11.4 Electromechanical Equipment

11.4.1 General

The Upper Seti storage hydroelectric plant will have a maximum output of 128 MW, using the gross head of 125.8 m to be made by constructing a dam and waterway, in order to cope with peak demand for six (6) hours. That plant consists of the following main equipment:

a. Hydraulic Turbine
b. Generator
c. Main Transformer
d. Switchyard Equipment

11.4.2 Unit Capacity and Number of Units

Generally, for a turbine-generator, a larger unit capacity is said to bring more economical merits of scale. However, the optimum unit size of a turbine-generator is determined in consideration of the following items:

a. The influence of the unit capacity to the power system
b. Transportation route for the heavy parts of equipment
c. The level of current manufacturing technology
d. The reliability and flexibility of maintenance for plant operation

For item a., in the case of one unit with 127 MW in output, the 127 MW unit will have 1.11 Hz of frequency adjustment capacity in FY2013/14 when the Upper Seti project is commissioned and total installation capacity in Nepal reaches 1,148 MW, since the 1.11 Hz nearly corresponds to the power frequency limit (+/- 1.25 Hz) stipulated in the NEA's Regulation, and faults of the 127 MW unit will seriously affect INPS, whereas in the case of two (2) units with 63.5 MW, one (1) unit will have 0.53 Hz of frequency adjustment capacity. If the 63.5 MW unit has a fault, the effects on INPS will be less significant than those of the 127 MW unit and permissible, based on the results of power system analysis in Nepal.

Regarding item b., the Study Team selects the same transportation route as that used for the Marsyangdi hydroelectric project, such as India - Birganj – Hetauda – Narayangad - Mugling – the current project site. The weight limit for that route was 24.8 tons according to a site survey conducted for that project.

The heaviest part to be transported is assumed to be the part of a main transformer (excluding insulation oil), which comes to approximately 100 tons in the case of two (2) units and around 200 tons in the case of one (1) unit respectively. The heaviest part weight during transportation, however, will be less than 24.8 tons when the transformer is divided into several parts.

During the detailed design stage, the road conditions of the transportation route in Nepal should be re-investigated to confirm whether the reinforcement or replacement of bridges will be necessary or not.

As per item c., although even the unit capacity of 127 MW is classified as a large category for the equipment, major global manufacturers have made it possible to manufacture equipment with a unit capacity of 127 MW.

Concerning item d., NEA has been maintaining Francis turbines at the Kali Gandaki A (48 MW/unit), Kulekhani II (16.5 MW/unit) and Marsyangdi (26 MW/unit) hydroelectric plants, meaning there is no issue in NEA maintaining Francis turbines for the project.

With the foregoing in mind, it is obviously that item a. "Influence caused by the unit capacity to power system" is the most important factor to be considered when examining unit capacity in this project. Therefore, it is concluded that the number of units should be two (2) with a unit capacity of 64 MW.

11.4.3 Hydraulic Turbine

(1) Turbine Output

The rated turbine output is designed as 65.1 MW per unit at 100% gate open with a rated effective head of 113.0 m as follows:

$$
\begin{aligned}
Pt &= 9.8 \times Hn \times Qt \times \eta t \\
&= 9.8 \times 112.5 \times 63.7 \times 0.927 \\
&\approx 65{,}100 \text{ kW}
\end{aligned}
$$

where,
- Pt : Rated turbine output (kW)
- Hn : Rated effective head (m)
- Qt : Rated water discharge per unit (m^3/s)
- ηt : Turbine efficiency (%)

(2) Turbine Type

Generally, the turbine type is determined based on the relation between the effective head and output. The vertical-shaft, single-runner, Francis type is selected as the turbine type in consideration of the above in the project.

An intermediate shaft for each unit will allow removal and re-installation of the runner; facilitating repair and inspection with outage time minimized and no need to disassemble the generator.

(3) Countermeasures on Turbine Abrasion by Suspended Solids[2]

Whether a turbine will be abraded by suspended solids or not depends on the particle size of the suspended solids, the hardness of the solids and the concentration of the suspended solid in water through the turbine. Based on the result of a site survey carried out by NEA, the 50% particle size of the suspended solid is around 0.07 mm, with annual average concentration of 2.9 kg/m^3. The particle hardness of solids, meanwhile, should be clarified separately by the quantitative analysis of mineral composition.

Although this project involves a reservoir (storage type), countermeasures on turbine abrasion should be necessary, because such measures are already taken for the turbines of hydroelectric plants with reservoirs located on rivers with considerable suspended solids in China.

Therefore, the following countermeasure shall be considered:

- Stainless steel with soft martensite (13/4 Cr/Ni) or equivalent should be specified as material.
- Turbines and related parts are treated with soft or hard coatings, which are very effective for abrasion resistance.

(4) Material of Runner and Its Spare

For the Francis runner components, 13/4 Cr/Ni stainless steel, with high abrasion resistance to suspended solids, is specified. In addition, a considerable quantity of suspended solids, which will result in abrasion on the surfaces of the runner and wear ring, will pass through the turbine. Soft or hard coating on the runner surfaces and wear ring, wicket gates, etc. is specified and details should be examined during the detailed design stage.

One spare runner will be provided for repair work.

(5) Turbine Center Setting

The centerline elevation of the turbine is determined based on the draft head (Hs), which in turn, is determined by the cavitation coefficient of the turbine related to the optimum turbine specific speed (Ns). Hs was obtained as – 9.2 m by using the above relation. Therefore, the centerline elevation of the turbine is set at EL. 280.0 m, which is 9.2 m below the normal tail water level of EL. 289.2 m

(6) Principal Runner Size

The runner size is designed to determine the principal dimensions of the turbine, the weight of the turbine and the plant layout. The dimension and weight of a runner are to be approximately

2 Particles with Moh's hardness of more than 5 are harmful for turbine material. 90% of Himalayan silt consists of quartz (SiO_2) having 7 on Moh's scale compared with 10 for diamonds. It is possible to use both metallic and non-metallic material for thin (0.2 – 0.5 mm) coating on hard materials, such as steel.

2.2 m with weight of 15 tons. However, the actual turbine dimensions will depend on proposals received from manufacturers of turbine-generator equipment.

(7) Revolving Speed

The specific speed (Ns) of Francis type turbine generally is between 70 to 300 m-kW. Ns 208 m-kW is obtained by calculating the relation between the effective head and specific speed previously adopted for similar projects. With this in mind, the revolving speed of the turbine is obtained as 300 r/min, based on the specific speed of Ns 208 m-kW, and shall be specified during the detailed design stage.

(8) Turbine Aeration System

An embedded piping system for aeration is provided for the turbine, head cover and draft tube.

(9) Penstock and Inlet Valve for Turbine

The one (1) line penstock is bifurcated into two (2) pipes for 2 units and connected to inlet valves. The Inlet Valve will be of the Butterfly Valve type with a diameter of approximately 3 m.

11.4.4 Generator

The rated generator capacity is calculated with the maximum output of turbine, power factor and generator efficiency as below:

$$Pg = Pt \times \eta g / p.f \text{ (kVA)}$$
$$= 65{,}100 \times 0.975 / 0.85$$
$$\approx 74{,}700 \text{ kVA}$$

where,

Pg	:	Rated generator capacity (kVA)
Pt	:	Rated out put of turbine (kW)
ηg	:	Generator efficiency (%)
p.f	:	Power factor (%)

The required characteristics of the generator are as follows:

Direction of rotation:	Clockwise view from above
Rated revolving speed:	300 r/min
Rated out put:	74.7 MVA
Rated current:	3,270 A
Power factor	0.85 lag
Rated voltage:	13.2 kV
Rated frequency:	50 Hz

The generator is of the vertical shaft type, 3-phase synchronous generator, brushless exciter with AVR (Automatic Voltage Regulator). The generator stator and rotor windings are provided with epoxy insulation of the class F type. The generator ventilation is performed with heat exchanger and self circulation.

11.4.5 Powerhouse Crane

A powerhouse crane is to be installed for use in assembling/disassembling the equipment, such as the turbine, generator and parts for maintenance.

The crane is of the indoor type, with a single trolley, overhead traveling wheel, and capacity of 150 tons determined based on the rotor weight (75 tons of two (2) cranes: to be finalized at the detailed design stage) for the main hook, and 10 tons for the auxiliary hook is to be provided. The crane bridge has a span of approximately 20 m and a lifting height of approximately 6 m for main hook.

The two (2) cranes are capable of working in tandem for the heaviest equipment.

11.4.6 Main Transformer

The power transformer of two (2) units is to be installed in the transformer room in the underground powerhouse.

The rated capacity of the main transformer is decided based on the rated capacity of the generator. The required characteristics of the power transformer are as follows:

Rated capacity:	74.7 MVA	
Rated voltage:	Primary	13.2 kV
	Secondary	220 kV
Rated current:	Primary	3,270 A
	Secondary	196 A
Rated frequency:	50 Hz	
Cooling system:	Indoor, OFWF (forced oil, water cooled type)	

There are four types of power transformer such as the single-phase type, three-phase type, special-three-phase type and package three-phase type respectively. The type is selected in consideration of the transportation limitations on the weight, efficiency and installed spaces, etc. The proposed transportation route to the project site is capable of carrying a maximum load of 24.8 tons (including the weight of the trailer). If the package transformer, which can be divided into several parts, such as the winding, core, tank, etc., for transportation to the site and re-assembly of those ports at the site, is adopted, it is possible to transport the main transformer, with a total weight of 100 tons, with a divided maximum weight of 13 tons. Therefore, the package three-phase type is selected.

