2. PANCHESHWAR HIGH DAM

2.1 INTRODUCTION

PHD is the major component of PMP. It comprises a 315 m high rock fill dam, a spillway, two underground powerhouses and associated structures. Upon completion, PHD will rank amongst the tallest dams in the world, second only to Rogun Dam that is presently under construction in Tajikistan.

2.2 LOCATION

PHD is proposed on the Mahakali River at Pancheshwar village, about 2.5 km downstream of the confluence of Mahakali with the Saryu River (Figure 1-1, Figure 1-2). Its project area, including its reservoir, spreads across latitudes 29° 7' 30" N and 29° 48' N and longitudes 79° 55' E and 80° 35' E. This area abuts on Darchula and Baitadi Districts of Nepal and Dharchula and Champawat Districts of Uttarakhand, India.

PHD is located approximately 520 km west of Kathmandu and 290 km east of New Delhi. The nearest Nepali towns to the dam site, Mahendranagar and Amargadhi, are situated 70 km south and 60 km west, respectively.

2.3 ACCESS

Vehicular access to the PHD site is currently available only through India via a 40 km long all-weather road from Lohaghat in Uttarakhand State. The dam abutment in Nepal, and all of the proposed project infrastructure and facilities, borrow areas, quarry sites and spoil disposal areas within the Nepali territory can only be accessed through foot trails.

Vehicular access to settlements along the PHD reservoir is also generally available through India. A few settlements in Nepal, such as Jhulaghat of Baitadi District and Joljibi and Dattu of Darchula District, can be accessed from road heads in India through pedestrian bridges built across the Mahakali River. Jhulaghat can also be reached on vehicle from Satbanjh on the Mahakali Highway in Nepal. This highway also connects to some of the upper parts of the PHD reservoir along the Chameliya River. A 6 m wide earthen road connects Joljibi and Lali settlements that lie on the reservoir rim. This road will be submerged by the reservoir.

2.4 PRINCIPAL PROJECT COMPONENTS

The planning and design of PHD, its appurtenances and its facilities have evolved over six decades. In the present design (PACO, 1992a; PACO, 1992b), the principal components of PHD are its dam, reservoir, spillway, power intake, headrace tunnel, powerhouse complex

and switchyard (Figure 2-2). These components are briefly described below, and their salient features are listed in Table 2-1.

2.4.1 Main Dam

PHD is a 315 m high, rock-filled zoned storage structure with a central clay core (Figure 2-3). Its crest length is 860 m, and its crest elevation and deepest foundation level are 695 m amsl and 380 m above mean sea level (amsl), respectively. The volume of dam mass will be 62.7 million m^3.

Photo 2-1: PHD site

2.4.2 Reservoir

The PHD reservoir, formed by the damming of the Mahakali River, will extend from Pancheshwar to Dattu Village Development Committee (VDC) of Darchula District along the Mahakali River and up to Gokuleshwar VDCs of Baitadi and Darchula Districts along the Chameliya River. It will have a total surface area of 13,400 ha, of which 3,850 ha will lie in Nepal. The reservoir will have a Minimum Operation Level (MOL) of 615 m amsl and a Normal Maximum Water Level (NMWL) of 680 m amsl, resulting in a depletion depth of 65 m. The total storage volume of the reservoir at NMWL will be 12.26 billion m^3, of which the live storage volume will be 6.56 billion m^3.

