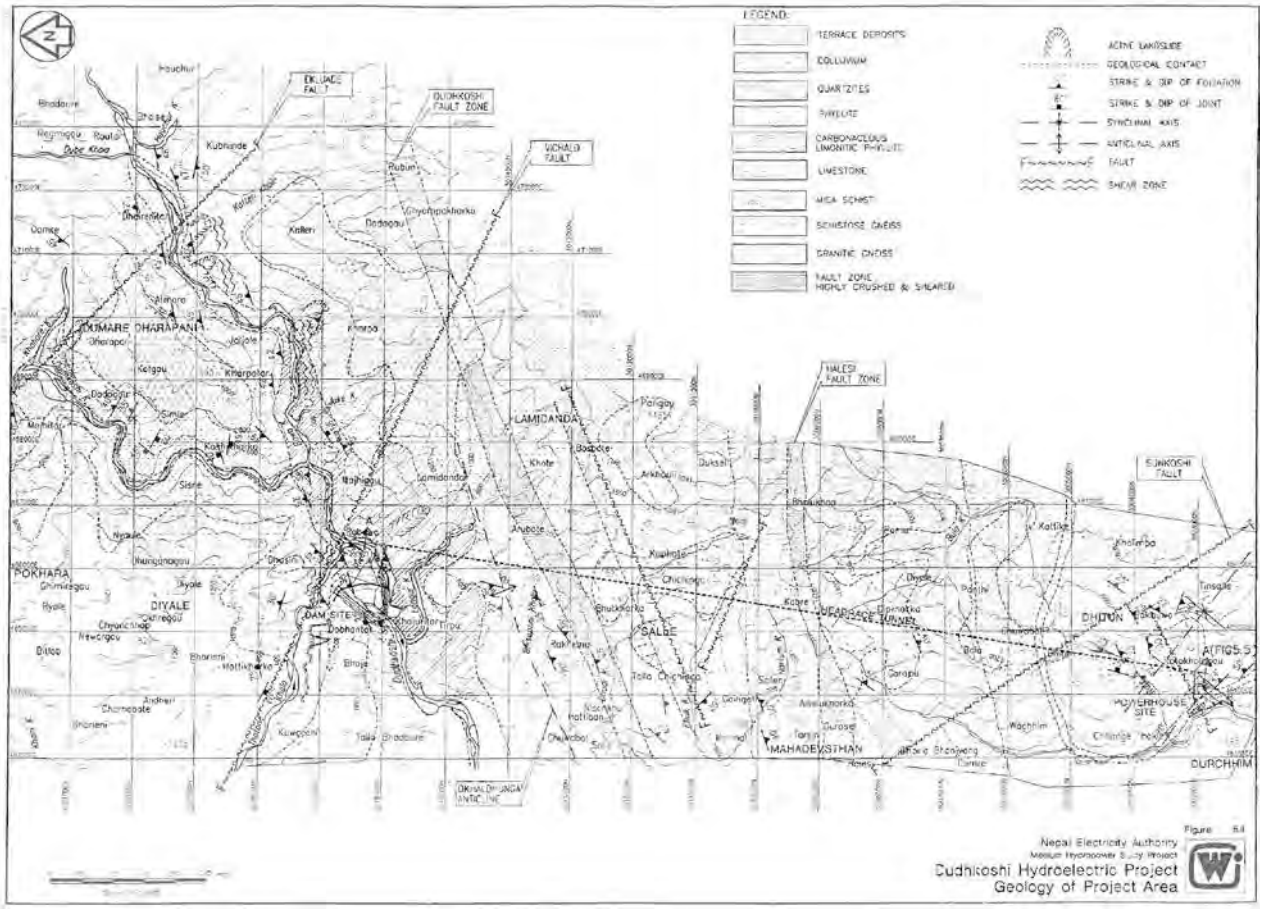
For concrete aggregate, river sand and gravel distributed in the vicinity of the dam site are not suitable in terms of soundness, but quartzite distributed in the vicinity of the dam site is available. This quartzite is also available for rock materials. It has been confirmed that enough volume of soil materials are distributed in the vicinity of the dam site.

2) Site Geology

Among large tectonic thrust, MCT is located to the northwest of the dam site at a distance of 26 km. MBT is located to the southwest of the dam site at a distance of 26 km. The Thotane fault is a local major fault located to the west of the dam site at a distance of about 500 m.

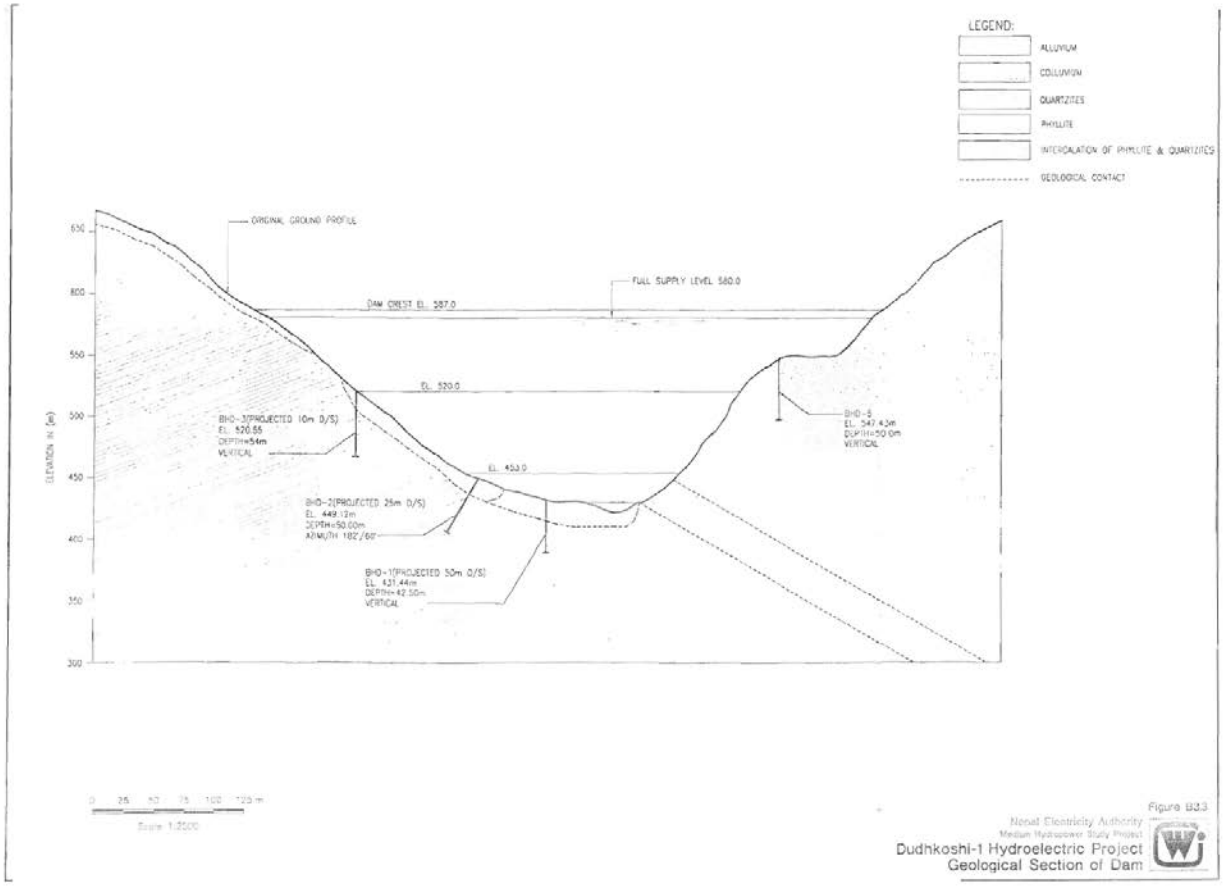
3) Seismicity

The Project area is located in Lesser Himalaya. The horizontal ground acceleration of this area is 240 mgal according to the Seismic Hazard Map of Nepal. The nearest epicenter of M≧4 to the dam site is located to the northeast at a distance of about 10 km.



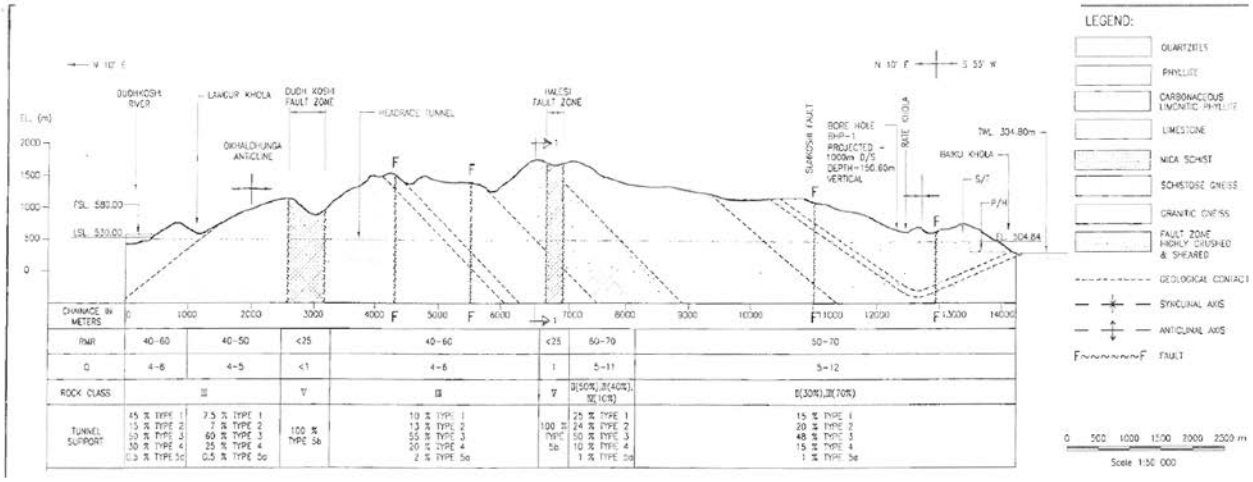
Source: Dudh Koshi Hydroelectric Project Feasibility Study, 1998, CIWEC

Figure A.2.1-5 Geological map of the project area



Source: Dudh Koshi Hydroelectric Project Feasibility Study, 1998, CIWEC

Figure A.2.1-6 Geological section of dam site



Source: Dudh Koshi Hydroelectric Project Feasibility Study, 1998, CIWEC

Figure A.2.1-7 Geological profile along headrace tunnel

(4) Development Plan

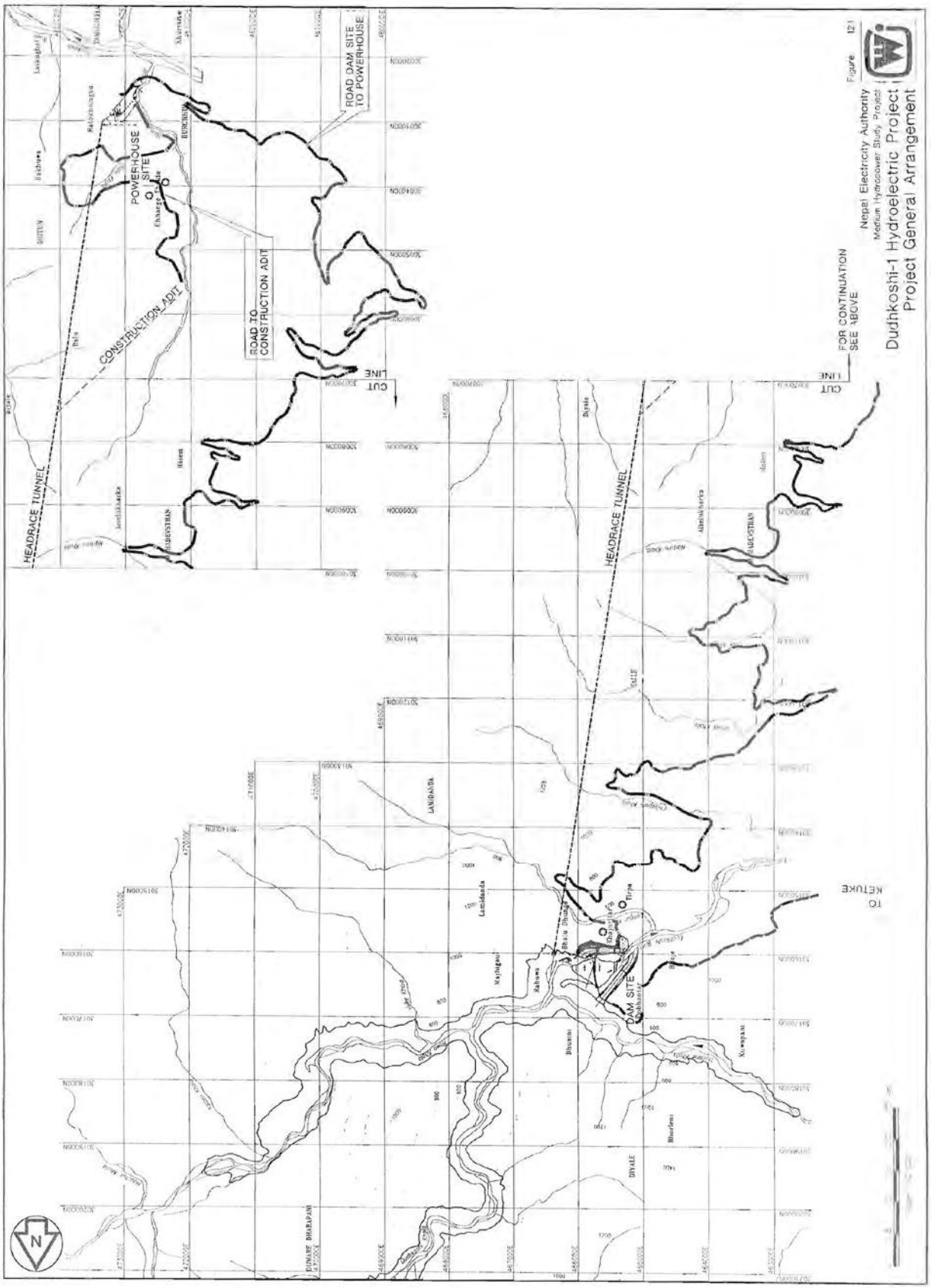
The Dudh Koshi project is a dam and waterway-type hydropower project. Since the study level stays at feasibility study level, a set of the basic design drawings is available.

The salient features of principal layout and basic layout drawings of the project are as follows:

Table A.2.1-9 Salient Features of Project

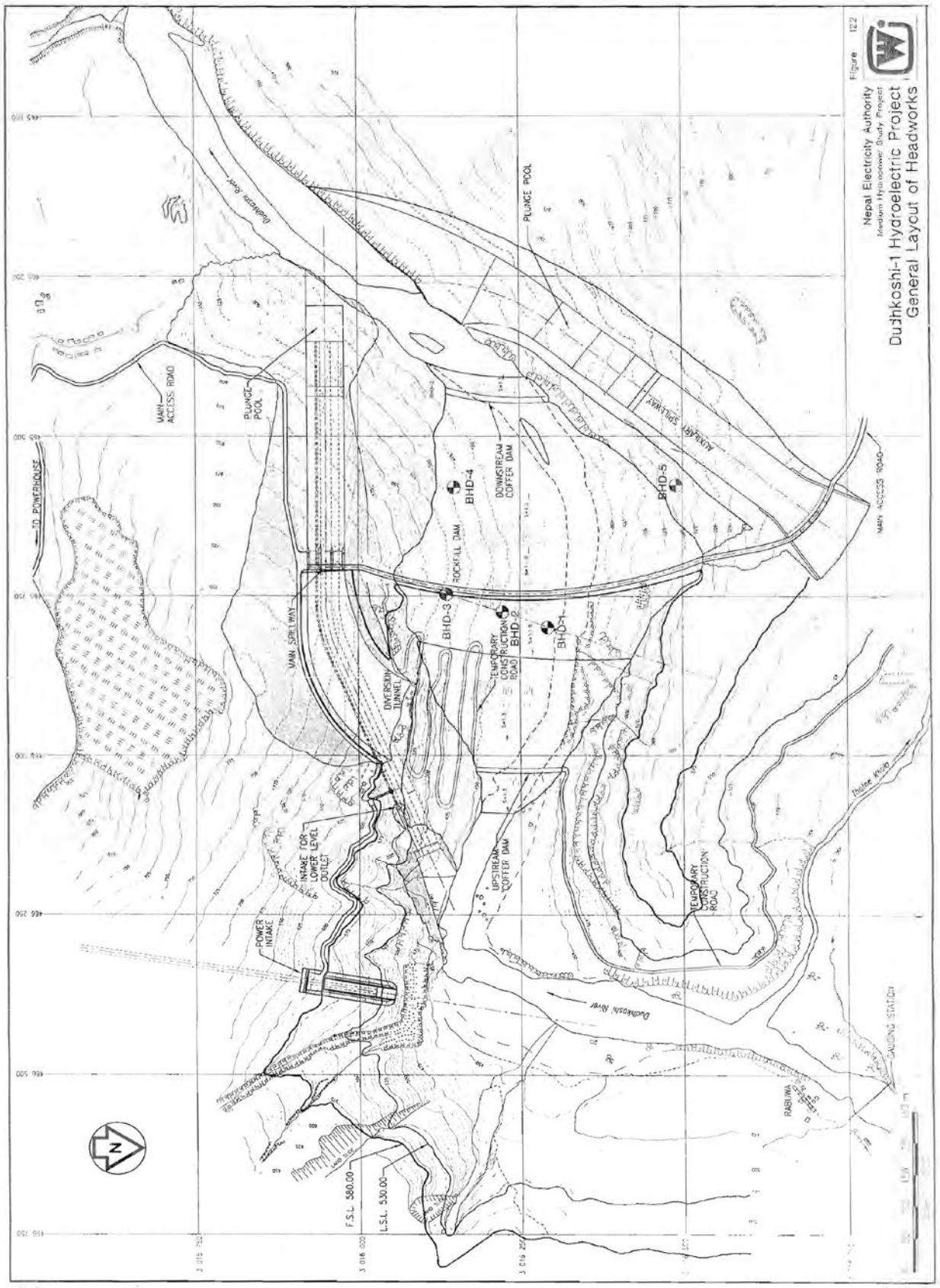
Item	Unit	Dudh Koshi	Remarks
Reservoir			
Reservoir Area at FSL	km^2	11.1	
Total Storage Capacity	MCM	687.4	
Effective Storage Capacity	MCM	442.1	
Full Supply Level (FSL)	m	580.0	
Minimum Operating Level (MOL)	m	530.0	
Dam			
Type of Dam	-	Rockfill	
Dam Volume	MCM	9.2	
Total Dam Height	m	180	
River Bed Level at Dam Axis	m	430	
Spillway Type	-	Gated Spillway	Service Spillway
Waterway & Powerhouse			
Intake Type	-	Normal Pressure	
Concrete Lined Headrace Tunnel	m	13,260	
Modified Horseshoe Tunnel Diameter	m	9.0 / 7.3	(Shotcrete / Concrete)
Penstock Length	m	153	Drop Shaft
Type of Powerhouse	-	Underground	
Turbine Type	-	Vertical Francis	
Installed Capacity	MW	300	(5 x 60 MW)
Design Discharge	m^3/s	136.0	
Rated Net Head	m	249.3	
Tail Water Level	m	303.4	
Tailrace Length	m	370	
Tailrace Tunnel Diameter	m	9	(Shotcrete)

Source: Dudh Koshi Hydroelectric Project Feasibility Study, 1998, CIWEC



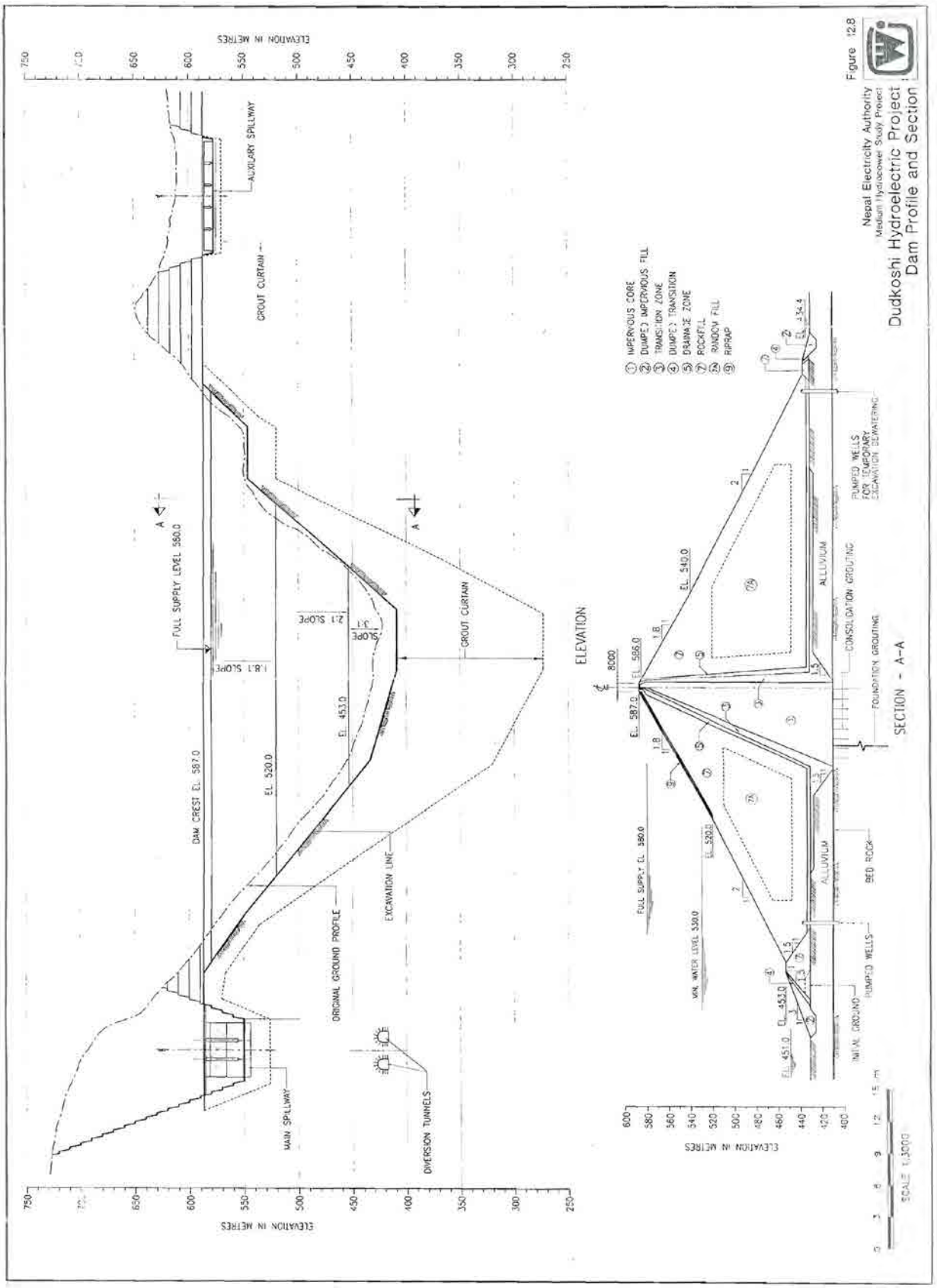
Source: Dudh Koshi Hydroelectric Project Feasibility Study, 1998, CIWEC

Figure A.2.1-8 General Layout



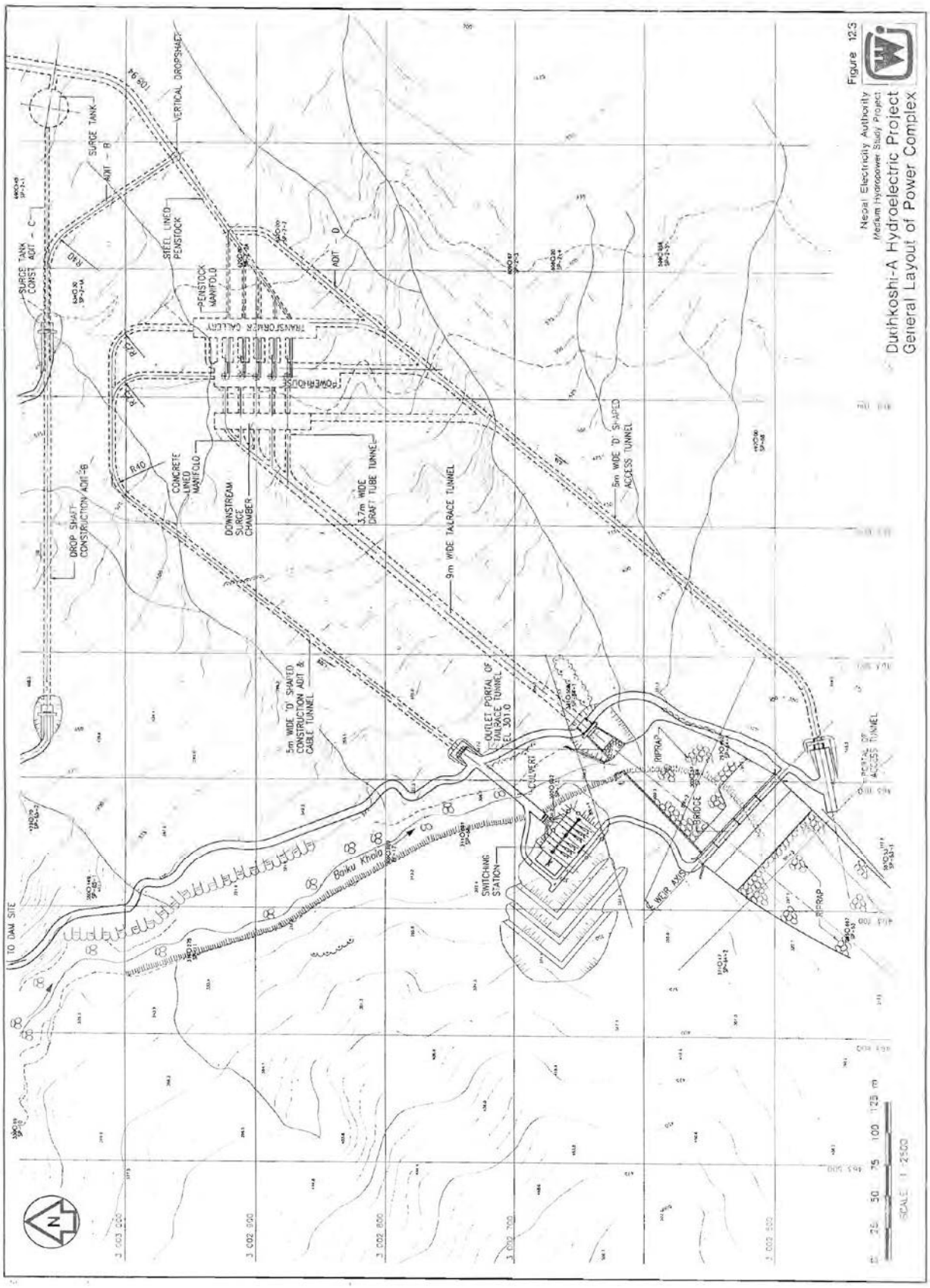
Source: Dudh Koshi Hydroelectric Project Feasibility Study, 1998, CIWEC