The power cables (XLPE type) of 220 kV will be connected between the secondary terminal of the mains transformer and outdoor switchyard.

11.4.7 Other Equipment

(1) Station Service Equipment

The station service switchgear system consists of two (2) station service transformers and a 400V/230V, 3-phase, 4-wire bus with switchgear equipment. The loads of the powerhouse, switchyard, complex, etc. are supplied from the station service circuit.

(2) Emergency Power Source

An emergency diesel generator in the powerhouse will be provided as a backup power source for essential loads and black start-up operation, while the other emergency diesel generator will also be provided as backup power for the intake gates, spillway gates and other dam structures in the dam area.

(3) Fire Fighting System

Water from the draft tube, with an uninterrupted water supply system, will be used for the fire fighting system in the powerhouse. Fire hydrants are also to be provided in appropriate places on each floor for the main transformers, generators and inside of the powerhouse.

Portable wheeled and wall-hung CO_2 extinguishers are to be provided in the office, powerhouse, dam facilities, etc.

(4) Computer Control System

A Computer Control System, connected with a LAN, is based on fully integrated programmable logic controllers (PLC) and personal computers (PC), which provide centralized control and monitoring of the power plant. The computer control system consists of the station control level with the operator console, CRTs and a mimic diagram board, the unit control level of unit Nos. 1 and 2, station auxiliary, switchyard and RUT. The Computer Control System is linked to the monitoring functions of the spillway and intake gates.

11.4.8 Switchyard Equipment

(1) Upper Seti Switchyard

The switchyard is located outdoors on EL. 370 m and connected with 220 kV power cables approximately 680 m in length from the main transformer secondary terminal in the underground transformer room. The administration office, including the control room, is located near the switchyard.

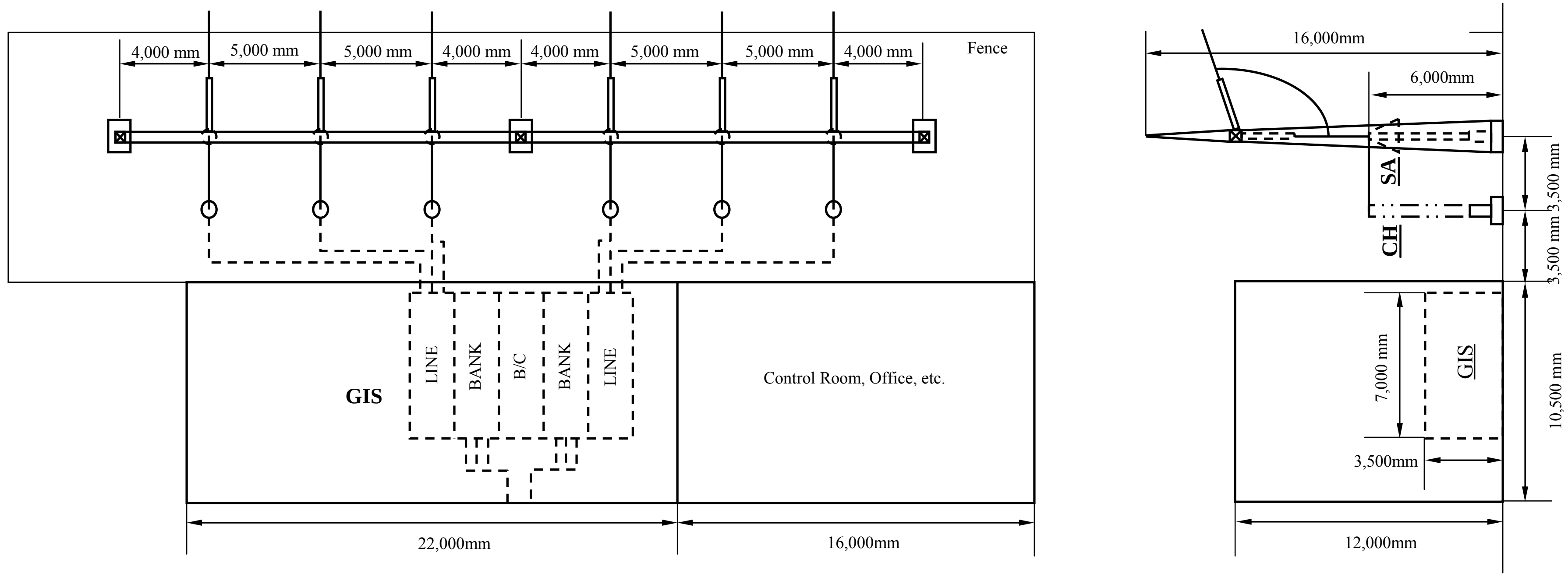
A cable tunnel is provided between the switchyard and powerhouse for the installation of the power cables and control cables, etc., while cargo and maintenance personnel are accessible from the access tunnel leading to the powerhouse from the switchyard.

A GIS (Gas Insulated Switchgear) consists of a 220 kV single bus system, including gas circuit breakers, disconnecting switches and necessary apparatus. The outgoing lines from the switchyard are to be connected to the first transmission tower of 220 kV transmission lines to evacuate power to the New Bharatpur switchyard. **Fig. 11.4.8-1** shows the location of the switchyard equipment.

(2) New Bharatpur Switchyard

Power from Upper Seti switchyard is to be evacuated with 220 kV to the New Bharatpur switchyard constructed in Narayangadh city. The New Bharatpur switchyard will connect two (2) circuits of 220 kV transmission lines between Bardghat and Hetauda substation in FY2013/14. Power generated in the Upper Seti hydroelectric plant will be supplied to the eastern area in Nepal and Kathmandu via the Bardghat – Hetauda transmission line.

The outdoor conventional type switchgear in Bharatpur consists of a 220 kV doubble bus system with gas circuit breakers, disconnecting switches and the necessary apparatus.



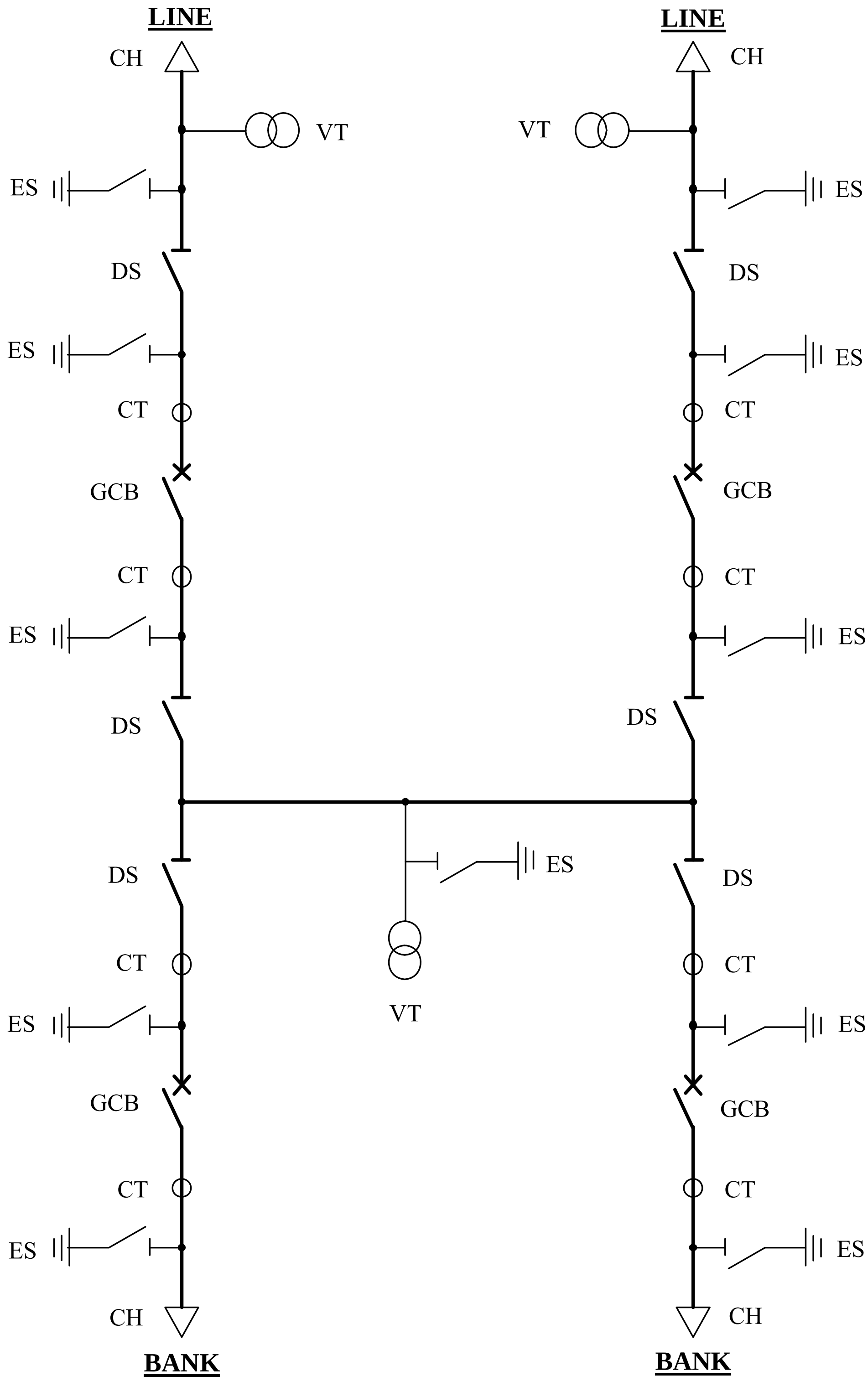
Legend

CH	Cable head
SA	Surge Arrester
GIS	Gas Insulation Switchyard

Upgrading Feasibility Study on Upper Seti (Damauli) Hydroelectric Project, NEPAL

Location of Switchyard Equipment

Fig. : 11.4.8-1 (1/2) | *Date : February, 2007*



Regend

GCB : Gas Circuit Breaker　VT : Voltage Transformer
DS : Disconnecting Switch　CT : Current Transformer
ES : Earth Switch　CH : Cable Head

