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Environmental Impact and Management Plan for Alaknanda H.E. Project, Uttarakhand

Prepared for :
GMR Energy Limited, New Delhi

CENTRE FOR INTER-DISCIPLINARY STUDIES OF MOUNTAIN & HILL ENVIRONMENT
University of Delhi, Delhi

EXECUTIVE SUMMARY

1. INTRODUCTION

Geographically Uttarakhand is situated between 28□43'45" to 31□8'10" N latitude and 77□35'5" to 81□2'25" E longitude. For administrative purpose Uttarakhand state is divided into 13 districts (Fig 1). According to the Census of India, 2001 the population of the state is 84,89,349, which is 0.8 per cent of the total population of India. People of all faiths – Hindu, Muslims, Christians, Sikhs and Bodhs – live in the state, though majority of population is of Hindu faith.

The present project, Alaknanda Hydro-electric project (300 MW) is located in Joshimath tehsil of Chamoli district in Uttarakhand. The total population of Joshimath tehsil is 39,919 (Census, 2001). There are around 16 villages in the vicinity of the Alaknanda H.E. project (within 10 km radius from the project sites). These villages fall under six revenue villages, namely Khirao, Mana, Badrinath, Lambagar, Binayak Chatti and Pandukeshwar. Only Khirao is directly affected due to the different project activities.

1.1 Salient Features of Alaknanda H.E. Project

The 300 MW Alaknanda H. E. project is proposed on Alaknanda River. Alaknanda H.E. Project is proposed to be a Run of the River scheme. The project propose to generate 300 MW of power and involves construction of a 18 m high diversion barrage across the Alaknanda river 3 km downstream of Badrinath town. The 2.87 km long headrace tunnel will be of a horseshoe shape and 4.3 m dia and an underground power house is proposed near Khirao Ganga (Fig. 2). The tail water will be discharged through an underground tail water tunnel upstream of tail of reservoir of under operation Vishnuprayag H. E. project. The salient features of the project are given in Table 1.

Table 1. Salient features of Alaknanda H.E. project

1. LOCATION	
State	Uttarakhand

District	Chamoli
River	Alaknanda
Location of Barrage site	3 km downstream of the Badrinath Shrine on the Alaknanda River
	79^0 29.7'E, 30^0 43.4' N
Location of Power House	79^0 30.3'E, 30^0 41.2' N
2. HYDROLOGY	
Catchment area at the Barrage Site	1015.93 sq km
Snow Catchment	660 sq km
Design flood (SPF)	1780 m^3/s
PMF	2880 m^3/s
3. BARRAGE & RESERVOIR	
Type	Gated Barrage
FRL	2922.0 m (three units operating)
Reservoir Area	2.27 ha
MOL	2920.5 m (one unit operating)
Average river bed level at axis	2905.0 m
Width of barrage	40 m
Sill Level	2907.0 m
Design discharge	1780 m^3/s (SPF)
Gates	4 No radial gates, 7m wide x 15.5 m high
4. INTAKE STRUCTURE	
Width of Intake	4 x 10m openings at the screens
Orientation with respect to barrage axis	90^0
Regulating gates	2 Nos. 3.5 m wide x 3.5 m high
Design discharge	68.5 m^3/s (including silt flushing discharge)
5. DESILTING ARRANGEMENT	
No. and size of desilting galleries	2 nos. 11 m wide x 11.4 m deep (settling zone)
Length	250 m
Particle size to be excluded	0.20 mm and above
Flow through velocity	0.24 m/s
6. HEAD RACE TUNNEL	
Size and type	4.3 m dia horseshoe section
Velocity	3.68 m/s

Length	2,886 m
Design discharge	57.1 m^3/s
Slope	1:98
7. SURGE SHAFT	
Type	Underground, restricted orifice
Diameter	15.0 m
Height	46 m
Orifice Diameter	4.2m
Top level	2941.0 m
Bottom level	2895.0 m
Maximum upsurge	2936.0 m
Minimum down surge	2906.8 m
Adit at Top	5 m dia D-section
8. PRESSURE SHAFT	
Main penstock	775 m long x 3.6 to 3.0 m dia
Branches	1.8 m dia (unit penstocks)
9. POWER HOUSE	
Type	Underground
Installed capacity	300 MW
Size of Power house	85.0 m x 20.0 m x 39.82 m
Gross head	621.8 m
Net head	603.20 m
Centre line of jet	El.2300.2
10. TAILRACE	
Type	5 m dia D-section
Length	1780 m
No. & Size of unit duct	3 Nos., 3.5 m dia D-section
Bed gradient	1:300
Draft tube gates	3.5 m wide x 3.5 m high
Highest Flood Level	2283 m approx
11. TURBINE	
No. & Type	3 nos. Pelton, vertical axis
Rated Power	100.0 MW
Rated net head	603.20 m
Max / Min net head	619.04 m/ 603.20 m

Rated discharge	19.1 m^3/s per unit
Speed	300 rpm
Specific speed	32.13
Wheel Pitch Diameter	3.33 m
12. MAIN INLET VALVE	
Type	Spherical Valve
Diameter	1.6 m
Location	Inside machine hall
13. GENERATOR	
Type	Synchronous
Numbers	3
Rated Capacity	100 MW
Speed	300 rpm
No. of Phases	3
Frequency	50 Hz
Power Factor	0.9
Rated Terminal Voltage	11 kv
Excitation System	Thyristor excitation system
14. GENERATOR STEP UP TRANSFORMER	
Location	Inside Transformer cavern
No.	10
Rated	Bank of 3 1- ϕ, 127.65 MVA
Voltage Ratio	11/220/$\sqrt{3}$kV
Frequency	50 Hz
Type of Cooling	OFWF
15. TRANSMISSION LINES (220 kV)	
Type	Double circuit
Terminating Station	Kauripass (Joshimath)
Total Length	17 km
16. ESTIMATED COST (2006 PRICE LEVEL)	
Civil Works (including preliminary and Miscellaneous items)	567.01 crores
Elec / Mech Works	442.70 crores
Transmission Works	20.13 crores
Interest during Construction	296.77 crores

Escalation	125.47 crores
Total project cost	1,452.08 crores
Cost per MW installed	4.84 crores / MW
17. POWER BENEFITS	
90% dependable year	1117.0 GWh (Design energy)
50% dependable year	1278.2 GWh
18. ECONOMIC AND FINANCIAL ASPECTS	
Debt Equity Ratio	70:30
Interest on loan	10.25%
Loan repayment period	12 years
Return on equity	14%
Sale rate of energy	
19. CONSTRUCTION PERIOD	67 months including commissioning

2. PHYSIOGRAPHY

The physiography of a river basin refers to the sculptures on the land surface developed by various geomorphic processes which are controlled by the prevalent climate and the internal dynamism of the earth. The Alaknanda and Saraswati valleys are U-shaped in the initial stretches; a typical feature of glaciated valleys. There are ice pinnacles, rocky knobs, moraines, cirque glaciers, valley glaciers, talus cones in the catchment of Alaknanda river. Huge dumps of rock fragments at the base of hill slopes or valley side floors, known as scree fans, is one of the most common features observed above 4,000 m.

Alaknanda river has two major tributaries, the Saraswati draining the Arwa valley and Dhauliganga coming from Niti Pass. Alaknanda river originates at the water divide between Satopanth and Bhagirath glaciers (near Vashundhara Falls), flows eastward and joins Saraswati river at Mana and then flows in a SE direction up to Joshimath where it meets Dhauliganga. After this confluence, it takes a swerve and starts flowing in the SW direction to meet Bhagirathi river at Devprayag. The drainage network of the Alaknanda watershed up to the proposed barrage site is shown in Fig. 3. River Sarswati is a major tributary of Alaknanda, which receives Arwa Nala, Nagthuni Gad and Anadeb

Gad from left bank. In the downstream of Saraswati confluence, the river Alaknanda is joined by Kanchan Ganga at 2970 m from left bank. The first right bank tributary is Rishi Ganga. It flows eastward and confluences with Alaknanda river on its right bank near Badrinath at 2,960 m near Bamni village. Two streams from Dhamling Dhar region joined Alaknanda at 3,020 and 2,950 m respectively on the right bank. The important large tributaries with substantial water discharge joining the Alaknanda river on left and right bank at 3.36 km and 4.7 km downstream of barrage axis are Ghrit Ganga and Khirao Ganga, respectively. Before confluencing with river Bhagirathi at Deoprayag, river Alaknanda is joined by major tributaries like rivers Birahi, Nandakini, Pindar (left bank tributaries), Balkila and Mandakini (right bank tributaries).

The gradient of the river channel up to power house is 1:10. The gradient of entire course (31 km) of Saraswati river is 1:17. The tributaries joining the Saraswati river on its left bank have high gradient of the order of 1:3.5. The right bank tributaries have low gradient (1:16). The profile of the Rishi Ganga joining Alaknanda on its right bank has high gradient (1:5.8).

In the catchment region of Alaknanda H.E. Project, very steep (50-70%) slope category covers only 2% of the entire catchment. Moderately steep slope (15-20%) category covers about 42% of the total catchment followed by steep slope (30-50%) category covering 29% (Fig. 4). Strongly sloping (8-15%) category has a substantial coverage of 16%. Moderately sloping (2-8%) and gently sloping categories together cover about 11% of the catchment. The gently sloping (0-2%) areas cover 5.3% of the catchment.

The Digital Elevation Model (DEM) formed the basis for the generation of elevation-relief and aspect maps. As evident from the relief map major part (81.5%) of the catchment area lies in the elevational range 4,400 to 6,000 m of which 27.3% lies within 5,200-5,600 m. About 9.0% of the catchment lies within 4,000-4,400 m. Only small portion (0.6%) of the area lies above 6800 m.

The aspect map indicates that in the catchment there is almost equal coverage of the aspects NW-N-NE, NE-E-SE, and SW-W-NW. The slopes with SW-W-NW aspects

are predominant on the left bank of Saraswati and the slopes with NW-N-NE aspects are predominant on its right bank.

3. GLACIERS, GLACIAL LAKES & GLACIAL/ SNOW AVALANCHE HAZARDS

The glaciers are the frozen water reserves in the high altitude regions of Himalaya and are one of the most important natural resources in the region. They act as a source of life by providing fresh water to hundreds of millions of people living in the mountainous region as well as in the adjoining plains. They are also the repositories of information for exploring Quaternary climate changes, as they remain sensitive to global temperature conditions as indicated by their continuous retreat. The fast melting of glaciers and their retreating trend particularly after the industrial revolution is a major concern to scientists and planners in the region.

In the high altitude Himalayan region, many glacial lakes are known to have formed in the last half a century and a number of GLOFs have been reported in the region in the last few decades, particularly from the eastern sector of the region. However, so far, no GLOF event has been reported from the Uttarakhand Himalaya. These changes in climate will inevitably interact with changes in glaciers and glacial lakes. Results show that the recession rate has increased with rising temperature.

The glaciated area in the catchment of Alaknanda H.E. project extends from 30º 42' N to 31º 43' N latitude and 79° 13' E to 79° 37' E longitude. Alaknanda river basin which includes Alaknanda river as well as Dhauliganga river, its major tributary, consists of 457 glaciers, covering an area of 1434.55 sq. km and ice reserves of 170.37 km^3. Most of the glaciers are oriented towards north, northwest, southeast and west. All seven types of glaciers viz. cirque, ice apron, ice cap, mountain basin, mountain glacier, niche and valley glacier are present in this basin. Approximately 870.43 sq. km area covering 60.67% of the catchment is covered with valley glacier followed by mountain basin glacier (356.39 sq. km and 25%) and Mountain glacier (159.85 sq. km, 11.14%). Only 2 sq. km is covered with ice cap. There are 28 valley glaciers.