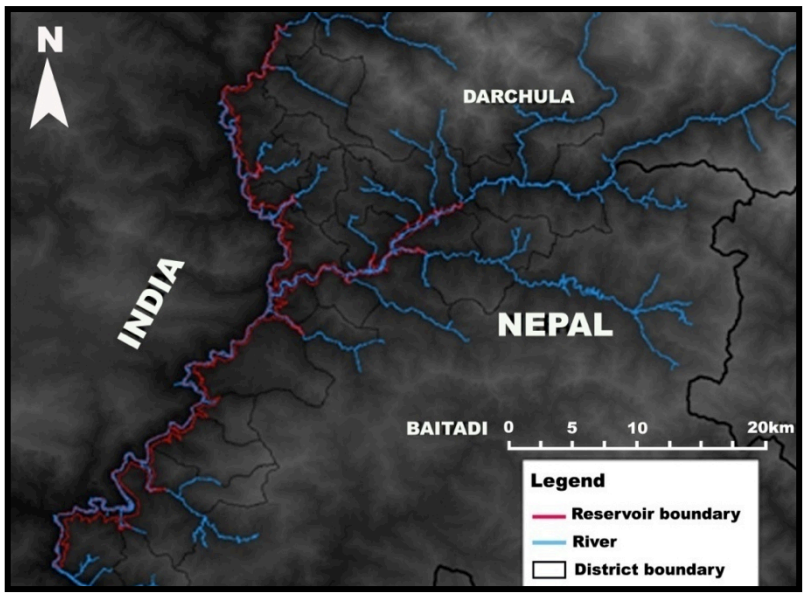


Figure 2-1: PHD reservoir area in Nepali territory

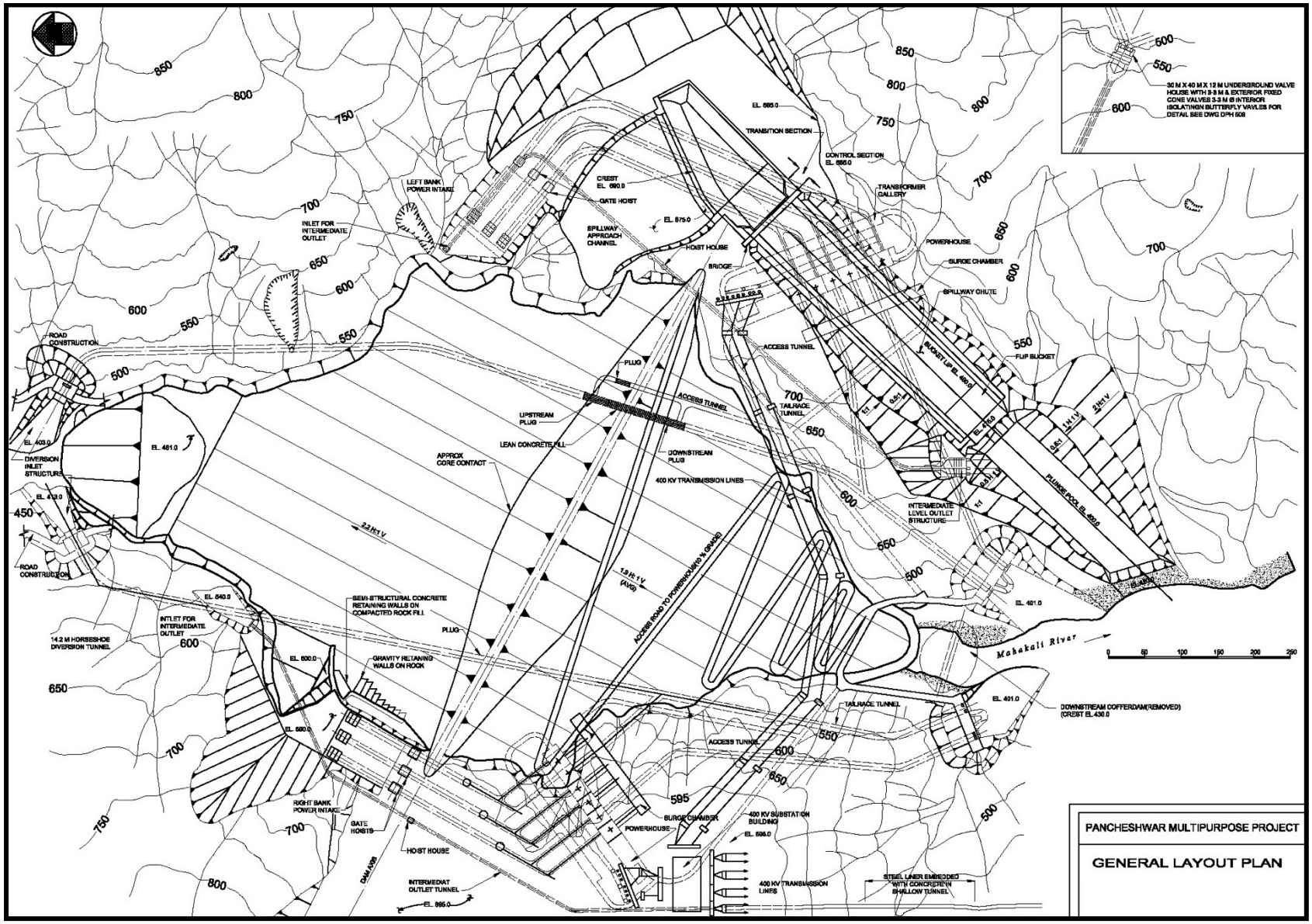
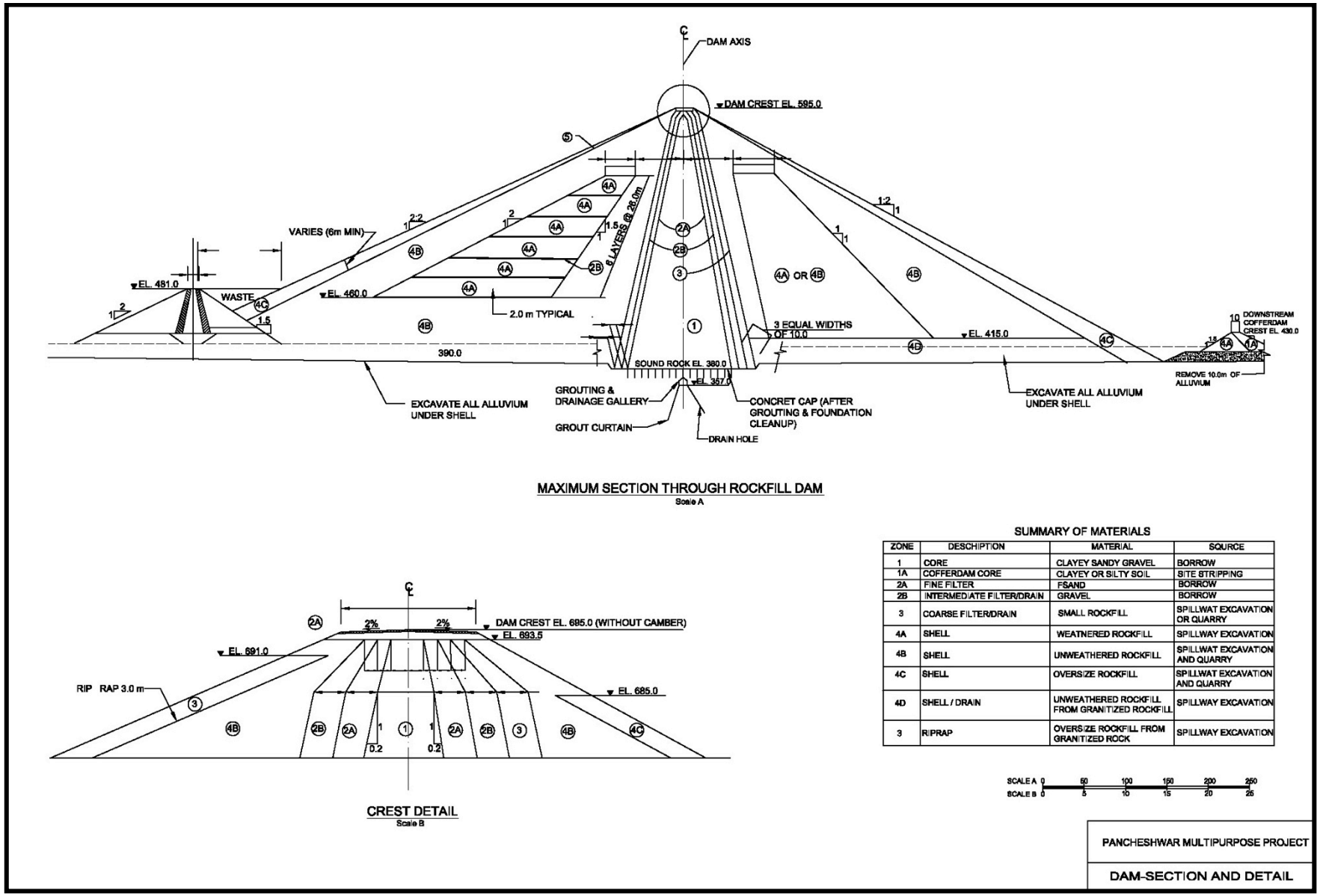