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Single Line Diagram (Switchyard Equipment)

Fig. : 11.4.8-1 (2/2)　*Date : February, 2007*

11.4.9 Generation Facility by Environmental Flow

The outlet conduit is to be installed in the Upper Seti dam for the discharge of a environmental flow (2.4 m^3/s). By using the environmental flow, power will be generated for rural electrification in the upstream areas of the dam.

The feature of the generation facility is as follows:

Rated output power	:	1,900 kW
Rated effective head	:	95 m (Normal Water Level: EL. 405 m, Normal Tail Water Level: EL. 310 m)
Rated discharge	:	2.4 m^3/s
Transmission line Voltage	:	11 kV or 33 kV
Turbine type	:	Horizontal type, Francis turbine
Generator type	:	Horizontal type, 3-phase synchronous generator
Main transformer	:	Oil immersed transformer, Capacity: 1,970 kVA

11.5 Transmission Line

11.5.1 Transmission Line Route

The electric power generated at the Upper Seti Hydropower Station is to be evacuated with a new 220 kV transmission line to the Bharatpur area, as described in **section 5.2.4**, and the new Transmission Line will be connected to the 220 kV Hetauda- Bardghat Transmission Line.

The starting point of the transmission line is the Upper Seti Hydropower Station, while its terminal point is the connecting point of the 220 kV Hetauda- Bardghat Transmission Line in the Bharatpur area. The route survey of this transmission line was carried out by NEA and the review result of this route survey is described as follows: Evaluation on the selection of transmission line routes with the environment in mind is described in **Chapter 9**.

(1) Planning of the transmission line route

In this route survey, initially, three route plans were developed in a desk study by using 1/25,000 maps. The field reconnaissance of the route plans was executed, and a suitable transmission line route was selected in consideration of the passage area and construction conditions etc. Subsequently, a survey on the selected transmission line route was executed in the field, and the plan and profile were established.

(2) The start and terminal points of the transmission line

1) Location of the first tower

The first tower of the transmission line at the Upper Seti Hydropower Station side is located in the vicinity of the proposed switchyard site, and judged to be a proper site.

2) Location of the terminal tower

Regarding the connecting point of Bharatpur side, land in the vicinity of the Ganesthan area is selected as the first candidate for the Switchyard (Substation) site. The candidate site is located several kilometers north of the existing Bharatpur substation. The candidate terminal point is the "AP20B1" standing point of 220 kV Hetauda- Bardghat Transmission Line, which is located in the center line of the 220 kV Transmission line. According to a site survey by the Study Team, the surrounding area of the candidate mainly consists of forest and residential area and the construction of the switchyard (substation) is thought to be comparatively easy, because of the flat topography.

(3) Outline of desk study routes

The three route plans prepared in the desk study are divided into two sections. The first section is between Upper Seti Hydropower Station - Bagarkhola, while the second is between Bagarkhola- Bharatpur.

1) Section 1

In the first section, there were two route plans from the Upper Seti Hydropower Station to the Bagarkhola section.

Plan A	Route in parallel with the 132 kV Pokhara- Bharatpur Transmission Line via the Rumsi area
Plan B	Route passing over the vicinity of the ridge in the Seti River left bank

Based on the result of the desk study and site reconnaissance, Plan B was judged to be relatively undesirable, with deforestation and the access road condition in mind, meaning Plan A was selected after site reconnaissance.

The route outline of Plan A, from the Upper Seti Hydropower Station up to Bagarkhola is as follows:

The transmission line route passes from the Upper Seti Hydropower Station to Bagarkhola via Rumsi. From Rumsi, the route goes in parallel with the existing 132 kV Pokhara-Bharatpur Transmission Line. The passage area mainly consists of hills, cultivated areas, and mountainous areas, but some private houses are found in some places. Near Bagarkhola point, the topographic features become mountainous terrains, and the route will pass on about EL. 900 m. The transportation of materials during construction will be carried out by truck and manpower via existing roads and paths.

2) Section 2

In the second section, there were three route plans, the outline of which is described as follows:

(Route plan 1)

a) Bagarkhola- Duighare section

After passing at Bagarkhola, the route crosses Seti River, passes at Bargau, Cherghere and Sidada on the right bank of the Seti River, across Trishuli River and the main highway, before arriving at Duighare. In this section, the route does not go in parallel with the existing 132 kV Pokhara- Bharatpur Transmission Line.

The route passes over the mountainous area ranging from about EL. 400 m to EL. 900 m or more. Topographic features are assumed to be steep land, meaning the transportation of materials is presumed difficult.

b) Duighare- Dasdhunga section

From the Duighare, the route goes in parallel with the existing 132 kV Pokhara - Bharatpur Transmission Line again, and arrives at Dasdhunga. During this section, the route passes over the mountainous area in the vicinity of the Kamatpur, up to about EL. 1,000 m. Afterwards, the topographic features consists of slopes as the altitude falls. The circumstances for the materials transportation are the same as in the previous section.

c) Dasdhunga- Bharatpur section

After passing Dasdhunga, to avoid the village near Devitar, the route crosses the existing 132 kV Pokhara- Bharatpur Transmission Line. Moreover, at Jugedi Bajar, the route crosses the existing 132 kV Marsyangdi- Bharatpur Transmission Line, before then going east of two 132 kV existing Transmission Lines. The topographic features consist of hilly terrain up to Jugedi Bajar, before then traversing flat forested area and arriving at the Bharatpur connecting point.

The advantage of route plan 1 is the fact that deforestation is minimized. Because it is a route that goes in parallel with the existing transmission line, the amount of deforestation is minimized, even though the route goes through forests from the vicinity of the Juedi Bajar point near Bhartpur to the final connecting point of the route.

(Route plan 2)

a) Bagarkhola- Duighare section

In this section, the route goes in parallel with the existing 132 kV Pokhara- Bharatpur Transmission Line.

b) Duighare- Bharatpur section

From Duighare, the route goes west of the existing 132 kV Pokhara- Bharatpur Transmission Line. Near the Bharatpur area, the route crosses two existing 132 kV Transmission Lines and arrives at the Bharatpur connecting point. This Route plan 2 passes over villages such as Jugedi Bajar etc.

The feature of Route plan 2 is a route passing west of existing 132 kV the Pokhara- Bharatpur and Marsyangdi- Bharatpur Transmission Lines and over the residential areas. We therefore consider that Route plan 2 has less feasibility than Route plan 1.

(Route plan 3)

a) Bagarkhola- Kyuditar section

After passing Bagarkhola, the route crosses the Seti River near Saranghat, before then going south on the Trishuli River right bank. The main road for materials transportation is located on the left bank, and there are no roads for transportation on the right bank, making material transportation very difficult in this section.

b) Kyuditar- Bharatpur section

After crossing Trishuli River, the route goes further south, and passes flat through forests and hilly terrains. This route is located west of the existing 132 kV Pokhara- Bharatpur and Marsyandi- Pokhara Transmission Lines, meaning the route should cross over these two transmission lines in the vicinity of the Bharatpur area. After doing so, the route arrives at the Bharatpur connecting point.

The notable features of Route plan 3 are the difficulty of transportation from Bangarkhola to Kyuditar and the increased deforestation involved. Material transportation is considered difficult because of the lack of main access roads. From a deforestation perspective, the route passes through forests and not in parallel with existing transmission lines, thus increasing the amount of trees that have to be cut down. Consequently, it is judged that Route plan 3 is not an appropriate route.

(4) Comparison of each Route Plan

The comparison of each Route plan in section 2 is shown in **Table 11.5.2-1,** in section 1, where Plan A is selected from all plans of section 2. Consequently, the route plan considered most feasible and comprehensively the best option is judged to be Route Plan 1, based on which the actual route survey was executed. Each route plan is shown in **Fig. 11.5.1-1**. and the final route after the route survey is shown in **Fig. 11.5.1-2**.