The glaciers with NW aspects have wide coverage (432.04 sq km, 30.12%) in the basin followed by those with N aspects (346.15 sq m, 24.13%). Less number of glaciers lie on the slope with SW aspects and therefore have minimal coverage in the catchment (1.21%). Maximum numbers of glaciers (134) lie on slopes with northern aspect in the catchment followed by NW slopes (123).

There are 136 glaciers in the Alaknanda river catchment up to barrage site. Most of the glaciers are of Mountain Glacier type (38) or Mountain Basin type (36). However, maximum percentage (59.65%) of area is under Valley Glaciers of which Satopanth is the largest. More than 77% of ice reserve lies in Valley Galciers. Most of the glaciers are oriented towards SE and SW.

There are seven types of glacial lakes viz. blocked, cirque, end moraine, erosion, supraglacial and valley lakes in Alaknanda river basin. These lakes cover an area of 1.03 sq km. There are 27 supraglacial lakes covering 0.43 sq km. The area covered by the largest supraglacial lake is 0.20 sq km. In Alaknanda H. E. project catchment, there are 13 glacial lakes covering total area of 28.21 ha. Majority of these lakes are supraglacial lakes, however, maximum area of lakes is under valley lakes.

Glaciers in many parts of the Himalaya have undergone significant shrinkage in the last century in response to climatic warming, which in some areas is occurring faster than the global average. A particular problem associated with glacier shrinkage is the formation and catastrophic drainage of large **moraine-dammed lakes**, causing significant environmental hazards in many Himalayan valleys. In the Himalaya, large ice-contact lakes form in association with **debris-covered glaciers**, which behave differently to normal, clean glaciers.

The area immediately upstream of barrage site up to Badrinath constitutes the avalanche prone upstream catchment of this project. The tributary streams on both the banks, pose potential hazard for draining assorted debris masses into the river, and block the river channel with the possibility to form temporary lakes. The bursting of the temporary dam formed by the debris has invariably led to flashflood conditions in the

past. There were repeated evidences of such happenings in the recent times as well as the early history of the river. The vegetation cover in the area is scanty. Huge masses of the denudation product lie at slopes and gets gradually transported and deposited in form of debris cones etc. The wind action is severe, which cuts through the rocks making them look craggy. The rain, snow melt, snow slides, avalanches, and wind action are the active agents of sediment transport.

Four streams drains to reservoir are potential source of glacier avalanches and have a renowned history of depositing large amounts of debris brought by avalanche slides with almost annual frequency. In the kind of terrain on the right bank, it would be difficult to construct approach road for HRT and desilting chamber, etc. Any attempt to make roads in this area will destabilize the slopes which will be vulnerable to further damage by avalanches and heavy landslides. It will create serious environmental hazard in area, which is ecologically sensitive.

4. HYDROMETEOROLOGY

The hydrometerological parameters play an important role in determining the discharge and sediment load in a basin. Thus, the hydrometeorological regime of a river basin not only manifests the prevalent environment of the basin but also determines the setting up and viability of any developmental project in it. Alaknanda is a parent stream of the Ganga. Alaknanda basin is situated in southern slopes of the outer Himalayas. The total catchment area of Alaknanda up to the proposed barrage site is 1,015 sq km.

Badrinath falls on the 900 mm isohyet (annual average rainfall), which is in the catchment of the Alaknanda H.E. project, is drier with about an 800 mm average rainfall. In the Joshimath about 64% of the total rainfall (1109.6 mm) falls in the monsoon period (May-Sept) amounting to 714.4 mm. The rainfall during the monsoon period at Badrinath amounts to 469.62 mm. During the winter, at these altitudes, all precipitation falls as snowfall.

Summer temperatures at barrage site peak before the onset of the monsoon in May/June at around 20°C, whilst the minimum average temperature is in January. During the night, temperatures in the mid-winter fall to well below zero at the barrage site, with the minimum daily winter temperatures falling as low as -10°C. The lowest temperature of -15°C recorded at Joshimath in the month of January 1974 and the highest temperature of 34°C was recorded in the month of June 1978. During the winter months the temperature at Badrinath can go down up to -6°C. During the monsoon period the temperature rises up to 20-25°C and 25-35°C at Badrinath and Joshimath, respectively. The water temperature at Vishnuprayag, downstream of the Alaknanda power station varies from -4°C to +10°C. The relative humidity in the Joshimath region during the monsoon season ranges from 45-90%. The wind speed at Joshimath in Alaknanda valley usually vary from 1-19 km per hour in E, NE, SE or SW directions.

The year-wise variation of annual total discharge for the 33 years (1970 to 2004) flow series at the barrage site indicates that the annual discharge during the 33 years varied between 1485 to 2206 MCum during the time period 1974-75 to 20003-04, excepting the year 2001-02, during which the flood discharge contributed to the rise in annual discharge to 3011.43 MCum. The to total annual in flow for 50% dependable year (1979-80) and 90% dependable year (1973-74) are 1270.5 and 899.2 Mcum, respectively.

The sediment load during monsoon season is estimated to be about 4,86,000 tonnes. The bed load may be expected to be 25% of this, or about 1,21,500 tonnes. The suspended sediment contains major proportion (79-82%) of quartz and subordinate amount of feldspar, magnetite and mica.

5. SOIL

The soils of the catchment area of proposed Alaknanda H.E. project composed of 11 soil series associations including glacier and glacier association belong to 5 families. Typic Cryorthents – Typic Cryorthents and Typic Udorthents – Typic Udorthents series are predominant in the river valley, characterized by excessively

drained, coarse loamy and moderate erosion and stoniness soil. Typic Cryorthents – Lithic Cryorthents is the most dominant association in the catchment, covering 35.2% of the total area. This series is characterized by steep slopes, severe erosion and coarse loamy soil.

Soil series Lithic Cryorthents - Lithic Cryorthents is most dominant around the project site especially on right slopes (Fig. 5). It is characterized by sandy skeletal soil, steep slopes and very severe erosion. Lithic Udorthents – Typic Udorthents soil series is predominant from the left slopes of the project sites. It is also prone to severe erosion.

Nearly 60% of the soil was comprised of boulders, gravels, pebbles, medium sand and very fine sand. The confluence area and left bank of Khirao Ganga have higher percentage of very fine sand, coarse and medium sand and fine silt with clay. These sites were relatively rich in the vegetation cover. The soils of upper sites were relatively alkaline while lower sites were acidic. There was a considerable variation between two sites near power house and two sites near barrage site in their physical and chemical characteristics. It seems to reflect in their vegetation cover. The lower sites were relatively rich in vegetation cover. However, overall scenario indicates a poor vegetation cover in the vicinity.

In general fungal population in soil samples of this region were very high than the bacterial population. Maximum population was observed in the soil samples collected from the Khirao Ganga region, near to powerhouse (9.0×10^6 cfug^{-1}). The region has thick perennial as well seasonal vegetation and on the right bank of Khirao Ganga there is deposition of humus. The soil samples collected from Benakuli region showed minimum number of fungal colonies (1.5×10^6 cfug^{-1})

The bacterial population was poorly represented in the soil samples of Alaknanda HE project area. There were few bacterial colonies in the soil samples collected from Khirao Ganga and Benakuli region. Maximum bacterial colonies were observed in the soil samples taken from Badrinath afforestation region (3.88×10^8 mpng^{-1}).

6. GEOLOGY AND SEISMICITY

In the Badrinath area of Alaknanda valley, the rocks of the Central Crystalline are overlain by Mesoproterozoic-Neoproterozoic II rocks - Dar Formation (Vaikrita) and intrusive undifferentiated biotite granite (ca 500 Ma) and tourmaline granite (ca 21 Ma) are exposed. The basal part of the Martoli Group (Rilkot/Dar formation) overlies the Central Crystalline Group in the north and in the south the latter is in tectonic contact with the upper Garhwal Group of rocks; the pervasive tectonic plane is known as the Main Central thrust.

Central Crystalline zone contact with the Garhwal Group (Super sequence II) represents a tectonic plane referred to as the Main Central Thrust (MCT). The gneisses, migmatites, crystalline schist, thick quartzite with conspicuous horizons of calc-silicates with psammite gneisses in the upper part form bulk of metasediments. Imprints of tectonothermal events, ca 2500, 2100 and 1900 Ma, probably related to Paleoproterozoic orogenic movements, are identifiable in the form of granite-gneisses. It also contains other younger granites (ca 21-500 Ma), which are related to younger tectonothermal events of which Tertiary granites are more conspicuous. The Central Crystalline is well exposed in the Alaknanda valley from Helang (south of Joshimath) to Badrinath. The Central Crystalline groups of rocks are *Ragsi Formation, Bhimgora Quartzite, Pandukeshwar Formation, Badrinath Formation, Martoli Group* and *Quaternary deposits*. The important discontinuity surfaces present in the region around the project area are Main Central Thrust (MCT), Dar-Martoli Fault and Niti Fault (NF). The Central Crystalline exhibits three phases of megascopic deformation.

The main relief of the project varies in between 4,800 m and 6,000 m. This zone is characterised by highly rugged topography with snow-bound high peaks viz. the Chaukhamba (7,138 m), Kamet (7,756 m), Banderpunch (6,315 m), Gangotri (6,614 m), Kedarnath (6,940 m) etc. In the Alaknanda Valley, there are a number of glaciers such as the Bhagirath Kharak and Satopanth etc. The area remains snow bound from November to May and is characterized mainly by glacial landforms such as moraines, cirques, arêtes and horns. The project itself lies in the Mid Himalaya range.

At km stone 297 near Hanuman Chatti on Rishikesh-Badrinath road on the right bank of Alaknanda toe erosion by Alaknanda river damages the road for about 4,00 m. Rocks of Central Crystalline Group comprising garnetiferous schist, gneisses and sericite quartzite are exposed in the slide zone. The landslide zone is 45 m high and 3,00 m wide and inclined towards south.

The rocks of the Pandukeshwar and Badrinath Formations of the Central Crystalline Group are exposed in the project area. In the powerhouse site the rocks of the Pandukeshwar Formation, with E-W strike and 45-55° dip towards N are well exposed. Along the Khirao Ganga the beds strike in ENE-WSW and dip 35-45° towards north. The variation in attitude is probably related to an anticlinal flexure in this zone. Two sets of Joints with attitude i) 80 to 85° → E and ii) 45 to 55° → N are well developed in the rocks. The foliation planes of the rocks of Badrinath Formation, well exposed around Rarang Chatti, strike ENE–WSE and dip at 60-65° northerly. This formation continues up to about half km south of Badrinath and overlies the Pandukeshwar Formation.

At the upstream site, the overburden comprises fluvio-glacial deposits of sand, gravel and boulders of gneiss. These deposits are covered by talus cones. Rock outcrops of gneiss are found on both abutments only at higher elevations (> 3,000m). At the downstream site the overburden on the left bank is composed of fluvio-glacial deposits of sand, gravel and boulders of gneiss overlain by a talus slope which extends for hundreds of meters above the level of the barrage. The proposed location for the intake portal of the headrace tunnel lies beneath the terrace material on the right bank. From the disposition of lithology on the geological map it is expected that the portal will be located in sound gneiss.