Figure 2-2: General layout of PHD



SUMMARY OF MATERIALS

ZONE	DESCHIPTION	MATERIAL	SOURCE
1	CORE	CLAYEY SANDY GRAVEL	BORROW
1A	COFFERDAM CORE	CLAYEY OR SILTY SOIL	SITE STRIPPING
2A	FINE FILTER	FSAND	BORROW
2B	INTERMEDIATE FILTER/DRAIN	GRAVEL	BORROW
3	COARSE FILTER/DRAIN	SMALL ROCKFILL	SPILLWAT EXCAVATION OR QUARRY
4A	SHELL	WEATNERED ROCKFILL	SPILLWAY EXCAVATION
4B	SHELL	UNWEATHERED ROCKFILL	SPILLWAT EXCAVATION AND QUARRY
4C	SHELL	OVERSIZE ROCKFILL	SPILLWAT EXCAVATION AND QUARRY
4D	SHELL / DRAIN	UNWEATHERED ROCKFILL FROM GRANITIZED ROCKFILL	SPILLWAY EXCAVATION
3	RIPRAP	OVERSIZE ROCKFILL FROM GRANITIZED ROCK	SPILLWAY EXCAVATION

Figure 2-3: Dam cross-section

2.4.3 Spillway

The main dam has an ogee-shaped, 175 m wide, concrete lined, gateless spillway with sill elevation at 680 m amsl. The spillway will first discharge into a side channel, from where the water will be conveyed to a 400 m long, 70 m wide, trapezoidal chute spillway, which in turn terminate with a flip bucket discharging into the terminal plunge pool. The spillway can pass the 18,000 m^3/s of water with a maximum exceptional reservoir water level of 693.3 m amsl, leaving 1.7 m freeboard on the dam crest. The spillway will be constructed adjacent to the dam on the left abutment, i.e. on the Nepali side, in Gankatya and Rol villages.

2.4.4 Conveyance System

On each bank, three power intakes will supply water from the reservoir to three, 10 m diameter, concrete-lined low-pressure power tunnels (Figure 2-4). Each tunnel will pass 512 m^3/s of water, which will be conveyed to the powerhouse through 8 m diameter, steel-lined vertical shafts and short, high-pressure tunnels with terminal bifurcations.

2.4.5 Powerhouse with Tailrace Outlet Structure

Two underground powerhouses, one on each bank, are proposed. Each powerhouse will accommodate six, 540 MW vertical Francis generator units. Upstream transformer caverns, containing high and low voltage electrical equipment, are provided with each powerhouse cavern. Two tailrace channels, one of which connects to the diversion tunnel, convey water from the powerhouse back to the river. A downstream surge chamber cavern is provided with each powerhouse.

2.4.6 Substation

A 400 kV surface substation is provided for power evacuation. It will be connected to the transformer cavern through a bus duct shaft.

2.4.7 River Diversion Structures

River diversion for construction will be achieved through two cofferdams on the Mahakali River. The upstream cofferdam will be a 71 m high embankment rock-fill structure with crest elevation at 461 m amsl, while the downstream cofferdam will be 40 m high rock-fill structure with crest elevation at 430 m amsl. The upstream cofferdam will be incorporated into the main dam.

Water diverted from the upstream cofferdam will be routed through 1,500 m long, concrete-lined diversion tunnels, one on each abutment. The tunnels are designed to pass the 1 in 500 years flood without overtopping of the upstream cofferdam. Both tunnels will be horseshoe shaped, with 12.2 m width and 17 m height. After diversion closure, the lower parts of both tunnels will be used as a part of tailrace tunnel.

2.4.8 Access Roads

In Nepal, the PHD site will be linked with the East-West Highway through the 135 km long Brahamadev-Pancheswar Access Road proposed along the Mahakali River. A 64 km long access between Patan in Baitadi district and Pancheshwar is also proposed. This road will connect the PHD site with the Mahakali Highway.