Table 11.5.1-1 Comparison of each of the Route Plans

Table 11.5.1-1 Comparison of each of the Route plans

	Route plan 1	Route plan 2	Route plan 3
(Route data)			
Route length	39.0 km	37.1 km	39.8 km
Number of angle points	13 points	7 points	10 points
(Evaluation)			
1) Economical view of facility	2	1	3
2) Deforestation	1	2	3
3) Site access (ease of transportation)	2	2	3
4) Topographic features	2	2	2
5) Transmission line crossing	1	2	2
6) Passing over villages	1	3	1
Comprehensive evaluation	1	2	2

* Legend; 1: Good, 2: Fair, 3: Not good, Not feasible
* Notes;

1) Economical view of facility
The Three Route Plans are ranked from the viewpoint of route length and the number of angle points.

2) Deforestation
The length of passing in forests is respectively compared. A route plan involving fewer trees to be cut down is ranked higher.

3) Site access / Ease of transportation
There are many places where transportation by manpower is necessary, meaning evaluation of access is not so good for any route plan. In particular, Route Plan 3, passing over an area where there are no access roads en-route, was considered to be the lowest ranked.

4) Topographic features
It is not impossible to construct steel towers, though each route passes through mountainous areas. It is considered that some towers will have to be located on steep slopes and the three Route Plans have similar topographic features.

5) Transmission line crossing
Because high towers are expected, route plans passing over flat areas and villages lowers the ranking.

6) Passing over villages
To cross the residential area in Route Plan 2, the evaluation was lowered.