The headrace tunnel will be reached by a length of cut-and-cover tunnel through the terrace material. The HRT will pass through the gneiss of the Badrinath formation, quartzite of the Pandukeshwar formation with foliation joints dipping between 30° to 40° and the tunnel route is aligned at 70°-85° to the strike of the foliation joints. The contact zone between the Badrinath Gneiss and the Pandukeshwar Quartzite is perhaps faulted

and, therefore, fault zone material is likely to be encountered by the tunnel in this stretch. It is expected that quartzite from the Pandukeshwar formation will be encountered throughout the surge shaft. The Power House and Transformer caverns will be entirely situated in the Pandukeshwar quartzite formation. The Tailrace, Main Access and Cable tunnels will pass through the quartzites of the Pandukeshwar formation.

In Alaknanda valley thermal springs are present at eight localities *viz*. Badrinath, Helang, Kanakar, Hanuman Chatti, Ghorshila, Langsi, Gulabkoti and Loani (Thussu, 2002). Of these, the thermal spring at Badrinath, which lies in the catchment area, is hottest.

The revised Seismic zoning map of India (BIS: 2002), encompasses four zones namely II, III, IV and V. On the seismic zoning map of India, the Alaknanda H.E. project region lies within the ambit of the Seismic Zone V (zone factor 0.36) of I.S. code 1893-1984/1998/2002. Uttarkashi Earthquakes of 20 October, 1991 and Chamoli Earthquake of March 29, 1999 are important recent earthquakes which struck the Uttarakhand Himalaya.

7. LAND USE/ LAND COVER

The digital vector layers of state of Alaknanda river catchment up to the Alaknanda H.E. project barrage site as well as the administrative boundaries of different sub-watersheds of free-draining catchment were prepared from the Survey of India (SOI) toposheets at 1:50,000 scale. These vector layers were used as masks to extract the sub-watersheds from the images for further processing. A mosaic image was prepared from IRS-1D LISS-III scene and then from this, a mask of above mentioned study area was extracted. From this image, masks of different districts and watersheds were also extracted.

The study deals with the natural and managed ecosystems of Alaknanda river catchment which is the major tributary catchment of Alaknanda river basin in Northwestern Himalaya. The vegetation is constituted mostly of the Dry deciduous

scrub and Himalayan chir-pine forests at the lower altitudes of the project area. In the mid hills Temperate moist broad-leaved and Chir-pine forests are prevalent. Open canopy Temperate evergreen and Mixed deciduous forests, Sub-alpine birch–rhododendron, Alpine scrubs and Alpine pastures occur at higher elevations.

There are no dense and open forests in the catchment of Alaknanda river basin. More than 81.59% of the catchment area up to the proposed barrage site is covered with snow and glaciers. Of the total catchment area, 2.15% area (48,079.80 ha) is comprised of scrub while barren/ rocky land cover 11.04% of the area up to the barrage site. About 4,210.15 ha (4.14%) of the catchment area is under moraines. The human settlements comprise about 44.33 ha (Fig. 6).

The land use/ land cover of different sub-watersheds was extracted from the thematic land use/ land cover map prepared for the entire catchment. These land use/ land cover layers were used for erosion mapping in different sub-watersheds.

Alaknanda river watershed comprising the project area has a good open forest cover. Major part of the project area along Alaknanda river on higher elevations from the barrage site up to the proposed powerhouse site is covered with open forest (5.62%). However, at lower elevations, there is low concentration due to the concentration of human settlements all along the river valley as settlement areas (108.70 ha; 0.32%) are mostly clustered near the floodplains and depositional landforms. Major part of the area at higher elevation is barren/ rocky land (36.84%) while snow and glacier covers 31.36% of the project area.

Most part of the area to be submerged is under scrub (49.35%) and snow (38.13%), and the rest is comprised of wasteland 8.15%. The proposed reservoir will not lead to submergence of any household or agricultural land.

8. FOREST TYPES

The vegetation is comprised of mixed temperate coniferous forests in the lower altitudes of the project area. In the upper reaches sub-alpine, alpine scrubs and pastures are prevalent. The entire area of project falls in the buffer zone of Nanda Devi Biosphere Reserve. The catchment area is mainly drained by Alaknanda river, Kanchan Ganga, Khiraoganga, Saraswati river and many other small snow fed streams. In the entire area of catchment, mixed forest of some tall trees are present in the lower altitude, whereas the cold chilled areas of upper reach is devoid of tree vegetation and represented by only stunted species of scrubs and herbs.

The forests present in the Alaknanda, Saraswati and adjoining Rishi Ganga, have been grouped into different forest types following the classification of Champion & Seth (1968), Negi (1989, 1996) and Srivastava and Singh (2005). The major forest types found in this catchment are discussed below.

12/C I c Moist deodar forest

This is more or less pure forest of deodar (*Cedrus deodara*) with a little proportion of other species. The forest is found near Hanuman Chatti area between 2500-2600 m elevations. Some important tree associates found in the forests are *Abies pindrow, Hippophae rhamnoides* and *Populus ciliata*. Climbers and epiphytes are absent.

12/C I d Western mixed coniferous forest

These forests are found in Lambagar and Hanuman Chatti areas between 2300 m-2800 m altitude. This is a mixed coniferous forest of fir, deodar, blue pine and *Taxus*, but it lacks *Picea smithiana* in this area. Among important shrubs include *Berberis aristata, Cotoneaster microphyllus, Elsholtzia fruticosa, Hippophae rhamnoides, Prinsepia utilis, Sarcococca salingna, Sorbaria tomentosa, Spiraea canescens,* etc. Herbs and grasses are represented by *Adiantum lunulatum, Anaphalis triplinervis, Anemone obtusiloba, Agrostis stolonifera, Calamagrostis emodensis, Circium wallichii, Fragaria nubicola, Geranium robertianum, Impatiens sulcata,* etc.

14/C I b West Himalayan sub-alpine birch/fir forests

This is an irregular forest consisting mainly of fir, birch and Rhododendron bushes. These forests are found between 2,900-3,500 m altitudes. The forest is mainly evergreen, although most of other broadleaved species are deciduous. The important species found in this forest are *Abies spectabilis, Betula utilis* and *Viburnum grandiflorum*. This type of forest is found in the vicinity of reservoir. Herbaceous flora is represented by *Agrostis stolonifera, Artemisia maritima, Anaphalis triplinervis, Calamagrostis emodensis, Carex obscura, Festuca* sp., *Morina longifolia, origanum vulgare, Poa* spp., etc.

15/CI Birch-Rhododendron alpine scrub forest

This is low evergreen forest dominated by Rhododendron bushes and other deciduous species. Important species are *Betula utilis, Rhododendron hypenanthum, R. lepidotum,* etc. Other woody species are *Berberis umbellata, Cotoneaster microphyllus*, *Lonicera webbiana*, *Salix denticulata*, etc. This type is found only in the upstream catchment.

15/CII Deciduous alpine scrub

This is low deciduous scrub formation forming a dense continuous cover over extensive areas. The important species are *Betula utilis, Berberis umbellata*, *Cotoneaster microphyllus*, *Juniperus communis*, *Rosa sericea* and *Salix denticulata*.

15/ E I Dwarf Rhododendron scrub

This scrub vegetation consists of the three consociations which are dominated by species of *Rhododendron anthopogon* and *R. lepidotum*.

15/C3 Alpine pastures

They are composed mostly of perennial mesophytic herbs with very little grass. Important herbs are species of *Aconitum, Anemone, Delphinium, Geranium, Gentiana, Pedicularis, Poa, Primula, Ranunculus,* etc.

9. VEGETATION STRUCTURE

The project locations fall under buffer zone of Nanda Devi Biosphere Reserve, which allows the limited human activities in the area. The boundary of Valley of Flowers, core zone of biosphere reserve, is about 6 km aerial distance from proposed Alaknanda powerhouse site. The catchment area is mainly drained by Alaknanda river, Kanchanganga, Saraswati river and other small streams. In the Alaknanda catchment, there are number of glaciers and the area is characterized mainly by glacial landforms such as moraines, meadows and horn peaks. Human settlement is few and only seasonal, particularly summer and rainy in the catchment area along the Alaknanda river.

The proposed Alaknanda H.E. project area extends from Benakuli to Rarang, downstream of Kanchanganga, and Rarang to Vasudhara along the Alaknanda river. In all 187 species of angiosperms and gymnosperms were recorded from Alaknanda catchment. Out of 20,000 flowering plant species in India and more than 3,000 in Himalaya, about 180 species of angiosperms were recorded from the Alaknanda catchment. These species belong to 130 genera (out of 2,917 in India) and 49 families (out of 327 in India). Out of 49 families represented in these areas 41 are dicots and 8 are monocots. The dicotyledons are represented by 147 species belonging to 103 genera while the monocotyledons are represented by 27 genera and 32 species. Gymnosperms are represented by 4 families, 6 genera and 8 species.

Asteraceae with 13 genera and 17 species and Poaceae with 12 genera and 13 species are the largest families of dicots and monocots, respectively. Among Gymnosperms, Pinaceae is the most dominant family represented by 3 genera and 4 species.

The diversity of vegetation in Alaknanda and its adjacent areas in the catchment was assessed in terms of the physiognomy of its floral elements. The herbaceous species (75.13%) constitute bulk of the flora followed by shrubs (16.93%), trees (6.8%), climber (0.5%) and parasites (0.5%). About 62% families of the flowering plants are

comprised of only herbaceous species of which Asteraceae, Poaceae and Ranunculaceae are the dominant ones, each represented by more than 12 species. Comparatively, there are only a few families (13.6%) which are comprised of entirely shrubby species and are largely represented by Berberidaceae, Buxaceae, Caprifoliaceae, Elaegnaceae, Ericaceae, Hydrangeaceae, Rutaceae and Loranthaceae. Similarly, Betulaceae, Juglandaceae, Salicaceae, Pinaceae and Taxaceae are some of the families present in the area which are represented exclusively by tree species. *Herpetospermum pendunculosum* (Cucurbitaceae) and *Trachydium roylei* (Apiaceae) are monotypic taxa in the catchment while *Carex nandadevensis* and *Cotoneaster garhwalensis* are endemic species.

Some of the plants observed in the area belonging to vulnerable (VU) plant category are *Allium stracheyi* and *Hedysarum microcalyx* In addition to the Vulnerable (VU) plants, there are number of plants that are not listed in Red Data Book such as *Aconitum falconeri, A. heterophyllum, Carum carvi, Epilobium latifolium, Orchis chusua* and *Viola biflora,* etc are threatened due to habitat destruction.

A single parasitic plant was observed in the catchment during the survey, which belonged to family Loranthaceae. *Scurrula elata* is a shrubby parasitic plant species which grows on branches of *Populus ciliata*.

The catchment area is very rich in medicinal plant diversity. Large number of wild plants of medicinal value are distributed in the area altitudinally. Some of the plants like *Aconitum heterophyllum, A. falconeri, Astragalus rhizanthus, Carum carvi, Delphinium denudatum, Ephedra gerardiana, Hedychium spicatum, Viola biflora,* etc. are important medicinal plants of high altitude zones. The human population of the catchment depends largely on naturally growing shrubs, herbs and grasses for the fodder requirements of their cattle and livestock. Important grasses used for fodder include *Agrostis stolonifera, Brachypodium sylvaticum, Bromus ramosus, Calamagrostis emodensis, Carex obscura, Danthonia cachemyriana, Themeda triandra,* etc. Important timber yielding trees of the catchment areas include *Abies pindrow*, *Cedrus deodara*, *Juglans regia, Pinus wallichiana, Populus ciliata* and *Taxus baccata*.