Figure A.2.1-9 Dam Plan



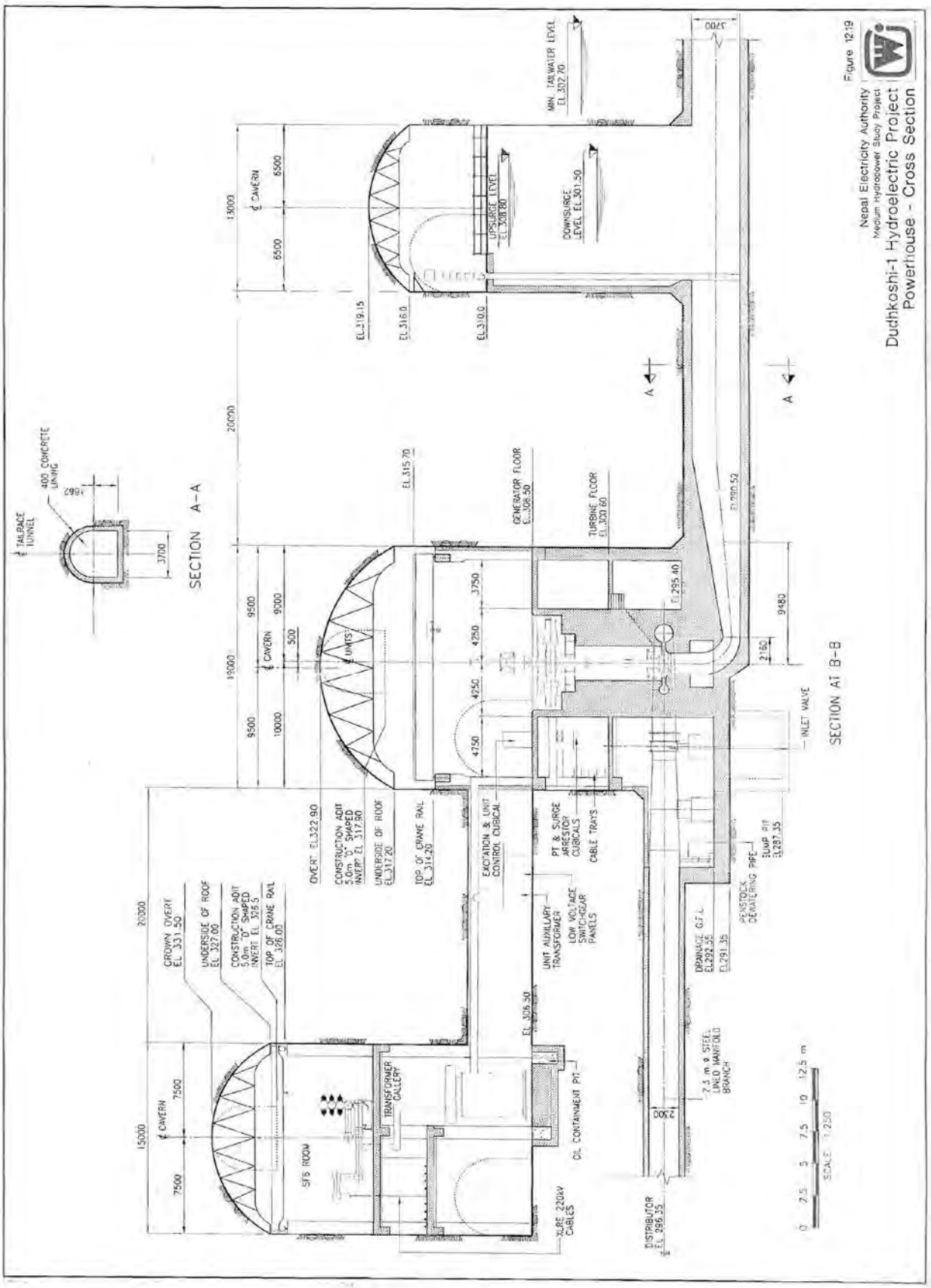
Source: Dudh Koshi Hydroelectric Project Feasibility Study, 1998, CIWEC

Figure A.2.1-10 Dam Section



Source: Dudh Koshi Hydroelectric Project Feasibility Study, 1998, CIWEC

Figure A.2.1-11 Powerhouse Plan



Source: Dudh Koshi Hydroelectric Project Feasibility Study, 1998, CIWEC

Figure A.2.1-12 Powerhouse Section

Further, the findings attained by the Study Team through site reconnaissance conducted in June, 2012 in terms of dam site and powerhouse site are summarized below.

Dam Site

The dam site examined in the "Dudh Koshi Hydroelectric Project FS (1998)" conducted by CIWEC (Canadian International Water and Energy Consultants) is located at approximately 2 km downstream of the confluence of the Dudh Koshi river and the Rawa Khola river, where the curved river is flowing east-west direction. The coordinate at the dam axis is approximately 27º15'50"N, 86º39'09"E and river bed elevation is 430m.

The left bank abutment has uniform 40 degrees inclination. The thickness of the ridge at FSL is approximately 500m. The right bank abutment is a relatively thin ridge between the Dudh Koshi river and the Thotne Khola river which is joining immediately upstream of the dam site from the right bank side. The main stream and the tributary form U-shape edging the ridge, an emergency spillway is laid out on the ridge. The right bank abutment is laid out at the place where the thickness of the ridge is relatively small so that the excavation volume for the emergency spillway will be minimized. The distance between the tributary and main stream at FSL seems less than 200 m according to the drawings in the FS.

Powerhouse Site

According to the FS, a 150 m of head is gained by the dam, as the river bed elevation is 430 m and the FSL is 580 m. On the other hand, the tail water level is set at EL.303.35 considering FSL of Sapta Koshi dam (EL.304.8), Therefore, the rated gross head is 277.35 m. Namely, the gained head by conducting water to the powerhouse with 13.3 km headrace tunnel is 127.35 m.

While, in the "Master Plan Study on the Koshi River Water Resources Development (1985)" conducted by JICA, the tail water level is set at EL.424.6 m which is the FSL of the Sun Koshi No.1 project. A 2.6 km headrace tunnel conducts the water to the powerhouse without gaining head.

Therefore, a possible alternative for the present layout in the FS would be to lay out the powerhouse at immediately downstream of the dam at the left bank by changing the stream direction of the emergency spillway toward more downstream side. However, this layout was studied as an alternative adopting concrete dam and concluded to be less economical in the FS.

Although inflow into the Kurule dam which diverts river water from the Sun Koshi river to the Kamala river for irrigation and hydropower projects in the Sun Koshi Multipurpose Scheme (Phase I) would decrease since the Kurule dam is located at upstream of the outlet of the Dudh Koshi project, it is concluded that there would be no adverse effect because necessary water volume could be secured for the projects in the FS.

The location of powerhouse has to be determined by setting the tail water level considering the reservoir water levels of downstream projects. Regarding FSL of the Sapta Koshi dam, there seems different information. One is that the FSL was set at 304.8m in 1985 JICA study, the other is that the FSL was set at 335.25m in the FS conducted in India. Therefore, it should be confirmed that which water level has to be considered to determine the tail water level and location of powerhouse.

(5) Electrical/Mechanical Equipment and Transmission Line

1) General

Rated effective head, power discharge and installed capacity of the Dudh Koshi Project are as follows;

Rated Effective Head	: 249.30 m
Rated Power Discharge	: 136 m^3/s
Installed Capacity	: 300 MW

The HD Wiz (developed by J-POWER, based on existing hydropower plant data around world) has been used for reviewing design of electrical/mechanical equipment taking above information into consideration. Turbine efficiency and generator efficiency have been improved in recent years and installed capacity exceeded above-mentioned 300MW consequently.

2) Unit Capacity and Number of Unit

Generally, for the turbine-generator, a large unit capacity is said to be more economical merits of scale. However, optimum unit capacity of the turbine-generator is determined in consideration of influence to the power system, development timing and transportation restriction.

In this project, all electrical and mechanical equipment will be transporting from foreign countries via Indian national road and un-maintained Nepalese national road to the project site. Therefore maximum unit capacity shall be set as around 100 MW and number of 5 units plan has been adopted for the project.

3) Turbine

a) Turbine Output

Rated turbine output at rated effective head of 249.30m and rated power discharge of 27.20 m^3/s per unit can be calculated as follow;

$$Pt = 9.8 \times Hn \times Qt \times \eta t$$
$$= 9.8 \times 249.3 \times 27.20 \times 0.922$$
$$\approx 61{,}200 \text{ kW}$$

where

Pt : Rated turbine output per unit (kW)
Hn : Rated effective head (m)
Qt : Rated power discharge per unit (m^3/s)
ηt : Turbine efficiency

b) Type of Turbine

Generally, type of turbine can be determined by close relation between effective head and turbine output. Vertical shaft Francis type turbine can be selected taking rated effective head and turbine output into consideration.

c) Runner Material

Stainless steel anti-corrosion type such as 13 chrome high nickels stainless steel is recommended to be applied for the runner material. Surface of runner and wear ring shall be coated (hard or soft) in case of water quality. Detailed coating method shall be specified in the detailed design stage.

d) Installed Capacity

Installed capacity can be calculated from aforementioned turbine output per unit as follow;

61,200 kW × 5 = 306,000 kW

Review of energy calculation is conducted by using above installed capacity.

4) Generator

A three phase alternating current synchronous generator with vertical shaft rated capacity of 66,400 kVA and power factor of 90% lag are selected.

a) Generator Capacity

Rated generator capacity can be calculated from rated turbine output, power factor and generator efficiency as follows;

$$Pg = Pt \times \eta g / p.f \ (kVA)$$
$$= 61,200 \times 0.970 / 0.90$$
$$\approx 66,400 \ kVA$$

where

Pg : Rated generator capacity (kVA)
Pt : Rated turbine output (kW)
ηg : Generator efficiency
p.f : Power factor, lag

As the results of above calculation, rated generator capacity is 66,400 kVA.

5) Transmission Line

Regarding designing of the transmission line, transmission line shall be connected to the closest substation based on 400 kV Transmission Line Power Development Plan by the NEA. And also thermal capacity and maximum surface potential gradient have been taken into consideration for designing of the transmission line and following specifications have been adopted. As for the transmission line length, the direct length from project area to closest substation was measured from map. Therefore, some allowance has been taken into consideration.

Connected Substation	: Okhaldhunga Substation
Transmission Line Voltage	: 220 kV
Length of Transmission Line	: 43 km
Conductor Type	: Moose × 1, 2 circuits

2.2 Kokhajor-1 Project (E-06)

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A.2.2 Kokhajor-1 (E-06)

(1) Project Summary

The Kokhajor-1 Project is a 111.5 MW storage-type hydroelectric power project located in the Sinduli and Kabhrepalanchok Districts in the eastern region. The intake is located at the Kokhajor river and the outlet is located at the Bagmati river. The latest study for this project was conducted in the "Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA." The study level for this project stays at the desk study level.

As hydrological characteristics, the annual rainfall at Panchkhal gauging station nearest to the project site is 1,209.5 mm and the average river discharge at the dam site is 17 m^3/s. The drainage area is 281 km^2, and the specific sediment volume is estimated to be 5,900 $t/km^2/year$. This is larger than 3,300 $t/km^2/year$, which is the value adopted by the NEA as average specific sedimentation volume in the eastern region. No glacier lake having a high risk of a GLOF is identified in the drainage basin.

From a geological view point, the project area lies in the Sub Himalaya Zone and is composed mainly of conglomerate, sandstone and mudstone. The reservoir area is underlain mainly by conglomerate and sandstone. The conglomerate, not well cemented and pervious, provides a corner where water tightness should be confirmed and has slopes which are easily eroded. The dam site is underlain by sandstone and mudstone which form a relatively soft and relatively pervious rock. The headrace tunnel route passes sandstone and mudstone, which form a medium hard to relatively soft rock. The portions close to a maximum overburden of about 600 m and need strong tunnel support. The bedrock of the powerhouse site is composed of sandstone and mudstone. The project area is located in an area where a large acceleration of 300 mgal is shown on the seismic hazard map. It is close to a large tectonic thrust (MBT) at a short distance of 2.5 km. It is away from epicenters larger than M4 at a long distance of 26 km.

Impact on both the Natural Environment and the Social Environment is average. Kokhajor-1 is located in Bagmati river basin, and the reservoir area is 4.6 km^2, which is the smallest next to Chera-1. The number of recorded fauna is relatively low, with numbers such as 13 mammals, 21 birds, and 8 Herpetofauna. The number of resettlements is 92, which are the lowest next to Dudh Koshi and the number of resettlement per unit generation is also low, at about 0.83 HH/MW. The affected Agricultural Land area is the lowest at 1.7 km^2. There are only 2 affected irrigation schemes. One micro hydropower plant exists in the reservoir area. No fishermen were observed and neither drivable roads nor suspension bridges are affected. There used to be trouble related to construction of a cement plant. The Indigenous groups in the reservoir area are the Magar (Disadvantaged) and Tamang (Disadvantaged).

From the view point of hydropower planning, the proposed rockfill dam, which has a height of 107 m and volume of 4.7 million m^3, is the smallest among the 10 promising projects. Therefore, the risk in construction of the dam seems relatively low. In terms of the waterway layout, the length of the headrace tunnel is 6.6 km and the penstock is 2 km. Since the length of the waterway is relatively long, the works for the headrace tunnel will be on the critical path in the construction stage.

The location, basic layout and salient features of the project are shown below.

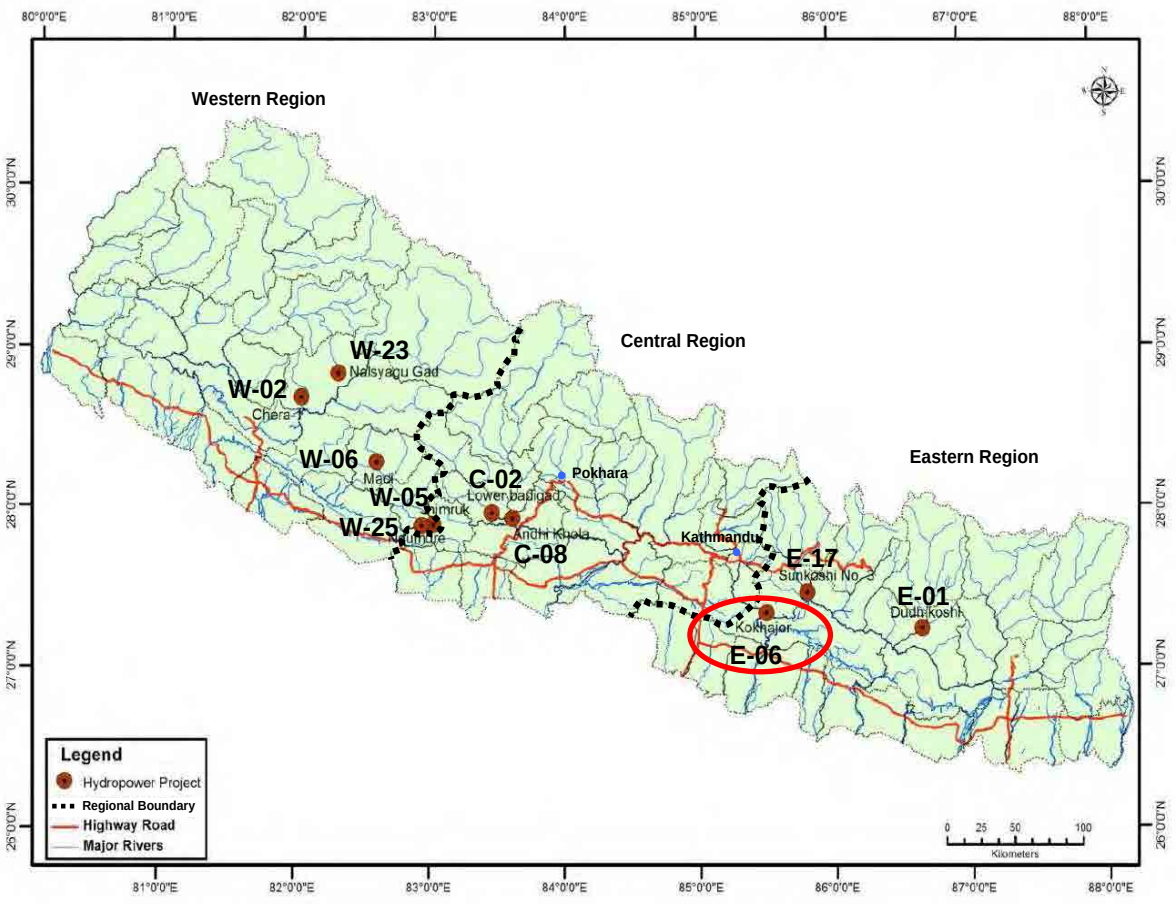


Figure A.2.2-1 Location of the Kokhajor-1 Project (E-06)

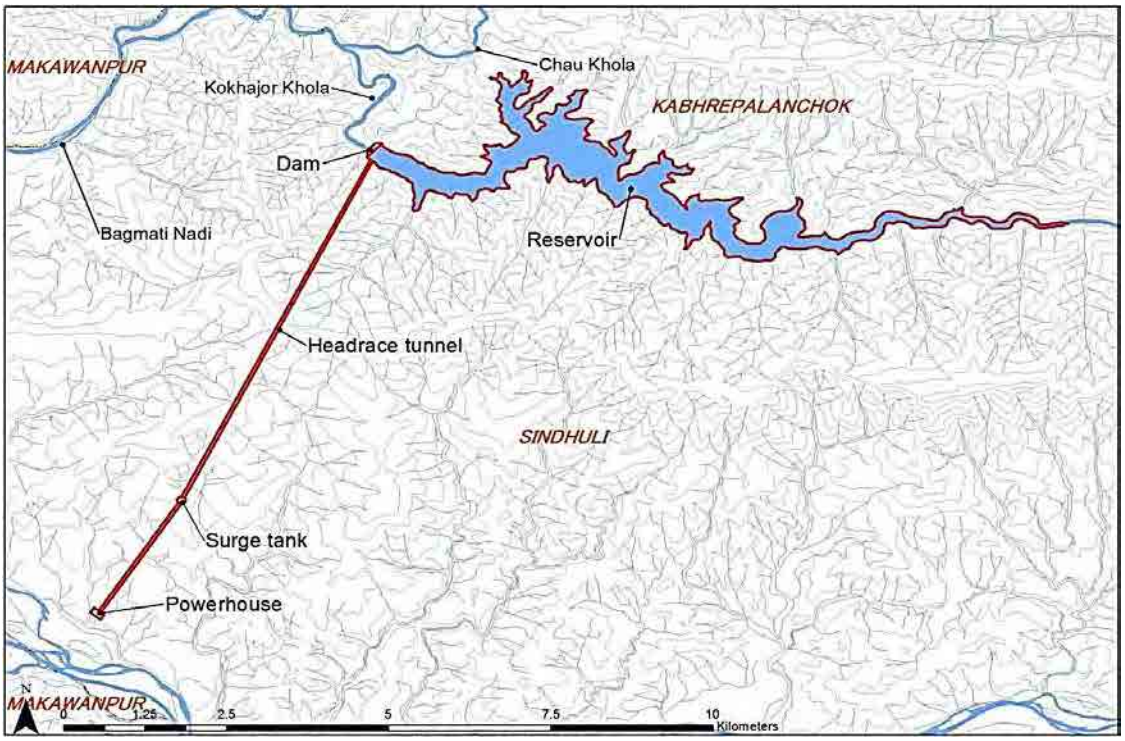


Figure A.2.2-2 General Layout of the Kokhajor-1 Project (E-06)

Table A.2.2-1 Project Description

Item	Unit	Kokhajor-1	Remarks
Location	(District)	Sinduli, Kabhrepalanchok	
Name of the River	(River)	Kokhajor to Bagmati	
Installed Capacity	MW	111.5	
Catchment Area	km^2	281	
Location of Dam Site	Longitude/ Latitude	85° 30' 27.11" 27° 21' 16.34"	
Dam Height	m	107.0	
Total Storage Volume	MCM	218.7	
Effective Storage Volume	MCM	166.1	
Regulating Capability Factor	%	31.5	
Reservoir Area at FSL	km^2	8.9	
Full Supply Level	m	437.0	
Minimum Operation Level	m	390.0	
Tail Water Level	m	200.0	
Rated Gross Head	m	226.3	
Rated Net Head	m	205.6	
Rated Power Discharge	m^3/s	63.9	
Total Energy	GWh	278.9	Estimated by the Study Team
Dry Energy (December-April)	GWh	94.1	Estimated by the Study Team
Length of Access Road	km	22	
Length of Transmission Line	km	62	Estimated by the Study Team.
Number of Household	nos	219	Surveyed by the Study Team in 2012.
Project Cost	MUS$	476.5	Estimated by the Study Team at 2013 price level.
Unit Generation Cost	cent/kWh	17.1	Estimated by the Study Team.
EIRR (8% of Interest Rate, 12NRs/kWh)	%	7.6	Estimated by the Study Team.
FIRR (8% of Interest Rate, 12NRs/kWh)	%	n.a.	Estimated by the Study Team.

Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA (except remarked items)

In addition, the summary of natural and social environmental investigation result and its evaluation are shown below. The detailed information is summarized in Appendix 3 and 5.

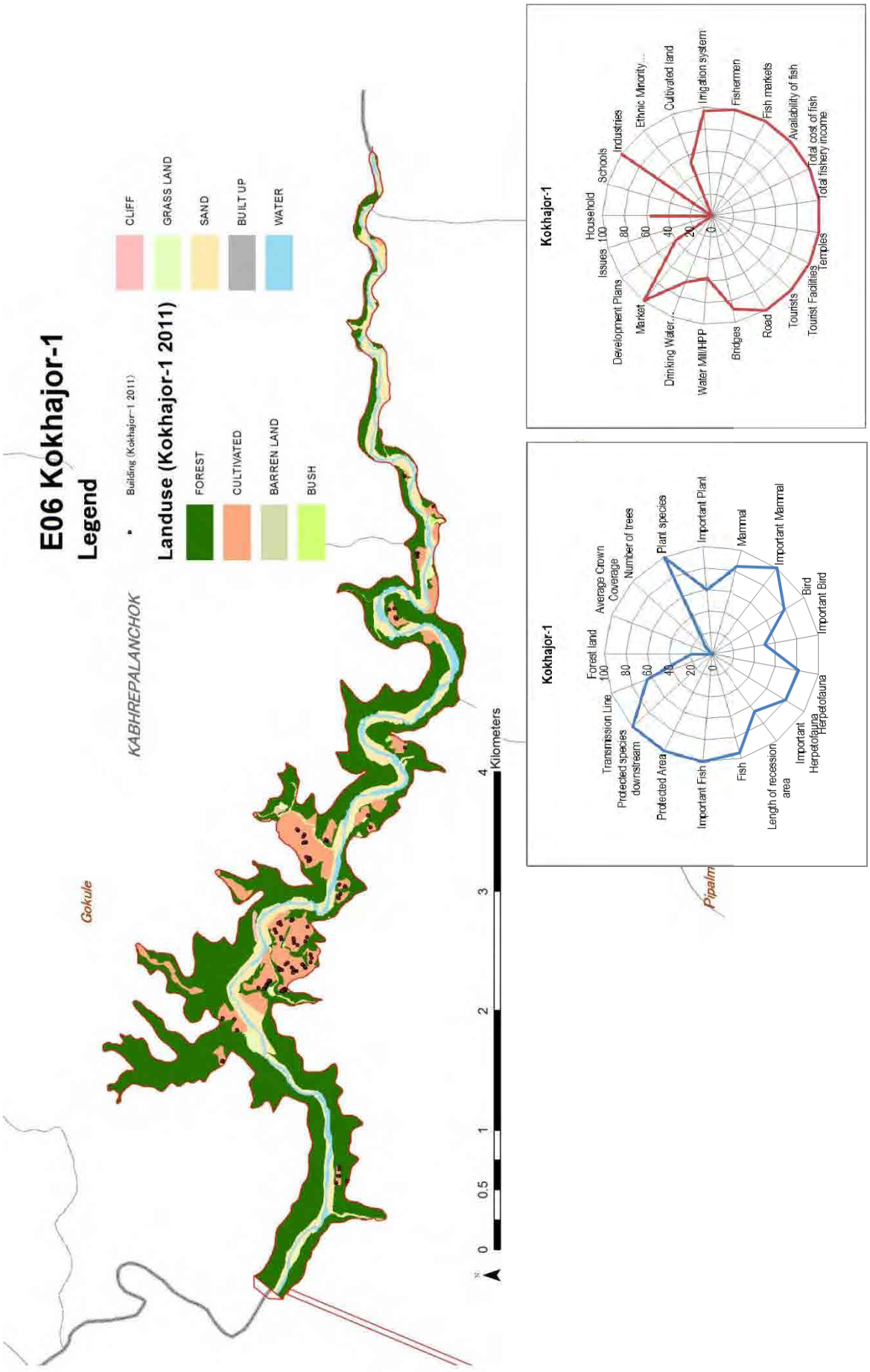


Figure A.2.2-3 Land Use and Buildings in the Reservoir Area of the Kokhajor-1 Project

(2) Meteorology & Hydrology

With regard to the Kokhajor-1 project, the characteristic of meteorology and the criteria of hydrology such as reliability of flow data, risk of a GLOF and sedimentation are as follows.

1) Meteorology

The Kokhajor-1 project site is located at the Kokhajor river. The districts where the project site is located at are Sindhuli and Kabhreplanchok.

The climatology station (1107) is located in the Sindhuli district. The climatology station (1036) is located in the Kabhrepalanchok district. Table A.2.2-2 shows the monthly rainfall at the Sindhuli Gadhi staion. Table A.2.2-3 shows the monthly rainfall at the Kabhrepalanchok station.

Table A.2.2-2 Monthly Rainfall at the Sindhuli Gadhi Station

Name	Index	District	Type of Station	Start to Record	Location		Elevation
					Latitude	Longitude	(m)
SINDHULI GADHI	1107	Sindhuli	CLIMATOLOGY	Jan, 56	27.28	85.97	1,463

Precipitation (mm)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
24.8	15.3	38.7	98.0	203.9	437.7	691.2	581.0	423.2	132.8	14.8	10.2	2,671.6

Source: Department of Hydrology and Meteorology: DHM

Table A.2.2-3 Monthly Rainfall at the Kabhrepalanchok Station

Name	Index	District	Type of Station	Start to Record	Location		Elevation
					Latitude	Longitude	(m)
PANCHKHAL	1036	Kabhre	CLIMATOLOGY	Jan, 76	27.68	85.63	865

Precipitation (mm)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
11.8	16.9	21.4	44.2	98.1	202.2	291.3	286.4	165.3	51.0	7.6	13.4	1,209.5

Source: Department of Hydrology and Meteorology: DHM

2) Reliability of flow data

As there is no gauging station near the Kokhajor-1 project site, the flow of the project is calculated by the Regional Analysis. The reliability of flow data of the project is relatively low.

Table A.2.2-4 shows the monthly flow data used for energy calculation.