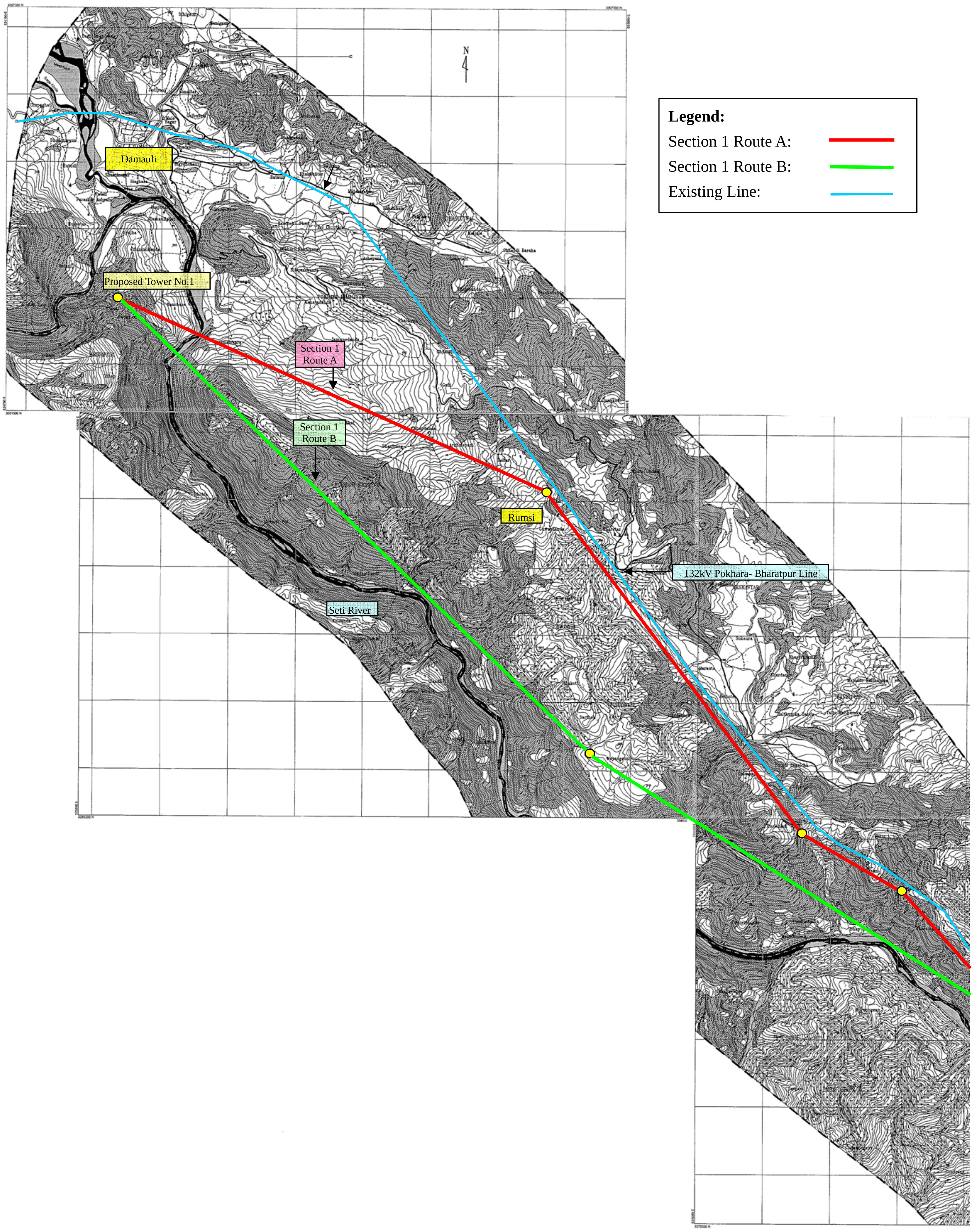

Fig. 11.5.1-1 (1)   Desk study route-1

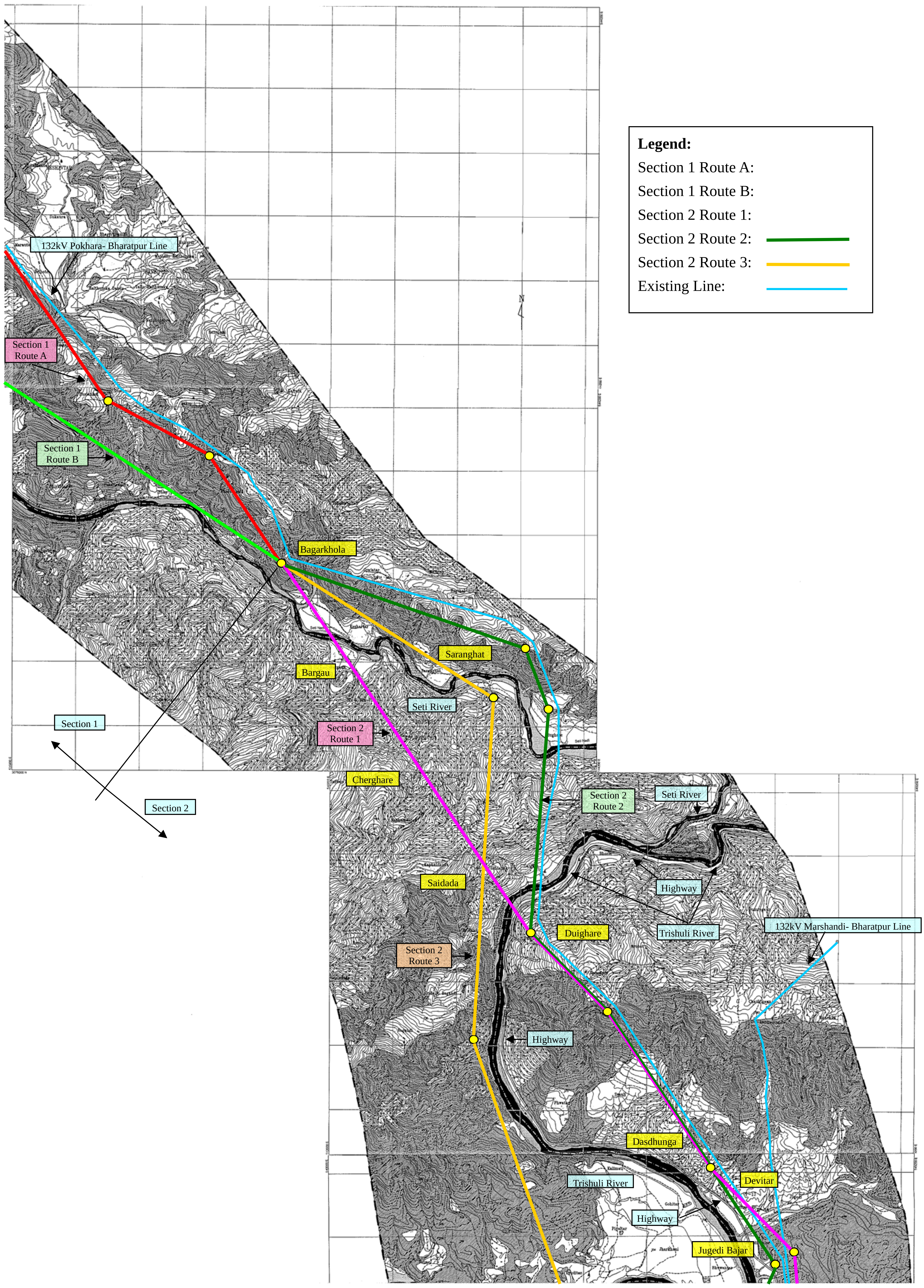

Fig. 11.5.1-1 (2) Desk study route-2

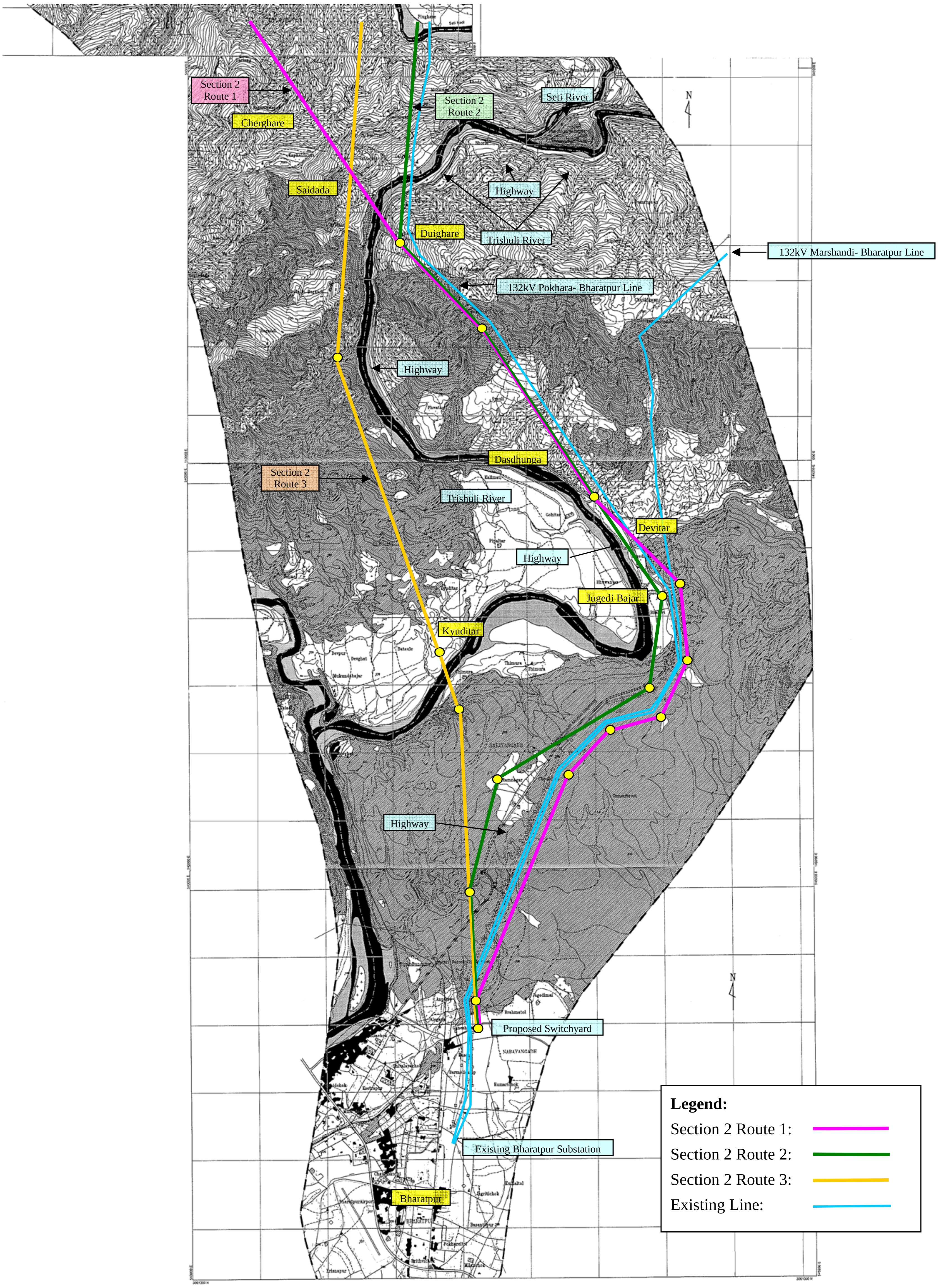

Fig. 11.5.1-1 (3) Desk study route-3

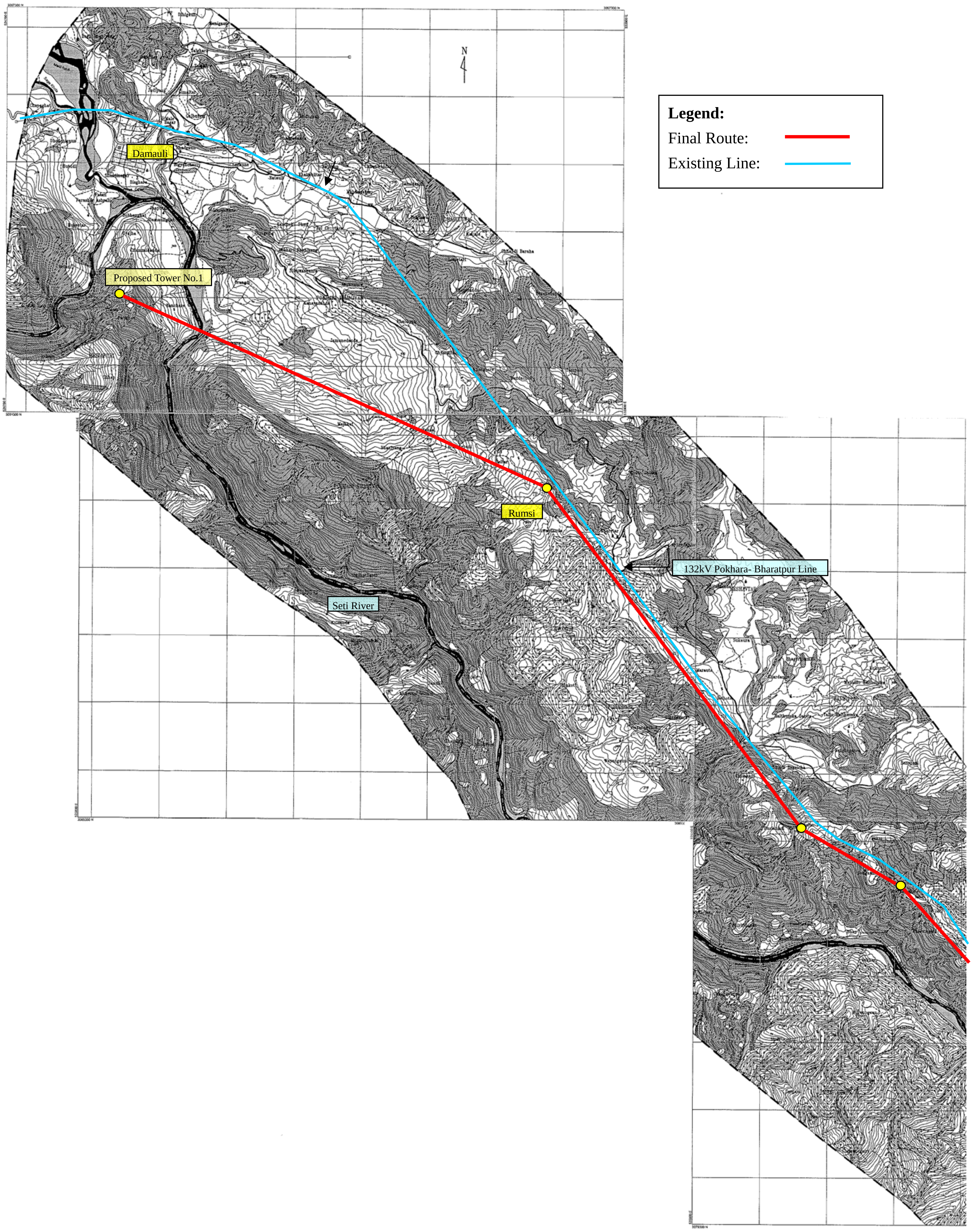

Fig. 11.5.1-2 (1) Final route-1

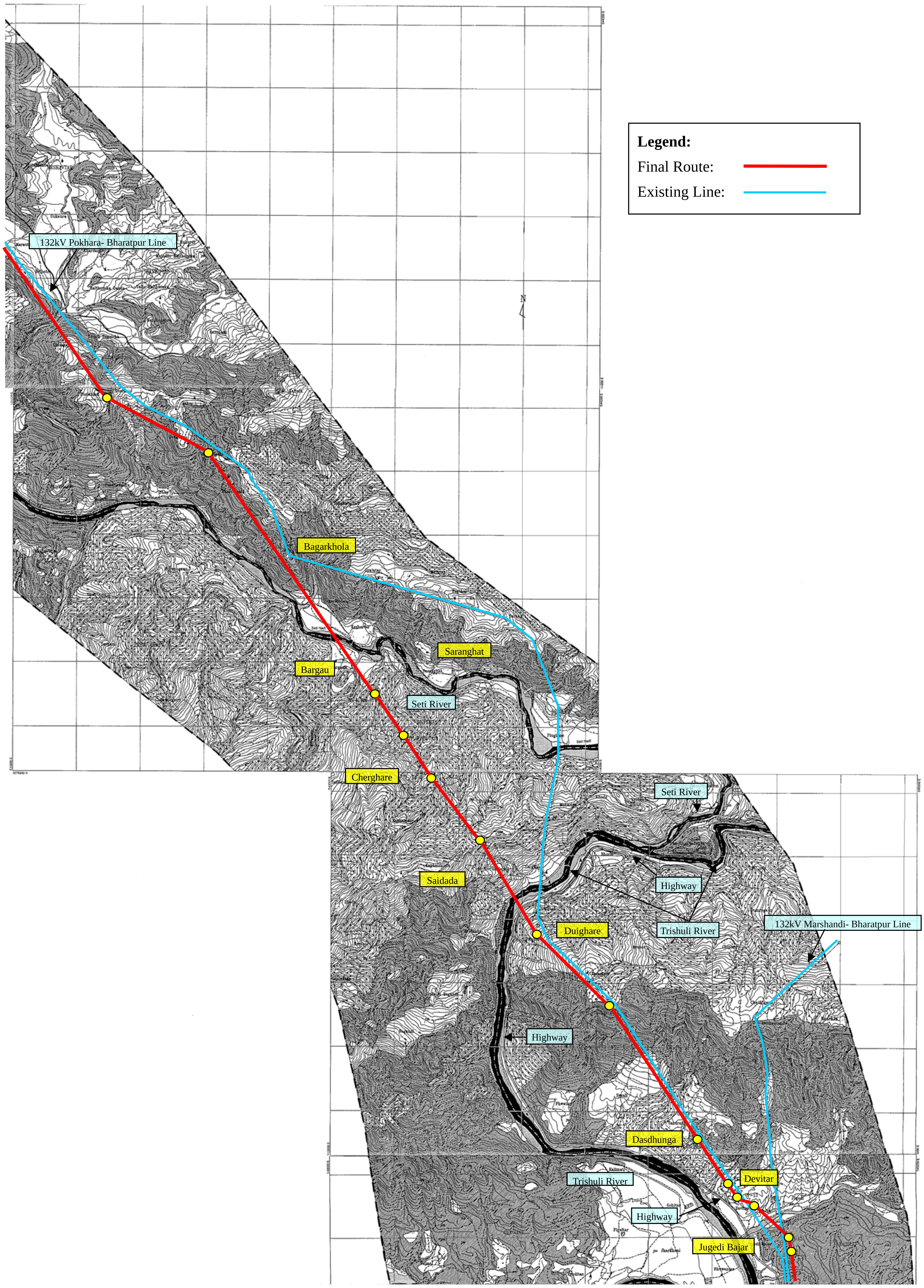

Fig. 11.5.1-2 (2) Final route-2

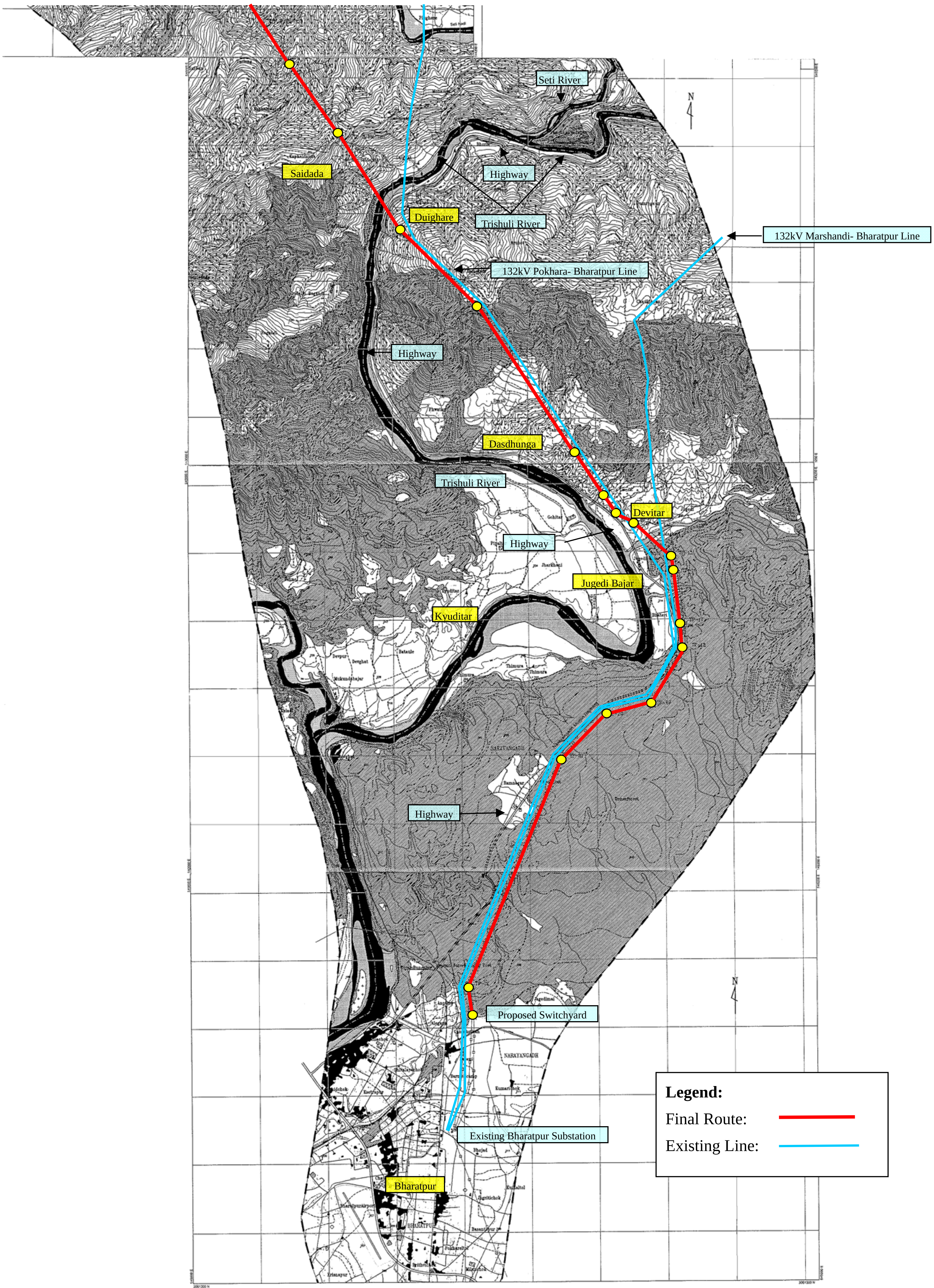

Fig. 11.5.1-2 (3)   Final route-3

11.5.2 Connection at Bharatpur

The power generated at the Upper Seti Hydropower Station is to be evacuated to Bharatpur and connected there to the 220 kV Hetauda-Bardghat Transmission Line.

In 220 kV, the Hetauda- Bardghat Transmission Line Project was launched, for which Yen Credit was applied by the Government of Nepal. However, no plan to connect the Hetauda- Bardghat Transmission Line and the Upper Seti- Bharatpur Transmission Line in Bharatpur has been included.

The T-Branch Method is considered to be a method of connecting two transmission lines. In the T-Branch Method, because two transmission lines are physically and electrically connected, therefore, it is difficult to disconnect the transmission line for the Upper Seti from the 220 kV Hetauda- Bardghat Transmission Line, which will be one of the most important trunk lines in Nepal. Hence, the T- Branch Link is not recommended because of the proneness to lightning accidents (such as single contingency, etc.) and maintenance work difficulties. It is recommended that two transmission lines be connected via a switchyard.

11.5.3 Basic Specification of Transmission Facilities

The outline of the main transmission line basic specification is described as follows:

(1) Specification

Section of Transmission Line:	From Upper Seti Hydropower Station
	To: New Bharatpur switchyard
Route Length:	Approximately 40 km
Nominal voltage:	220 kV
Electrical System:	AC, Three- phase Three-wire system
Number of circuit:	2 circuits
Structure of phase conductor:	Single conductor
Number of overhead ground wire:	2 wires
Frequency:	50 Hz

(2) Conductor