Other roads, such as haul roads, link roads and service roads, will be located in the vicinity of the dam site, borrow and quarry sites, waste disposal areas and other project facility sites (Figure 2-5). In addition, an approximately 50 km long ring road is envisaged along the reservoir area connecting the PHD site to the upper reaches of the reservoir (up to Dattu village of Darchula).

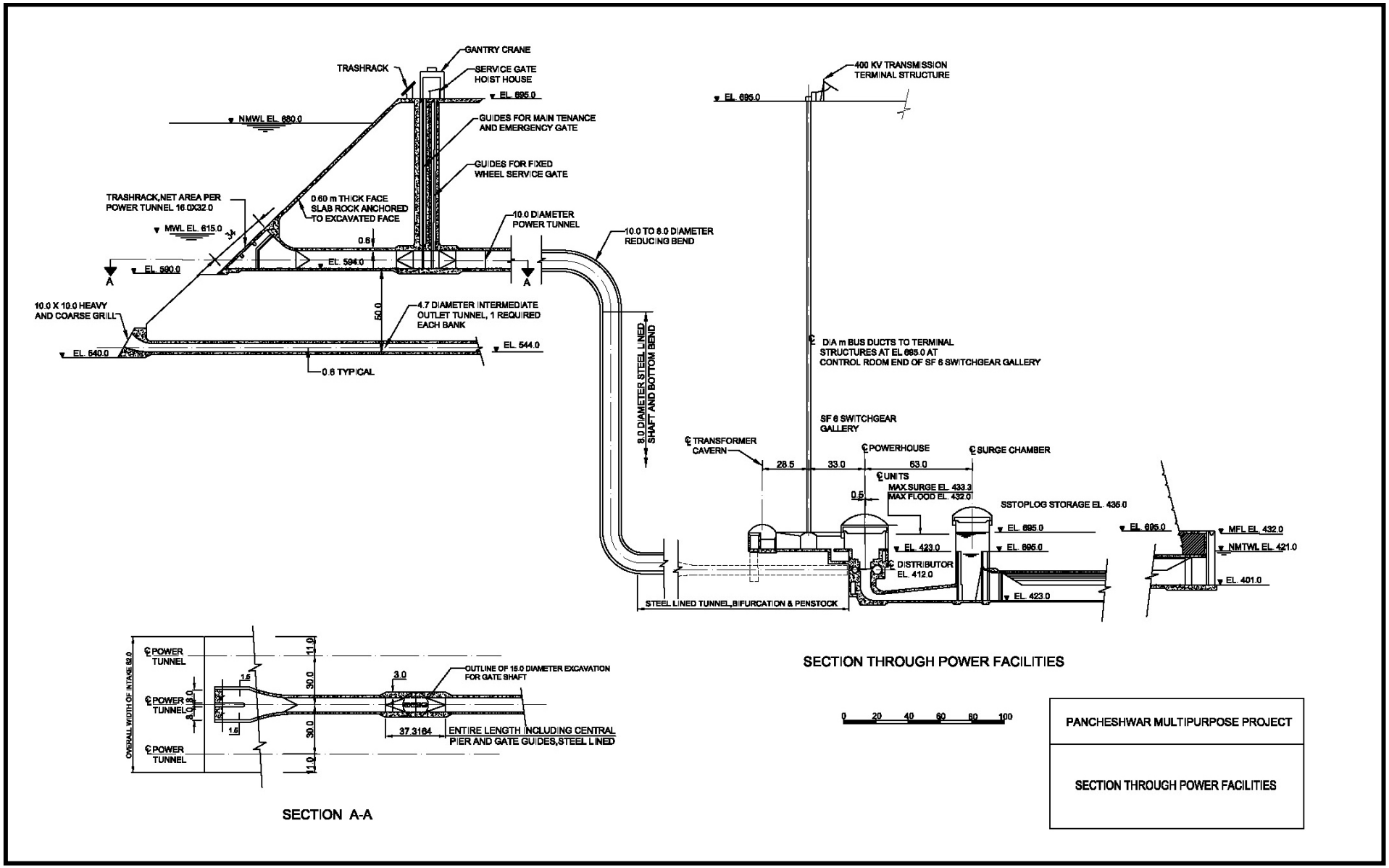


Figure 2-4: Section through power facilities

Table 2-1: Salient features of Pancheshwar High Dam (EDC, 1995a)

Hydrology	
Drainage area	12,100 sq. km (2,380 in Nepal and 9,720 in India)
Average flow	582 m^3/s
Design flood	23,500 m^3/s
Annual sediment load	64 million T
Probable maximum flood	23,237 m^3/s
Reservoir	
Normal Maximum Water Level	680 m amsl
Minimum Operating Level	615 m amsl
Live storage	6.56 billion m^3
Dead storage	5.7 billion m^3
Surface area at NMWL	13,400 hectares (total), 3,850 hectares in Nepal
Dam (Zoned rock-fill with central clay core)	
Height	315 m
Crest elevation	695 amsl
Crest length	860 m
Deepest foundation elevation	380 amsl
Slopes	Upstream face: 2.2:1, downstream face: 1.9:1
Volume of dam	62.7 million m^3
Spillway (Side channel, free overflow type)	
Probable Maximum Flood	23,500 m^3/s
Ogee crest elevation	680 m amsl
Maximum Flood level	693.3 m amsl
River Diversion Works	
Diversion flow	8,000 m^3/s
Number of diversion tunnels	Two (one on each bank of Mahakali River)
Length of diversion tunnels	1,500 m
Tunnel dimension	12.2 m wide, 17 m high, horse shoe
Upstream coffer dam	Rockfill type, 71 m high
Downstream coffer dam	Rockfill type 40 m high
Power Facilities	
Powerhouse	Two underground powerhouses (one each in Nepal and India)
Net design head	236.8 m
Installed capacity	6,480 MW
Generating units	12x540 MW (6 in Nepal and 6 in India)
Firm capacity	4,850 MW
Plant Factor	0.2
Firm energy	8,216 GWh/year
Total energy	10,671 GWh/year
Implementation Period	
Total implementation period	13.5 years
Estimated Cost (as of 1995)	
Total implementation cost	US $ 3,730 million
Unit cost of installed capacity	US $ 550/ kW