Table A.2.2-4 Flow Data of the Kokhajor-1 Project

(m^3/s)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
3.65	3.10	2.91	3.17	4.58	16.08	44.97	53.17	38.30	17.35	8.20	5.25	16.73

3) Risk of GLOF

There is no potentially critical glacier lake which may cause a GLOF in the upstream area of the Kokhajor-1 project site.

4) Sedimentation

The specific sediment yield of the Kokhajor-1 project site was estimated to be 5,900 t/km$^{2/}$year based on the sediment data at the gauging station (589) near the project site. By using this yield, the life of the reservoir is estimated. The life of reservoir is an index to evaluate the sediment impact to reservoir and calculated dividing total storage volume by mean annual sediment yield.

Table A.2.2-5 shows the calculation result of the life of reservoir. The life of reservoir of the Kokhajor-1 project is 199 years.

Table A.2.2-5 Life of Reservoir

a) Specific Sediment Yield	5,900 t/km^2/yr
b) Sediment Yield (Catchment Area × Specific Sediment Yield / Sediment Density)	1.1×10^6 m^3/yr (281 km^2 × 5,900 t/km^2/yr / 1.5 t/m^3)
c) Total Storage Volume	218.7×10^6 m^3
d) Life time of Storage (Total Storage Volume / Sediment Yield)	199 years (218.7×10^6 m^3 / 1.1×10^6 m^3/yr)

(3) Geology

1) Site Geology

The Kokhajor-1 project area belongs to the Sindhuli district, central in Nepal. The dam site is located in the valley of the Kokhajor river about 2 km upstream of the confluence of the Chau river. The powerhouse site is located on the left bank of the Baghmati river. According to the field geological survey, geology and engineering geology of the project area are as follows.

The geological map of the project area is shown in Figure A.2.2-2. The project area lies in the Sub Himalayan Zone, and is underlain by the Lower Siwaliks Formation mainly composed of sandstone and mudstone, the Middle Siwaliks Formation mainly composed of sandstone and the Upper Siwaliks Formation mainly composed of conglomerate. Bedding planes of the project area incline at angles about 50 degrees toward north.

The engineering geological map of the reservoir and its surrounding area is shown in Figure

A.2.2-3. Rock exposed area is widely distributed. Reservoir and its surrounding area are underlain by the Middle Siwaliks Formation and Upper Siwaliks Formation. Sandstone of the Middle Siwaliks Formation is medium hard. Conglomerate of the Upper Siwaliks Formation, however, is not well cemented and pervious. There is an area underlain by the Upper Siwaliks Formation on the right bank where the pass length of leakage is relatively short. The Upper Siwaliks Formation is eroded rather easily. Many shallow instabilities are observed in the area underlain by the Upper Siwaliks Formation.

The dam site is underlain by sandstone and mudstone of the Middle Siwaliks Formation, which is rather soft and rather pervious. Bedding planes of the dam site incline at angles of about 50 degrees toward north i.e. toward right bank. The depth of river deposits is assumed to be 10 to some 30 m.

The headrace tunnel route passes the ridge between the Kokhaj and Baghmati river. The reservoir side of the tunnel route passes the Middle Siwaliks Formation composed of medium hard sandstone. Remaining section of the tunnel route passes the Lower Siwaliks Formation composed of rather soft rocks. Bedding planes, which strike is about perpendicular to the tunnel direction, incline toward the intake at angles of about 50 degrees. The overburden of this tunnel is up to 600 m.

The powerhouse site is located on the alluvial terrace on the left bank of the Baghmati river. This site is composed of the Lower Siwaliks Formation. Bedding planes at this site incline toward the mountain. The depth of river deposits is assumed to be 10 to 20 m.

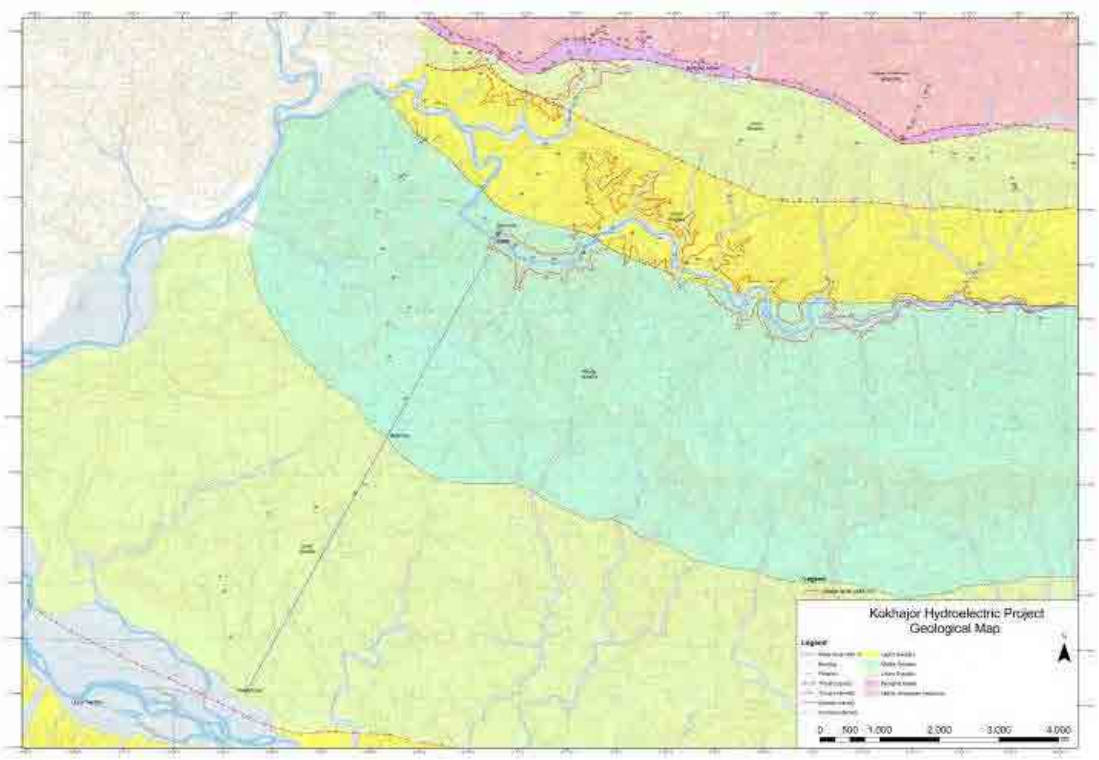
Sand and gravel for concrete aggregates are distributed on the riverbed of the Baghmati river about 10 km downstream of the dam site. Colluvium and residual soil distributed in the area underlain by mudstone would be investigated for borrow areas of soil materials. Sandstones in the vicinity of the dam site may available for rock materials.

2) Thrust and Fault

Among large tectonic thrust, MBT is located to the north of dam site at a distance of 2.5 km. A local major fault has not been found in the vicinity of the dam site.

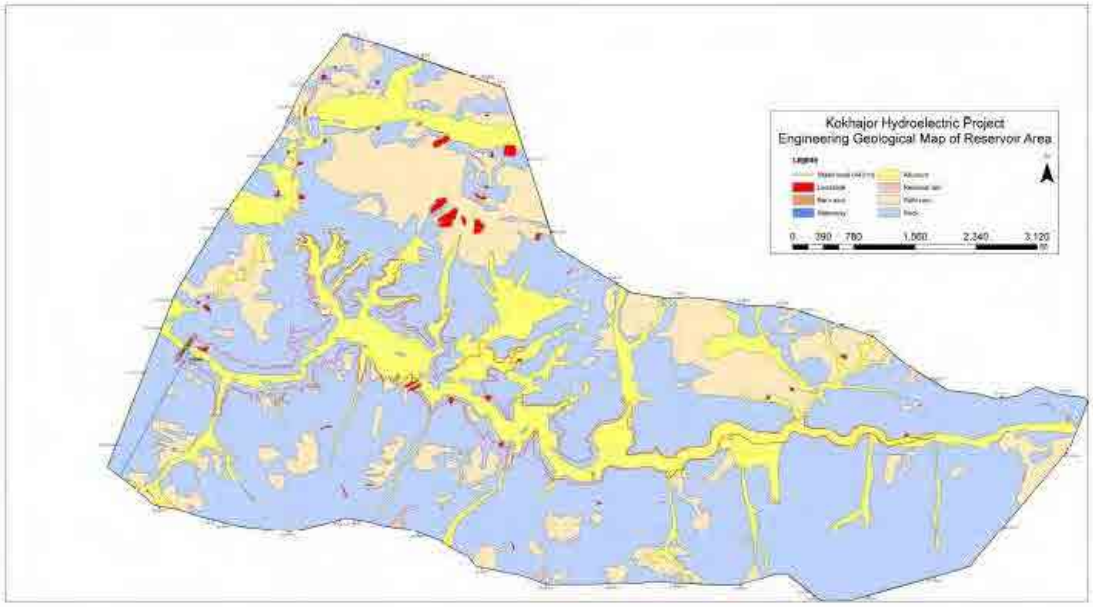
3) Seismicity

The Project area is located in Sub Himalaya. The horizontal ground acceleration of this area is 300mgal according to the Seismic Hazard Map of Nepal. The nearest epicenter of $M \geqq 4$ to the dam site is located to the NNE at a distance of about 26km.



Source: NESS Field Survey, 2012

Figure A.2.2-4 Geological map of the project area



Source: NESS Field Survey, 2012

Figure A.2.2-5 Engineering geological map of the reservoir and its surrounding region

(4) Development Plan

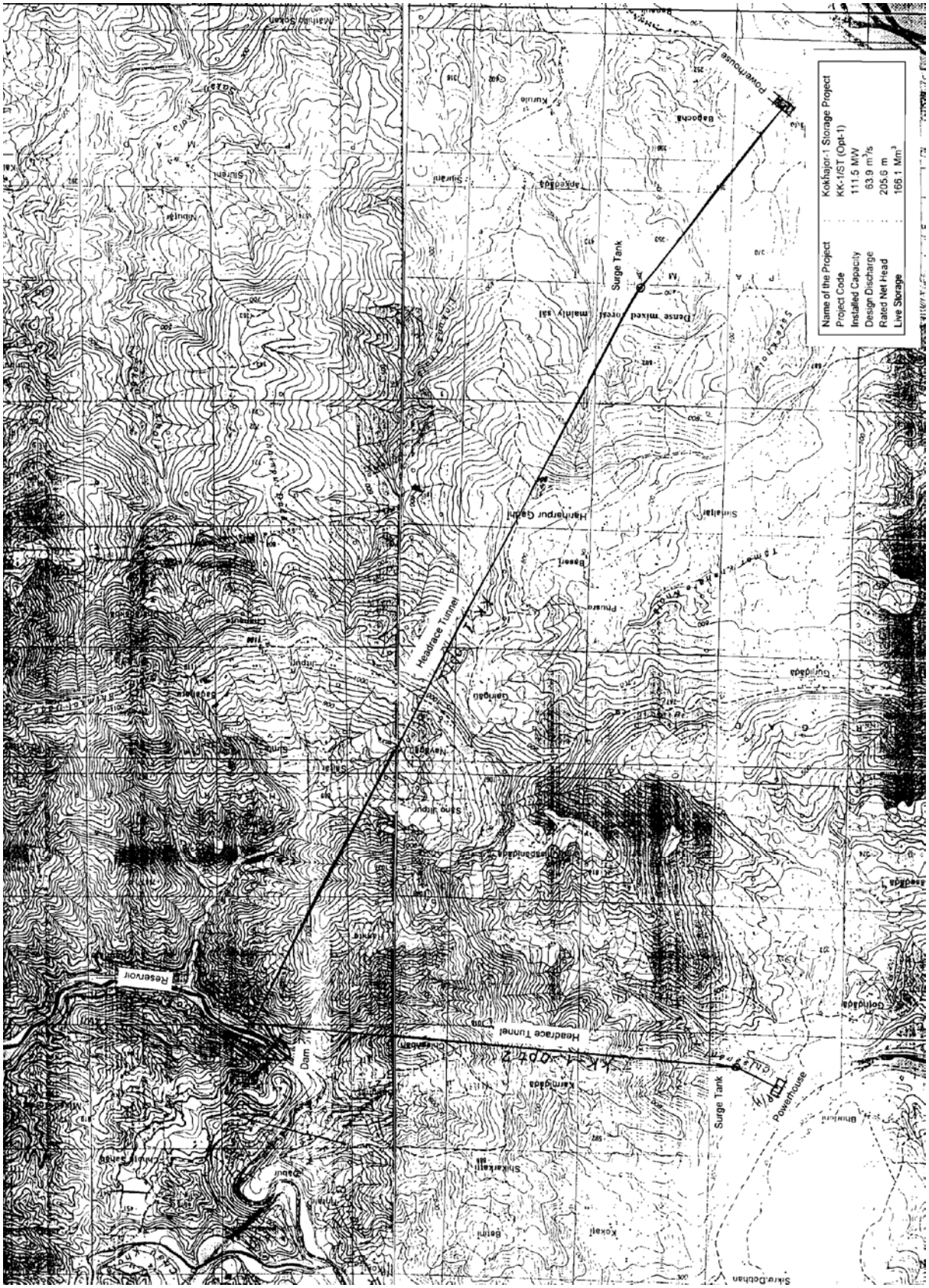
Kokhajor-1 project is a dam and waterway-type hydropower project. Since the study level stays at desk study level, the basic design drawings are not available.

The salient features of principal layout and basic layout drawing of the project are as follows:

Table A.2.2-6 Salient Features

Item	Unit	Kokhajor-1	Remarks
Reservoir			
Reservoir Area at FSL	km^2	4.6	
Total Storage Capacity	MCM	218.7	
Effective Storage Capacity	MCM	166.1	
Full Supply Level (FSL)	m	437.0	
Minimum Operating Level (MOL)	m	390.0	
Dam			
Type of Dam	-	Rockfill	
Dam Volume	MCM	4.69	
Total Dam Height	m	107	
River Bed Level at Dam Axis	m	335	
Spillway Type	-	Gated Spillway	
Waterway & Powerhouse			
Intake Type	-	Normal Pressure Intake	
Concrete Lined Headrace Tunnel Length	m	6,625	
Circular Tunnel Diameter	m	5.23	
Penstock Length	m	2,000	
Type of Powerhouse	-	Surface	
Turbine Type	-	Vertical Francis	
Installed Capacity	MW	111.5	
Design Discharge	m^3/s	63.9	
Rated Net Head	m	205.6	
Tail Water Level	m	200	
Tailrace Length	m	100	

Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA



Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA

Figure A.2.2-6 General Layout

(5) Electrical/Mechanical Equipment and Transmission Line

1) General

Rated effective head, power discharge and installed capacity of the Kokhajor-1 Project are as follows;

Rated Effective Head	: 205.60 m
Rated Power Discharge	: 63.90 m^3/s
Installed Capacity	: 111.5 MW

The HD Wiz (developed by J-POWER, based on existing hydropower plant data around world) has been used for reviewing design of electrical/mechanical equipment taking above information into consideration. Turbine efficiency and generator efficiency have been improved in recent years and installed capacity exceeded above-mentioned 111.5 MW consequently.

2) Unit Capacity and Number of Unit

Generally, for the turbine-generator, a large unit capacity is said to be more economical merits of scale. However, optimum unit capacity of the turbine-generator is determined in consideration of influence to the power system, development timing and transportation restriction.

In this project, all electrical and mechanical equipment will be transporting from foreign countries via Indian national road and un-maintained Nepalese national road to the project site. Therefore maximum unit capacity shall be set as around 100 MW and number of 2 units plan has been adopted for the project taking accident, maintenance and operation into consideration.

3) Turbine

a) Turbine Output

Rated turbine output at rated effective head of 205.60m and rated power discharge of 31.35 m^3/s per unit can be calculated as follow;

$$Pt = 9.8 \times Hn \times Qt \times \eta t$$
$$= 9.8 \times 205.60 \times 31.95 \times 0.926$$
$$\fallingdotseq 59{,}600 \text{ kW}$$

Where,

Pg : Rated generator capacity (kVA)
Hn : Rated effective head (m)
Qt : Rated power discharge per unit (m^3/s)
ηt : Turbine efficiency

b) Type of Turbine

Generally, type of turbine can be determined by close relation between effective head and turbine output. Vertical shaft Francis type turbine can be selected taking rated effective head and turbine output into consideration.

c) Runner Material

Stainless steel anti-corrosion type such as 13 chrome high nickels stainless steel is recommended to be applied for the runner material. Surface of runner and wear ring shall be coated (hard or soft) in case of water quality. Detailed coating method shall be specified in the detailed design stage.

d) Installed Capacity

Installed capacity can be calculated from aforementioned turbine output per unit as follow;

59,600 kW × 2 = 119,200 kW

Review of energy calculation is conducted by using above installed capacity.

4) Generator

A three phase alternating current synchronous generator with vertical shaft rated capacity of 64,700 kVA and power factor of 90% lag are selected.

a) Generator Capacity

Rated generator capacity can be calculated from rated turbine output, power factor and generator efficiency as follows;

$$Pg = Pt \times \eta g / p.f \text{ (kVA)}$$
$$= 59,600 \times 0.977 / 0.90$$
$$\approx 64,700 \text{ kVA}$$

where

Pg : Rated generator capacity (kVA)
Pt : Rated turbine output (kW)
ηg : Generator efficiency
p.f : Power factor, lag

As the results of above calculation, rated generator capacity is 64,700 kVA.

5) Transmission Line

Regarding designing of the transmission line, transmission line shall be connected to the closest substation based on 400 kV Transmission Line Power Development Plan by the NEA. And also thermal capacity and maximum surface potential gradient have been taken into consideration for designing of the transmission line and following specifications have been adopted. As for the transmission line length, the direct length from project area to closest substation was measured from map. Therefore, some allowance has been taken into consideration.

Connected Substation	: Hetauda Substation
Transmission Line Voltage	: 220 kV
Length of Transmission Line	: 62 km
Conductor Type	: Bison × 1, 2 circuits

2.3 Sun Koshi No.3 Project (E-17)

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A.2.3 Sun Koshi No.3 (E-17)

(1) Project Summary

The Sun Koshi No.3 Project is a 536 MW storage-type hydroelectric power project located at the Sun Koshi river in the Ramechhap, Kabhrepalanchok and Sindhupalchok Districts in the eastern region. This project was originally discovered in the "Master Plan Study on the Koshi River Water Resource Development, 1985" carried out by JICA. The study level for this project stays at the desk study level.

Further, the JICA Study Team conducted a site reconnaissance at Sun Koshi No.3 project site in June 2012. The findings attained through site reconnaissance are also summarized in this clause.

As hydrological characteristics, the annual rainfall at Manthali gauging station nearest to the project site is 994 mm, however, the average river discharge at the dam site is significant, 220 m^3/s. The catchment area is 5,520 km^2, and the specific sediment volume is estimated to be 1,871 $t/km^2/year$. This is smaller than 3,300 $t/km^2/year$, which is the value adopted by the NEA as average specific sedimentation volume in the eastern region. It has to be noted that two glacier lakes having a high risk of a GLOF are identified in the drainage basin.

From a geological view point, the project area lies in the Lesser Himalaya Zone and is composed mainly of quartzite, slate and phyllite. The reservoir area is underlain mainly by quartzite and slate. This area is water tight, but slopes in its surrounding area are widely covered with colluvium, which would provide many unstable slopes. The dam site is underlain by quartzite, which is intercalated by phyllite and forms hard and impervious rock. The headrace tunnel route passes through quartzite which is intercalated by phyllite, and forms hard and compact rock. The bedrock of the powerhouse site is composed of quartzite and phyllite. The project area is located in the area where a medium acceleration of 190 mgal is shown on the seismic hazard map. It is away from a large tectonic thrust (MBT) at a long distance of 16 km and from epicenters larger than M4 at a long distance of 28 km.

The impact on the Natural Environment is average and the impact on the Social Environment is high. Sun Koshi No.3 is located in the Koshi river basin and the reservoir area is 30.1 km^2, which is the largest in the 10 promising projects. The impact on forest is also the largest, which is 8.15 km^2. The number of recorded fishes is 21, which are relatively high. The dewatering area is the smallest at 0.5 km. The length of the Transmission Line is relatively shorter and is about 35 km. The number of resettlements is 1,599, which is the largest next to Lower Badigad. The affected Agricultural land is also the largest at 9.4 km^2. The number of affected fishermen will be 712 and the affected fish markets will be 7, which is the highest out of the 10 promising projects. Around 20,000 tourists are visiting the project site every year, which is the biggest impact on tourism. 15km of paved roads, 24.4 km of drivable roads, 13 suspension bridges, and 22 water supply schemes will be affected. Two irrigation projects, one ring road, one bridge, one water pump, and four road expansion projects are planned in the reservoir area. There used to be trouble related to the road expansion plan. The Indigenous groups in the reservoir area are the Newar (Advanced), Magar (Disadvantaged), Tamang (Disadvantaged), Majhi (Marginalised) and Tharu (Marginalised).

From the view point of hydropower planning, the proposed concrete dam with a height of 140 m makes a large effective reservoir volume of 555 million m^3. The large rated power discharge of 570 m^3/s is required to gain 536 MW of installed capacity due to the small effective head of 109 m. Therefore, a large size of electromechanical equipment is also required, which makes the construction cost relatively high. The setting of a full supply level of the reservoir has to be reviewed since 6 km of the Araniko Highway which will connect Nepal and China is to be submerged in the reservoir, having a length of 30 km in the current layout. Furthermore, a spillway which can control a GLOF and a sand flushing facility which enables flushing out sedimentation produced by a GLOF has to be planned.

The location, basic layout and salient features of the project are shown below.

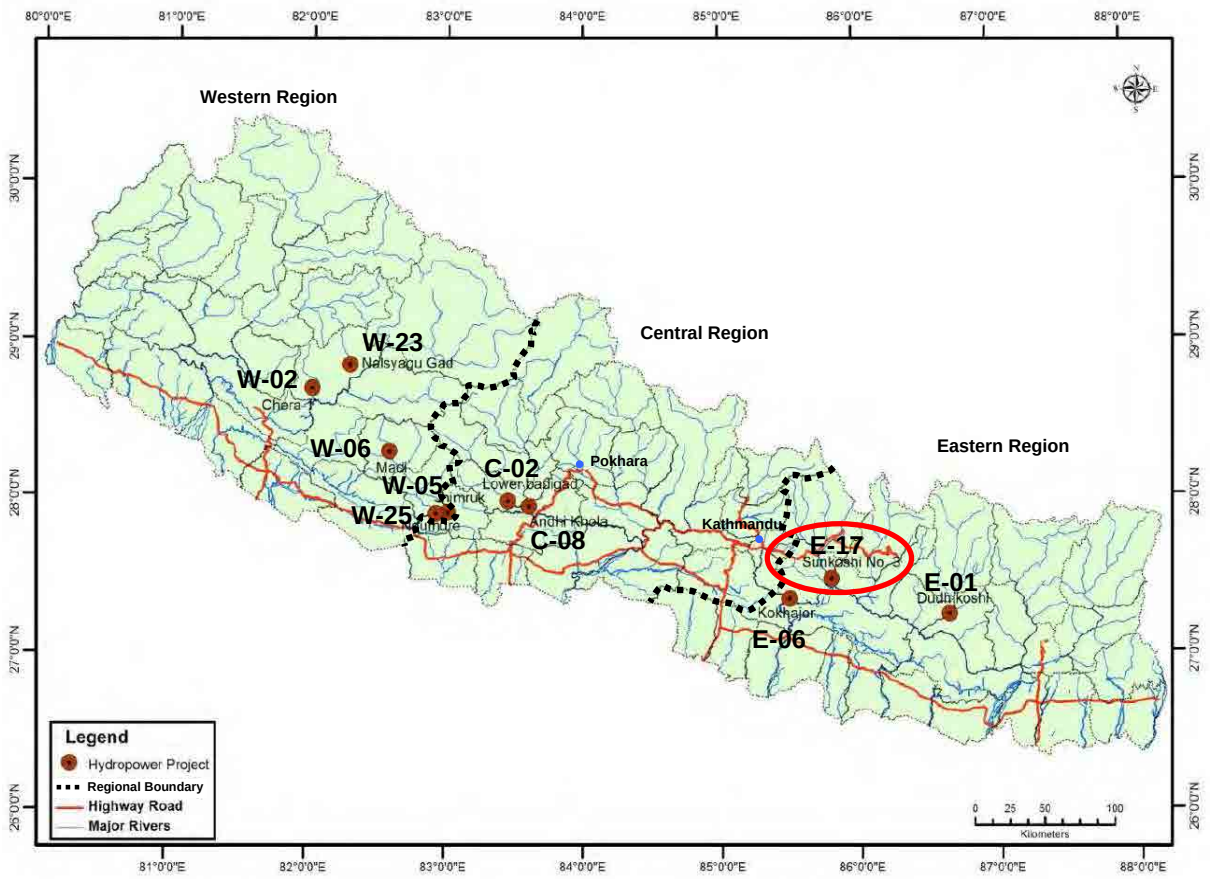

Figure A.2.3-1 Location of the Sun Koshi No.3 Project (E-17)

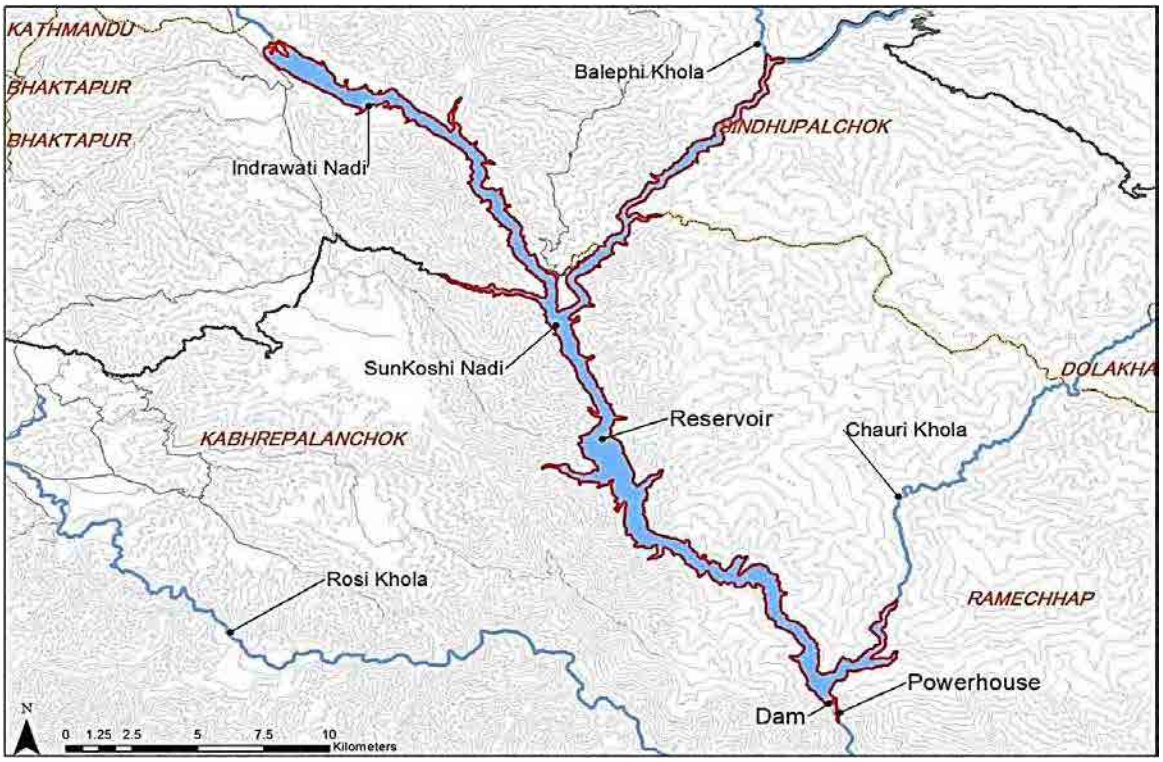

Figure A.2.3-2 General Layout of the Sun Koshi No.3 Project (E-17)

Table A.2.3-1 Project Description

Item	Unit	Sun Koshi No.3	Remarks
Location	(District)	Ramechhap, Kabhrepalanchok, Sindhupalchok	
Name of the River	(River)	Sun Koshi	
Installed Capacity	MW	536.0	
Catchment Area	km^2	5,520	
Location of Dam Site	Longitude/ Latitude	85° 48' 14.3" 27° 29' 50.5"	
Dam Height	m	140.0	
Total Storage Volume	MCM	1,220.0	
Effective Storage Volume	MCM	555.0	
Regulating Capability Factor	%	7.9	
Reservoir Area at FSL	km^2	30.1	
Full Supply Level	m	700.0	
Minimum Operation Level	m	674.0	
Tail Water Level	m	575.0	
Rated Gross Head	m	116.3	
Rated Net Head	m	109.3	
Rated Power Discharge	m^3/s	570	
Total Energy	GWh	1,883.6	Estimated by the Study Team.
Dry Energy (December-April)	GWh	335.9	Estimated by the Study Team.
Length of Access Road	km	20.0	
Length of Transmission Line	km	35.0	Estimated by the Study Team.
Number of Household	nos	1,599	Surveyed by the Study Team in 2012.
Project Cost	MUS$	1,690.5	Estimated by the Study Team at 2013 price level.
Unit Generation Cost	cent/kWh	9.0	Estimated by the Study Team.
EIRR (8% of Interest Rate, 12NRs/kWh)	%	13.1	Estimated by the Study Team.
FIRR (8% of Interest Rate, 12NRs/kWh)	%	19.4	Estimated by the Study Team.