Because Nepal is an inland country, conductor corrosion caused by sea salt need not be taken into consideration. As a result of the site survey by the Study Team, no factor generating corrosive gases, such as factories and volcanoes, were considered to exist around the route, meaning normal aluminum conductor steel reinforced (ACSR) is adopted.

The size of the conductor, number of phase conductors, thermal capacity of the transmission line and corona influence are studied for the adoption of the conductor. Consequently, the ACSR Bison single conductor was selected.

In comparison with proven values of existing facilities in Japan, surface potential gradient of the ACSR Bison (single) conductor is relatively high and depending on the operation, there are slight concerns about radio interference etc. from the viewpoint of corona (refer to the **Appendix**). A bison (single) conductor was selected as one of conductors for 220 kV in the Transmission System Master Plan, which was carried out in 1998 under ADB assistance. NEA wants to unify their own facilities via the specification of a conductor, which is described in the Transmission System Master Plan, meaning an ACSR Bison (single) conductor is selected.

The thermal capacity of the transmission line and the allowable current of the conductor are as follows: A bison (single) conductor can send the rated outputs of the Upper Seti Hydropower Station.

ACSR Bison single conductor;

Conductor allowable current:	670 A (at 80°C)
Thermal capacity of transmission line:	240 MW per circuit (continuous)

Three routes of transmission lines will be passed through Bharatpur and its vicinity as shown in **Figs. 11.5.1-2 (2)** and **(3)** and consequently it is considered that it is difficult to keep the new route of transmission line for the sake of other power stations in future. Therefore, the latest Corporate Development Plan should be considered at the detailed design stage and it is necessary to decide the appropriate conductor size and structure.

(3) Overhead Ground wire

The main reasons for the installation of overhead ground wire are as follows:

- Protection of direct lightning to conductor
- Prevention of tower flashover

For the overhead ground wire, EHS wire is adopted, which is the wire usually used by the NEA. Two overhead ground wires are to be installed, as mentioned in 5.2.4, and the desired shielding angle adopted is 0 degrees.