The forests in the vicinity of the project area are comprised of mixed scrub sub-alpine forest. At left bank of Alaknanda river, there is no large tree but has stunted growth of scrubs with herbs and grasses. *Betula utilis, Berberis umbellata, Cotoneaster microphyllus, Hippophae rhamnoides, Juniperus indica, Rosa sericea, Rhododendron hypenanthum, R. lepidotum, Skimmia laureola, Sorbaria tomentosa, Viburnum grandiflorum,* etc. are some important shrubs. Climbers and epiphytes are almost absent. Among herbs and grasses are *Agrostis stolonifera, Anaphalis busua, Androsace sarmentosa, Artemisia nilagirica, Calamagrostis emodensis, Campanula alsinoides, Micromeria biflora, Morina longifolia, Pedicularis hoffmeistteri, Potentilla cuneata* and *Viola pilosa*.

A power house site has been proposed on the right bank of Alaknanda river and left bank of Khirao Ganga near Benakuli village. A fairly dense mixed temperate coniferous forest is found at this bank. Important trees in the canopy include *Abies pindrow, Cedrus deodara, Hippophae rhamnoides, Pinus wallichiana* and *Populus ciliata*. Among shrubs are *Berberis aristata*, *Prinsepia utilis, Rhododendron arboreum, Rubus ellipticus, Sorbaria tomentosa* and *Spiraea canescens*. Climbers and epiphytes are very few. Herbaceous flora is represented by *Anaphalis triplinervis, Artemisia nilagirica, Epilobium latifolium, Galium aparine, Geranium robertianum, Miscanthus nepalensis, Pilea umbrosa, Saccharum spontaneum* and *Themeda triandra*.

The maximum numbers of trees were recorded at d/s of barrage site, whereas scrubs were maximum at barrage site as compared to lower and middle stretch. The herb layer was poor in both the project sites. On the Lower stretch the tree and sapling strata were dominated by *Hippophae rhamnoides*. The associated species in the tree canopy were *Populus ciliata, Salix disperma* and *Abies pindrow*. In the shrub layer *Sorbaria tomentosa* was found as most dominant species with high density.

On the middle stretch tree strata was dominated by *Cedrus deodara* having maximum density (80 trees/ ha). The associated species of the tree layer were *Populus ciliata, Pinus wallichiana, Taxus baccata, Abies pindrow* and *Betula alnoides*. *Populus ciliata* was found dominant species in the sapling layer. At site Barrage site, there are

no trees even saplings and seedlings of the trees were not recorded. Among shrubs *Cotoneaster microphyllus* showed maximum density. Other associates were *Rhododendron lepidotum, Skimmia laureola, Salix denticulata, Juniperus indica, Rosa sericea, Hippophae rhamnoides, Betula utilis, Sorbaria tomentosa,* etc.

The value of species diversity (H) in the tree stratum ranged from 1.119 at site powerhouse to 1.568 at site middle stretch. The species diversity for sapling and shrub strata ranged from 0.501 to 1.314 and 0.963 to 1.997, respectively. The diversity indices for shrubs were higher at barrage site as compared to middle and lower stretch.

10 FAUNAL ELEMENTS

Fauna of the Higher Himalaya has strong affinities with that of Palaearctic region. Many faunal species viz. Leopard (*Panthera uncia*), Sloth bear (*Melursus ursinus*), Brown bear (*Ursus arctos*), Himalayan Black bear (*Selenarctos thibetanus*) are common in the both sides of Himalaya belong to Palaearctic and Oriental regions. However, micro climatic conditions play an important role in the composition and distribution of animals. The catchment area of the proposed project represents a pristine ecosystem naturally and falls in the buffer zone of Nanda Devi Biosphere Reserve. However, it is largely influenced by the pilgrimage and tourism activities from May to October. The fauna, its composition and distribution are described in the following paragraphs. The secondary sources and field observations indicate the presence of 14 species in the catchment, which belong to 8 families viz. Bovidae, Cervidae, Felidae, Ursidae, Mustellidae, Ochotonidae, Muridae and Cercopithecidae. Vole sighting is common near the project site. Common leopard, Yellow throated marten, Rhesus macaque and Common langur inhabit the lower reaches while Bharal, Snow leopard and Brown bear are found in upper catchments having meadows and moraines. Serow, Goral, Himalayan tahr and Black bear inhabit steep slopes with sparse coniferous forest cover.

On the basis of IUCN criterion Snow leopard (*Panthera uncia*), Bharal (*Pseudois nayaur* Himalayan tahr (*Hemitragus jemlahicus*), Serow (*Capricornis sumatraensis*), Common leopard (*Panthera pardus*) and Black bear (*Selenarctos thibetanus*) are

threatened species. On the hand ZSI (1994) criterion categorizes 7 species namely Himalayan tahr, Musk deer, Snow leopard, Brown bear, Bharal, Serow and Common leopard as threatened. Out of 14 species, 8 are kept in the Schedule-I while 3 species in Schedule-II on the basis of Wildlife Protection Act (1972).

Birds species belong to 25 families. Family Corvidae is largest, represented by 7 species. Many families like Falconidae, Upupidae, Dicruridae, Cuculidae, Capitonidae, etc. are represented by single species in the vicinity. Most of the passerines are confined to the lower zones. The species belong to families Accipitridae and Falconidae have wide range of their distribution while Galliformes inhabit slopes of lower catchment having coniferous trees and bushes. A few species viz. Common chough, Yellow billed chough, Common Mynah, Jungle crow and water loving birds (redstarts, dippers) are common in the upper reaches of the catchment. Majority of the birds species in the catchment area are common residents, and accounts for 94.9% of the total number of species that are recorded from this catchment.. Himalayan golden eagle, Wood pigeon, and Rufous turtle dove are altitudinal migrant whereas only *Falco* sp. is seasonal migrant.

As per the IUCN (2006) criterion, all species of the catchment are in the 'least concern of lower risk' category. However, *Gypaetus barbatus* and *Lophophorus impejanus* are considered as 'endangered' species and *Pucrasia macrolopha* as 'vulnerable' species in the Red Data Book of ZSI (1994). Regarding the conservation most of the species inhabiting the catchment are kept in the Schedule-IV, however, all species of families Accipitridae and Falconidae, Himalayan swiftlet and Himalayan snow cock are included in Schedule-I. Only common crow is categorized as 'Vermin' (Schedule-V). None of the species in the catchment is endemic to region.

Bird sightings were low near project sites. A total of 9 species viz. Himalayan griffon, Snow pigeon, Jungle crow, Blue whistling thrush, Blue fronted redstart, White caped redstart, Grey wagtail, Brown dipper and Alpine accentor were recorded from the project sites, in which Himalayan griffon is Schedule-I species (see Plate 11.1) and remaining belong to Schedule-IV.

Herpetofauna in alpine zone comprises of frogs, lizards and snakes. There are about 7 species of amphibia and 3 species of reptiles in the catchment area of Alaknanda H.E. project. None of the herpetofaunal species belongs to threatened category. Five species of butterflies were recorded from the project sites. However, There are earlier records of 80 species and 27 species from the Nanda Devi Biosphere Reserve (NDBR) including buffer zone. The present project lies in the buffer zone of NDBR. Mainly four families *viz*. Papilionidae, Pieridae, Nymphalidae and Lycanidae are expected to inhabit the catchment. The important species of alpine catchment are Yellow swallowtail (*Papilio machaon),* Common blue apollo (*Papilio hardwickei*), Dark clouded yellow (*Colias electo fieldii*), Painted lady (*Cynthia cardui*), Indian tortoiseshell (*Aglais cashmirensis*), Indian fritillary (*Argyreus hyperbius*), Queen of Spain fritillary (*Issoria lathonia*) and Comma (*Polygonia album*).

11 PROTECTED AREAS

Nanda Devi Biosphere Reserve (NDBR), comprised of two core zones - Nanda Devi National Park and Valley of Flower National park, is well known for its unique high altitude floral and faunal diversity; many of them are nationally and globally threatened. The Nanda Devi National Park is a 'World Heritage Site' and forms one of the core zones of the Nanda Devi Biosphere Reserve which was established in 1988 with a total area of ca 2236.74 sq. km. The other core zone is the Valley of Flowers National Park (VONP) covers an area of 3623.69 sq km was subsequently added to it. The total area of Nanda Devi Biosphere Reserve is 5,860.69 sq km. The area covered under buffer zone is 5148.57 sq km. The biosphere reserve is situated between 30^0 16' to 30^0 41' N latitude and 79^0 40' to 80^0 05' E longitude. The core zone of the biosphere reserve falls in district Chamoli, while buffer zone includes areas in districts Chamoli, Pithoragarh and Bageswar in Uttarakhand state which includes 47 villages (Fig. 7).

Nanda Devi Biosphere Reserve is bordered by the upper catchment areas of Saraswati and Ganesh and the Malari-Lapthal zone in the north; village Khati and river Sunderdhunga in the south; Bam Padhura, Kala glacier and catchment area of Girthiganga in the east; and by upper catchment of Alaknanda, Nanda Ghunti peak,

Hom kund and Roop kund in the west. The Rishi Ganga is the major river that flows through the National Park and joined by various tributaries at different locations inside the park.

In NDBR Lower Western Himalayan Temperate Forests include Moru -Oak forests (2100-2800 m), Moist deodar forests (*Cedrus deodara*) (1,700-2,700 m), Western mixed coniferous forest, Moist temperate deciduous forests include Low level Blue pine forest (*P. wallichiana*), Kharsu oak (*Quercus semecarpifolia*) 2500-3300 m) forests. The West Himalayan Sub-alpine Birch/Fir Forests include Hippophae / Myricaria brakes, Deciduous sub-alpine scrub and Sub-alpine pasture. The Birch-Rhododendron Alpine Scrub Forests in NDBR comprises of Dwarf Rhododendron scrub, Alpine pastures and Dwarf Juniper scrub forest.

Nanda Devi Biosphere Reserve is represented by 739 species belonging to 378 genera and 98 families. In addition to this, there are 11 species of gymnosperms and 51 species of pteridophytes are also present in the area. The dicotyledons are represented by 600 species belonging to 301 genera and 86 families, while the monocotyledons are represented by 12 families, 77 genera and 139 species. Gymnosperms are represented by 4 families, 8 genera and 11 species. In dicots, Asteraceae shows maximum diversity with 44 genera and 82 species. Similarly, *Carex* is the largest genus in monocots consisting of 14 species.

Carex nandadeviensis, Festuca nandadevica, Listera nandadeviensis and *Saussurea sudhanshui* are endemic species in Nanda Devi Biosphere reserve. Due to various biotic and abiotic factors some plants have become rare and threatened from the biosphere reserve. The important species are *Aconitum balfouri, A. falconeri, A. ferox, A. violaceum, Allium stracheyi, Arnebia benthamii, Cypripedium elegans, Dioscorea deltoidea, Megacarpaea polyandra, Nardostachys grandifllora, Picrorhiza kurooa, Saussurea gossypiphora*.

Mammalian fauna of Nanda Devi Biosphere reserve is comprised of Himalayan musk deer (*Moschus chrysogaster)*, mainland serow (*Capricornus sumatrensis*),

Himalayan tahr (*Hemitragus jemlahicu*), Bharal (*Pseudois nayur*), Snow leopard (*Panthera uncia*), Goral (*Naemorhaedus goral*), Black bear (*Selenarctos thibetanus*), Brown bear (*Ursus arctos*), Common leopard (*Panthera pardus*), Red fox (*Vulpes vulpes*), Hanuman langur (*Semnopithecus entellus*) and Rhesus macaque (*Macaca mullata*). Blue sheep, Himalayan tahr, Musk deer, Serow, Snow leopard, Common leopard and Red fox are 'threatened' species.