Source: Master Plan Study on the Kosi River Water Resources Development, 1985, JICA (except remarked items)

In addition, the summary of natural and social environmental investigation result and its evaluation are shown below. The detailed information is summarized in Appendix 3 and 5.

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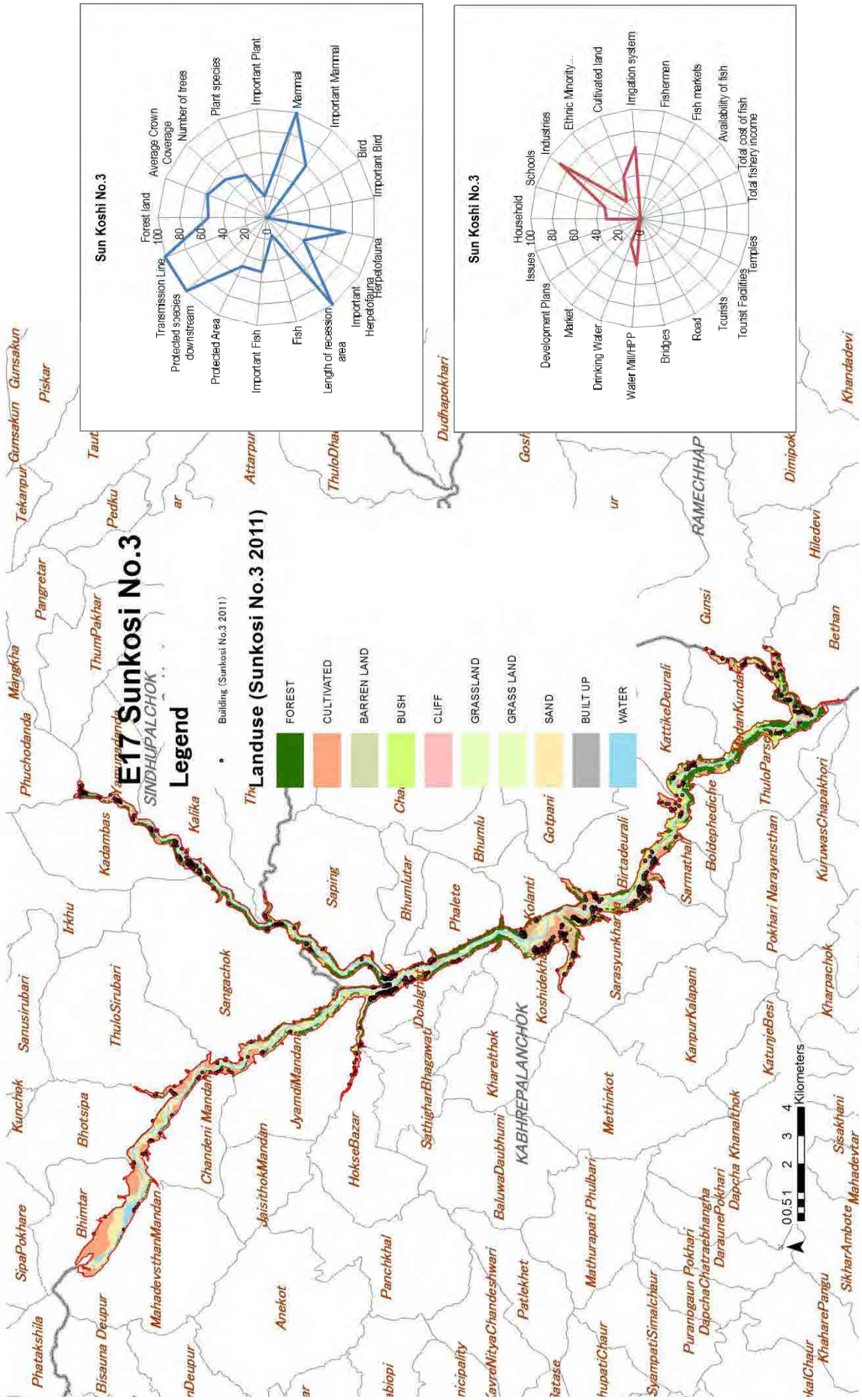


Figure A.2.3-3 Land Use and Buildings in the Reservoir Area of the Sun Koshi No.3 Project

(2) Meteorology & Hydrology

With regard to the Sun Koshi No.3 project, the meteorological characteristics and the criteria for hydrological evaluation, namely reliability of flow data, risk of a GLOF and sediment impact are mentioned below.

1) Meteorology

The Sun Koshi No.3 project site is located at the Sun Koshi river. The districts where the project site is located at are Ramechhap, Kabhrepalanchok and Sindhupalchok.

The precipitation station (1123) is located in the Ramechhap district. Table A.2.3-2 shows the monthly rainfall at the Ramechhap station.

Table A.2.3-2 Monthly Rainfall at the Ramechhap Station

Name	Index	District	Type of Station	Start to Record	Location		Elevation
					Latitude	Longitude	(m)
MANTHALI	1123	Ramechhap	PRECIPITATION	Jan, 92	27.47	86.08	495

Precipitation (mm)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
14.3	13.6	24.2	40.5	85.8	143.6	295.7	203.8	123.7	36.1	5.6	7.0	994.0

Source: Department of Hydrology and Meteorology: DHM

2) Reliability of flow data

As the gauging station (630) is located at 8 km upstream of the dam axis, multiplying the flow data of the gauging station by the rate of catchment area of the project site to one of gauging station gives the flow data of the Sun Koshi No.3 project. The reliability of flow data of the project is relatively high.

Table A.2.3-3 shows the monthly flow data for energy calculation.

Table A.2.3-3 Flow Data for the Sun Koshi No.3 Project

(m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
1997	56.66	48.47	45.10	51.50	60.59	143.61	494.78	608.10	368.00	150.34	94.13	77.53	183.23
1998	56.77	49.14	51.50	68.21	153.71	299.56	696.73	905.41	418.49	224.39	107.93	76.18	259.00
1999	58.57	49.37	46.11	50.82	83.02	222.15	639.51	674.29	509.37	297.32	129.02	87.96	237.29
2000	64.62	55.09	47.68	55.65	96.04	300.68	697.85	887.46	555.37	171.66	98.06	72.48	258.55
2001	60.14	54.08	50.60	48.13	77.08	242.34	456.63	842.59	397.17	166.05	89.53	65.97	212.53
2002	55.09	50.94	48.02	53.63	86.61	171.66	575.56	739.37	359.02	205.32	96.60	60.81	208.55
2003	51.61	48.47	48.36	53.74	58.68	173.90	702.34	655.22	641.76	186.24	91.66	64.62	231.38
2004	60.92	55.99	51.27	51.61	67.32	191.85	509.37	629.41	447.66	296.20	135.76	100.75	216.51
2005	84.03	75.06	69.56	75.40	87.96	139.12	468.98	605.85	347.80	200.83	108.83	90.88	196.19
2006	76.29	71.80	69.79	77.53	129.02	232.24	506.00	462.24	355.66	185.12	115.56	90.20	197.62
Ave.	62.47	55.84	52.80	58.62	90.00	211.71	574.78	701.00	440.03	208.35	106.71	78.74	220.09

3) Risk of GLOF

The Sun Koshi basin is a trans-boundary river basin between Tibet and Nepal. It is extended from 26° 37' to 28° 32' N latitude and 85° 43' to 86° 18' E longitude with an altitude range from 640 m to 8,012 m. The basin covers an area of approximately 3,394 km^2, within which 2,007 km^2 is within Tibet and 1,387 km^2 is within Nepal. The length of the basin is 107 km and the width is 33 km.

There are nine potentially critical glacial lakes in terms of a GLOF upstream of the Sun Koshi basin. All of them are located in Tibet. Table A.2.3-4 shows the list of potentially critical glacial lakes in terms of a GLOF in the Sun Koshi basin. The Lumi Chimi Lake and the Gangxi Co Lake are the high-risk glacial lakes. Both of them are formed by the end moraines and classified into category I. When a feasibility study for the Sun Koshi No.3 project is conducted in future, it is necessary to consider the impact of GLOF quantitatively.

Table A.2.3-4 Potentially Critical Glacial Lake in term of GLOF in the Sun Koshi Basin

Lake number	Lake name	Latitude	Longitude	Altitude (masl)	Length (m)	Area (m^2)	Class	Category	Distance from GL to site (km)
Poiqu_26	Lumi Chimi Lake	85°50.49'E	28°19.01'N	5,100	3,216	3,136,591	M(e)	I	116
Poiqu_54	Gangxi Co Lake	85°52.58'E	28°21.62'N	5,290	3,636	3,373,971	M(e)	I	123
Poiqu_59		86°15.44'E	28°22.49'N	5,560	634	168,282			–
Poiqu_60		86°13.48'E	28°20.99'N	5,360	1,293	371,695			–
Poiqu_63		86°11.47'E	28°20.14'N	5,510	1,416	610,469			–
Poiqu_64		86°9.51'E	28°19.27'N	5,560	697	228,632			–
Poiqu_65		86°9.48'E	28°18.22'N	5,376	2,064	594,534			–
Poiqu_66		86°9.09'E	28°17.66'N	5,360	856	161,224			–
Poiqu_67		86°7.87'E	28°17.64'N	5,260	1,023	239,205			–

Source: Pumqu, Rongxer, Poiqu, Zangbuqin, Jilongcancbu, Majiacangbu, Daoliqu and Jiazhagangge basins, Tibet Autonomous Region, People's Republic China, Inventory of Glaciers, Glacial Lakes and the Identification of Potential Glacial Lake Outburst Floods (GLOFs) Affected by Global Warming in the Mountains of Himalayan Region, 2005, CAREERI, BHT, APN, START, ICIMOD, UNEP

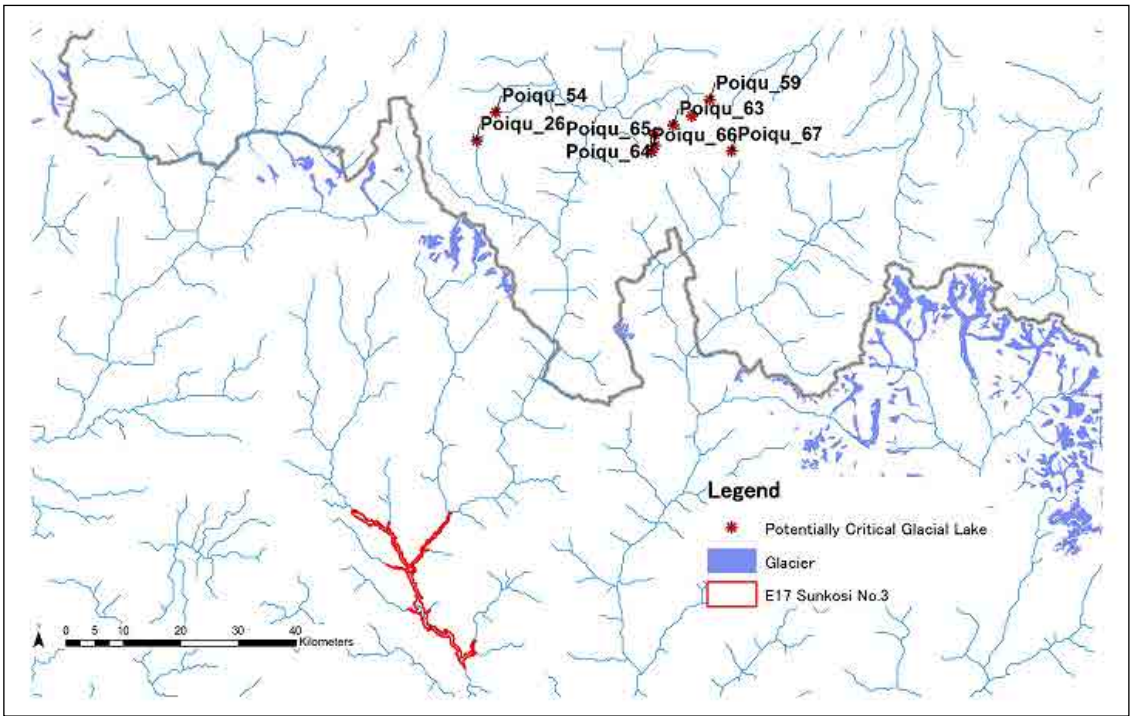


Figure A.2.3-4 Potentially Critical Glacial Lakes for a GLOF for the Sun Koshi No.3 Project

4) Sediment Impact

The specific sediment yield of the Sun Koshi No.3 project site is estimated to be 1,871 t/km^2/year based on the specific sediment yields classified according to the Himalayan geological zone as shown in Table 2.3.3-1 in the Main Report. By using this yield, the life of the reservoir is estimated. The life of reservoir is an index to evaluate the sediment impact to reservoir and calculated dividing total storage volume by mean annual sediment yield. It indicates how many years it will take to fulfill a reservoir by sedimentation.

Table A.2.3-5 shows the calculation result of the life of reservoir. The life of reservoir of the project is estimated to be 177 years.

Table A.2.3-5 Life of Reservoir

a) Specific Sediment Yield	1,871 t/km^2/yr
b) Sediment Yield (Catchment Area × Specific Sediment Yield / Sediment Density)	6.9×10^6 m^3/yr (5,520 km^2 × 1,871 t/km^2/yr / 1.5 t/m^3)
c) Total Storage Volume	$1,220 \times 10^6$ m^3
d) Life time of Storage (Total Storage Volume / Sediment Yield)	177 years ($1,220 \times 10^6$ m^3 / 6.9×10^6 m^3/yr)

(3) Geology

1) Site Geology

The Sun Koshi No.3 project area belongs to the Ramechhap district, central in Nepal. The dam site is located in the valley of the Sun Koshi river about 9 km upstream of the confluence of the Roshi river. The powerhouse site is located on the left bank of the Sun Koshi river. According to the field geological survey, geology and engineering geology of the project area are as follows.

The geological map of the project area is shown in Figure A.2.3-3. The project area lies in the Lesser Himalayan Zone, and is underlain by the Kuncha Formation and the Benighat Formation. The Kuncha Formation is mainly composed of phyllite and quartzite. The Benighat Formation is mainly composed of slate.

The reservoir and its surrounding area are underlain by the Kuncha Formation and the Benighat Formation. The Kuncha Formation is distributed in upstream and downstream portion of the reservoir area and composed of quartzite with intercalation of schist. The Benighat Formation is distributed in middle stream portion of the reservoir area and composed of slate accompanied by siliceous to dolomitic limestone. The Kuncha Formation of upstream portion is separated from The Benighat Formation by a fault which extends along the Indrawati river. Limestone beds of the Benighat Formation are distributed in middle stream of the reservoir area and cause no problem in the reservoir watertightness. The engineering geological map of the reservoir and its surrounding area is shown in Figure A.2.3-4. These areas are covered with colluvium, which would provide many unstable slopes.

The engineering geological map of the project of dam site, headrace tunnel route and power house site is shown in Figure A.2.3-5. The dam site is underlain by quartzite of the Kuncha Formation intercalated by thin phyllite. Bed rock is hard and impervious. Bedding planes incline toward upstream and right bank at angle of about 30 degrees.

The headrace tunnel route is located on the left bank of the Sun Koshi river where composed of .quartzite of the Kuncha Formation with thin phyllite. The overburden of this tunnel is less than 100 m.

The powerhouse site is located on the alluvial terrace on the left bank of the Sun Koshi river. This site is composed of slate of the Kuncha Formation with thin quartzite.

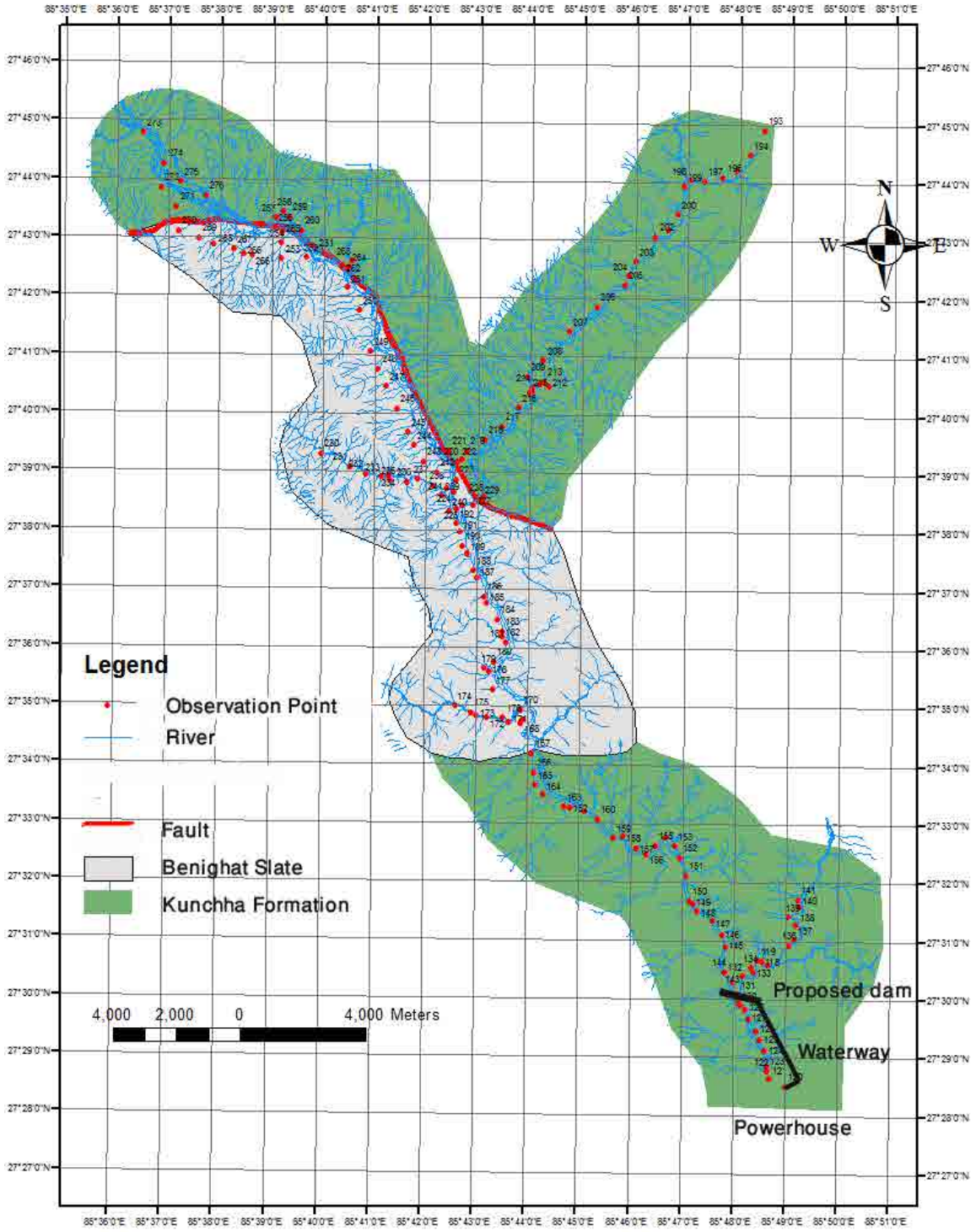
Sands distributed near the confluence of the Roshi river 9 km downstream of the dam site is available for fine concrete aggregate. For coarse concrete aggregate, river gravels and quartzite distributed in the vicinity of the dam site are available. This quartzite is also suitable for rock materials. Colluvium and residual soil distributed in the area underlain by pelitic rocks would be investigated for borrow areas of soil materials.

2) Thrust and Fault

Among large tectonic thrust, MBT is located to the south of the dam site at a distance of about 16 km. A local major fault has not been found in the vicinity of the dam site.

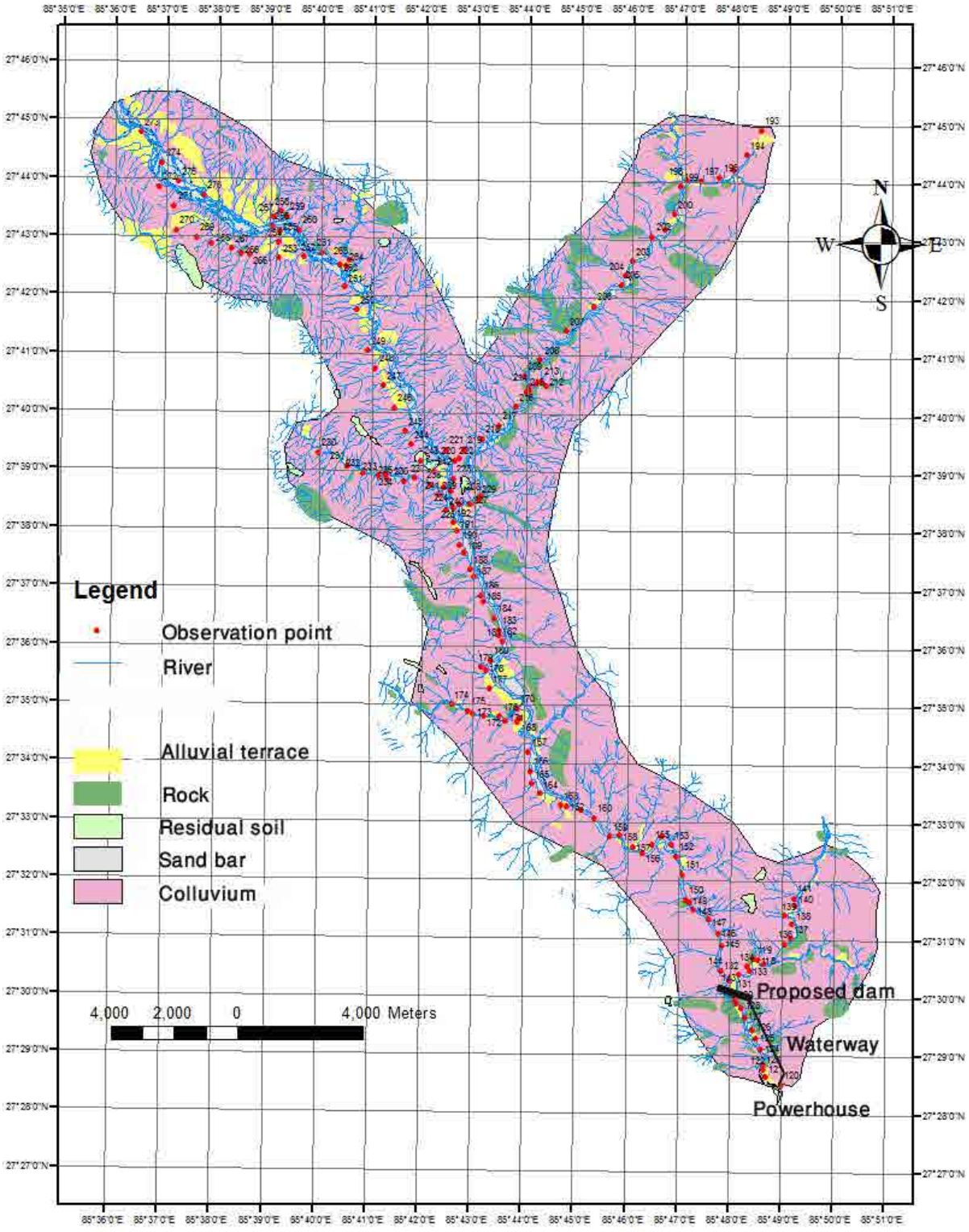
3) Seismicity

The project area is located in Lesser Himalaya. The horizontal ground acceleration of this area is 190 mgal according to the Seismic Hazard Map of Nepal. The nearest epicenter of M≧4 to the dam site is located to the northwest at a distance of about 24 km.