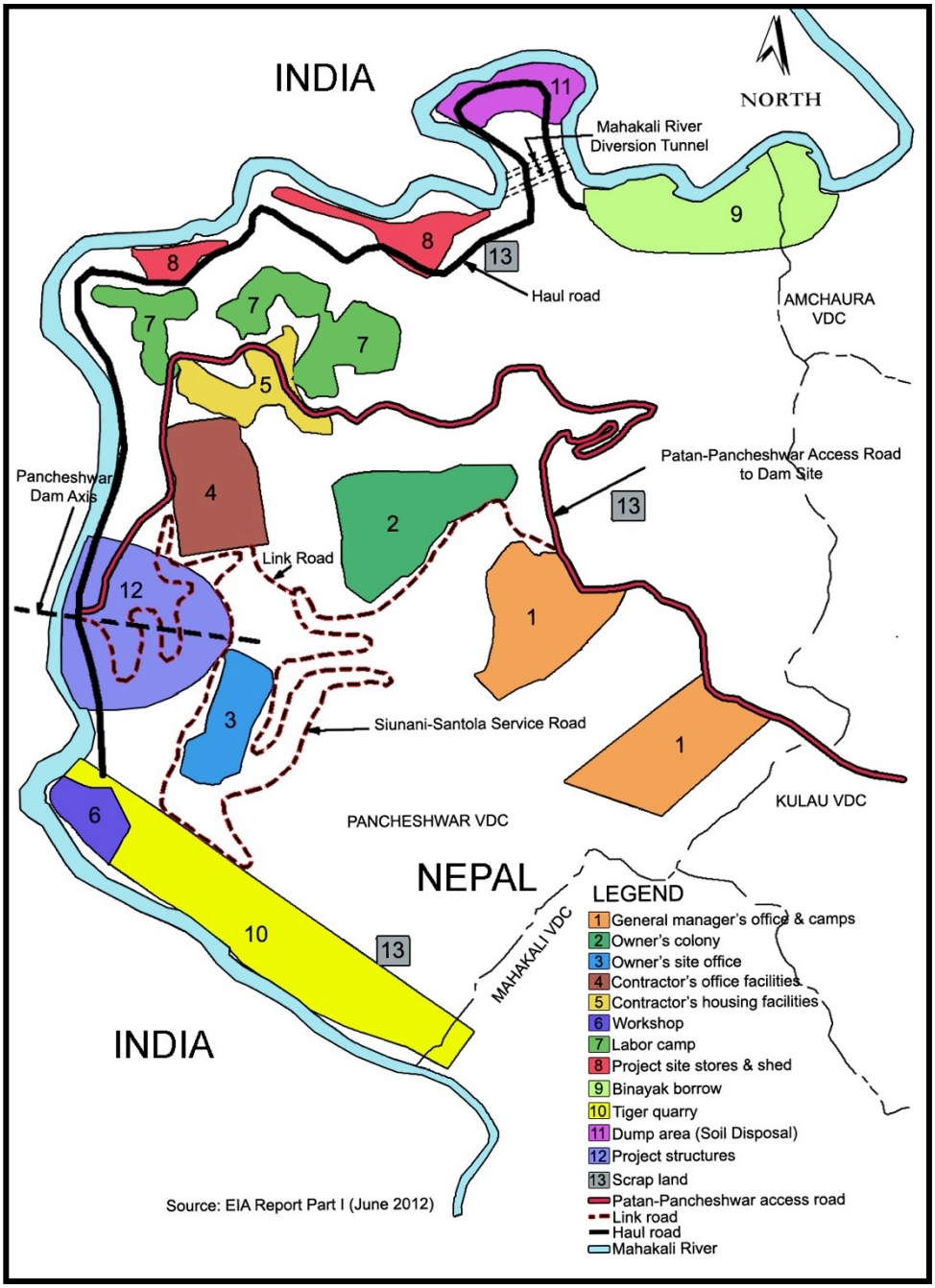


Figure 2-5: Project infrastructures and facilities

2.5 PROJECT OFFICES AND CAMPS

The proposed project offices and camps for PHD include the General Manager's office and camps, owner's colony, owner's site office and project site stores and shed. These facilities are proposed at or around various settlements of Pancheshwar VDC.

2.5.1 General Manager's Office and Camps

Two sites within Pancheshwar VDC, viz. Lek (Ward No. 1) and Paladi (Ward No. 2), are identified for the office and residences for the General Manager's Office and Camps (Figure 2-5). Of these, the Lek site appears preferable due to its proximity to the main water supply tank at Siunani.