There is a record of 175 species of birds in the buffer and core zones of Nanda Devi Biosphere reserve (NDBR). An inventory of 114 species was made by Sankaran (1993) in Nanda Devi National Park. The avifaunal composition is almost similar in the Nanda Devi National Park and Valley of Flower National Park. The areas are well known for the pheasants, partridges and quails. Himalayan monal (*Lophophora impejanus*), Koklas pheasant (*Pucrasia macroplopha*) Snow partridge (*Lerwa lerwa*), Himalayan Snowcock (*Tetraogallus himalayensis*) and Chukar partridgte are important Galliformes of the core zones. Among the Falconiformes Himalayan golden Eagle (*Aqiula chrysaetos*), Himalayan Griffon (*Gyps himalayensis*) and Lammergeier (*Gypaetus barbatus*) are very common species. About 80 species of butterflies are known to inhabit NDBR. The important species of core and Buffer zones are The dark clouded yellow (*Colias electo fieldii*), Painted lady (*Cynthia cardui*), Indian tortoiseshell (*Aglais cashmirensis*), Indian fritillary (*Argyreus hyperbius*), Queen of Spain fritillary (*Issoria lathonia*) and Comma (*Polygonia album*).

12. AQUATIC ECOLOGY AND WATER QUALITY

To assess the water quality the present study was carried out in river Alaknanda for four seasons - winter, Pre-monsoon, monsoon and post-monsoon during 2006-2007. The samplings were conducted at three sites namely proposed barrage site, middle stretch at Hanuman Chatti and power house site. Besides these, river Alaknanda and river Saraswati near Mana village were sampled during pre-monsoon and monsoon seasons while Ghrit Ganga was sampled in post-monsoon season. A right bank tributary Khirao Ganga was sampled for pre-monsoon, monsoon and post-monsoon seasons.

The vegetation, rocks and land use in the surroundings are most important controlling factors of the water quality. The river stretch, proposed for the project, falls in the sub alpine and alpine zone and undergoes through glacial action. The area is predominants with moraines and meadows and very sparse covering of conifer trees. In general soils are excessively drained, coarse loamy and moderate erosion and stoniness. The rocks are generally characterized by the sand, gravel and boulders of gneiss. For the most of the months the area is inhabited very low human population but it becomes overcrowded in the summer due to arrival of pilgrims and river water becomes prone to deterioration at the Badrinath. All these factors influence the various characteristics of the river water, described below. River water is characterized low temperature, high current velocity, alkaline pH, high dissolved oxygen concentration, moderate electric conductivity, TDS hardness and alkalinity and low nutrients.

The presence of coliforms was recorded from the proposed power house site during winter and post-monsoon seasons and from Khirao Ganga in post-monsoon season. Low density of zooplankton was recorded from the present stretch of river Alaknanda and its tributaries. It ranged from 0 to 36 individuals/lit with maximum in Khirao Ganga in post-monsoon season. Zooplankton community comprised mainly of rotifers and Cyclopes. Phytoplankton density ranged from 0 – 12436 cells/lit. in river Alaknanda and 0 – 36756 cells/lit in tributaries with maximum in Khirao Ganga. The density of phytobenthos ranged from 0 to 71536 cell/ cm^2 in the river Alaknanda and 0 to 14171 cell/ cm^2 in tributaries. Algal communities comprised of 4 species of Chlorophyceae (*Ulothrix* sp., *Oscillatoria* sp., *Lyngbya* sp. and *Spirogyra* sp.) and more than 50 species of Bacillariophyceae. *Achnanthes minutissima*, *Cymbella ventricosa*, *Cymbella affinis*, *Reimaria sinuata, Gomphonema olivaceum* were the most common species among the Algal communities. *Achnanthes minutissima*, *Cymbella ventricosa, Reimaria sinuate* and *Gomphonema olvaceoides* dominated the river stretch strongly.

In the river Alaknanda macro-invertebrates density decreased gradually from lower to upper site. About 12 families of macro-invertebrates were recorded in river Alaknanda while tributaries recorded 11 families. Heptgeniidae, Baetidae and chironomidae were most common taxa in all streams. Chironomidae dominated the

proposed power house site and Khirao Ganga. Corydalidae, Musidae and perlidae were rare taxa in these rivers. Family Corydalidae, a very rare taxon of Himalayan river was also observed in the Ghrit Ganga and lower site of Alaknanda river.

The majority of the diatom species in the phytobenthic and plankton communities were pollution intolerant. Also, these species viz. *Achnanthes minutissima*, *Cymbella ventricosa, Reimaria sinuate, Gomphonema olvaceoides* etc. dominate the river water. On the other hand dominance of chironomids among the macro-invertebrates in lower sites and low BMWP score and ASPT indicated a stressed condition in Alaknanda. Though, reports suggested that chironomidae can grow in clear water too. The status of physical and chemical characteristics designated the river water in 'A' grade but presence of coliforms and pollution tolerant chironomids indicated a seasonal stress on the river water.

13. FISH AND FISHERIES

On the basis of fish species Himalayan streams have been divided broadly into (i) head water zone dominated by loaches and exotic trout, if introduced (ii) large stream zone dominated by *Schizothorax* spp. and *Schizothoraicthys* spp. and (iii) slow moving meandering zone, dominated by mahseer and carp species. The proposed Alaknanda H.E. power project lies in the head water zone, characterized by very low temperature (2^0C in winter), high water current velocity, dissolved oxygen, rough river bed surface and low availability of food. These adverse climatic conditions can be attributed with very low fish diversity. None of the fish species during the survey could be landed from the present stretch of the river Alaknanda. Also, fish fry and fingerlings from the pools and ditches were not observed. The physical and chemical characteristics of river water seem to be conducive for the exotic trout viz. *Salmo trutta fario* and *S. gairdneri gairdneri*, which are not introduced in the upper stretches of Alaknanda. However, the presence of a rheophilic species like *Noemacheilus, staliczkae, Noemacheilus gracilis* and *Glyptosternum retucilatum* is expected to inhibit this head water zone. After traversing about 15 to 20 km, large stream zone of Alaknanda starts, which is inhabited abundantly by snow trout (*Schizothorax,*

richardsoni, S. plagiostomus, Schizothoraicthys esocinus, etc). These species are known to take local upstream migration. Therefore, there is possibility of these species to visit the upper stretch of Alaknanda river during summer.

None of the fish species inhabiting upper stretch of Alaknanda river is migratory but snow trout species (*Schizothorax richardsonii* and *Schizothorax esocimus, S, progastus* etc) found in the downstream of the proposed project (after confluence of Alaknanda and Dhauliganga) are known to take upstream movements. The river stretch is also lack of endemic and threatened fish species.

14. AIR ENVIRONMENT

The proposed Alaknanda H.E. project on Alaknanda river does not come in the category of air polluting projects and whatever impacts will be there, those will be at the time of construction phase. The air environment of the region is also very clean. The total human population beyond Pandukeshar up to Mana (last village in the region) is less than 4401 living in six villages and in Badrinath town. National Highway 58 is the only metalled road connecting all these villages. Traffic flow on this road remains only for three to four months from May to August mainly due to famous religious and tourist destinations like Badrinath, Hemkund and Valley of Flower. During winters only local vehicles ply, which is also little in number. There is no industry in the region. Most of the people are engaged in agriculture and animal rearing. Kitchen fuel for the households could be only source for gaseous pollution like nitrogen dioxide, sulphur dioxide and carbon monoxide. The SPM in the region could be due to loose soil lying along the road due to slides and slips, open agricultural fields and less forest or vegetation cover. The instrument, High Volume Air Sampler (APM 460 BL), was run at Pandukeshar and Lambagar to assess the levels of SPM, NO_2 and SO_2 in the ambient air of the region during monsoon and non-monsoon season.

From Joshimath to Badrinath, which is around 40 km, the traffic is regulated and is one way only. During the months of May to Jul, number of vehicles plying in the area per day is more than 130 per hour. Whereas, in the month of Dec Jan the number of

vehicles, mostly jeeps, were just 8 to 15 per day. National highway No. 58 is the only road from Joshimath to Badrinath. Near by villages are connected by foot track to the main road (NH-58). It was Govind Ghat (one km down of Pandukeshar), where maximum number of vehicles were observed within in one hour. The reason could be due to midpoint of two important religious places, Badrinath and Hemkund Sahib.

Among the air quality parameters the level of the SPM ranged from a minimum of 38.3 $\mu g/m^3$ to 191.1 $\mu g/m^3$ at project sites. At Lambagar during April 2007 the level of SPM was more than at Pandukeshar. However, at both the locations the SPM level in the ambient air was quite lower then the national standard level given by Central Pollution Control Board (CPCB). At Pandukeshwar the SPM level was comparatively higher in April (non-monsoon period) than observed in June (monsoon). During June end (beginning of monsoon) the SPM level at Pandukeshwar was around 38.3 $\mu g/m^3$ may be due to rain in the area, which has washed the air. The values of RSPM and NRSPM are quite lower than the standard levels given by CPCB for different areas like industrial and residential. The sources of SPM in the region were mainly vehicles and open degraded land and land slides. The average NOx in the project area was nearly negligible when compared to the standard levels of CPCB. Maximum level of NOx was observed at Pandukeshwar (20.56 $\mu g/m^3$) in monsoon (June) and at the same place its level was one fourth in the month of April. The average level of SO_2 observed in the region was around 7.28 $\mu g/m^3$. Again it was Pandukeshwar, where maximum level of SO_2 was observed in the air. The sound level in the project area ranged from a minimum of 42.0 to 77.39 dBA. At the river bank the sound level remained constant, whereas on the road the sound level ranged from 58.9 dBA to more than 77.0 dBA. At any given time maximum ambient sound level observed in the region was around 86.2 dBA (when vehicles were passing very close to the observation point). During the construction of the barrage there will be increase in the traffic flow. Vehicles like trucks, dumpers, excavators will be continuously plying at the construction site. Heavy diesel generator sets will also be in operation for electric supply. There will be heavy noise and vibrations as well as emission of soot in the region. The noise will disturb the behavior of animals in that region. The level of SPM will increase in the region and there will also be increase in the level of NOx and SO2. Increased noise levels and continuous noise

may disturb the breeding, feeding and various other activities of the animals and birds in the region.

15. SOCIO-ECONOMIC PROFILE

The proposed Alaknanda H.E. project is located in the Joshimath tehsil of Chamoli district of Uttarakhand. District Chamoli is bordered by Tibet in the north - east, district Pithoragarh of Uttarakhand in the north – east, district Uttarkashi in north-west, district Rudraprayag in west, district Bageshwar in south –east and districts Pauri and Almora in south. District is divided into 7 sub-divisions (tehsils) namely Chamoli, Joshimath, Pokhari, Karanprayag, Gair Sain and Tharali. The total population of district Chamoli is 3,70,359 with a sex ratio of 1015. About 86.3% of the total population inhabits the rural areas. Total literacy rate of district is 75.4% with maximum in males. Joshimath is one the largest tehsils of Chamoli district in term of area. It is comprised of 93 villages and 27 notified wards. Total population of tehsil is 39,919 with a sex ratio of 774. Literacy rate of Joshimath tehsil is 78.8%. About 62.7% of the total population is rural.

Five villages and a notified ward are located in the 10 km radius of the proposed Alaknanda H.E. project. Total population of these villages is 4701, which belong to 1038 households. Badrinath is largest unit, however, the inhabitants are seasonal migrant. They reside it from mid April to September. Scheduled Castes (SC) and Scheduled Tribes (ST) account for 5.7% and 15.6% of the total population, respectively. These populations are absent in Lambagar village. An average literacy rate in these villages is 89.1% with considerably higher in males. Seven schools cater the facility of primary education, which is absent in Badrinath and Binaik. Middle schools are present in the Mana and Pandukeshwar villages while secondary school is located only in Mana village. Potato, beans and finger millets are main crops in these villages except Badrinath. The inhabitants of Badrinath are engaged in business activities. About 54.7% of the total population comes under the workers category. In which 38.3% are main workers and 16.4% are marginal workers. Land of Bardrinath town is notified, therefore, is not divided into different categories. Khirao is largest village, covers about 97% of the

total land. About 37.6% of total land is forest land while 30.1% land is not available for cultivation.