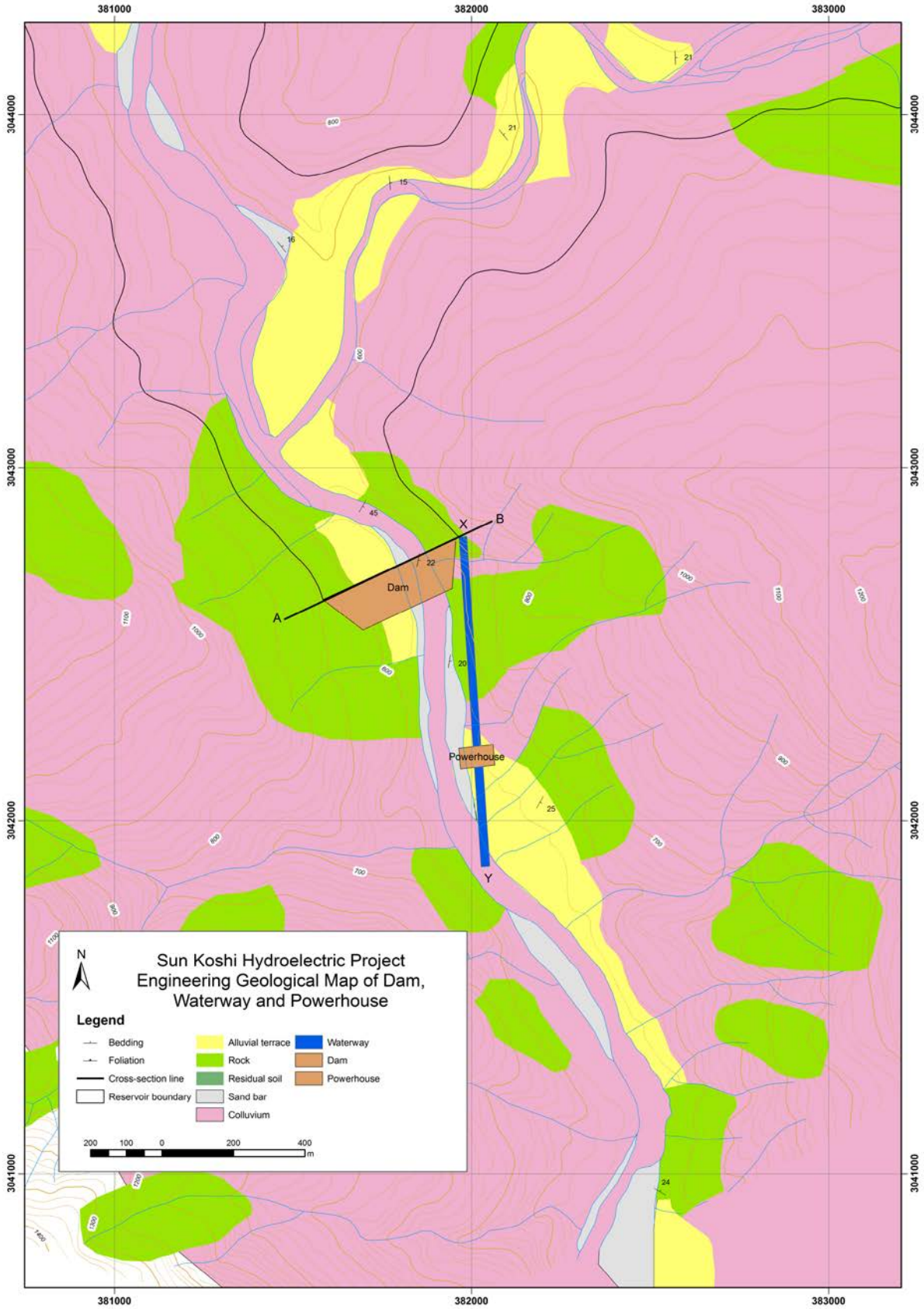
Source: NESS Field Survey, 2012

Figure A.2.3-5 Geological map of the project area



Source: NESS Field Survey, 2012

Figure A.2.3-6 Engineering geological map of the reservoir and its surrounding region



Source: NESS Field Survey, 2012

Figure A.2.3-7 Engineering geological map of the dam axis, waterway and powerhouse area.

(4) Development Plan

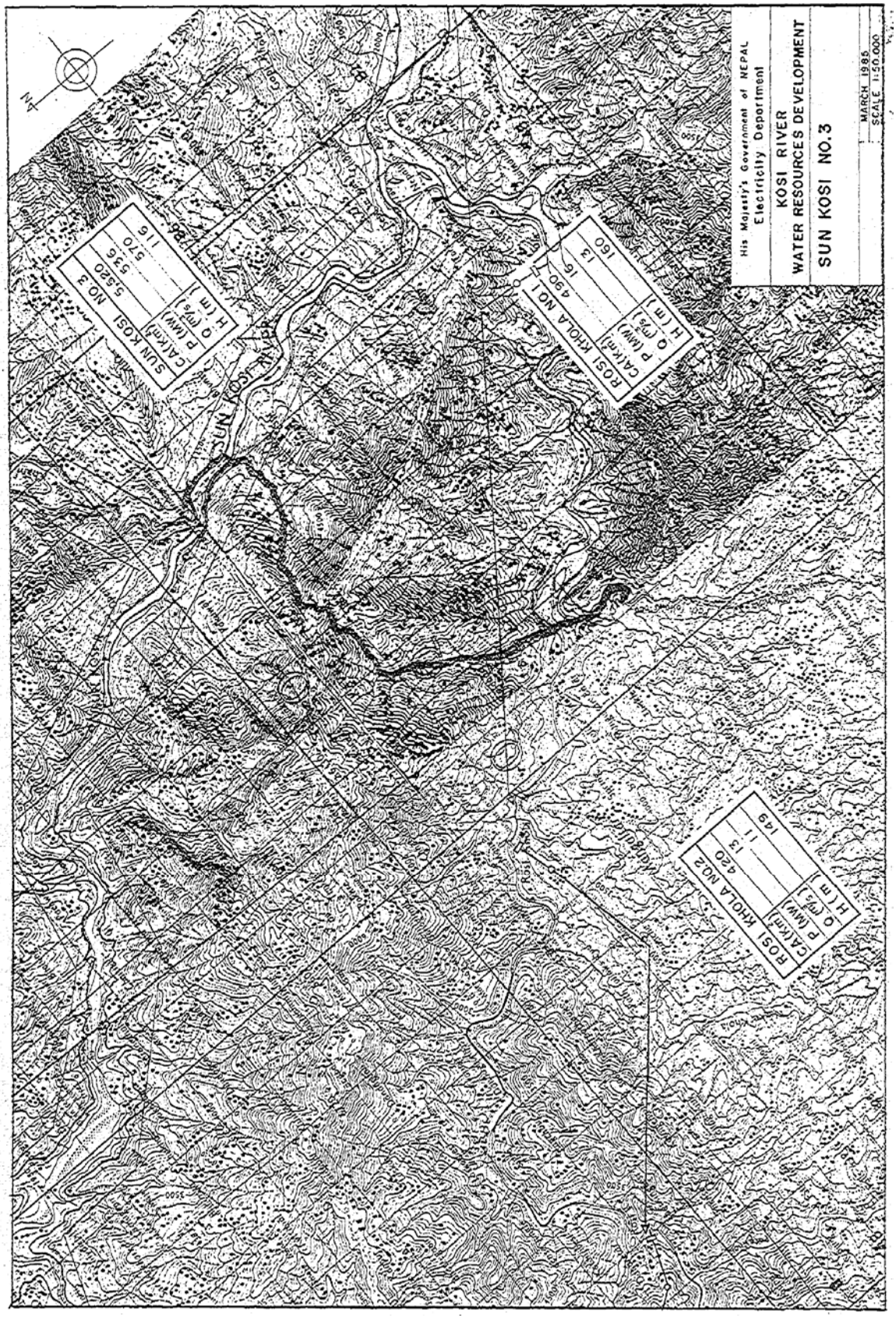
The Sun Koshi No.3 Project is a dam-type hydropower project. Since the study level stays at desk study level, the basic design drawings are not available.

The salient features of principal layout and basic layout drawing of the project are as follows:

Table A.2.3-6 Salient Features

Item	Unit	Sun Koshi No.3	Remarks
Reservoir			
Reservoir Area at FSL	km^2	30.1	
Total Storage Capacity	MCM	1,220.0	
Effective Storage Capacity	MCM	555.0	
Full Supply Level (FSL)	m	700.0	
Minimum Operating Level (MOL)	m	674.0	
Dam			
Type of Dam	-	Concrete Gravity	
Dam Volume	MCM	1.935	
Total Dam Height	m	140	
River Bed Level at Dam Axis	m	-	
Spillway Type	-	Gated Spillway	
Waterway & Powerhouse			
Intake Type	-	Normal Pressure Intake	
Concrete Lined Headrace Tunnel Length	m	-	
Circular Tunnel Diameter	m	-	
Penstock Length	m	-	
Type of Powerhouse	-	Surface	
Turbine Type	-	Vertical Francis	
Installed Capacity	MW	536	
Design Discharge	m^3/s	570	
Rated Net Head	m	109.3	
Tail Water Level	m	575	
Tailrace Length	m	-	

Source: Master Plan Study on the Kosi River Water Resources Development, 1985, JICA



Source: Master Plan Study on the Kosi River Water Resources Development, 1985, JICA

Figure A.2.3-8 General Layout

Further, the findings attained by the Study Team through the site reconnaissance conducted in June, 2012 in terms of the dam site and powerhouse site are summarized below.

Dam site

The dam site proposed in "Master Plan Study on the Koshi River Water Resources Development (1985)" conducted by JICA is located at approximately 1 km upstream of the Chiyantar village, 9 km of the Nepalthok town. The coordinate at dam axis is approximately 27º29'51"N, 85º48'06"E and river bed elevation is 575 m.

The both left bank and right bank are steep slopes with the height of more than 400 m from the river bed.

There is an unpaved road (Direct Distance: 5.5 km) at the right bank from the Nepalthok town located at the confluence of the Sun Koshi river and its tributary, the Roshi Khola river to the vicinity of the dam site. However, a new 150 m bridge will be required at around the existing suspension bridge over the Roshi Khola river, as it is impossible to cross the river in rainy seasons due to lack of the bridge which enables car transportation. Furthermore, as the paved road is on the high location from the river bed, it is necessary to construct some branch roads toward the river bed.

Powerhouse site

Although the location of powerhouse is not clearly shown in the Master Plan report, a site 1 km downstream of the dam site close to the Chiyantar village at the left bank is studied by the NEA.

Others

In the present layout, the FSL of the Sun Koshi No.3 project is EL.700 m and the length of the reservoir extends approximately 30 km. In the upstream Dolaghat town, there are bridges over the Indrawati river and the Botekoshi river of which elevation is approximately EL.630 m, as a part of the Anrico highway connecting Nepal and China. Therefore, the bridges and 6 km of the highway are to be inundated.

It would be an alternative to develop the project by lowering FSL down to EL.620m as run of river scheme in order to minimize the impact of inundation. However, it would be difficult to keep the dead volume for sediment in the reservoir and to flush sediment due to the gentle inclination of river bed. Therefore, the countermeasure for sediment would be a challenge in this alternative.

With regard to the Sun Koshi No.3 project, a feasibility study will be started in FY2013 by the NEA.

(5) Electrical/Mechanical Equipment and Transmission Line

1) General

Rated effective head, power discharge and installed capacity of the Sun Koshi No.3 Project are as follows;

Rated Effective Head	: 109.30 m
Rated Power Discharge	: 570 m^3/s
Installed Capacity	: 536 MW

The HD Wiz (developed by J-POWER, based on existing hydropower plant data around world) has been used for reviewing design of electrical/mechanical equipment taking above information into consideration. Turbine efficiency and generator efficiency have been improved in recent years and installed capacity exceeded above-mentioned 536 MW consequently.

2) Unit Capacity and Number of Unit

Generally, for the turbine-generator, a large unit capacity is said to be more economical merits of scale. However, optimum unit capacity of the turbine-generator is determined in consideration of influence to the power system, development timing and transportation restriction.

In this project, all electrical and mechanical equipment will be transporting from foreign countries via Indian national road and un-maintained Nepalese national road to the project site. Therefore maximum unit capacity shall be set as around 100 MW and number of 6 units plan has been adopted for the project.

3) Turbine

a) Turbine Output

Rated turbine output at rated effective head of 109.30m and rated power discharge of 95.00 m^3/s per unit can be calculated as follow;

$$Pt = 9.8 \times Hn \times Qt \times \eta t$$
$$= 9.8 \times 109.30 \times 95.00 \times 0.925$$
$$\approx 94{,}100kW$$

where

Pt : Rated turbine output per unit (kW)
Hn : Rated effective head (m)
Qt : Rated power discharge per unit (m^3/s)
ηt : Turbine efficiency

b) Type of Turbine

Generally, type of turbine can be determined by close relation between effective head and turbine output. Vertical shaft Francis type turbine can be selected taking rated effective head and turbine output into consideration.

c) Runner Material

Stainless steel anti-corrosion type such as 13 chrome high nickels stainless steel is recommended to be applied for the runner material. Surface of runner and wear ring shall be coated (hard or soft) in case of water quality. Detailed coating method shall be specified in the detailed design stage.

d) Installed Capacity

Installed capacity can be calculated from aforementioned turbine output per unit as follow;

94,100 kW × 6 = 564,600 kW

Review of energy calculation is conducted by using above installed capacity.

4) Generator

A three phase alternating current synchronous generator with vertical shaft rated capacity of 102,300 kVA and power factor of 90% lag are selected.

a) Generator Capacity

Rated generator capacity can be calculated from rated turbine output, power factor and generator efficiency as follows;

$$Pg = Pt \times \eta g / p.f \text{ (kVA)}$$
$$= 94,100 \times 0.979 / 0.90$$
$$\approx 102,300 \text{ kVA}$$

where

Pg : Rated generator capacity (kVA)
Pt : Rated turbine output (kW)
ηg : Generator efficiency
p.f : Power factor, lag

As the results of above calculation, rated generator capacity is 102,300 kVA.

5) Transmission Line

Regarding designing of the transmission line, transmission line shall be connected to the closest substation based on 400 kV Transmission Line Power Development Plan by the NEA. And also thermal capacity and maximum surface potential gradient have been taken into consideration for designing of the transmission line and following specifications have been adopted. As for the transmission line length, the direct length from project area to closest substation was measured from map. Therefore, some allowance has been taken into consideration.

Connected Substation	: Barhabise Substation
Transmission Line Voltage	: 220 kV
Length of Transmission Line	: 35 km
Conductor Type	: Moose × 2, 2 circuits

2.4 Lower Badigad Project (C-02)

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A.2.4 Lower Badigad (C-02)

(1) Project Summary

The Lower Badigad Project is a 380.3 MW storage-type hydroelectric power project located at the Badigad river in Gulmi District in the central region. The latest study for this project was conducted in the "Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA." The study level for this project stays at the desk study level.

Further, the JICA Study Team conducted a site reconnaissance at Lower Badigad project site in June 2012. The findings attained through site reconnaissance are also summarized in this clause.

As hydrological characteristics, the annual rainfall at the Tamghas gauging station nearest to the project site is 1,879 mm and the average river discharge at the dam site is 83.7 m^3/s. The drainage area is 2,050 km^2, and the specific sediment volume is estimated to be 2,526 $t/km^2/year$. This is larger than 4,400 $t/km^2/year$, which is the value adopted by the NEA as average specific sedimentation volume in the central region. No glacier lakes having a high risk of a GLOF are identified in the drainage basin.

From a geological view point, the project area lies in the Lesser Himalaya Zone and is composed mainly of quartzite, slate, phyllite and limestone. There is an active fault (named the Badigad Fault) along the Badigad River. The reservoir area is underlain mainly by slate and limestone. Limestone is limited in the reservoir area and would not affect water tightness. However, there is a major active landslide named Gultung Pahiro, which is located in the area surrounding the reservoir area and provides a large volume of sediment. The dam site is underlain by quartzite and slate, but it is crossed by the active Badigad Fault. The headrace tunnel route passes through slate and quartzite, which form hard and compact rock. Power house site is underlain mainly by slate. It is covered with thick river deposits. The project area is located in the area where a relatively small acceleration of 170mgal is shown on the seismic hazard map. It is away from a large tectonic thrust (MBT) at a long distance of 25km, but an active fault (the Badigad Fault) crosses the dam site. It is away from epicenters larger than M4 at a long distance of 30km.

The impact on the Natural Environment is average and the impact on the Social Environment is high. Lower Badigad is located in the Gandaki River Basin. The reservoir area is 13.7 km^2. There are three protected areas downstream of the river and five important species which depend on water habitat that are known. The length of the Transmission Line is relatively short at 49 km. The number of resettlements is the highest at 1,606. The number of resettlements per unit generation is the biggest at 4.22 HH/MW. The number of affected industries is also the highest at 11. The number of Indigenous groups is 7 (Newar (Advanced), Thakali (Advanced), Magar (Disadvantaged), Gurung (Disadvantaged), Tharu (Marginalised), Bote (Highly Marginalised), Majhi (Highly Marginalised)) which is the highest. The affected agricultural land is 5.9 km^2 which is relatively large. The affected irrigation systems are 58, which is the highest. The number of the fishermen is 217, which is relatively high. 26.1 km drivable roads, 11 suspension bridges, 2 micro hydropower plants and 29 water supply schemes will be affected.

From the view point of hydropower planning, the proposed rockfill dam with a height of 191 m

makes a large effective reservoir volume of 505 million m^3. The rated power discharge of 233 m^3/s is required to gain 380 MW of installed capacity with an effective head of 192.5 m. Although the specific sediment yield for the Lower Badigad project is estimated from that for Andhi Khola project located adjacent to Lower Badigad, there is a possibility that the actual specific sediment yield would be substantially larger than the estimation since a large-scale land slide is confirmed in the reservoir as a result of the site reconnaissance. Therefore, a sand flushing facility such as that adopted in the Tanahu project, which enables flushing out the sediment, has to be planned. Furthermore, the dam type that enables installing such a sand flushing facility in the dam also has to be studied.

The location, basic layout and salient features of the project are shown below.

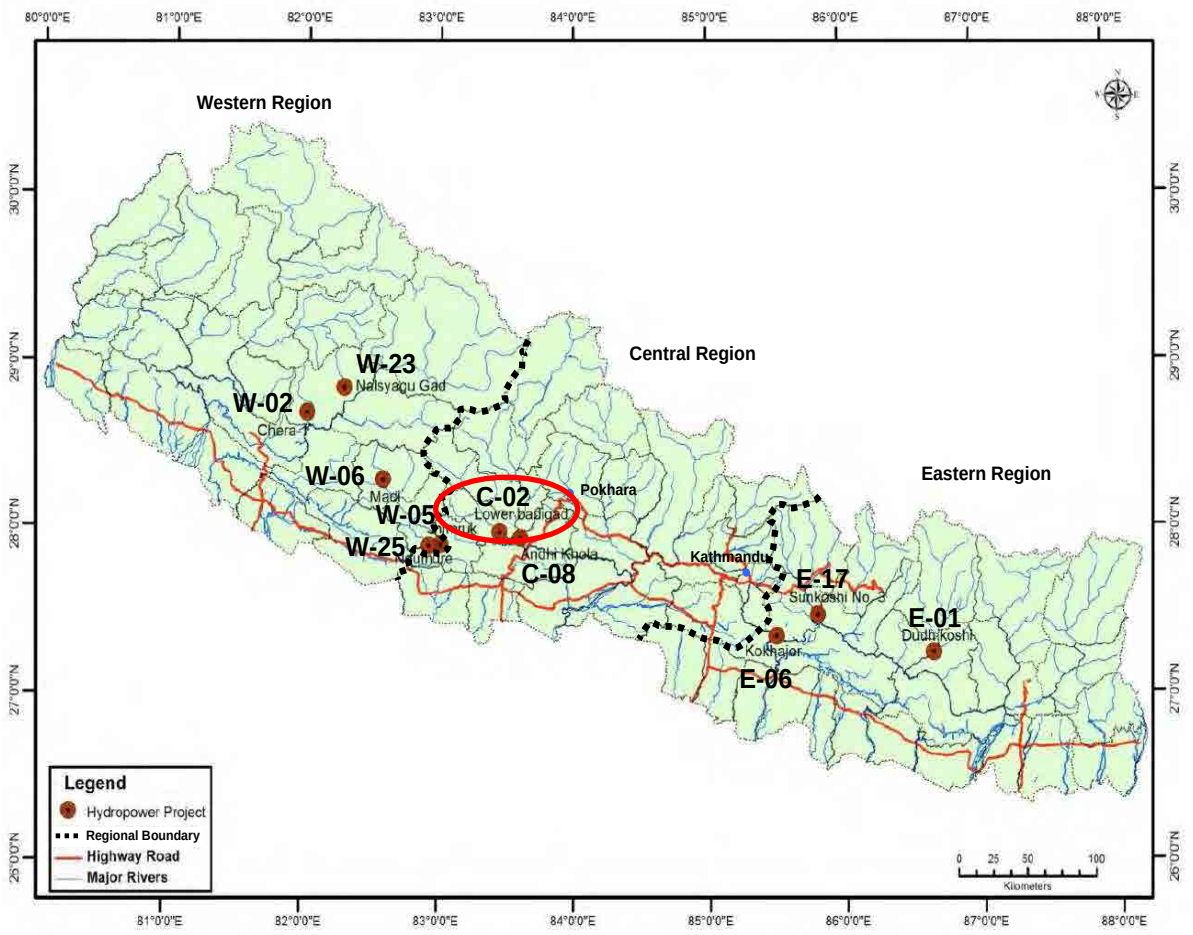


Figure A.2.4-1 Location of the Lower Badigad Project (C-02)

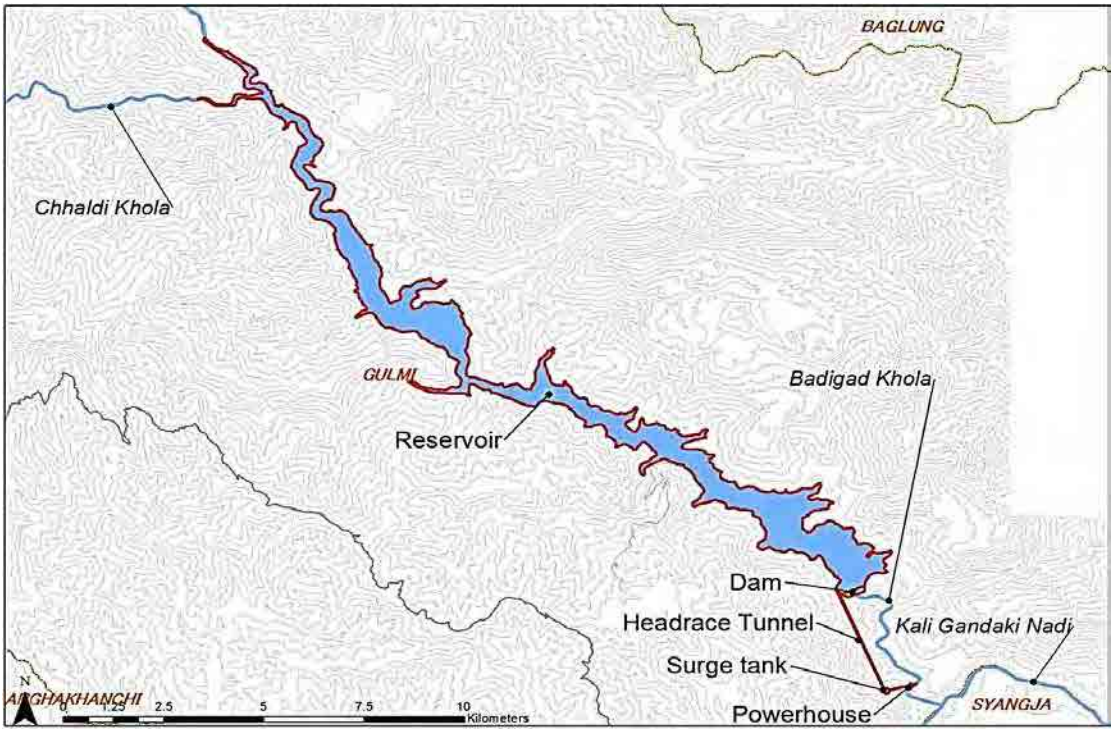


Figure A.2.4-2 General Layout of the Lower Badigad Project (C-02)

Table A.2.4-1 Project Description

Item	Unit	Lower Badigad	Remarks
Location	(District)	Gulmi	
Name of the River	(River)	Badigad	
Installed Capacity	MW	380.3	
Catchment Area	km^2	2,050	
Location of Dam Site	Longitude/ Latitude	83° 27' 22.2" 28° 0' 0.6"	
Dam Height	m	191.0	
Total Storage Volume	MCM	995.9	
Effective Storage Volume	MCM	505.5	
Regulating Capability Factor	%	19.1	
Reservoir Area at FSL	km^2	13.7	
Full Supply Level	m	688.0	
Minimum Operation Level	m	654.0	
Tail Water Level	m	475.0	
Rated Gross Head	m	196.0	
Rated Net Head	m	192.5	
Rated Power Discharge	m^3/s	232.6	
Total Energy	GWh	1,366.6	Estimated by the Study Team.
Dry Energy (December-April)	GWh	354.7	Estimated by the Study Team.
Length of Access Road	km	0	
Length of Transmission Line	km	49.0	Estimated by the Study Team.
Number of Households	nos	1,606	Surveyed by the Study Team in 2012.
Project Cost	MUS$	1,209.8	Estimated by the Study Team at 2013 price level.
Unit Generation Cost	cent/kWh	8.9	Estimated by the Study Team.
EIRR (8% of Interest Rate, 12NRs/kWh)	%	13.2	Estimated by the Study Team.
FIRR (8% of Interest Rate, 12NRs/kWh)	%	19.8	Estimated by the Study Team.

Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA (except remarked items)

In addition, the summary of natural and social environmental investigation result and its evaluation are shown below. The detailed information is summarized in Appendix 3 and 5.

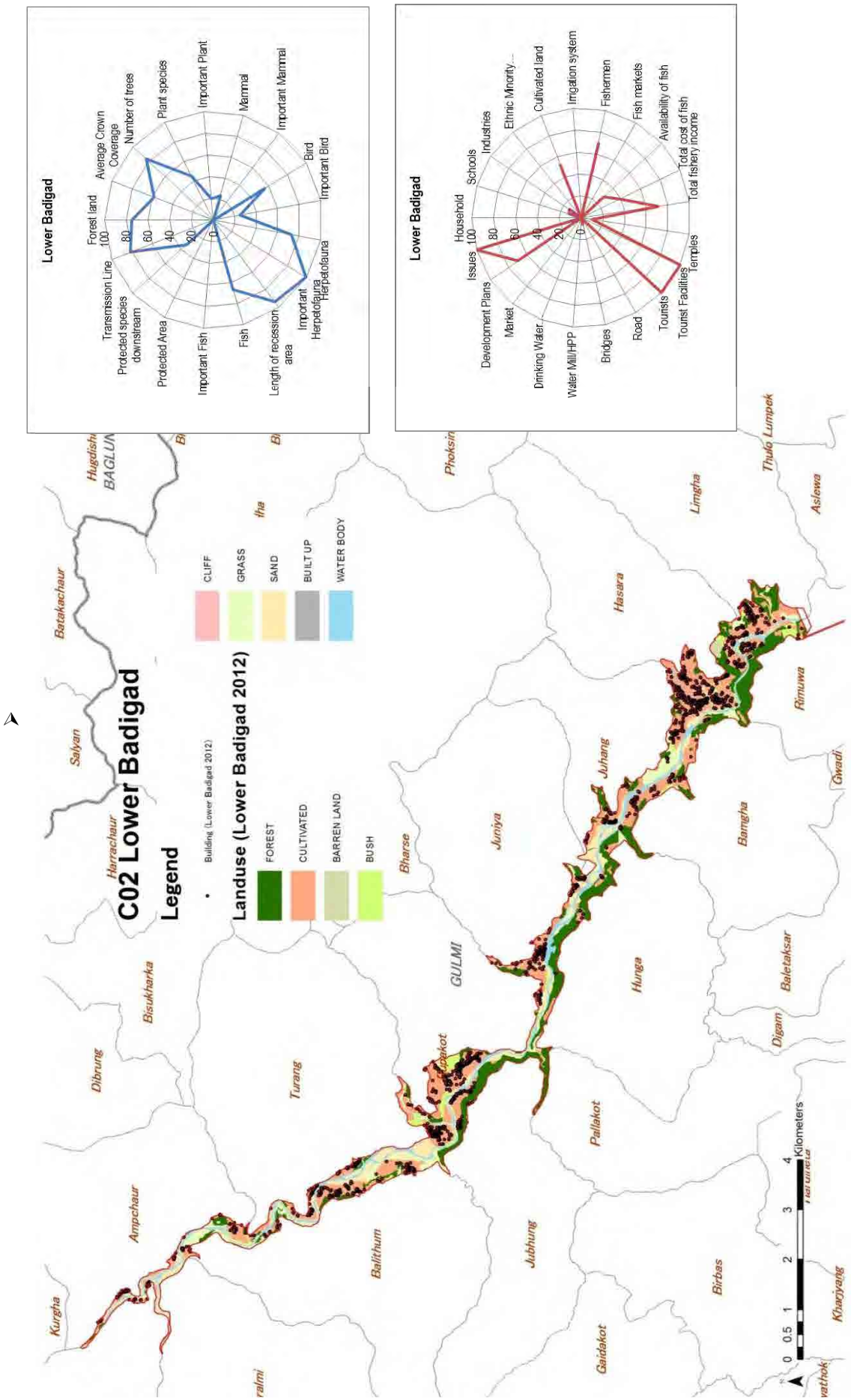


Figure A.2.4-3 Land Use and Buildings in the Reservoir Area of the Lower Badigad Project

(2) Meteorology & Hydrology

With regard to the Lower Badigad project, the meteorological characteristics and the criteria for hydrological evaluation, namely reliability of flow data, risk of a GLOF and sediment impact are mentioned below.