Infrastructure facilities for office and residence accommodation are planned for 75 persons. The premise is divided into five zones, viz. housing for senior staff (General Manager, Financial Advisor, Chief Engineer) and support staff, social infrastructure facilities (school,

health center and play area), office complex, guesthouses and helipad and, lastly, water tank and recreation.

2.5.2 Owner's Colony

The Owner's Colony is planned on a hilltop near Siunani and Dhamkudi settlements, about 2 km east of the dam site (Figure 2-5). The colony consists of housing for executives, junior and assistant engineers, social infrastructure facilities (hospital, housing for medical staff, etc.), sports, recreation facilities, school, services (police station, fire station, offices and commerce), water reservoir, guesthouse and helipad.

2.5.3 Owner's Site Office

The Owner's Site Office is proposed in Santola settlement (Figure 2-5). The infrastructure and facilities at this site include offices for senior executives, executives and other engineers, sports, playground, guesthouse, helipad and water reservoir. The site can be assessed from the Patan – Pancheshwar access road.

2.5.4 Project Site Store and Shed

The Site Store and Shed for the PHD will be located in Aptyad and Dumnaula settlements on the left bank of the Mahakali River (Figure 2-5), close to Pancheshwar temple. The sites lie along the proposed haul road which links Binayak borrow area, the main disposal area and the Tiger Quarry.

2.6 CONTRACTORS' AND LABOR CAMPS

Facilities for contractors include housing, offices and labor camps. These are proposed at Dhamkudi, Chamtada, Aptyad and Suryakhal settlements of Pancheshwar VDC.

2.6.1 Contractors' Office

The Contractors' Office will be developed in Chamtada settlement (Figure 2-5). This site will contain offices for contractors' executives and engineers, facilities for sports, dining and recreation, guesthouse, helipad and water reservoir. The site will be linked to the proposed Patan – Pancheshwar access road leading to the dam site.

2.6.2 Contractors' Housing

The Contractors' Housing is proposed in the upper parts of Dhamkudi settlement (Figure 2-5). This site contains housing and related facilities for contractors, including residences for executives and engineers, technical staff dormitory, offices, guesthouse, hospital, school, playground, housing for medical and teaching staff, police station, fire security office and water reservoir. It will be linked to the proposed Patan – Pancheshwar access road.

2.6.3 Labor Camps

Labor camps are proposed at Suryakhal and the upper part of Aptyad settlement (Figure 2-5). A total of 440 sq. m of sheds for laborers' shed, divided in blocks to accommodate 20 workers each, is planned. The campsites will be linked to the Patan – Pancheshwar access road.

2.7 WORKSHOP

The PMP DPR (EDC, 1995c) earmarks an area of about 35 ha for a workshop combined with stores, warehouse yard and equipment park. This area will house about 65,000 m^2 of buildings and sheds, including surrounding stores.

Although the PMP DPR does not elaborate on the workshop locations, a subsequent study on infrastructural requirements has allotted an area of 18.4 ha for workshops within Nepal (ITECO, 2002). This workshop is proposed within the Tiger Quarry site (Figure 2-5) on the left bank of the Mahakali River, about 1.5 km downstream of the dam site.

2.8 CONSTRUCTION PLAN

Construction of PHD is scheduled to be complete in 13.5 years (Figure 2-6). This period includes the pre-construction phase, during which additional field investigations, detailed designs, tendering of various components, land acquisition and resettlement and rehabilitation works will be performed.

Construction of access roads, camp facilities and other infrastructure will start only towards the end of the second year. The actual works on the project structures will commence in the first quarter of the fourth year, when construction of the cofferdams and diversion tunnels will begin. Because of the large height of the upstream cofferdam, construction of these structures will be done in stages.

Initial works on the main dam, such as excavation, foundation preparation, embankment, etc., will start by the first quarter of the fourth year, and construction of the main dam will commence by middle of the sixth year. The spillway construction will start along with the initial works of the main dam and will last for 82 months. Construction of intermediate-level outlets will start in the middle of the fifth year and will be completed in 63 months. Works on the conveyance system will begin from the middle of the fourth year and will be finished in six years. Excavation of powerhouse facilities will start from the sixth year and last for 18 months. Concreting of these facilities will start three years later and will span over five years. Testing and commissioning of units (12 in total) will take about three years, starting from the middle of the eleventh year.

2.9 CONSTRUCTION MATERIALS

The construction material required for the PHD main dam are listed in Table 2-2.

Table 2-2: Materials required for main dam (EDC, 1995b)