Only 2 hamlets in the revenue Dewagni and Benakuli under the revenue village Khirao are affected due to the Alaknanda H.E. project. The socio-economic profile of affected village is described in the following paragraphs. Total population of Khirao village is 132 belonging to 44 households. The sex ratio is 1062. ST population accounts for 59% of the total population while SC population accounts for only 6%. An average literacy rate of the revenue village Khirao is 61.86%. The literacy is considerably higher in males (84.3%) as compared to that of females (39.78%). Only 2 primary schools cater to this revenue village. About 75.7% of the total population comprises total work force of the affected revenue village Khirao. In the total work force, main workers account for 98% while only 2% to the total work force comes in the category of marginal workers. About 24.2% of the total population is non-workers. Revenue village Khirao covers an area of 39139.4 ha, in which 15106.4 ha comes under the forest. About 30.65% of the area is not available for cultivation while only 0.08% is cultivable waste. Total unirrigated land accounts for 30.65%. There is no health facility available in this revenue village Khirao. The village has potable water supply. Post office facility is also available.

Total 12 families are affected due to proposed Alaknanda H.E. project, which were surveyed from the two affected villages of Khirao revenue village. The total population of affected families is 227 with maximum in Dewagni village and minimum in Benakuli. The sex ratio is 876. The age group of 0-6 yrs accounts for 6.60% of the total population. About 74.8% families belong to the Scheduled Tribe category among the total affected families. The average literacy rate of the affected families is 56.6% with maximum in Benakuli. Majority of the population is graduate i.e.16%, this percentage gradually decreases to 5% for primary level education. Livestock population of the affected families comprises mainly of goats, cows and oxen. Almost all families have electric supply and drinking water. About 9 families are connected with telephones. A total of 11 families have access of television. Most of the families use LPG and Kerosene for cooking purposes. The economy of the affected families depends mainly

on agriculture, however, government services also strengthen their economy. About 51 individuals among these are engaged in agriculture, 34 individuals are engaged in government and private sector and 7 individuals are engaged in small scale business for their livelihood. Potato, Beans, Amaranths and vegetables are main crops of these families. The annual income per family ranges from rupees fifty thousand to rupees ten lakhs. The annual average income per family is around three lakhs.

The total land affected due to various project activities is 7.53 ha, which belong to 12 families of the two villages. The total land holdings of these families are about 11.6509 ha. The maximum land would be acquired from Benakuli village.

During field survey of the affected families of the Alaknanda H.E. Project it was observed that people were aware of the upcoming project. People gave positive as well as negative opinions about the proposed project as it was a matter of their infrastructural development and progress in the society besides loss of ancestral land. It was observed that out of the total people surveyed, around 70% of the people felt that due to constructional work of the project they will get more employment which is the basic need for sustaining their life. About 82% of the people surveyed felt that upcoming project would bring development to their area as it would improve educational, transportation and medical facilities. While 77% suggested that their area can become a tourist spot because of the barrage and powerhouse and most of the people are of the opinion that it would increase their welfare facilities and development. People were equally concerned about the adverse impacts due to project related activities. Around 77% of the people surveyed informed that their agricultural land will be lost due to acquisition and 38% of them felt that this will bring loss to their agricultural crops and this will further lead to decrease in crop production.

16. IMPACT ASSESSMENT AND EVALUATION

The environmental impacts of the proposed Alaknanda H.E. project are being forecast in light of the activities that would be undertaken during the construction of barrage, coffer dam, drilling and blasting during tunneling for head race tunnel, adits,

roads, construction of permanent and temporary housing and labour colonies, quarrying for construction material and dumping of muck generated from various project works and other working areas. The likely impacts have been considered on ecosystems, both aquatic and terrestrial, as a whole, and also on individual critical species, if any. Impacts have also been assessed on the geophysical environment of the area which may lead to serious negative consequences. Environmental impacts both direct and indirect on various environmental attributes due to proposed hydropower project on the surrounding environment, during construction and operational phase are discussed. The impacts due to the construction of Alaknanda H.E. project and powerhouse installation commence right from the start of exploration activities, construction of adit tunnels, head race tunnels and approach roads, etc. and may continue up to generation of hydel power, with the nature and extent of impacts varying throughout the stages of project development. The activities like site preparation, approach roads, excavation, drilling, blasting, foundation, tunneling, deployment of machinery, erection, transportation, dumping are taken up during construction phase. Different types of impacts have been summarized below.

16.1 Impact on Terrestrial Ecosystems

Habitat disturbance, degradation, fragmentation and destruction due to construction activities would lead to disruption of flora and fauna. The proposed area to be submerged by the proposed project is about 2.27 ha, which is mainly under forest. The vegetation in the vicinity of the proposed project area is scattered composed of Temperate mixed coniferous and scrub forest. On the right bank, there are trees of *Betula alnoides, Ilex excelsa, Rhododendron arboreum, Taxus baccata* and *Viburnum grandiflorum* and shrubs like *Berberis umbellata*, *Cotoneaster rotundifolius, Rhododendron campanulatum, Rosa macrophylla, Sorbus tomentosa, Viburnum cotinifolium,* etc. Herbaceous flora is comprised of *Anaphalis busua, Arabis amplexicaulis, Cardamine impatiens, Cerastium glomeratum, Corydalis cornuta, Epilobium palustre, Geranium wallichianum, Imperata cylindrica, Potentilla cuneata, Sedum ewersii,* etc. Therefore, no species of conservation significance is likely to be lost due to submergence. However, the reservoir would hamper the movement of wildlife. The creation of a barrage across the river and formation of a reservoir would

result in the change of habitat and would lead to fragmentation of habitat. This reservoir will function as a physical barrier, which comes in the way of animal migration and dispersal. Even though the proposed project envisages a 18 m high diversion barrage, which would not result in inundation of large area and also would not store large quantity of water, therefore, yet it would restrict and hamper the movement of wildlife in this area. The proposed project activities like drilling, blasting, etc. would lead to increased noise levels in the area, which may cause disturbance to the wildlife in the area. The components of the project are mostly on agricultural land, barren land and or underground and large area of cultivable land is required for the project. The construction of the project facilities would involve deforestation. Thus the danger of erosion and disturbance to hill slopes is high.

Major construction of road is required. The construction of roads and project components will involve felling of large number of trees and huge deposition of excavated material in the river and tributary streams would affect the environment adversely. In addition to the project is located in buffer zone of Nanda Devi Biosphere Reserve and also evident from land use/ land cover map of the project catchment as well as project construction area Alaknanda river, the clearing of forests for project construction activities would result in change in land use/ land cover.

16.2 Impact on Aquatic Ecosystems

The most obvious impact of hydro-electric projects is the upstream inundation of terrestrial ecosystems and, in the river channel, the conversion of lotic to lentic systems. They also alter the downstream flow regime. Reservoirs reduce flow velocity and so enhance sedimentation. The rate at which sedimentation occurs within a reservoir depends on the physiographic features and land-use practices of the catchment, as well as the way the barrage is operated. It is estimated that between 0.5% and 1% of the storage volume of the world's reservoirs is lost annually due to sediment deposition.

Downstream of the barrage, reduction in sediment load in the river can result in increased erosion of river-banks and beds and loss of floodplains (through erosion and decreased over-bank accretion). Reservoir flushing (i.e. the selective release of highly

turbid waters) is a technique sometimes used to reduce in-reservoir sedimentation. As the proposed project would result in submergence of 2.27 ha and it may lead to adverse changes in the river ecosystem. However, for mitigating the downstream impacts, it is mandatory to maintain at least 10% of the lean season flow in the river. The river stretch of about 5.8 km downstream of the barrage site would become dry during the lean season, therefore, the project authorities have been advised to maintain sufficient amount of discharge during the lean period to maintain and sustain the aquatic ecosystem functions in this stretch. The likely impacts on the water quality arise from inappropriate disposal of muck, effluents from crushers and other sources and sewage from labour camps and colonies. The major impact on the water quality arises when the muck is disposed along the river bank. The muck will essentially come from the road-building activity, tunneling and other excavation works. The unassorted waste going into the river channel will greatly contribute to the turbidity of water continuously for long time periods. The presence of labours and other work force, which are generally located near the river bank would lead to deterioration of the water quality in the stream. Therefore, in order to avoid any deterioration in water quality and subsequent changes in the aquatic biota, project authorities propose to have a proper sewage disposal system in and around various labour colonies to check the discharge of waste and refuse into the river. In absence of such measures there is bound to be deterioration in water quality and the subsequent changes in the aquatic biota. The degradation in water quality will mainly arises from discharge of waste and refuse into the river channel by the labour colonies and other temporary human habitations.

16.3 Geo-physical Impacts

The area lies in the seismically active Zone-V of the seismic zoning map of India and has witnessed micro-seismic activity. From the spatial disposition of the project area in the regional seismo-tectonic setup of Uttarakhand, it is evident that the project area is very close to seismically active zone in the vicinity of MCT. Therefore, it is essential to adopt suitable seismic coefficient in the design for various appurtenant structures of the project.

The construction of roads is an important geo-physical impact which can lead to Loss of forest trees and vegetation, Geological disturbance due to blasting, excavation, Soil erosion as cutting operation disturbs the natural slope & lead to land slides, Interruption of drainage pattern, Disturbance of water resources with blasting and discriminate disposal of fuel and lubricants from road construction machinery, Siltation of water channels/ reservoirs from excavated debris, Effect on flora and fauna, Air pollution due to dust from debris, road construction machinery, etc.

Therefore, most of the muck is proposed to be dumped at pre-identified locations. The dumping sites are mostly located downstream of the proposed reservoir, therefore, no negative impacts on the life of reservoir are foreseen due to this activity. The muck is proposed to be dumped in an environmentally sound manner in pre-identified dumping sites, which are proposed to be rehabilitated subsequently in an environmentally sound manner for which appropriate environmental management has been prepared.

16.4 Impact on Human Ecosystem

If the quantum of human population migrating from other areas is greater than the local human population in the area it would result in demographic changes and other repercussions that follow. Since the migrant workforce is generally from the different regions, diverse ethnic and cultural backgrounds and value systems, they are bound to affect the local socio-cultural and value systems. In addition, these migrants might be the probable carriers of various diseases not known so far in the region resulting in health risk for the local population. The threat of habitat disturbance, degradation and fragmentation may not only come from the constructional activities, but from the large labour population that is generally employed in such developmental projects. The presence of human population in large numbers in such areas is known to exert tremendous pressure on the natural ecosystems around the project activity sites.

Serious impacts outlined and envisaged above may not result at all the sites of project activity as the labour intensive activities and labour and office colonies are concentrated in areas away from pristine natural ecosystems. This, however, does not

preclude the possibility of human disturbance in the neighbouring natural ecosystems by the workers that would be employed during the construction of the project.

Some positive impacts like availability of jobs, electricity in rural areas, increase in road connectivity and ecotourism are anticipated on the socio-economic environment of the local people of villages of project area during the project construction and operation phases. On the other hand some negative impacts are also predicted. For example, the influx of labour will create problems of sewage disposal, solid waste management and requirement of fuel etc.