1) Meteorology

The Lower Badigad project site is located at the Badigad river. The district where the project site is located at is Gulmi.

The Tamghas climatology station (0725) is located in the Gulmi district. Table A.2.4-2 shows the monthly rainfall at the Tamghas station.

Table A.2.4-2 Monthly Rainfall at the Tamghas Station

Name	Index	District	Type of Station	Start to Record	Location		Elevation
					Latitude	Longitude	(m)
TAMGHAS	0725	Gulmi	CLIMATOLOGY	Jan, 80	28.07	83.25	1,530

Precipitation (mm)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
25.9	34.2	31.3	55.5	139.5	316.0	496.7	428.6	272.9	49.4	11.4	17.3	1,878.8

Source: Department of Hydrology and Meteorology: DHM

2) Reliability of flow data

As there is no gauging station near the Lower Badigad project site, the flow of the project is calculated by the Regional Analysis. The reliability of flow data of the Lower Badigad project is relatively low.

Table A.2.4-3 shows the monthly flow data used for energy calculation.

Table A.2.4-3 Flow data of the Lower Badigad Project

(m^3/s)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
21.19	18.26	17.54	20.28	31.80	85.05	216.73	261.64	184.14	82.14	39.70	26.26	83.73

3) Risk of GLOF

There is no potentially critical glacier lake in term of GLOF upstream of the Lower Badigad project site.

4) Sedimentation

As there is no sediment data of the Lower Badigad project site, the sediment data of the Andhi Khola project which is located near the Lower Badigad project site. The specific sediment yield

of Andhi Khola was estimated to be 2,526 m^3/km^2/year based on the measured data in the FS report. By using this yield, the life of the reservoir is estimated. The life of reservoir is an index to evaluate the sediment impact to reservoir and calculated dividing total storage volume by mean annual sediment yield.

Table A.2.4-4 shows the calculation result of the life of reservoir. The life of reservoir of the Lower Badigad project is estimated to be 192 years.

Table A.2.4-4 Life of Reservoir

a) Specific Sediment Yield	2,526 $m^3/km^2/yr$
b) Sediment Yield (Catchment Area × Specific Sediment Yield)	5.2×10^6 m^3/yr (2,050 km^2 × 2,526 $m^3/km^2/yr$)
c) Total Storage Volume	995.9×10^6 m^3
d) Life time of Storage (Total Storage Volume / Sediment Yield)	192 years (995.9×10^6 m^3 / 5.2×10^6 m^3/yr)

(3) Geology

1) Site Geology

The Lower Badigad project area belongs to the Gulmi district, west in Nepal. The dam site is located in the valley of the Badigad river about 3 km upstream of the confluence of the Kaligandaki river. The powerhouse site is located on the right bank of the Badigad river about 300 m upstream of the confluence. According to the field geological survey, geology and engineering geology of the project area are as follows.

The geological map of the project area is shown in Figure A.2.4-2. The project area lies in the Lesser Himalayan Zone, and is underlain by Benighat Slate mainly composed of slate and Dhading Dolomite composed of limestone and dolomite. Dhading Dolomite covering Benighat Slate is distributed on the upper part of slopes.

The reservoir and its surrounding areas are mainly underlain by Benighat Slate. The lower part of Benighat Slate is composed mainly of calcareous quartzite and quartzitic limestone intercalated with slate. The upper part of Benighat Slate is composed of slate intercalated with thin calcareous slate. Benighat Slate is impervious. Dhading Dolomite is composed of limestone and dolomite and would be permeable. But it is distributed on the limited area of the reservoir area. The Badigad Fault, supposed to be an active fault, extends along the reservoir area. The engineering geological map of the reservoir and its surrounding area is shown in Figure A.2.4-3. A major active landslide called Gultung Pahiro is distributed on the left bank of midstream portion of the reservoir area and is providing a large volume of sediments.

Bedrock of the dam site is composed of quartzite and slate of Benighat Slate and medium hard and impervious. Bedding planes, which strikes are perpendicular to the dam axis, incline toward right bank at angles of about 40 degrees. The depth of river deposits is assumed to be more than 30 m. The Badigad Fault, supposed to be an active fault, crosses the dam site.

The headrace tunnel route passes on the right bank of the Badigad river, where is composed mainly of slate, calcareous quartzite, and quartzitic limestone of Benighat Slate. Bedding

planes, which strikes are oblique to tunnel direction and incline toward surge tank. Overburden of this tunnel is up to 200 m.

The powerhouse site is located on an alluvial terrace on the right bank of the Badigad river. This site is composed of slate with quartzite of Benighat Slate. Beds at this site incline toward mountain. The depth of river deposits is assumed to be more than 50 m.

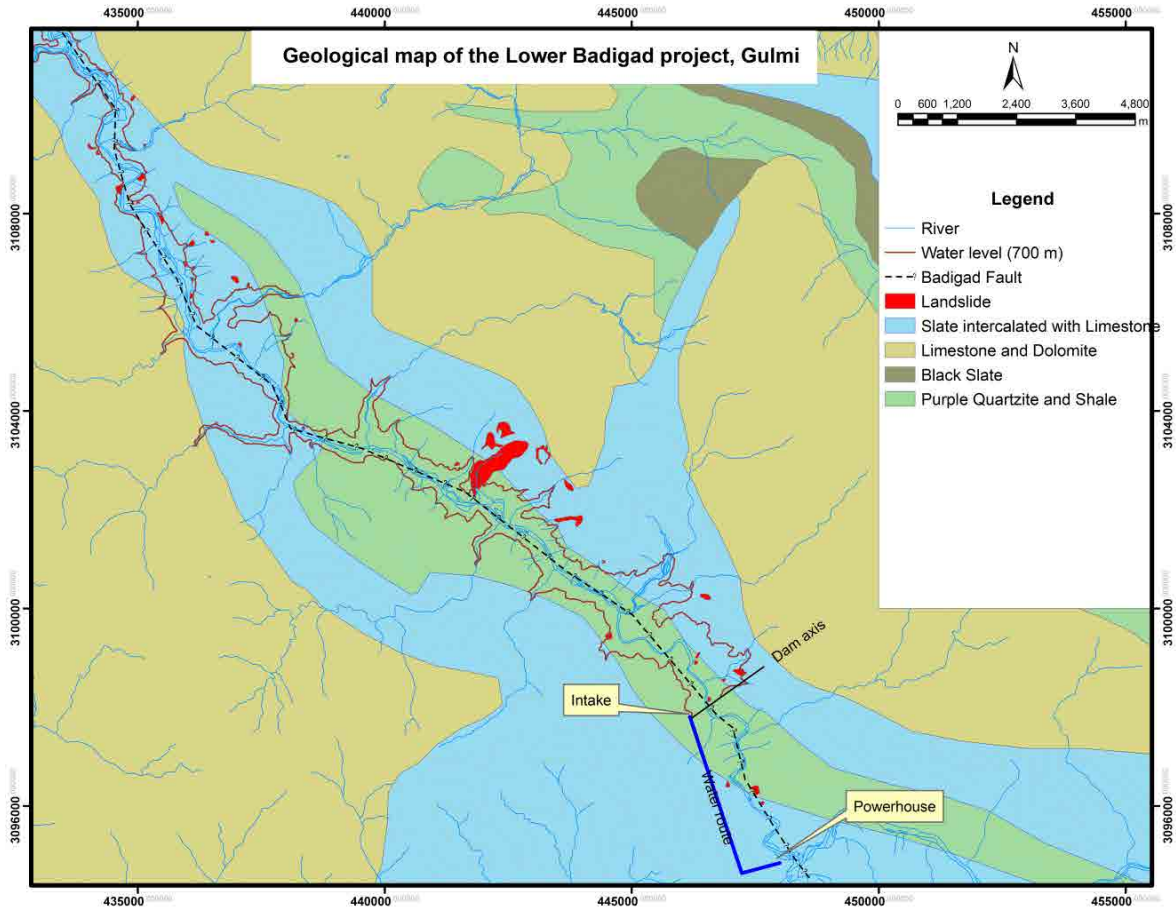
Enough volume of sand and gravel suitable for concrete aggregates are distributed near the confluence of the Kaligandaki river about 3 km downstream of the dam site. For coarse concrete aggregate, quartzite distributed in the vicinity of the dam site is available. This quartzite may be suitable for rock materials. Colluvium and residual soil distributed in the area underlain by slate would be investigated for borrow areas of soil materials.

2) Thrust and Fault

Among large tectonic thrust, MBT is located to the south of the dam site at a distance of 25 km. The Badigad Fault, supposed to be an active fault, extends to the dam site..

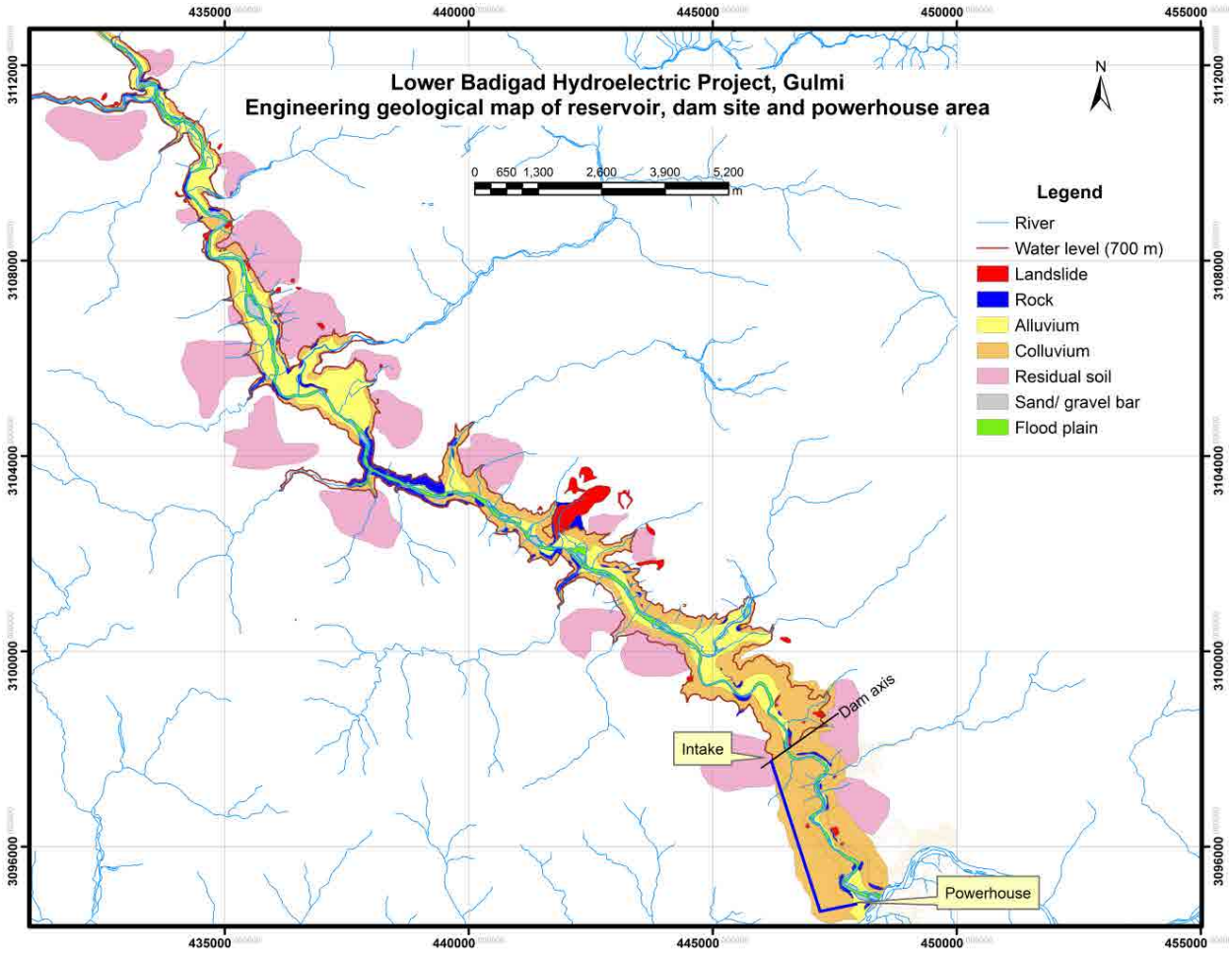
3) Seismicity

The Project area is located in Lesser Himalaya. The horizontal ground acceleration of this area is 170mgal according to the Seismic Hazard Map of Nepal. The nearest epicenter of M≧4 to the dam site is located to the north at a distance of about 30 km.



Source: NESS Field Survey, 2012

Figure A.2.4-4 Geological map of the project area



Source: NESS Field Survey, 2012

Figure A.2.4-5 Engineering geological map of the reservoir and its surrounding region

(4) Development Plan

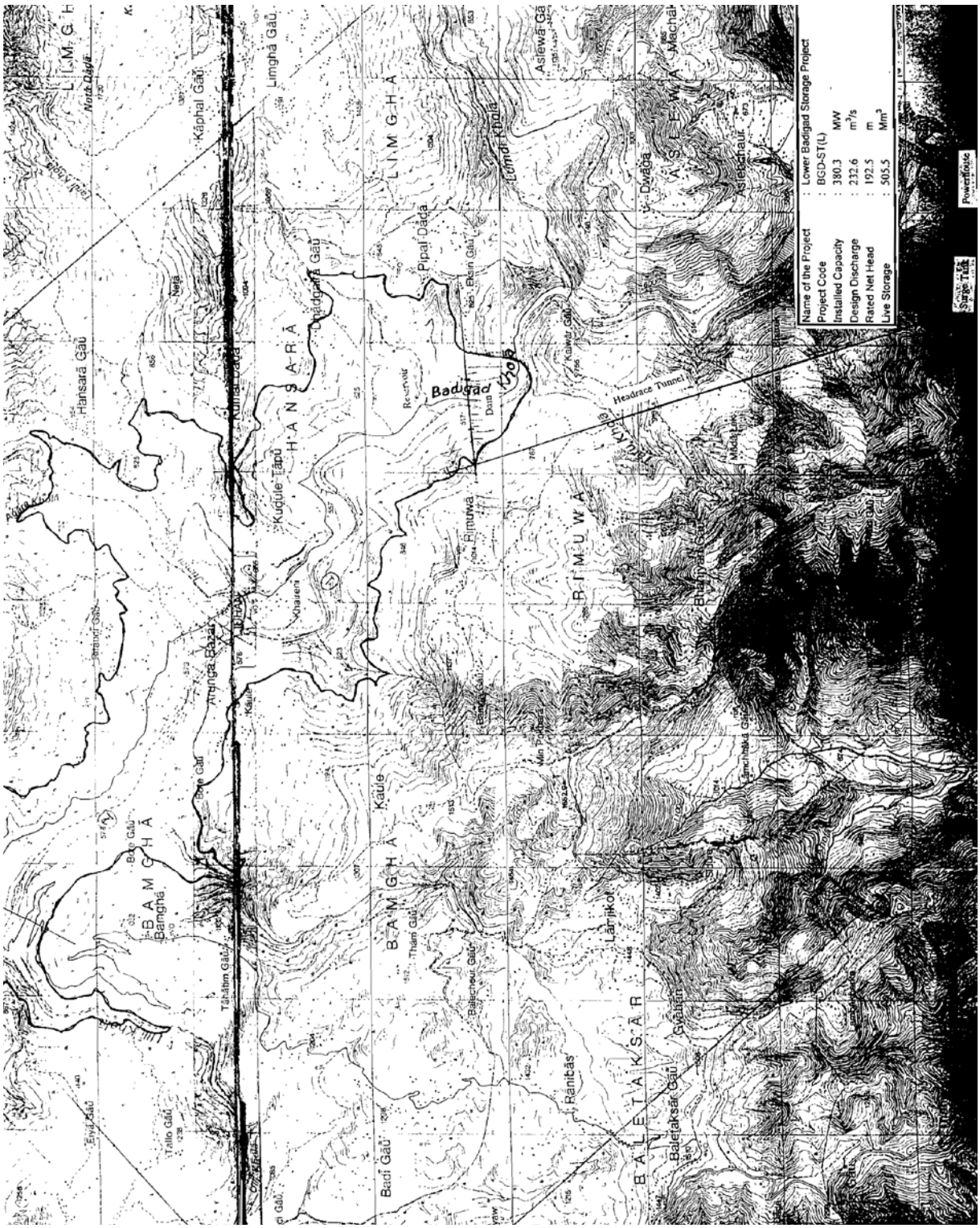
The Lower Badigad Project is a dam and waterway-type hydropower project. Since the study level stays at desk study level, the basic design drawings are not available.

The salient features of principal layout and basic layout drawing of the project are as follows:

Table A.2.4-5 Salient Features

Item	Unit	Lower Badigad	Remarks
Reservoir			
Reservoir Area at FSL	km^2	13.7	
Total Storage Capacity	MCM	995.9	
Effective Storage Capacity	MCM	505.5	
Full Supply Level (FSL)	m	688.0	
Minimum Operating Level (MOL)	m	654.0	
Dam			
Type of Dam	-	Rockfill	
Dam Volume	MCM	16.9	
Total Dam Height	m	191	
River Bed Level at Dam Axis	m	517	
Spillway Type	-	Gated Spillway	
Waterway & Powerhouse			
Intake Type	-	Normal Pressure Intake	
Concrete Lined Headrace Tunnel Length	m	4,400	
Circular Tunnel Diameter	m	10	
Penstock Length	m	400	
Type of Powerhouse	-	Surface	
Turbine Type	-	Vertical Francis	
Installed Capacity	MW	380.3	
Design Discharge	m^3/s	232.6	
Rated Net Head	m	192.5	
Tail Water Level	m	475	
Tailrace Length	m	50	

Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA



Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA

Figure A.2.4-6 General Layout

Further, the findings attained by the Study Team through the site reconnaissance conducted in June, 2012 in terms of dam site and powerhouse site are summarized below.

Dam Site

The dam site proposed in the "Update and Review of Identification and Feasibility Study of Storage Project (2002)" is located at approximately 4 km upstream of the confluence of the Kari Gandaki river and the Badigad river. The coordinate at dam axis is approximately 28º00'03"N, 83º27'14"E and river bed elevation is 517 m. The left bank abutment is a ridge of which thickness is approximately 300 m at FSL 688 m and area higher than 630 m is a farm land. The inclination of lower part seems steep, about 30 degree and upper part seems rather gentle according to the topographical map. At the right bank, some outcrop was confirmed at the water's edge and there are two steps of terraces being farm land above that. The inclination of the upper part seems 20–25 degree and rather gentle compared with the left bank. There is an unpaved road on the left bank, the height from the river bed to the road is approximately 15 m at the dam axis.

There is a large-scale land slide area due to the Badigad fault at the upstream of a creek located at the 6 km upstream left bank from the dam site. A large amount of sediment produced from the land slide area is flowing into the Badigad river. Therefore, it will be a key point for the project how to settle this sediment issue.

On the other hand, the Upper Badigad Storage project is planned at immediately upstream of the Lower Badigad project. The dam site of Upper Badigad project is located at 14 km upstream of the creek, 20 km upstream of the Lower Badigad dam site. In order to avoid above-mentioned sediment problem, it would be an alternative scheme to combine these two projects by moving Lower Badigad dam site from the original location to somewhere between the confluence of the creek and the Upper Badigad dam site and gain some head by constructing a certain length of headrace tunnel. In this case, it would be preferable for the powerhouse to be located at upstream of the creek so that the headrace tunnel will not cross the fault.

Powerhouse Site

The powerhouse site proposed in the "Update and Review of Identification and Feasibility Study of Storage Project (2002)" is located at the right bank of the Badigad river, approximately 1 km upstream of the confluence of the Kari Gandaki river and the Badigad river. An alternative powerhouse site at opposite side of the river (left bank) is studied by the NEA. In case that the powerhouse is laid out at the left bank, 300–350 m upstream of the studied site, just upstream of the river's curving to the right will be more preferable considering the layout of the waterway route though the excavation volume for powerhouse will slightly be larger. The coordinate of the site is approximately 27º58'53"N, 83º07'57"E and river bed elevation is 500 m. The elevation of the existing road is approximately EL.535 m, which enables an easy access. However, a bypass road will be required for the Ridi town if equipment and materials for construction are transported through the Ridi town. Further, as the length of waterway from the dam site to this powerhouse site will exceed 10 km in case that the Lower Badigad dam site is moved to upstream of the creek, to construct powerhouse at this site would be unrealistic.

(5) Electrical/Mechanical Equipment and Transmission Line

1) General

Rated effective head, power discharge and installed capacity of the Lower Badigad Project are as follows;

Rated Effective Head	: 192.50 m
Rated Power Discharge	: 232.60 m^3/s
Installed Capacity	: 380 MW

The HD Wiz (developed by J-POWER, based on existing hydropower plant data around world) has been used for reviewing design of electrical/mechanical equipment taking above information into consideration. Turbine efficiency and generator efficiency have been improved in recent years and installed capacity exceeded above-mentioned 380 MW consequently.

2) Unit Capacity and Number of Unit

Generally, for the turbine-generator, a large unit capacity is said to be more economical merits of scale. However, optimum unit capacity of the turbine-generator is determined in consideration of influence to the power system, development timing and transportation restriction.

In this project, all electrical and mechanical equipment will be transporting from foreign countries via Indian national road and un-maintained Nepalese national road to the project site. Therefore maximum unit capacity shall be set as around 100 MW and number of 4 units plan has been adopted for the project.

3) Turbine

a) Turbine Output

Rated turbine output at rated effective head of 192.50 m and rated power discharge of 58.15 m^3/s per unit can be calculated as follow;

$$Pt = 9.8 \times Hn \times Qt \times \eta t$$
$$= 9.8 \times 192.50 \times 58.15 \times 0.929$$
$$\approx 101{,}900 \text{ kW}$$

where

Pt : Rated turbine output per unit (kW)
Hn : Rated effective head (m)
Qt : Rated power discharge per unit (m^3/s)
ηt : Turbine efficiency

b) Type of Turbine

Generally, type of turbine can be determined by close relation between effective head and turbine output. Vertical shaft Francis type turbine can be selected taking rated effective head and turbine output into consideration.

c) Runner Material

Stainless steel anti-corrosion type such as 13 chrome high nickels stainless steel is recommended to be applied for the runner material. Surface of runner and wear ring shall be coated (hard or soft) in case of water quality. Detailed coating method shall be specified in the detailed design stage.

d) Installed Capacity

Installed capacity can be calculated from aforementioned turbine output per unit as follow;

101,900 kW × 4 = 407,600 kW

Review of energy calculation is conducted by using above installed capacity.

4) Generator

A three phase alternating current synchronous generator with vertical shaft rated capacity of 110,700 kVA and power factor of 90% lag are selected.

a) Generator Capacity

Rated generator capacity can be calculated from rated turbine output, power factor and generator efficiency as follows;

$$Pg = Pt \times \eta g / p.f \ (kVA)$$
$$= 101,900 \times 0.978 / 0.90$$
$$\approx 110,700 \ kVA$$

where

Pg : Rated generator capacity (kVA)
Pt : Rated turbine output (kW)
ηg : Generator efficiency
p.f : Power factor, lag

As the results of above calculation, rated generator capacity is 110,700 kVA.

5) Transmission Line

Regarding designing of the transmission line, transmission line shall be connected to the closest substation based on 400 kV Transmission Line Power Development Plan by the NEA. And also thermal capacity and maximum surface potential gradient have been taken into consideration for designing of the transmission line and following specifications have been adopted. As for the transmission line length, the direct length from project area to closest substation was measured from map. Therefore, some allowance has been taken into consideration.

Connected Substation	: Butwal Substation
Transmission Line Voltage	: 220 kV
Length of Transmission Line	: 49 km
Conductor Type	: Bison × 2, 2 circuits

2.5 Andhi Khola Project (C-08)

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A.2.5 Andhi Khola (C-08)

(1) Project Summary

The Andhi Khola Project is a 180 MW storage-type hydroelectric power project located in the Syangja District in the central region. The intake is located at the Andhi Khola river and the outlet is located at the Kali Gandaki river. The latest study for this project was conducted in the "Feasibility Study on the Andhi Khola Hydroelectric Project, 2002, NEA." The study level for this project attains the Feasibility Study level.

Further, the Study Team conducted a site reconnaissance at Andhi Khola project site in June 2012. The findings attained through site reconnaissance are also summarized in this clause.

As hydrological characteristics, the annual rainfall at the Chapkot gauging station nearest to the project site is 1,837 mm and the average river discharge at the dam site is 30.1 m^3/s. The drainage area is 4,750 km^2, and the specific sediment volume is estimated to be 2,526 $t/km^2/year$. This is larger than 4,400 $t/km^2/year$, which is the value adopted by the NEA as average specific sedimentation volume in the central region. No glacier lakes having a high risk of a GLOF are identified in the drainage basin.

From a geological view point, the project area lies in the Lesser Himalaya Zone and is composed mainly of slate. The reservoir area is mainly underlain by slate. This area is water tight, but many landslides are distributed on the slopes in its surrounding area. The dam site is underlain by slate, but it is not favorable for a dam site because its left bank is covered with thick deposits. The headrace tunnel route passes through slate, which forms fragile rock. The power house site is underlain by fragile slate. It is covered with thick river deposits. The project area is located in an area where a medium acceleration of 200 mgal is shown on the seismic hazard map. It is away from a large tectonic thrust (MBT) at a long distance of 25 km and from epicenters larger than M4 at a long distance of 40 km.