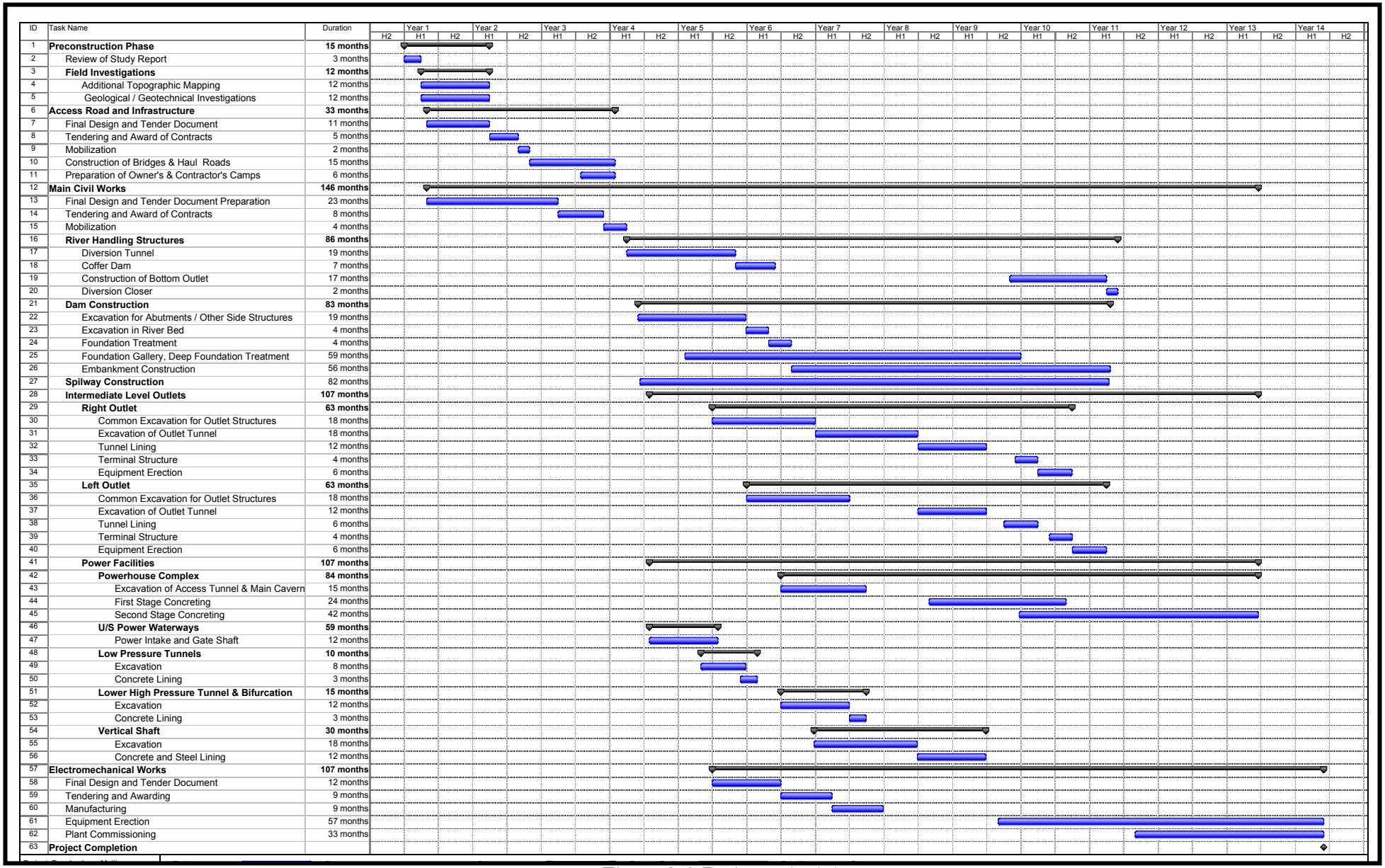
Type of material	Volume (million m^3)
Impervious material	5.8
Transition material	3.0
Filter and drains	4.5
Rock-fill	48.8
Structural concrete	1.0
Total	63.1

2.10 BORROW AREAS

Field investigations conducted in 1983 and between 1989 and 1991 confirmed four borrow sites in Nepal and India. These sites were located at Kharyani, Ratomato – Buddha and Khariyani in Baitadi, Nepal, and at Phulhindola in India (Table 2-3).

Table 2-3: Proposed borrow areas for PHD (EDC, 1995b; EDC, 1995c)

SN	Borrow site	Location	Distance from dam (km)	Material
1	Kharyani	Upstream of dam site, just below Ratomato	15	Filter and drain material/ high quality concrete aggregate; 1.5 million m^3 of clean sand, gravel, boulders
2	Ratomato – Buddha	Just above (1 km) Kharyani village, Baitadi	16	Impervious core material; 20 million m^3 of sand and gravel
3	Pulhindola	Southwest of dam site, in India	6	Impervious material
4	Binayak	Upstream of dam site, along Mahakali River	6	10.8 million m^3 of sand and gravel



ID	Task Name	Duration
1	**Preconstruction Phase**	**15 months**
2	Review of Study Report	3 months
3	**Field Investigations**	**12 months**
4	Additional Topographic Mapping	12 months
5	Geological / Geotechnical Investigations	12 months
6	**Access Road and Infrastructure**	**33 months**
7	Final Design and Tender Document	11 months
8	Tendering and Award of Contracts	5 months
9	Mobilization	2 months
10	Construction of Bridges & Haul Roads	15 months
11	Preparation of Owner's & Contractor's Camps	6 months
12	**Main Civil Works**	**146 months**
13	Final Design and Tender Document Preparation	23 months
14	Tendering and Award of Contracts	8 months
15	Mobilization	4 months
16	**River Handling Structures**	**86 months**
17	Diversion Tunnel	19 months
18	Coffer Dam	7 months
19	Construction of Bottom Outlet	17 months
20	Diversion Closer	2 months
21	**Dam Construction**	**83 months**
22	Excavation for Abutments / Other Side Structures	19 months
23	Excavation in River Bed	4 months
24	Foundation Treatment	4 months
25	Foundation Gallery, Deep Foundation Treatment	59 months
26	Embankment Construction	56 months
27	**Spilway Construction**	82 months
28	**Intermediate Level Outlets**	**107 months**
29	**Right Outlet**	**63 months**
30	Common Excavation for Outlet Structures	18 months
31	Excavation of Outlet Tunnel	18 months
32	Tunnel Lining	12 months
33	Terminal Structure	4 months
34	Equipment Erection	6 months
35	**Left Outlet**	**63 months**
36	Common Excavation for Outlet Structures	18 months
37	Excavation of Outlet Tunnel	12 months
38	Tunnel Lining	6 months
39	Terminal Structure	4 months
40	Equipment Erection	6 months
41	**Power Facilities**	**107 months**
42	**Powerhouse Complex**	**84 months**
43	Excavation of Access Tunnel & Main Cavern	15 months
44	First Stage Concreting	24 months
45	Second Stage Concreting	42 months
46	**U/S Power Waterways**	**59 months**
47	Power Intake and Gate Shaft	12 months
48	**Low Pressure Tunnels**	**10 months**
49	Excavation	8 months
50	Concrete Lining	3 months
51	**Lower High Pressure Tunnel & Bifurcation**	**15 months**
52	Excavation	12 months
53	Concrete Lining	3 months
54	**Vertical Shaft**	**30 months**
55	Excavation	18 months
56	Concrete and Steel Lining	12 months
57	**Electromechanical Works**	**107 months**
58	Final Design and Tender Document	12 months
59	Tendering and Awarding	9 months
60	Manufacturing	9 months
61	Equipment Erection	57 months
62	Plant Commissioning	33 months
63	**Project Completion**	