16.5 Impact on Air Environment

The construction of road, drilling, etc. would lead to increase in SPM levels in addition to increased NOx and SO_2 levels owing to increased traffic density in the project area, pollution due to consumption of fuel in DG sets and other construction equipment and emissions from crushers. Therefore, the project authorities are advised to use sprinklers, etc. to control the SPM levels in the air.

16.6 Downstream Impacts

Downstream impacts are important operational impacts. The diversion of water leads to various social, environmental and economic impacts in the downstream stretch. The downstream impacts may vary in their magnitude, they may be beneficial or harmful and they may be different for different sectors viz. social, economic, environmental etc. The *Changes in hydraulic regime* due to continuous fluctuation in water level, changes in water quality due to low dilution of water, impact on ground water and anthropogenic stresses on surface water quality are important downstream impacts, which would affect aquatic fauna negatively.

Within the project area, between barrage site and powerhouse, there are three villages, Hanuman Chatti, Benakuli and Khirao. Total population in this stretch is about 870 belonging to 107 households. Khirao is the only significant village in this stretch. This village is located on left bank of Khirao Ganga. The project colony and offices is to be developed in this area. People of all these villages are not dependent on Alaknanda

river for drinking water or for irrigation purpose. The reduction in the water discharge in this stretch of the river, therefore, will not have any adverse impact on the economy and social life of the local people. This is because of the fact that small streams are sufficient to fulfill the daily water requirement of local population.

17. EMVIRONMENT MANAGEMENT PLAN

17.1 Biodiversity Conservation & Management plan

17.1.1 *Objectives*

In view of the foreseen disturbance and degradation of natural ecosystems, a biodiversity conservation and management plan for proposed Alaknanda H.E. project area has been proposed with the following objectives in mind:

(i) Conservation and preservation of natural ecosystems and areas which may hold potentially important species from the conservation and/or economic significance,

(ii) Preservation of natural habitats in the catchment,

(iii) Rehabilitation of critical species, if any,

(iv) Special efforts for *in situ* or *ex situ* conservation of critical/ important plant/ animal species,

(v) Mitigation of biotic and/or abiotic pressures/influences on the habitats,

(vi) To improve habitat conditions by taking up afforestation and soil conservation measures,

(vii) To create awareness regarding conservation and ensure people's participation in the conservation efforts.

17.1.2 *Management Plan*

Even though no rare or endangered plant or animal species are likely to be affected by the project activities and submergence, the existing natural ecosystems in areas constituting upstream catchment of the proposed project need protection and further strengthening of conservation efforts. In order to ensure proper implementation of conservation policies and measures additional funding support will have to be provided to aid conservation efforts in the area. In order to ascertain that there is enough interest and

necessary funding support for the activities related to management and conservation of terrestrial ecosystems and various critical species, it is proposed to provide adequate funding support for activities of conservation and management of critical and important species and ecosystems in the region.

The specific issues discussed that are required to be dealt with are described below:

i) Poaching has been one of the major cause for destruction of wildlife. Besides poachers from the town and cities who kill these animals just for the sake of fun. The poaching is to be checked by regular patrolling and deployment of anti-poaching parties and enforcement of the Wildlife Protection Act of 1978.

ii) The project area catchment is under grazing pressure and is one of the main limiting factors for the wildlife because of following effects of grazing on wildlife.
   a) Interference
   b) Reduction in food availability for herbivores
   c) Disease propagation
   d) Reduction in area of wilderness needed for the wildlife

It is recommended that the Reserved Forests be declared as non-interference areas for any human activities. No activities should be permitted either by private or public agencies in these areas except for the rights of the local population which must be maintained in a regulated manner. The detailed nature of the regulatory framework and its implementation will be left to the State Government, however, an action plan for the preservation and management of these protected areas is indicated here.

(i) The State Government through its Department of Forests & Wildlife shall take up the work of Biodiversity Conservation for the critical areas with the financial support of the power development agency. This work shall be under the direct administrative control of the Principal Chief Conservator of Forests/ Chief Wildlife Warden, Uttarakhand.

(ii) A Committee under the Chairmanship of the Principal Chief Conservator of Forests, Uttarakhand shall govern the conservation work. It shall include two representatives each from State Forest Department (of the rank of

Conservator of Forests) and GMR Energy Ltd., two renowned Ecologists/ Conservationists, two representatives of local NGOs, and one Central Government representative of Ministry of Environment & Forests.

17.1.2.1 *Noise mitigation and management*

Some of the suggested methodologies for reduction and mitigation of noise so as to cause as little disturbance to the animals as possible are given in this section. Only well maintained/new equipment that produce lesser noise than old and worn out one would be installed at the work sites. The heavy equipment like rotating or impacting machines will be based on anti-vibration mountings. The combustion engines are required, they will be fitted with silencers. The traffic (trucks, etc.) used by the project works will be managed to produce a smooth flow instead of a noise producing stop and start flow. While clearing the land of vegetation for any project work, the project authorities will ensure that the work area has sufficient layers of tree cover around it. It will act as an effective noise absorber. It will be better not to have bigger trees lopped or cut around the periphery of the site. The tree layer will act as buffer zone and these are known to cut off noise by about 3-12 dB at a site depending upon the density of vegetation. These measures will be planned in advance and well before starting operation at any site.

17.1.3 Activities and Development Works to be undertaken

i) Augmentation of water supply facilities for bunds, check dams, wells and for transportation of water, pumping of water, etc.

ii) Habitat improvement by way of plantation of trees, fodder plant species, fire protection measures, prevention of soil erosion and denudation of slopes; removal of weedy plant species.

iii) For the improvement of vigilance and measures to check poaching, boundary demarcation, wireless and other equipment is required. In addition provision for rewards for informers for control of poaching and illegal trade, check-posts, watch towers.

iv) Maintenance and improvement of existing infrastructure like buildings, bridges, watch towers, inspection paths.

v) Publicity awareness and hoardings, conducting training camps, research documents, pamphlets, brochures, hoardings, etc.

It is proposed that the project authorities will provide funds to the tune of **Rs.585.00 lacs** for the conservation works and for period of nine years. Later on the expenditure for these works shall be borne by the State Government.

17.2 Action plan for Catchment Area Treatment

The Alaknanda H.E. Project catchment area treatment plan has been prepared with the following objectives:

i) Checking soil erosion and land degradation by taking up adequate and effective soil conservation measures in erosion prone areas (very severe and severe).
ii) Rehabilitation of degraded forest areas through afforestation and facilitating natural regeneration.
iii) Rehabilitation of degraded slopes and landslide prone areas.

Different types of erosion that occurs in the catchment of Alaknanda river are, i) sheet erosion, ii) gully erosion is the aggravated form of rill erosion and iii) stream bank erosion. Water is the single most important agent of erosion. Whenever water moves it erodes the boundaries alongside. Rainfall, streams and rivers all scour soil with their action. Drainage and slopes are important factors, induce soil erosion.

For the demarcation of sub-watersheds, hierarchical delineation system developed by AIS & LUS (AIS&LUS Technical Bulletin 9) was followed. The codification system as given in Watershed Atlas of India (AIS&LUS) was followed for Alaknanda river watershed on 1:50,000 Survey of India toposheets. The sub-watersheds of free draining catchment of the proposed Alaknanda H.E. project on Alaknanda river are comprised of watersheds – 2B5F3 (Saraswati), 2B5F4 (Arwa) and 2B5F5 (Rishi Ganga). These are in turn part of Alaknanda sub-catchment of Chamoli (2B5F) sub-catchment, in turn a part of Main Upper Most Ganga above confluence with Ramganga (2B5) of Upper Ganges above confluence with Ghaghara RB (2B) catchment as per the

AISLUS, watershed Atlas of India. The sub-watersheds in the catchment were named according to their parent watersheds i.e. Sr1 to Sr10 is part of Saraswati River sub-catchment and Ar1-Ar6 in Alaknanda River sub-catchment as per AISLUS, Watershed Atlas of India. The catchment treatment plan has been limited to catchment of Alaknanda H.E. project. Therefore, for the preparation of CAT plan, part of Alaknanda river catchment (2B5 as per AISLUS) comprising the catchment area was delineated into sixteen sub-watersheds in Alaknanda river as per the Watershed Atlas of India as cited earlier. In all**, 16** sub-watersheds have been delineated in the catchment area constituting an area of **1,01,593.41 ha** as per the codification system as given in Watershed Atlas of India (AIS&LUS) on 1:50,000 Survey of India toposheets of the project area.

Based upon the Sediment Yield Index (SYI), sub-watersheds that require treatment measures were prioritized for this purpose. The sub-watersheds like Ar1, Ar2 and Sr10 would be treated on priority in the treatment schedule to be followed and so on based upon the SYI for prioritization. In all total area of **704.26 ha** would be taken up for treatment measures with 8.69 ha under very severe category and 695.57 ha under severe erosion intensity category. The total area earmarked for treatment comprises more than **15.11% of the catchment area** and **0.69% of the total area under very severe and severe categories** in the catchment.

For undertaking soil conservation measures in the Alaknanda H.E. project catchment area up to barrage site various indirect or preventive measures like biological measures and direct or remedial measures like engineering measures have been discussed in the following paragraphs. Even as suggestions have been made regarding certain specific treatment measures to be undertaken in a particular sub-watershed, these measures, however, may require further micro-planning during the implementation stage.

The preventive measures that are suggested for the project area are Afforestation, fencing, weeding and mulching, watch and ward and fire protection, creation of nursery, assisted natural regeneration in existing forest, Forest infrastructure

development and engineering measures. In engineering measures brushwood check dam, DRSM (Dry Rubble Stone Masonary), check dams with stones available at the site and combination of DRSM and crate works have been suggested.

The amount of area and type of treatment to be undertaken is based upon the stream drainage pattern, extent of forest cover, accessibility of the area, landuse, soil profile and slope. The areas with very severe erosion intensity having very steep slopes and which are inaccessible would be left alone for natural rejuvenation. Sub watersheds of Alaknanda river are Rishi Ganga, Khular, Satopanth, Khuliagarvia, Bhagirath Kharak, Bhagnyu, Nagthuni Gad, Anadeb Gad,

The total estimated cost of catchment area treatment plan to be spent over a period of five years is **Rs. 545.86 lacs.** All the costs towards the administration during the implementation work have been included in the cost estimates of CAT.

17.3 Fisheries management

In case of river Alaknanda in the present stretch, fish of fishery interest and capture fishery are nil, the livelihood of people is not affected. On the other hand introduction of exotic trout is supposed to be harmful for the indigenous species. Therefore, the present fisheries management plan is suggested in respect to conservation of indigenous fish species. The construction of small check dams across the river may be helpful in maintaining the ecosystem sustainability. In order to the maintenance of pools small check dams are needed in the rivers. The pool thus created is fished, often much later in the dry season. These structures are made of wooden posts, earth and clay-filled sacks in the Senegal. At least 4 dams would require in the 12 km stretch of the river. The check dams would be supplied through regular water supply from the mandatory release of water (10%) from the dam and other small tributaries. In addition to the construction cost, there is a provision of an endowment grant, provided by the project authority to the forest department for the maintenance of pools and riffles. A total estimated cost for the Fisheries management Plan is **Rs. 59,00,000**/-

17.4 Public Health Delivery System

The existing medical facilities (traditional and government) will be totally insufficient for the influx of workers and their families from outside to work at project site. Proposal is made to set up one hospital (10 bed) at Benakuli village, one Primary Health Sub-Centres (PHSC) at Mana village. The PHSC facility at Mana will operate only during summer months. The proposed grant for establishing all these medical facilities and running cost would be **Rs. 297.22 lakhs**.