EHS;

Stranding:	7/35
Diameter:	10.05 mm

(4) Outline of the Insulation Design

As a result of various insulation designs, the number of insulators and clearance thereof are as follows:

Number of insulators:	250 mm Ball socket disc type insulator (standard)
	17 insulators, Connection length 146 mm
Minimum insulation gap:	1,500 mm
Standard insulation gap:	2,300 mm

(5) Insulator Assembly

In consideration of existing usage condition and strength, the following insulator is adopted. In the detailed design stage, insulator strength shall be subject to renewed scrutiny.

Insulator assembly:

Single suspension insulator strings:	70 kN 250 mm Ball socket disc type 17 insulators x 1
Double suspension insulator strings:	70 kN 250 mm Ball socket disc type 17 insulators x 2
Double tension insulator strings:	120 kN 250 mm Ball socket disc type 17 insulators x 2

The arcing horn is included in the insulator assembly.

(6) Support

The support is considered to be of the square type tower. A typical tower is shown in **Fig. 11.5.3-1**.

(7) Foundation

The following basic types are assumed, though the tower foundation depends on foundation conditions in the field:

- Pad and Chimney type
- Rock anchor type
- Pile type

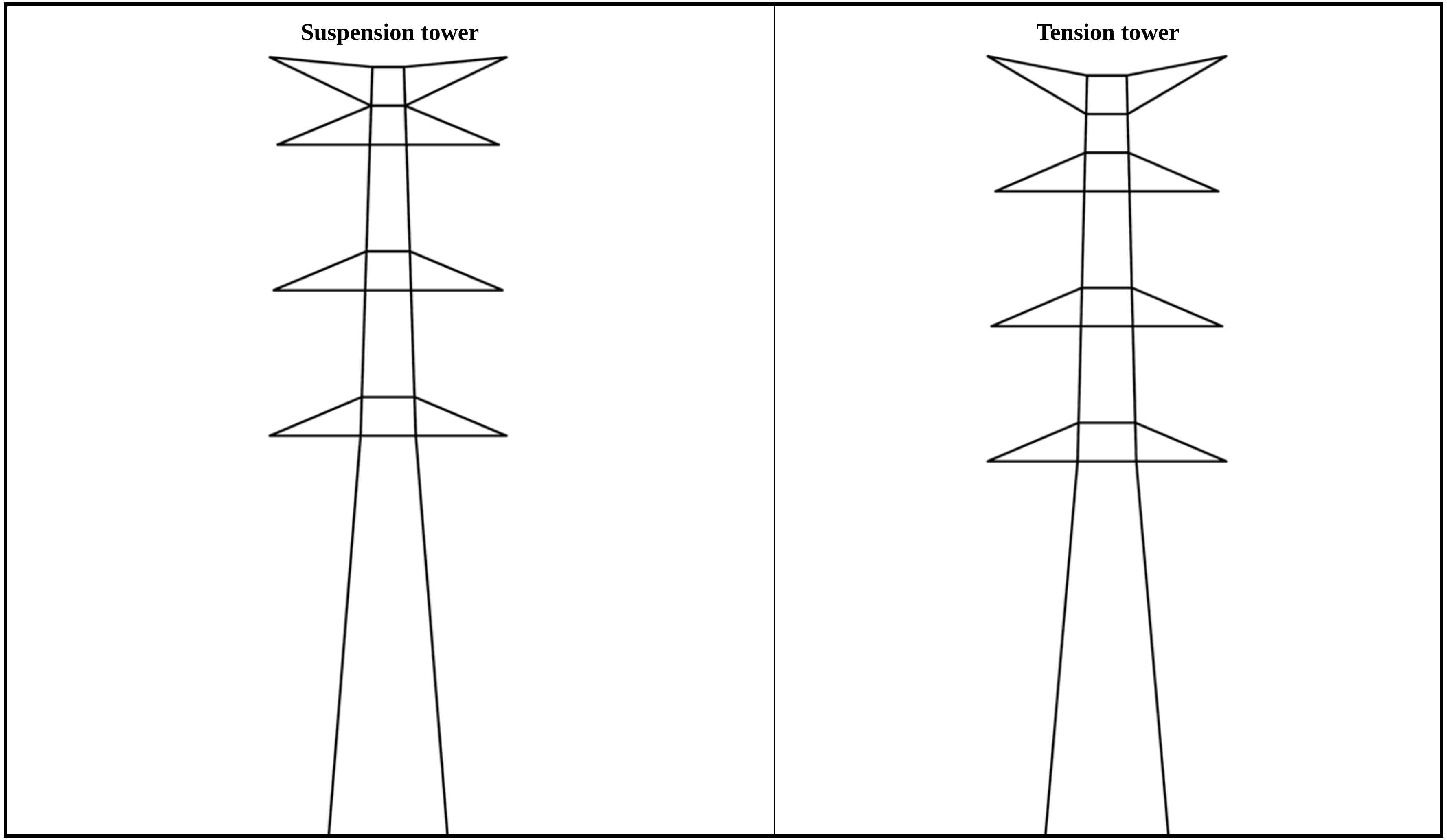

Fig. 11.5.3-1 Typical Tower Drawing

11.6 Annual Energy

In this section, a calculation method of annual energy generated by the Project with the sediment flushing operation and sediment in the reservoir is described.

11.6.1 Reservoir Operation Rule Optimization

In Project optimization study described in **Chapter 10**, annual energy estimation is made under the same reservoir operation rule based on hydrological property to compare project portfolio under the same conditions. In this section, reservoir operation rule optimization is executed for the proposed development plan shown in **Chapter 10** to make annual energy maximum.

The reservoir operation rule optimization is made by the Dynamic Program Method. The Dynamic Program’s mathematical meaning is to determine the control vector which can make the evaluating function value maximum or minimum under given restraint conditions, which is based upon the optimum principal. The optimum principal is the optimized plan which can make its decision the optimum on conditions from primary decision to result for whatever primary conditions and decision of the system.

In the case of reservoir operation rule optimization, evaluating function corresponds to annual energy, outflow discharge from reservoir and reservoir volume on given inflow discharge to reservoir correspond to restriction conditions, and control vector against above issues corresponds to reservoir operation rule.

As shown in **Chapter 10**, monthly discharge data of 36 years between 1964 and 1999 are given for energy calculation. The concept to derive targeted reservoir volume is as shown in **Fig 11.6.1-1**.

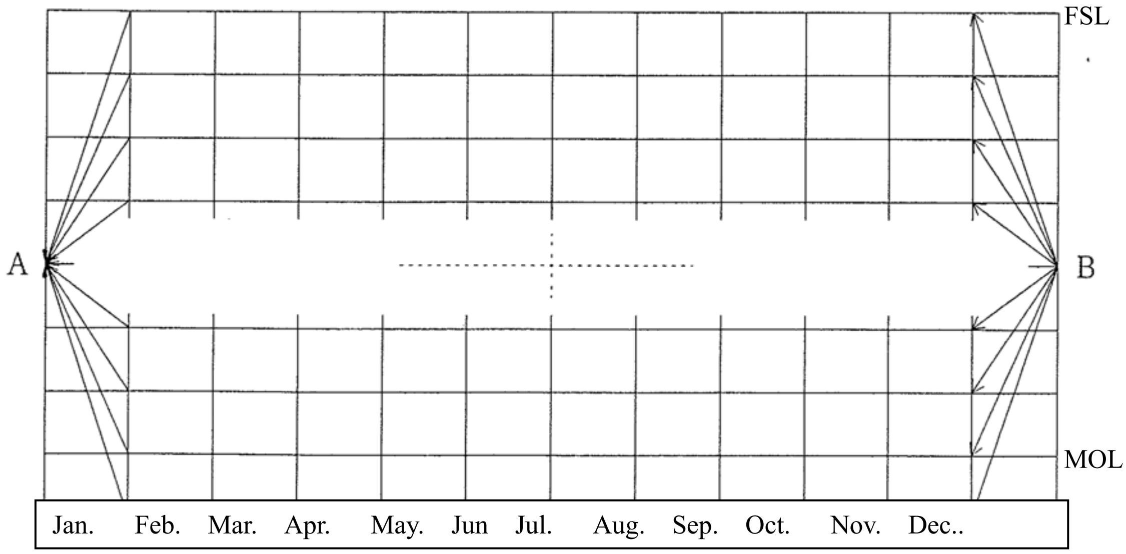

Fig. 11.6.1-1 Concept of Monthly Reservoir Volume (Water Level) Decision

At beginning, targeted reservoir volume of January is set at first, and then 36 outflow discharges against 36 inflow discharge data are decided. Here, targeted volume is determined by equalized 20 grids between MOL and FSL, which determine 20 targeted reservoir volumes through the curve between water level and reservoir volume. And thus, next month's targeted volumes are decided by each month's 36 outflow discharges, then finally 36 outflow discharges against 36 inflow discharges are decided at each December's targeted reservoir volume, and then targeted reservoir volume of next year's January is decided. By this procedure, various reservoir operation rules are decided. If primary value of reservoir volume on January first is equal to derived targeted reservoir volume on end of December by this procedure, the rule curve should be appropriate. But it sometimes happens that primary value of reservoir volume on January first should not correspond to derived targeted reservoir volume on end of December as shown in **Fig 11.6.1-2**.