Figure 2-6: Project schedule

Among the borrow areas identified in Nepal, the Kharyani borrow site, located 15 km upstream of the dam site, contains about 1.5 million m^3 of clean sand, gravel and sound boulders suitable for concrete aggregates or filter and drain material. It also contains a weathered mixture of well-rounded silty sand and gravel.

The Ratomato – Buddha borrow area, located just above Kharyani settlement about a km upstream, contains about 20 million m^3 material, ranging from reddish-brown clayey, sand to clayey and sand to clayey gravel, suitable for the impervious core of the rock fill dam. Access to this site is feasible along the Mahakali River, except for a short stretch of vertical cliffs.

The Binayak borrow site is located in Binayak settlement of Amchaura VDC, about six km upstream from the PHD site (Figure 2-5). The site contains about 10.8 million m^3 of excellent quality sand and gravel for either concrete aggregate or filter and drain material. This borrow site will be submerged in the reservoir.

2.11 QUARRY SITES

The 1983 and 1989 – 1991 field investigations identified four quarry sites – Tiger Quarry, Leopard Quarry and Little Elephant Quarry in Nepal and Big Elephant Quarry in India. Of these, the first two sites were discarded on grounds of difficult and costly transportation, and the remaining two were considered for construction of PHD.

Table 2-4: Proposed quarry sites for PHD (EDC, 1995b; EDC, 1995c)

SN	Quarry site	Location	Distance from dam (km)	Material
1	Little Elephant	On spillway approach (left bank, in Nepal)	Close to dam site	Concrete aggregate, rock fill and riprap material
2	Big Elephant	Along dam axis (right bank, in India)	Close to dam site	Concrete aggregate, rock fill and riprap material

The Little Elephant Quarry is located on left bank at the spillway approach channel. This site is considered as a quarry for the spillway approach, and it will be used, if needed, during the peak of rock fill work only.

The Big Elephant Quarry is located within the dam site along the right bank in India. Concrete aggregate, rock fill and riprap material can be obtained from this quarry site. The main advantage of this quarry site is its proximity to the dam site.

2.12 SPOIL DISPOSAL SITE

The spoil disposal site is proposed in the Parkoti settlement area of Pancheshwar VDC, on a U-bend of the Mahakali River about 6 km upstream of its confluence with the Saryu River (Figure 2-5). About 15 million m^3 of common excavation and rock excavation, which cannot be utilized for the dam embankment, will be disposed off at this site. This area will also be submerged in the reservoir.

2.13 MAIN DISPOSAL AREA AND DAM FILTER PROCESSING PLANT

The main disposal area is situated at about 3.5 km northeast of the confluence of the Saryu and Mahakali Rivers, on the U-turn of the Mahakali River near Bhora. The proposed area is created by diverting the Mahakali River through two tunnels.

The processing plant for dam filter material will be located at the main disposal area after compacting and leveling the latter. An estimated 1,920,000 m^3 of sand and gravel will be processed at this plant from the alluviums of the Mahakali River bed near Binayak area and from the intermediate and coarse filters from the initial excavations of the dam riverbed stockpiled close to the processing plant.

2.14 CONSTRUCTION STAFFING

The owner, consultants and contractors will require sizeable staffing during construction of PHD and its associated facilities. The owners and consultants will employ various levels and categories of staff for project management, design, construction supervision and support services. Likewise, the various contractors engaged in the civil, electromechanical and hydro-mechanical works of the project will employ managers, engineers, supervisors and different classes of laborers (skilled, semi-skilled and unskilled).

Initial estimates for peak-time construction workforce for the construction of PHD and its associated facilities stand at 5,000, consisting of 1,000 supervisory positions and 4,000 semi-skilled and unskilled laborers (PACO, 1992a). About 75% of the semi-skilled and unskilled laborers were estimated to be in-migrants. Revised estimates prepared in 2002 increased the total work force to 8,000, comprising 1,500 in supervisory positions and 6,500 laborers (ITECO, 2002). About half of the total revised work force was expected to be in-migrants from India.

The 2002 study estimated that housing facilities and other infrastructure/facilities in PHD camps would have to be planned for a total of 4,400 persons annually. Of these, 400 would be living and working in the Project Office and Owner's Camp, 750 would be present in the contractors' camps and 3,250 would be living in labor camps.