Both the impact on the Natural Environment and the Social Environment is average. Andhi Khola is located in the Gandaki River Basin and the reservoir area is 5.5 km^2. The affected forest area is only 1.51 km^2. The number of affected fauna is also low, with numbers such as 12 mammals, 16 birds, and 6 Herpetofauna. The dewatering area is 60 km, which is the longest together with Dudh Koshi. There are three protected areas downstream of the project site and five important species that depend on water are known. The length of the transmission line is 49 km, which is relatively short. The number of resettlement is 542, which is not high, but the resettlement per unit generation is relatively high at 3.01 HH/MW. The Indigenous groups in the reservoir area are the Newar (Advanced), Magar (Disadvantaged), and Gurung (Disadvantaged).

From the view point of hydropower planning, the location of proposed dam site for 157 m of a Concrete Faced Rockfill Dam (CFRD) has to be reviewed since the geological condition of the left bank of the dam site does not seem suitable as a foundation for a CFRD. The implementation of the Andhi Khola project will decrease inflow to the reservoir and energy production of the Kali Gandaki A project located downstream of the Andhi Khola project. On the other hand, rising of the intake dam is planned at the Kali Gandaki A Hydropower Plant. Therefore, implementation of the Andhi Khola project should be examined comprehensively in

consideration of the Kali Gandaki A Hydropower Project.

Further, the Andhi Khola Hydropower Plant (5.1 MW) is owned and operated by the Butwal Power Company, and the plant exists in the reservoir. A comparison study was conducted in FS. In the study, two cases were compared. One was for abolishment with full compensation and the other was to continue to operate with some renovation by implementation of the Andhi Khola Storage Project. As a result of the study, it was concluded that to operate with some renovation will be more economical. At the moment, the power plant is under renovation to expand the install capacity to 9 MW. The renovation work will be completed and commenced in 2013. Therefore, the handling of the renovated power plant in terms of compensation or reinforcement has to be reviewed.

The location, basic layout and salient features of the project are shown below.

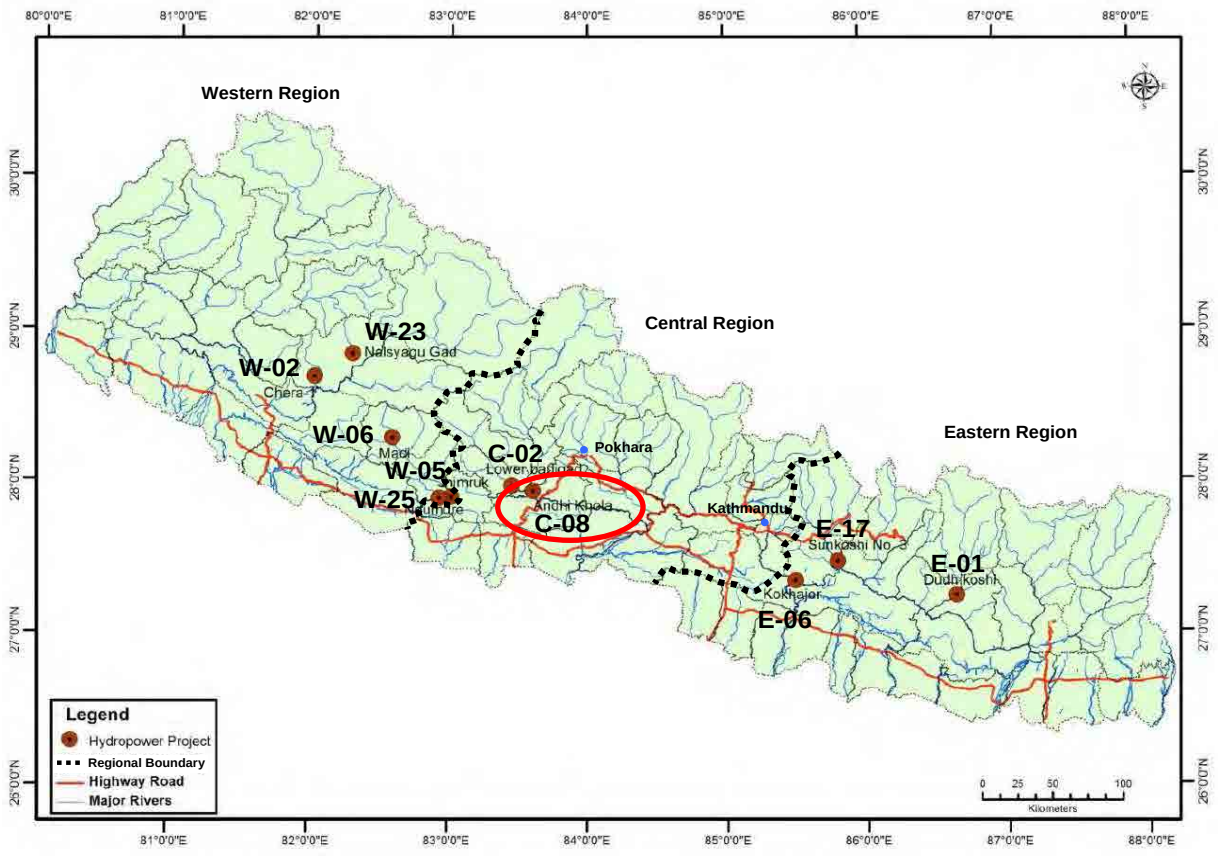


Figure A.2.5-1 Location of the Andhi Khola Project (C-08)

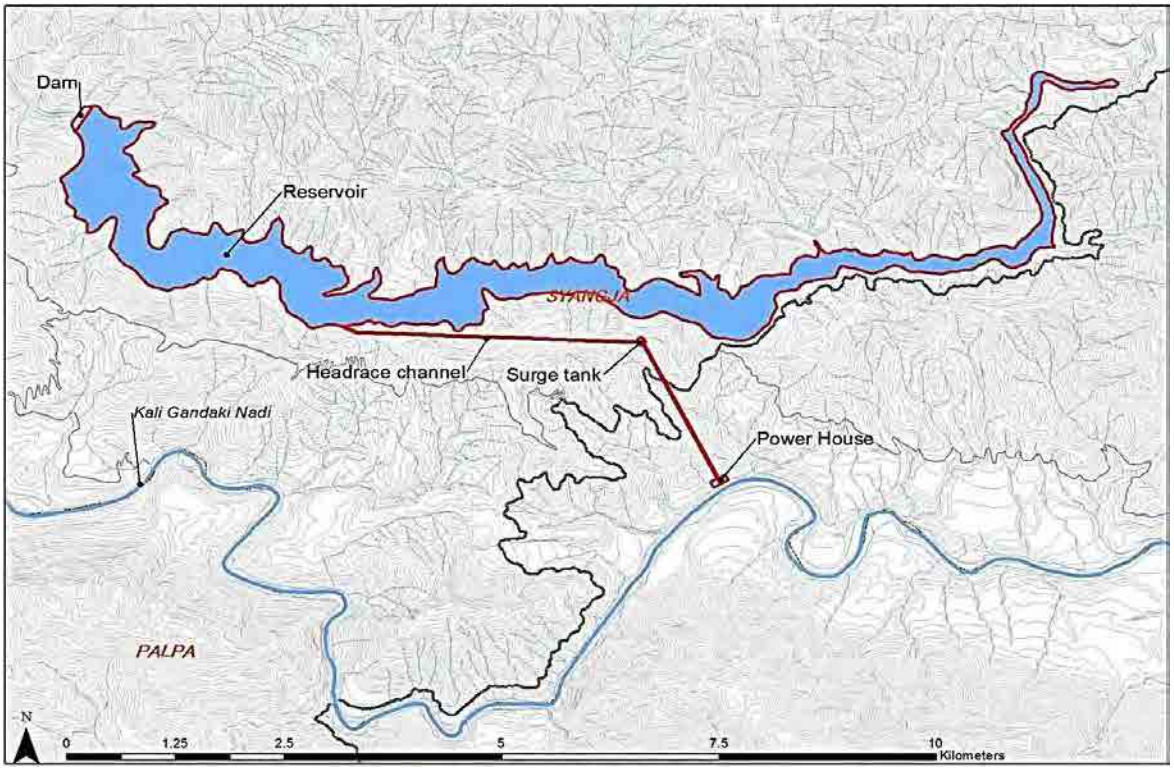


Figure A.2.5-2 General Layout of the Andhi Khola Project (C-08)

Table A.2.5-1 Project Description

Item	Unit	Andhi Khola	Remarks
Location	(District)	Syangja	
Name of the River	(River)	Andhi Khola to Kali Gandaki	
Installed Capacity	MW	180	
Catchment Area	km^2	475	
Location of Dam Site	Longitude/ Latitude	83° 36' 30.6" 27° 58' 2.6"	
Dam Height	m	157	
Total Storage Volume	MCM	336.5	
Effective Storage Volume	MCM	238.7	
Regulating Capability Factor	%	37.3	
Reservoir Area at FSL	km^2	5.5	
Full Supply Level	m	675.0	
Minimum Operation Level	m	626.7	
Tail Water Level	m	368.5	
Rated Gross Head	m	307.0	
Rated Net Head	m	286.3	
Rated Power Discharge	m^3/s	81.4	
Total Energy	GWh	648.7	Estimated by the Study Team.
Dry Energy (December-April)	GWh	137.1	Estimated by the Study Team.
Length of Access Road	km	8.0	
Length of Transmission Line	km	49.0	Estimated by the Study Team.
Number of Household	nos	542	Surveyed by the Study Team in 2012.
Project Cost	MUS$	665.8	Estimated by the Study Team at 2013 price level.
Unit Generation Cost	cent/kWh	10.3	Estimated by the Study Team
EIRR (8% of Interest Rate, 12NRs/kWh)	%	13.0	Estimated by the Study Team.
FIRR (8% of Interest Rate, 12NRs/kWh)	%	19.1	Estimated by the Study Team.

Source: Feasibility Study on Andhi Khola Hydroelectric Project, 1998, NEA (except remarked items)

In addition, the summary of natural and social environmental investigation result and its evaluation are shown below. The detailed information is summarized in Appendix 3 and 5.

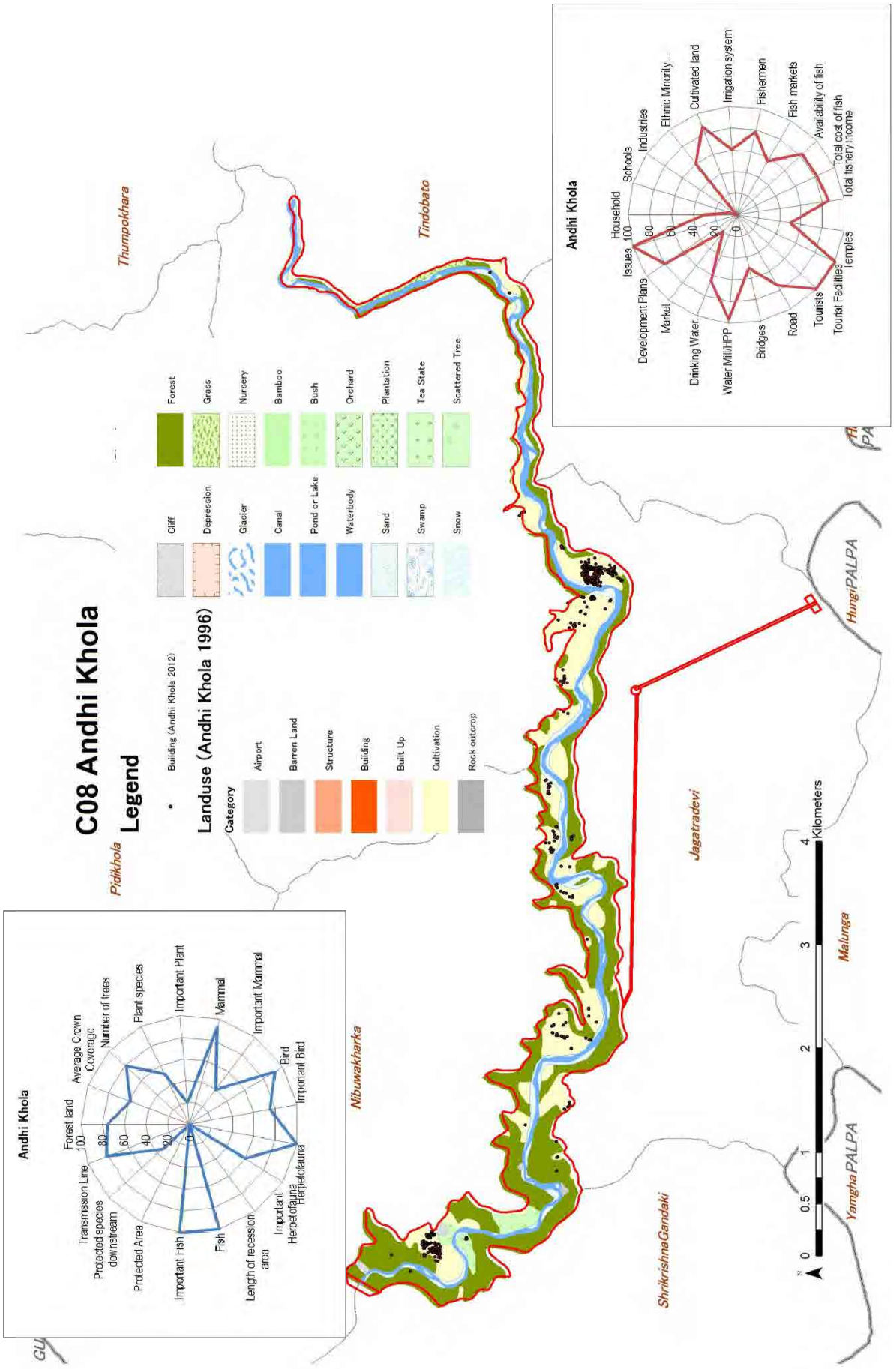


Figure A.2.5-3 Land Use and Buildings in the Reservoir Area of the Andhi Khola Project

(2) Meteorology & Hydrology

With regard to the Andhi Khola project, the meteorological characteristics and the criteria for hydrological evaluation, namely reliability of flow data, risk of a GLOF and sediment impact are mentioned below.

1) Meteorology

The Andhi Khola project site is located at the Andhi Khola river. The district where the project site is located at is Syangja.

The Chapkot climatology station (0810) is located in the Syangjya district. Table A.2.5-2 shows the monthly rainfall at the Chapkot station.

Table A.2.5-2 Monthly Rainfall at the Chapkot Station

Name	Index	District	Type of Station	Start to Record	Location		Elevation
					Latitude	Longitude	(m)
CHAPKOT	0810	Syangja	CLIMATOLOGY	Jan, 57	27.88	83.82	460

Precipitation (mm)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
23.2	24.4	33.8	57.3	140.7	332.7	520.3	377.7	236.7	68.1	7.2	14.7	1,836.8

Source: Department of Hydrology and Meteorology: DHM

2) Reliability of flow data

As the gauging station (415) is located at 1.5 km upstream of the dam axis, multiplying the flow data of the gauging station by the rate of catchment area of the dam site to one of gauging station gives the flow data of the Andhi Khola project. The reliability of flow data of the Andhi Khola project is relatively high.

Table A.2.5-3 shows the monthly flow data used for energy calculation. The latest 10 years flow data do not exist. The period of the existing data is from 1964 to 1991. Therefore, the average monthly flow data measured from 1964 to 1991 is adopted for energy calculation.

Table A.2.5-3 Flow Data of the Andi Khola Project

(m^3/s)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
4.74	3.85	3.17	2.96	6.31	33.33	99.79	94.10	67.16	26.74	9.87	6.14	29.85

3) Risk of GLOF

There is no potentially critical glacier lake which may cause a GLOF in the upstream area of the Andhi Khola project site.

4) Sedimentation

The specific sediment yield of Andhi Khola was estimated to be 2,526 m^3/km^2/year based on the measured data in the FS report. By using this yield, the life of the reservoir is estimated. The life of reservoir is an index to evaluate the sediment impact to reservoir and calculated dividing total storage volume by mean annual sediment yield.

Table A.2.5-4 shows the calculation result of the life of reservoir. The life of reservoir of the project is estimated to be 280 years.

Table A.2.5-4 Life of Reservoir

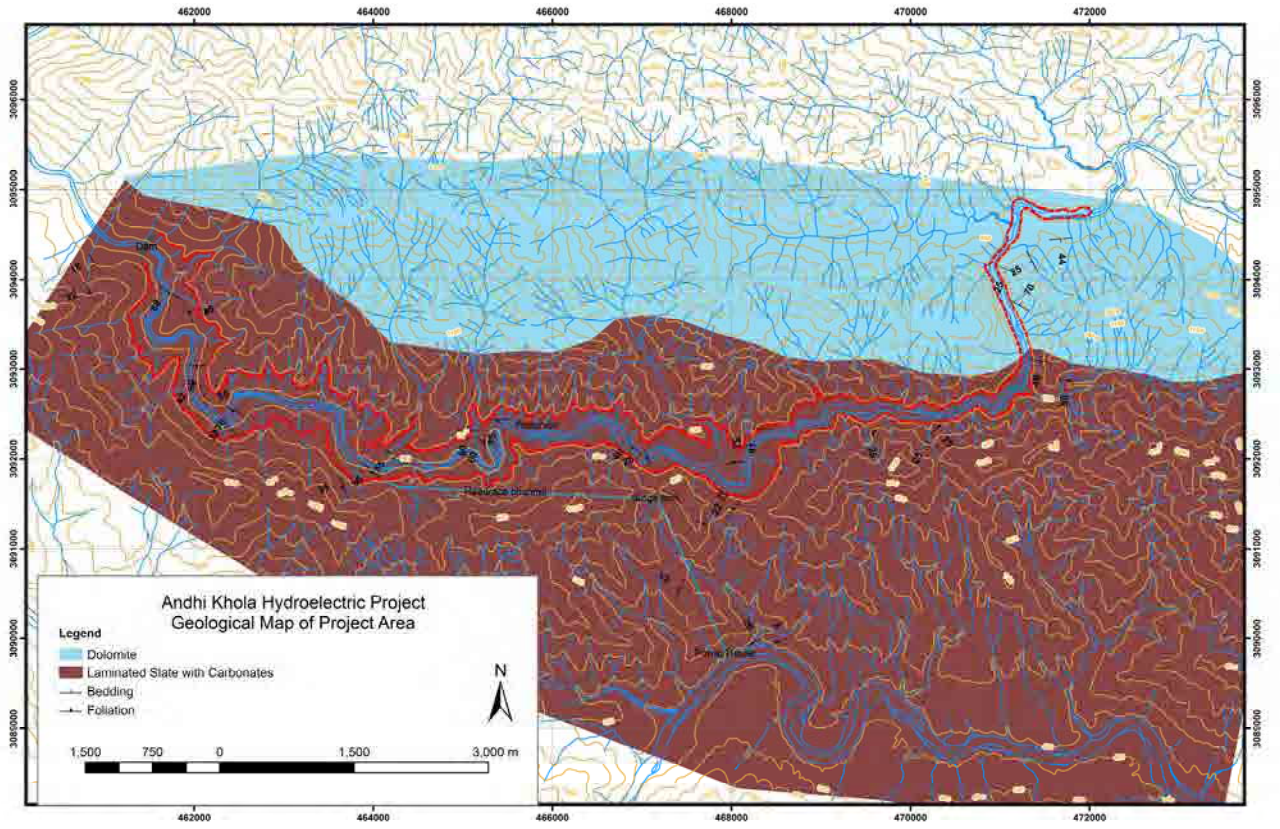
a) Specific Sediment Yield	2,526 m^3/km^2/yr
b) Sediment Yield (Catchment Area × Specific Sediment Yield)	1.2×10^6 m^3/yr (475 km^2 × 2,526 m^3/km^2/yr)
c) Total Storage Volume	336.5×10^6 m^3
d) Life time of Storage (Total Storage Volume / Sediment Yield)	280 years (336.5×10^6 m^3 / 1.2×10^6 m^3/yr)

(3) Geology

1) Site Geology

The Andhi Khola project area belongs to the Syahla district, west in Nepal. The dam site is located in the valley of the Andhi Khola river about 1.6 km upstream of the confluence of the Kaligandaki river. The powerhouse site is located on the left bank of the Kaligandaki river. According to the field geological survey and the FS report (1998), geology and engineering geology of the project area are as follows.

The regional geological map of the project area is shown in Figure A.2.5-2. The project area lies in the Lesser Himalayan Zone, and is underlain by Benighat Slate and Dhading Dolomite. Benighat Slate is mainly composed of slate with thin carbonate rock beds. Dhading Dolomite is composed of thick bedded dolomite. The FS report shows the Keware Fault along the contact of Benighat Slate and Dhading Dolomite and the Andhi Khola Fault about 1 km south of and parallel to the Keware Fault.



Source: NESS Field Survey, 2012

Figure A.2.5-4 Regional geological map of the project area.

The reservoir and its surrounding area are mainly underlain by Benighat Slate. Upstream most portion of the reservoir area is underlain by Dhading Dolomite. Benighat Slate composed of fragile slate. Dhading Dolomite is composed of very thick bedded dolomite. Dhading Dolomite may pervious, but it may not threaten the water tightness of the reservoir area because the possible leakage pass to outside of the reservoir area through this dolomite is very long. The Keware Fault and the Andhi Khola Fault cross the reservoir area.

The engineering geological map of the reservoir and its surrounding area is shown in Figure A.2.5-3. These areas are widely covered with colluviums and residual soil. Many landslides are observed in those areas.

The dam site is underlain by slate of Benighat Slate, which is medium hard and impermeable. Foliations incline toward downstream and right bank at angles of about 30 degrees. The depth of river deposits is confirmed to be 2.7 m by a boring. The full supply level of the reservoir is 675 m. But left bank above elevation 606 m is composed of terrace deposits. After FS, 1km upstream and 1.5 km upstream of the FS dam site were studied. The former is not suitable because an active large landslide on the left bank. The latter is also not favorable because of the sheared bed rock.

The headrace tunnel route obliquely passes the ridge between the Andhi Khola river and the Kaligandaki river. This route is underlain by fragile slate of Benighat Slate. Strike and dip of

foliations in different places are different. The overburden of this tunnel is up to 350 m.

The powerhouse site is located on an alluvial terrace on the left bank of the Kaligandaki river. This site is composed of Benighat Slate. The depth of river deposits was confirmed to be 45 m by a boring.

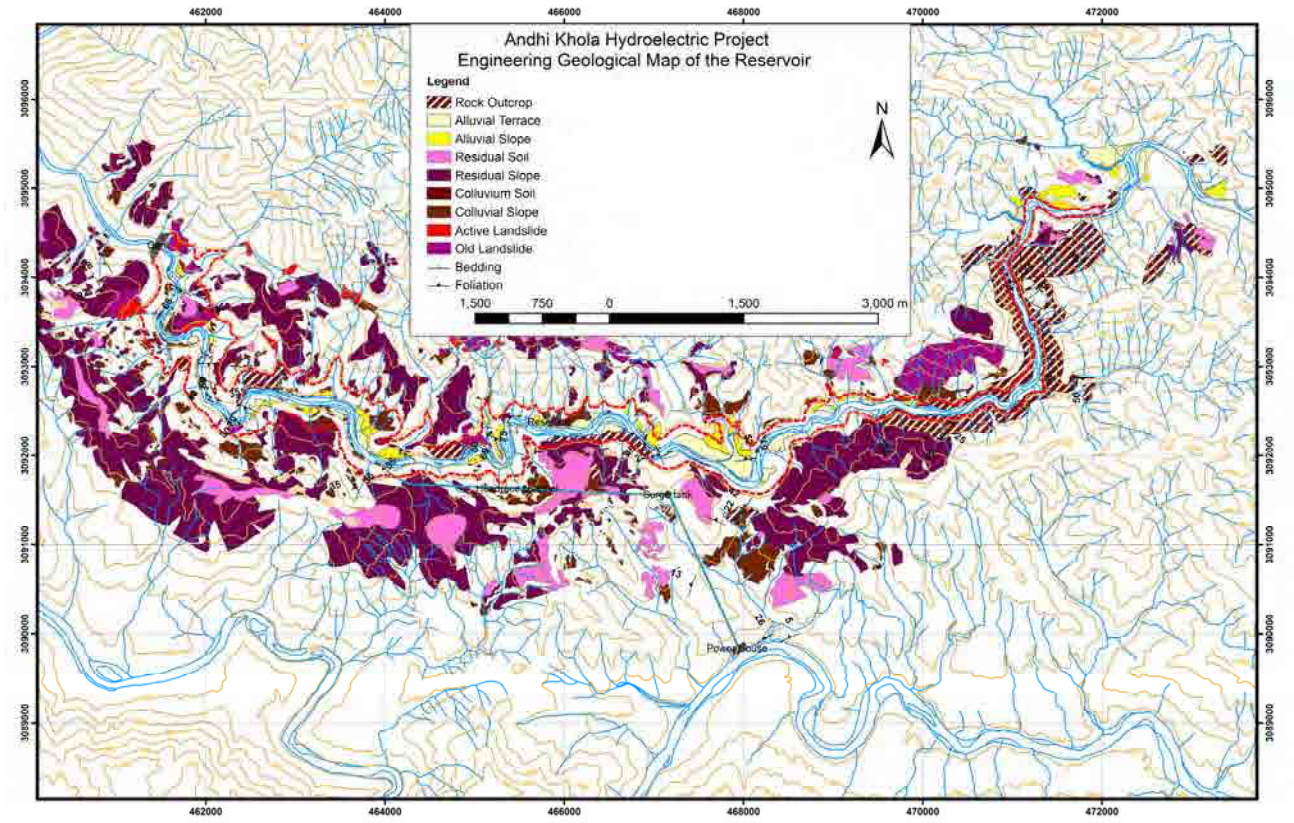
Gravels distributed on the river bed about 500 m upstream of the dam site are suitable for coarse aggregate. Fine aggregate will be obtained from the alluvial terrace near Sera and Illunga. Colluvium and residual soil distributed in the area underlain by slate are available for soil materials. Dolomites distributed near the dam site and along the Kaligandaki river are suitable for rock materials.

2) Thrust and Fault

Among large tectonic thrust, MBT is located to the south of the dam site at a distance of 25 km. The Andhi Khola fault may be distributed at a distance less than 1 km from the dam site.

3) Seismicity

The Project area is located in Lesser Himalaya. The horizontal ground acceleration of this area is 200 mgal according to the Seismic Hazard Map of Nepal. The nearest epicenter of M≧4 to the dam site is located to the northeast at a distance of about 40 km.



Source: NESS Field Survey, 2012

Figure A.2.5-5 Engineering geological map of the reservoir and its surrounding area.