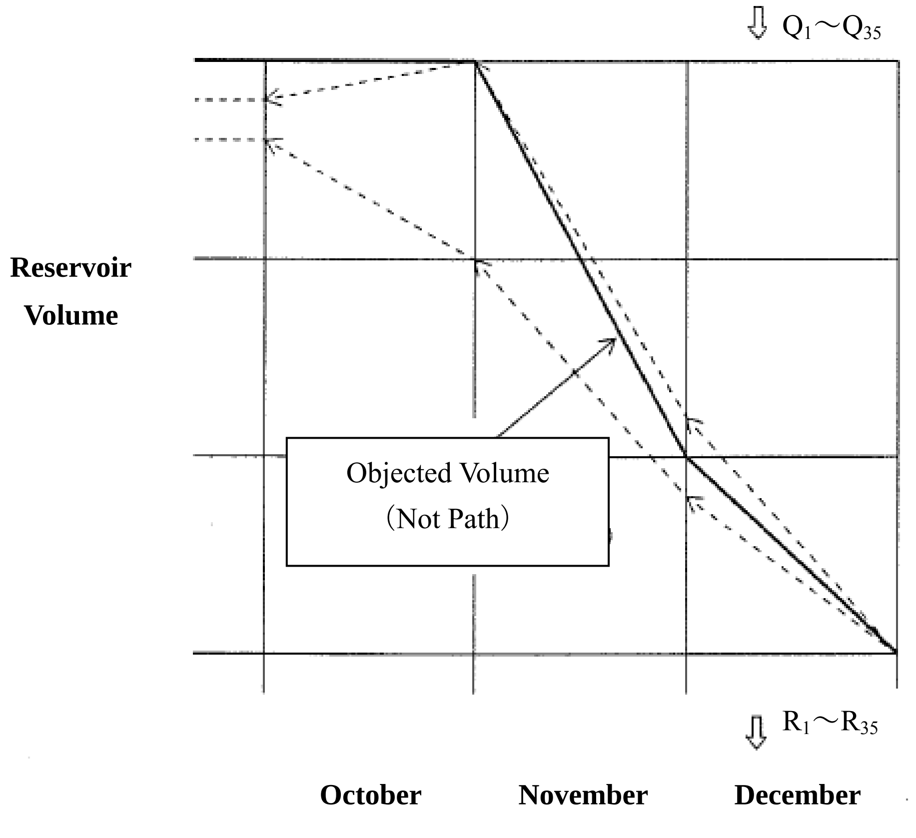

Fig. 11.6.1-2 How to decide Reservoir Rule Curve

The targeted volume is merely a target, and it happens that calculated volume can not reach targeted reservoir volume in some years as shown in **Fig 11.6-2** with dotted line. In this case, as there exist 20 candidates for targeted reservoir volume at January first, they are given as primary value for the end of December again, and calculated until calculated targeted volume at the end of December becomes converged to primary value. Among reservoir operation rules which fulfill above conditions, the one which produce maximum annual energy is chosen as optimized reservoir rule curve.

Fig. 11.6.1-3 shows the optimal reservoir operation rule curve without the sediment flushing operation, as mentioned above.

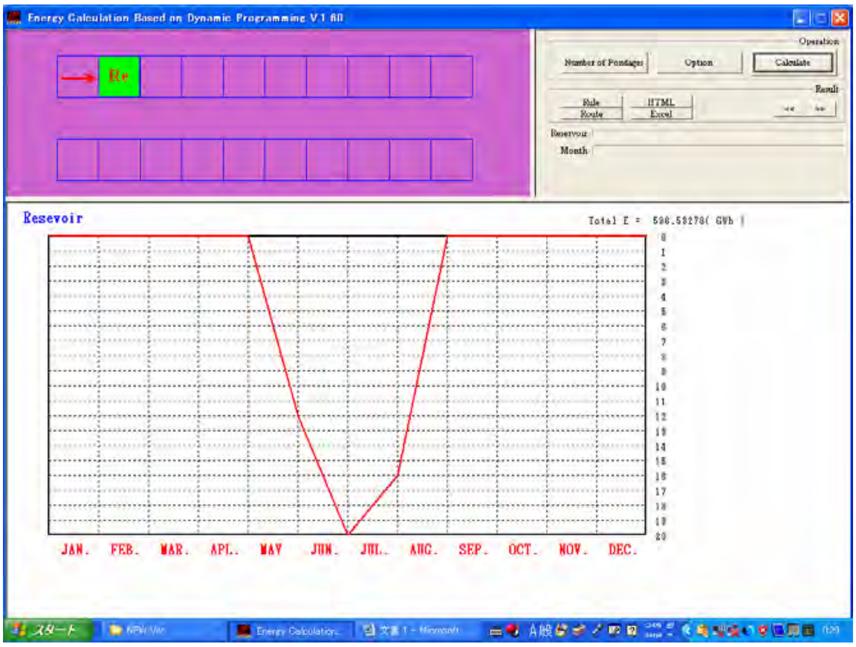

Fig. 11.6.1-3 Optimized Reservoir Operation Rule Curve

11.6.2 Calculation Conditions

(1) Consideration of Sediment Flushing Operation

Although the sediment flushing operation is not considered for annual energy calculation for optimization in **Chapter 10**, the operation will be taken into account. As mentioned in **Chapter 6**, reservoir water level is set every year for the sediment flushing operation as follows:

a. Lowering the water level from MOL to the sill elevation at EL. 320 m during the period from the 1st to 20th June

b. Conducting the flushing operation from June 20 to July 31

c. Restoring the water level from the sill elevation at EL. 320 m to MOL on 1st and 2nd August

The above conditions are considered in the annual energy calculation.

(2) Affect on Sediment

Sediment volume in the reservoir will increase year by year because sediment stored in the reservoir during a year is not fully washed away. Accordingly, the effective storage capacity of the reservoir will decrease. Hence annual energy will vary year by year. An average reservoir capacity curve during 50 years after completion of the Project is to be used for energy calculation, because the economic and financial evaluation of the Project is conducted for 50 years after completion.

The average sediment volume in the reservoir for 50 years after the completion of the Project is 71.5 MCM in the case of every year flushing with FSL at EL. 415 m. The volume of 71.5 MCM approximately equals to that 23 years after Project completion (71.3 MCM). For the reason, the reservoir capacity curve 23 years after completion of the Project is used for the annual energy calculation. **Fig. 11.6.2-1** shows both reservoir capacity curve without sediment and that 23 years after Project completion.

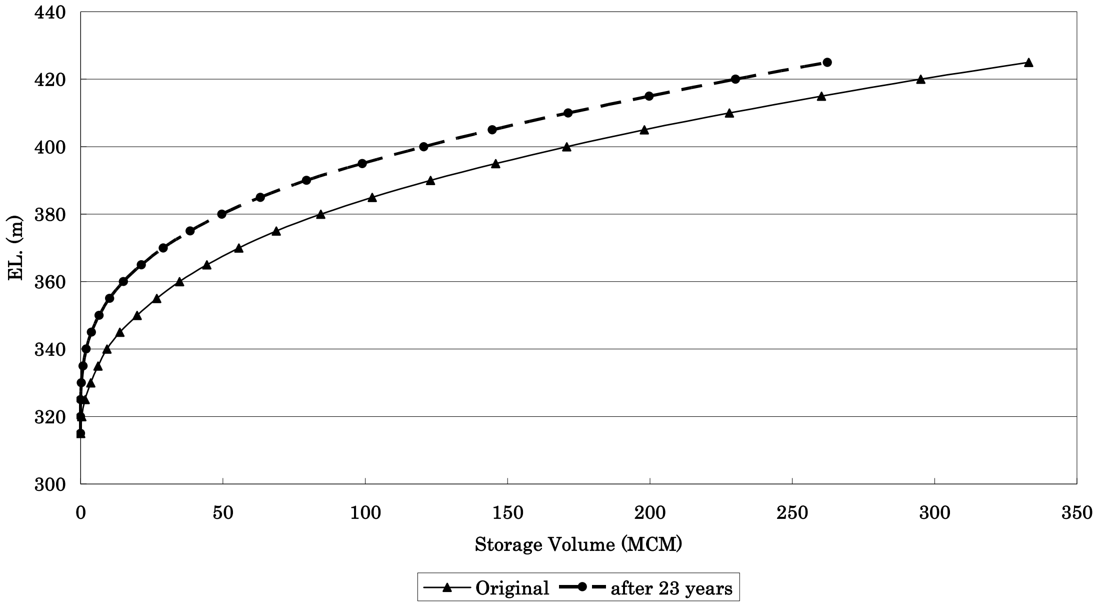

Fig. 11.6.2-1 Reservoir Capacity Curve without Sediment and after 23 Years

11.6.3 Annual Energy Calculation with Sediment Flushing

The calculation of the effective head with the optimum diameters described **Section 11.3** is attached in Appendix Chapter11, and the installed capacity of the Project is 127 MW.

The result of annual energy calculation with the conditions mentioned **Section 11.6.2** is summarized below:

Upper Seti Hydropower Plant	Primary:	216.9 GWh
	Secondary:	252.5 GWh
Generation Facility for Environmental Flow	Secondary:	15.0 GWh
	Total of Secondary:	267.5 GWh
	Total	484.4 GWh