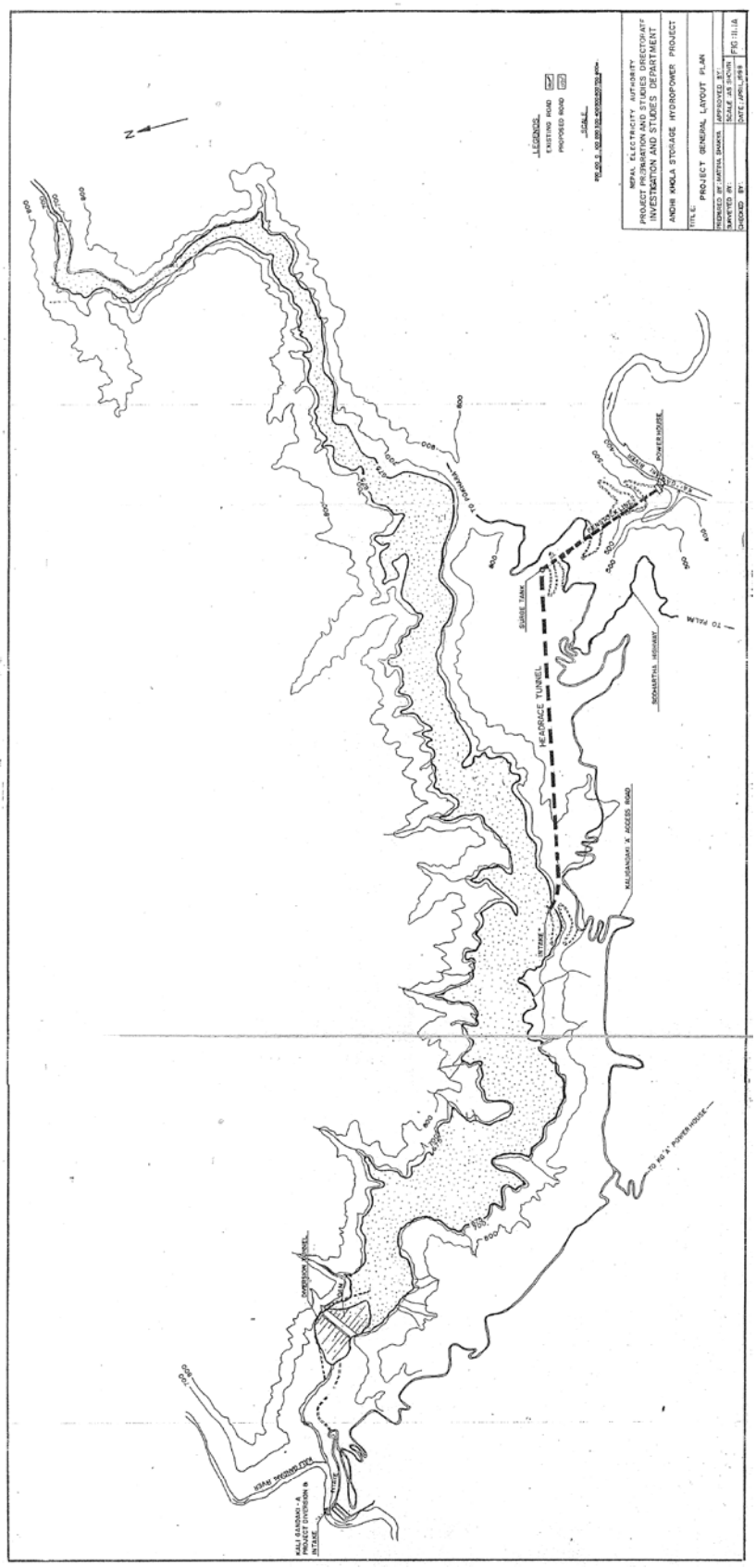
(4) Development Plan

The Andhi Khola Project is a dam and waterway-type hydropower project. Since the study level attains feasibility study level, a set of the basic design drawings are available. The salient features of principal layout and basic layout drawings of the project are as follows:

Table A.2.5-5 Salient Features

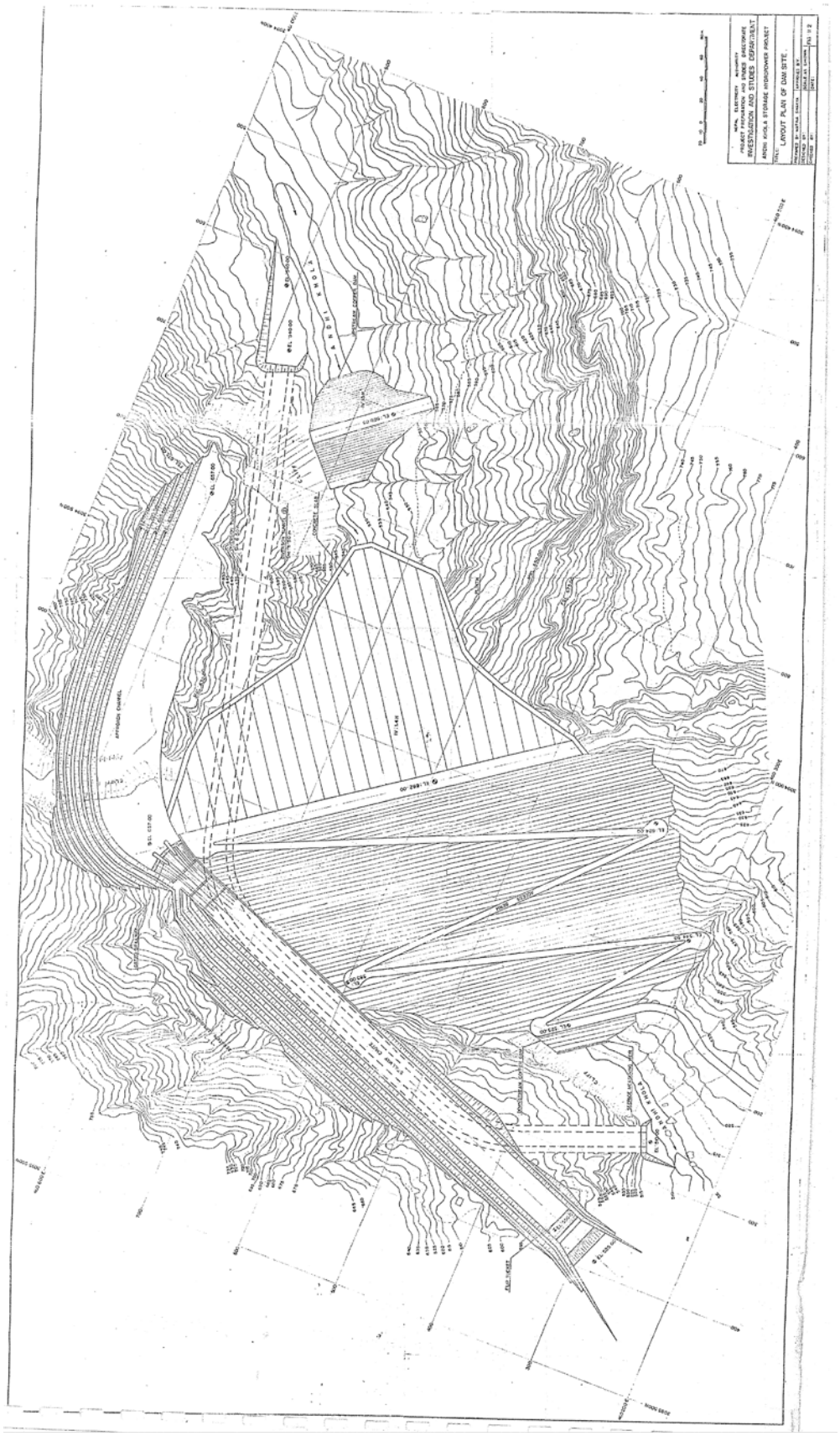
Item	Unit	Andhi Khola	Remarks
Reservoir			
Reservoir Area at FSL	km^2	5.5	
Total Storage Capacity	MCM	336.5	
Effective Storage Capacity	MCM	238.7	
Full Suply Level (FSL)	m	675.0	
Minimum Operating Level (MOL)	m	626.7	
Dam			
Type of Dam	-	CFRD	(Concrete Faced Rockfill Dam)
Dam Volume	MCM	8.2	
Total Dam Height	m	157	
River Bed Level at Dam Axis	m	525	
Spillway Type	-	Gated Spillway	(3 Radial Gate)
Waterway & Powerhouse			
Intake Type	-	Sloping Intake	
Concrete Lined Headrace Tunnel Length	m	3,395	
Tunnel Diameter	m	6.5	
Penstock Length	m	1,350	D = 4.8m
Type of Powerhouse	-	Surface	(Semi-underground)
Turbine Type	-	Vertical Francis	
Installed Capacity	MW	180	(3 x 60 MW)
Design Discharge	m^3/s	81.4	
Rated Net Head	m	286.3	
Tail Water Level	m	368.48	
Tailrace Length	m	85	

Source: Feasibility Study on Andhi Khola Hydroelectric Project, 1998, NEA



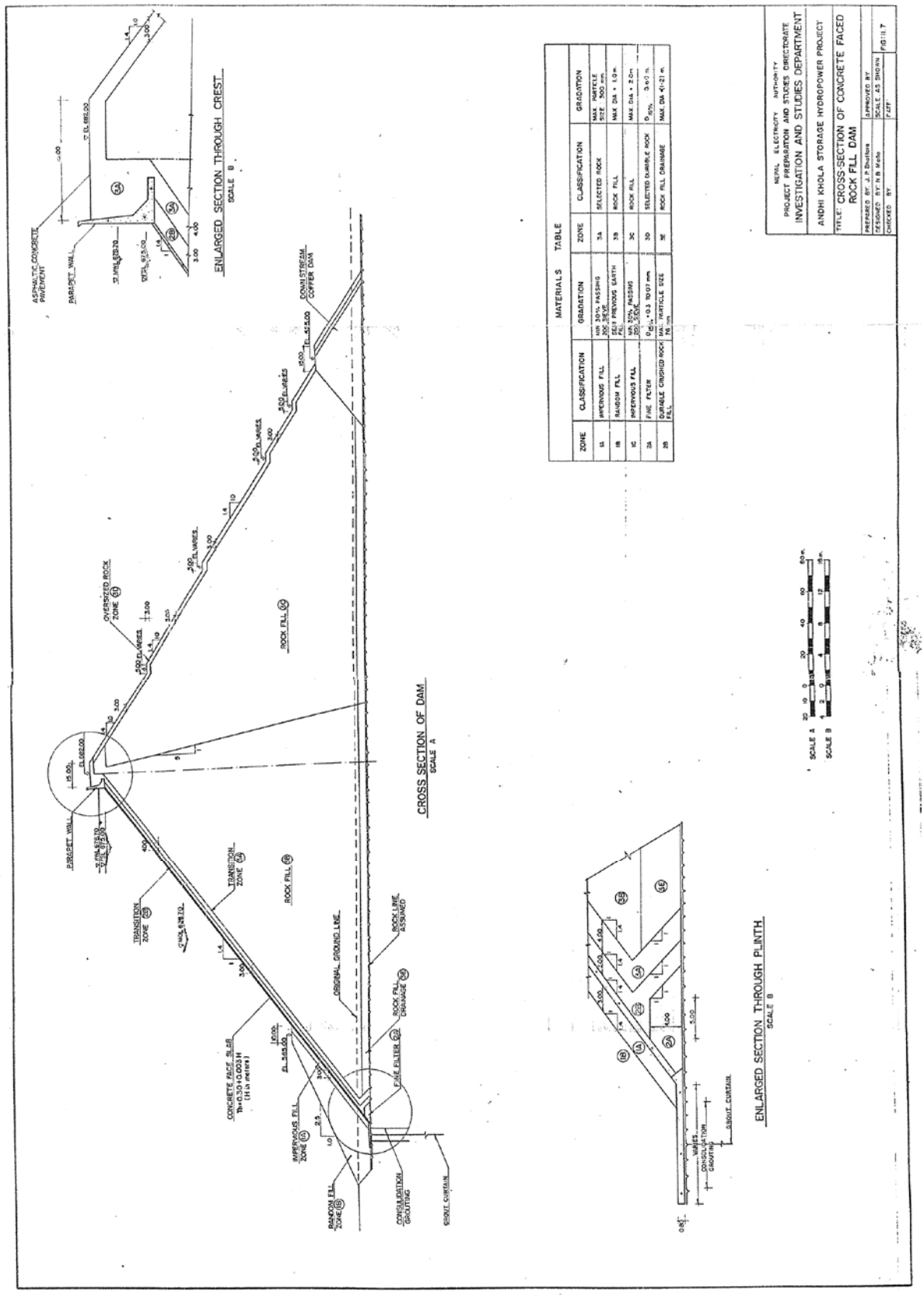
Source: Feasibility Study on Andhi Khola Hydroelectric Project, 1998, NEA

Figure A.2.5-6 General Layout



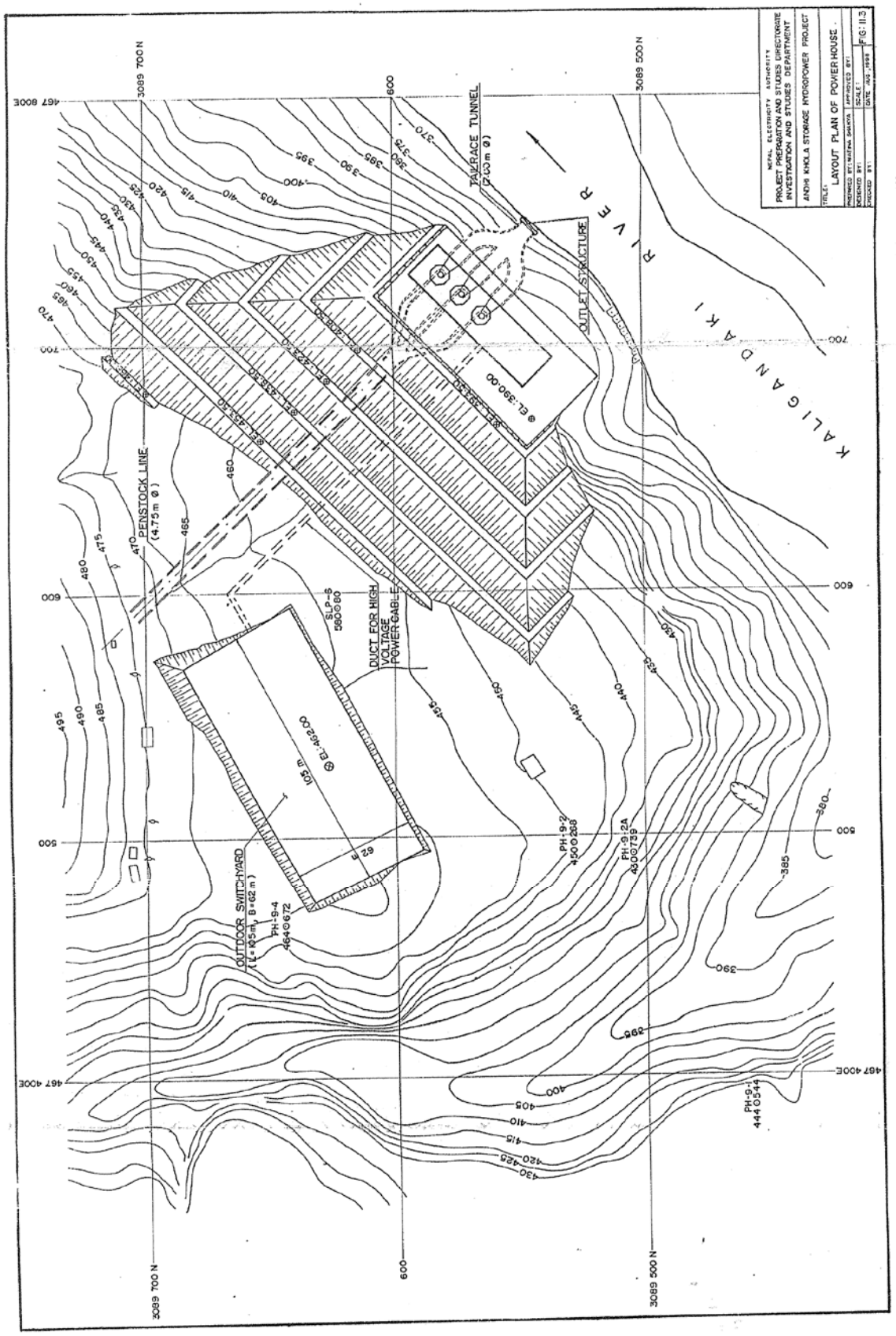
Source: Feasibility Study on Andhi Khola Hydroelectric Project, 1998, NEA

Figure A.2.5-7 Dam Plan



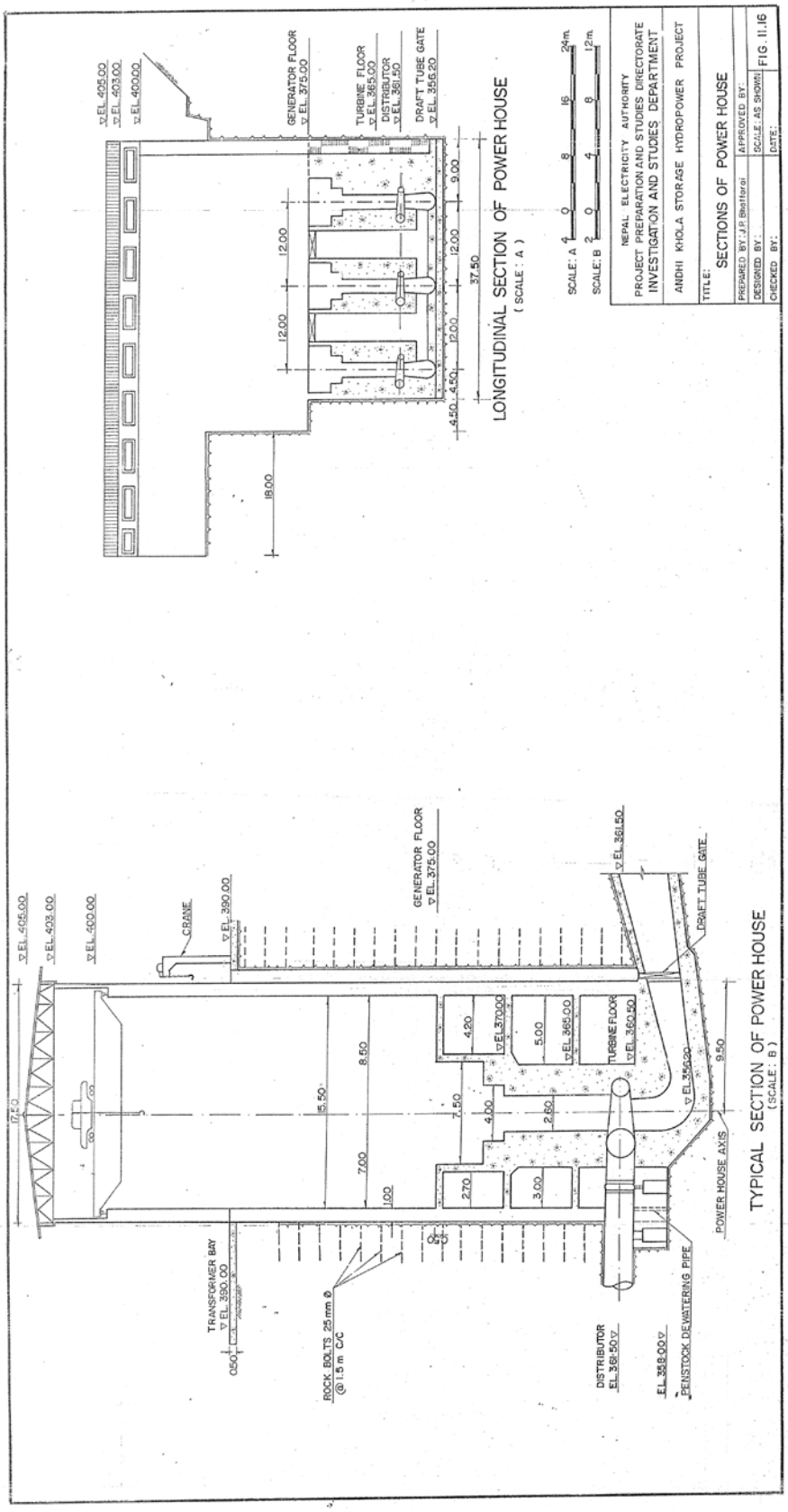
Source: Feasibility Study on Andhi Khola Hydroelectric Project, 1998, NEA

Figure A.2.5-8 Dam Section



Source: Feasibility Study on Andhi Khola Hydroelectric Project, 1998, NEA

Figure A.2.5-9 Powerhouse Plan



Source: Feasibility Study on Andhi Khola Hydroelectric Project, 1998, NEA

Figure A.2.5-10 Powerhouse Section

Further, the findings attained by the Study Team through the site reconnaissance conducted in June, 2012 in terms of dam site and powerhouse site are summarized below.

Dam Site

The dam site proposed in the FS is located at approximately 1.5 km upstream of the confluence of the Kari Gandaki river and the Andhi Khola river. The river bed elevation at dam axis is 525 m. There is the intake dam of the Kali Gandaki A Hydropower Plant (144 MW) owned by NEA at immediately downstream of the confluence. The Full Supply Level (FSL) of the peaking pond is 524 m.

A raising of the intake dam is planned at the Kali Gandaki A Hydropower Plant. Therefore, a shift of the dam site established in the FS to 2 km upstream from the original position is studied. The new dam site has originally been identified as an alternative in the FS, however, it was not adopted due mainly to geological reason. The river bed elevation at new dam axis is 30 m higher than the original site, namely, 555 m. Regarding the access to the dam site, there is a two-lanes paved road from the national highway connecting Butwal and Pokhara to the existing the Kali Gandaki A Hydropower Plant at the left bank of the Andhi Khola river. From the paved road at EL. 815 m to the Llunga village at EL. 700 m, there is a one-lane unpaved road. At the halfway of the unpaved road, there is a branch dirt road toward the dam site from the downstream side, on which tractors are going through. The unpaved road and dirt road could be the access road to the dam site with some improvement and expansion. At the moment, a topographic survey around the new dam site is being conducted by NEA. It should be careful to establish the dam axis considering some thin ridges are existing around the new dam site as the topographic features. It should be noted that geological investigations including core drillings for dam foundation, basic design of dam and waterways, construction planning and coat estimation have to be redone by moving dam site toward upstream. Further, the project optimization has to be reviewed drastically because the effective reservoir storage volume is to decrease some 30% of that of FS.

It should be recognized that it will take almost same amount of time and manpower as that for FS to redone the studies if the dam site is moved. Therefore, the moving dam site of Andhi Khola project should be examined comprehensively in consideration of the intake dam raising plan at Kali Gandaki A Hydropower Plant. Although it depends on how much the FSL of Kali Gandaki A will raise, it might be possible to deal with the raising FSL by constructing some structures such as concrete wall etc. instead of moving the dam site.

Powerhouse Site

The powerhouse is located at the left bank of the Kali Gandaki river. To change the location of powerhouse from the original location in FS toward 500 m downstream is being studied. The new powerhouse will be located at 400 m upstream of the outlet of existing Amdhikhola power plant (IPP). The coordinate is approximately 27º55’39”N, 83º40’26”E and the elevation of riverbed is approximately 380 m at the site. The average inclination of left bank from the river bed to EL.600 seems about 25 degree. There is a gentle slope farm land having lengths of 200

m upstream-downstream direction and 100–150 m transversal direction and inclination of 12–13 degree at EL 430–470. The area is planned to be used for switchyard in FS.

The access to the powerhouse site will relatively be easy by descending the gentle slope farm land with hairpin curves to the powerhouse site from the branch at 1.2 km upstream of the powerhouse on the national highway connecting Butwal and Pokhara. However, a bypass road will be required for the Ridi town if equipment and materials for construction are transported through the Ridi town.

Others

Regarding the existing Andhikhola Hydropower Plant (5.1 MW) owned and operated by Butwal Power Company, a comparison study was conducted in the FS. In the study, two cases were compared. One is to abolish with full compensation and the other was to continue to operate with some renovation by implementation of the Andhi Khola Project. As a result of the study, it was concluded that to operate with some renovation will be more economical. At the moment, the power plant is planning to expand the install capacity to 9 MW, and conducting a construction works to raise the intake dam. Regarding the powerhouse part, the renovation works will be commenced in 2012 the generation will be resumed in 2013.

Furthermore, as for the Andhi Khola Project, there is information that a Korean company offered to develop the project to the NEA though it has yet to reply.

(5) Electrical/Mechanical Equipment and Transmission Line

1) General

Rated effective head, power discharge and installed capacity of the Andhi Khola Project are as follows;

Rated Effective Head	: 286.30 m
Rated Power Discharge	: 81.40 m^3/s
Installed Capacity	: 180 MW

The HD Wiz (developed by J-POWER, based on existing hydropower plant data around world) has been used for reviewing design of electrical/mechanical equipment taking above information into consideration. Turbine efficiency and generator efficiency have been improved in recent years and installed capacity exceeded above-mentioned 180 MW consequently.

2) Unit Capacity and Number of Unit

Generally, for the turbine-generator, a large unit capacity is said to be more economical merits of scale. However, optimum unit capacity of the turbine-generator is determined in consideration of influence to the power system, development timing and transportation restriction.

In this project, all electrical and mechanical equipment will be transporting from foreign

countries via Indian national road and un-maintained Nepalese national road to the project site. Therefore maximum unit capacity shall be set as around 100 MW and number of 3 units plan has been adopted for the project.

3) Turbine

a) Turbine Output

Rated turbine output at rated effective head of 286.30m and rated power discharge of 27.13 m^3/s per unit can be calculated as follow;

$$Pt = 9.8 \times Hn \times Qt \times \eta t$$
$$= 9.8 \times 286.30 \times 27.13 \times 0.919$$
$$\approx 69{,}900 \text{ kW}$$

where

Pt : Rated turbine output per unit (kW)
Hn : Rated effective head (m)
Qt : Rated power discharge per unit (m^3/s)
ηt : Turbine efficiency

b) Type of Turbine

Generally, type of turbine can be determined by close relation between effective head and turbine output. Vertical shaft Francis type turbine can be selected taking rated effective head and turbine output into consideration.

c) Runner Material

Stainless steel anti-corrosion type such as 13 chrome high nickels stainless steel is recommended to be applied for the runner material. Surface of runner and wear ring shall be coated (hard or soft) in case of water quality. Detailed coating method shall be specified in the detailed design stage.

d) Installed Capacity

Installed capacity can be calculated from aforementioned turbine output per unit as follow;

$$69{,}900 \text{ kW} \times 3 = 209{,}700 \text{ kW}$$

Review of energy calculation is conducted by using above installed capacity.

4) Generator

A three phase alternating current synchronous generator with vertical shaft rated capacity of 75,800 kVA and power factor of 90% lag are selected.

a) Generator Capacity

Rated generator capacity can be calculated from rated turbine output, power factor and generator efficiency as follows;

$$Pg = Pt \times \eta g / p.f \text{ (kVA)}$$
$$= 69{,}900 \times 0.977 / 0.90$$
$$\approx 75{,}800 \text{ kVA}$$

where

Pg : Rated generator capacity (kVA)
Pt : Rated turbine output (kW)
ηg : Generator efficiency
p.f : Power factor, lag

As the results of above calculation, rated generator capacity is 75,800 kVA.

5) Transmission Line

Regarding designing of the transmission line, transmission line shall be connected to the closest substation based on 400 kV Transmission Line Power Development Plan by the NEA. And also thermal capacity and maximum surface potential gradient have been taken into consideration for designing of the transmission line and following specifications have been adopted. As for the transmission line length, the direct length from project area to closest substation was measured from map. Therefore, some allowance has been taken into consideration.

Connected Substation	: Hetauda Substation
Transmission Line Voltage	: 220 kV
Length of Transmission Line	: 49 km
Conductor Type	: Bison × 1, 2 circuits