17.5 Solid waste management

The project authorities will take sufficient precautions for developing proper system for the sewage treatment from the colonies of labours and workers, solid waste disposal and cleaning of the colony area. For these septic tanks and soak pits shall be provided for individual dwellings. There should be proper water facilities to these workers for drinking and other purposes. The project authorities will ensure proper waste disposal by adopting various disposable methods like incineration, composting etc. The project authority should also take care to keep the local villages clean and provide various facilities related to water and sanitation. At the time of peak construction work in the project, maximum of 650 persons may be engaged. Around 100 to 150 labourers will be from the local population. Around 200 or more of the work force, which will include technical, non-technical and service class, will come from outside. In India average per capita solid waste generated per day is considered as 425 g (dry weight). Therefore, for about 1878 persons an estimated amount of about 291.32 tonnes (0.425 kg x 1878 individuals x 365 days = 291324.75 kg per annum) of solid waste will be generated annually. The solid waste will be collected in masonry vats of at least 25 cum capacity constructed at suitable sites near the colony area. The garbage would be transported to the landfill sites located at least 0.5 km away from the colony area.

The total budget in order to manage the solid waste generated from this population, provisions for community toilets for labours and nearby villagers as well as septic tanks and soak-pits, garbage transporting vehicles with staff salaries has been proposed to **Rs. 90.85 lakhs.**

17.6 Provision for Fuel and Energy Conservation Measures

Many of the migrant workers will be coming to the project site for short duration and many will be without families (around 190). These people will not be much interested for cooking their own food, rather they would like to have prepared food. The community kitchen can be established at Benakuli, where the power house is proposed or at Hanuman Chatti, which is between powerhouse and barrage site. During the construction period of the project there will be around 300 to 380 families coming from outside for the project work. The project authority should make LPG and/or kerosene available as cooking fuel to these migrant workers. The LPG cylinder should be made available to each incoming family as well as to the local people either free of cost or at subsidized rate. Efficient cooking technologies should be provided. Indoor smoke in these regions is one of the main source of air pollution. The authority should provide smokeless chullahs to the families of migrant workers as well to the local villagers. Accordingly budget has been allocated for the supply of cookers and smokeless chullahs. A total grant of **Rs.20.80 lakhs** has been assigned towards the provision of kitchen fuel and other facilities including establishment of community kitchen or canteens.

17.7 Muck Disposal Plan

The total quantity/volume of material to be dug out or excavated during the construction of various project components is estimated to be about 7.11 lakh cubic meters of which 2.85 lakh cubic meters will be utilized for filling and construction purpose. The remaining 6.18 lakh cubic meter of muck needs to be rehabilitated in environmentally sound manner. These materials are to be dumped at four suitable locations identified specifically for this purpose. These proposed locations are spread over land area of 2.85 ha comprising of forest land as well as private land. For retaining the dumped material and for its subsequent stabilization, sausage walls of 150 m to 205 m length are proposed. The sausage walls will run parallel to the dumping yard. Sausage walls will also run along road alignment. The work plan formulated for re-vegetation of the dumping sites is based on the ‘Integrated Biotechnological Approach. The afforestation with suitable plant species of high ecological and economic value

which can adapt to local habitat will be undertaken with 1500-2000 plants per hectare depending upon the canopy cover required.

The estimated cost of the relocation and rehabilitation of excavated material will be **Rs. 750.00 lakhs.**

17.8 Landscaping and Restoration of Construction Areas & Quarry Sites

There is only one quarry sites proposed for the excavation of the rock material. The area will be extensively disturbed due to quarrying. The vegetation cover along with top soil will be removed and the area will become barren. After the completion of quarrying activity, these areas will be restored to their normal habitat conditions. To achieve this, appropriate measure would be adopted before and after quarrying activity at various sites in the project area so that the restoration work is effective and scientifically executed. In addition, two locations have be selected for the development of office area and colonies for staff and labours, locations have also been identified for plant area and construction facilities. These areas will be highly disturbed due to clearing of the vegetation and forests. The project authorities are suggested to ensure the rehabilitation and landscaping of the quarries, colony areas and construction sites through appropriate technologies. A laboratory has also been proposed for the isolation, culture and inoculation of VAM and other microflora. A plant nursery would be essential to provide the supply of plant samplings for the plantation at different sites in the colony and project area. **Rs.342.20 lakhs** would be required to restore and maintain the project area in its original/ near original condition.

17.9 Creation of Green Belt around Reservoir

A green belt around the reservoir will be created to avoid erosion of soil and prevention of land slips from the direct draining catchment into the reservoir. The creation of green belt on either side of the reservoir will ensure protection of the reservoir area from any minor slips due to fluctuation in the water level. The slopes on both the banks will be planted with suitable tree species for creation of a green belt around the reservoir rim. The green belt will start from the immediate vicinity of the reservoir rim on both the banks, up to the tail of the reservoir wherever moderately

steep slopes are available for plantation. The average width of the green belt will be around 35 m varying from only 10 m at places to 50 m or as physiographic and land features allow. There would be at least 2 layers of plantation. The plantation will start along 2930 m contour level and would go up to 2960 m contour level from the barrage axis up to the tail of the reservoir. Water loving species, preferably *Salix alba*, *S. acmophylla, Populus alba* and *P. ciliata* will be planted in the row nearest to the reservoir rim. Species like *Aesculus indica*, *Alnus nepalensi*, *Coriaria nepalensis* etc. will occupy the middle portions of the green belt. The outermost layer of the green belt will be composed of hardy tree species. The estimated cost for green belt is **Rs.4.00 lacs**.

17.10 Resettlement and Rehabilitation Plan

The proposed Alaknanda hydro-electric power project is a run of the river scheme. The land is required for the individual requirements of the project, muck disposal, colonies, temporary construction and access roads. Total land requirement for different components is 83.90 ha. It is divided into 47.63 ha for barrage and intake structure and 19.19 ha for power house complex. Of the total land 74.28 ha land will be acquired permanently while 9.62 ha land is for temporary acquisition. The requirement of total private land is 7.53 ha. Similarly, total forest land requirement is 73.87 ha, of which 64.56 ha would be acquired permanently.

Total Twelve affected families belong to the revenue village Khirao and its two hamlets Dewagni and Benakuli. The total population of affected families is 227 with maximum in Dewagni village and minimum in Benakuli. The sex ratio is 876. The age group of 0-6 yrs accounts for 6.60% of the total population. About 74.8% families belong to the Scheduled Tribes category among the total affected families. None of the village belongs to the SC population and Other Backward Classes (OBC). The average literacy rate of the affected families is 56.6% with maximum in Benakuli. Majority of the population is graduate i.e.16%, this percentage gradually decreases to 5% for primary level education. Livestock population of the affected families comprises mainly of goats, cows and oxen. Each family owns at least a cow. Although, milk is not a main source of income among these families. Only one family in Benakuli village owns 200 goats and

another family has a mule while there is no sheep and horse in both the villages. Goat and sheep rearing is not common in these families. Almost all families have electric supply and drinking water. About 9 families are connected with telephones. A total of 11 families have access of television. Most of the families use LPG and Kerosene for cooking purposes.

In addition to the rightful compensation project authority would undertake efforts for economic development, employment opportunities, educational facilities, recreation facilities, development of footpaths, merit scholarship programs and construction of rain shelters. The total financial layout for the Relief and rehabilitation and infrastructure development is **Rs. 1,53,38,000/-**

17.11 Disaster & Hazard Management Plan

The Himalayan valleys are subject to the occurrence of apparently sudden calamitous events. These events, in fact, represent the climax of the interaction of numerous independent or unrelated natural phenomena, whose final action is synchronized to produce a sudden and major catastrophic effect. For example, an earthquake represents the culmination of a sequence of tectonic events which trigger seismic action. The seismic waves may lead to the occurrence of significant geo-morphological changes and create conditions for massive landslides and trigger snow or debris avalanches. These events could set the stage for a temporary lake formation in a river valley. Such a lake will have potential of creating a catastrophic flood downstream in eventuality of overtopping. Similar effect could be generated by a cloud burst in any of the sub-watersheds. some of the potential phenomena and sites, where catastrophic conditions are foreseen in Alaknanda valley, are **glacial** lakes, cloud bursts – flash floods and avalanche hazard mitigation. The methods like structural control or afforestation arrests the creep and glide motion of snow on slopes, and thus avalanches too, artificial triggering helps to bring down the avalanches before they reach stupendous proportions. The latter method is relatively cheap. The passive methods include: a) Awareness, b) Forecasting and c) Safety and Rescue. The estimated cost of various activities to be undertaken **is Rs. 220.00 lakhs**.

17.12 Construction Methodology & Equipment planning

It is proposed to complete the project in 67 months period including access roads and mobilization period for the main works contractors. The schedule is based on a date of start of 1 May. Any change in the actual date of start is not likely to impact on the underground works but it could have an impact on the surface works especially the diversion and the re-diversion of the river at the barrage site.

Before undertaking construction activities, it is necessary to complete certain infrastructure facilities which will include:

- Employer's colony and offices
- Installation of construction power
- Access roads

Work on these facilities shall start three months prior to the start of the construction of main civil works. Contracts for basic infrastructure and these access roads would have to be fixed in time for their completion to be achieved before the mobilization by the main works contractors.

17.12.1 Construction of the Main Works

River Diversion

River Diversion and Barrage construction will be held in four stages: Stage 1: Construction of diversion channel 10m wide x 4m deep x 315m long; Stage 2: Excavation of river bank and construction of temporary bund to divert river into diversion channel which will be done during the lean season. Construction of upstream cofferdam with crest level at el. 2937m; Stage 3: Construction of Permanent works like barrage and power Intake; Stage 4: Re-diversion of River: Keep the barrage gates to be in open position and breach the cofferdam to allow water to flow through the barrage. This step shall be done during the lean season.

For Barrage the surface excavation involves common excavation. Large size boulders will be removed by employing drill and blast method. The estimated volume of surface excavation is about 94000 cum. The work in the river bed can be undertaken

only after completion of river diversion work. The estimated total volume of concreting in the barrage is about 80000 cum

Power Intake and Power Tunnels

The power intake structure comprises a concrete structure with two intakes. Each intake is connected to one de-silting chamber by a 3.5 m diameter power tunnel. The first 350m of each power tunnel must be excavated through overburden material to reach rock. First, the excavation for the power intake structure will be completed, after which the two power tunnels will be excavated from the power intake up to the rock line. This work will be carried out by soft-ground tunneling methods using a shield, with precast concrete segments for the primary support. The lengths of the power tunnels that are in rock will be excavated from the downstream end by conventional drill and blast methods from a construction adit near the de-silting chambers. Final concrete lining of the power tunnels will be carried out from the intake, following which the construction of the power intake structure can be completed.

Desilting Chambers

Excavation for the underground caverns for the de-silting chambers will be carried out initially through construction adits leading to the arches of the caverns. The first heading will be along the crown of the arch followed by headings on either side to excavate the full width of the cavern. The short crete and rock anchor supports for the arch will be installed progressively as the headings advance. After completion of excavation and support for the arch is complete the cavern shall be excavated by benching downwards. Spoil will be removed through the construction adits and the silt flushing tunnel at lower level. The shot Crete and rock anchor supports for the walls will be installed progressively from each bench as the excavation proceeds.

Headrace Tunnel – Excavation & Concreting

It is proposed to excavate the tunnel, by drill and blast method, from the upstream and downstream ends only. The upstream face will be accessed through a construction adit at the downstream ends of the desilting galleries and the downstream face will be accessed through a construction adit at the surge shaft. The lining work

shall be started after immediate completion of tunnel excavation works and will be completed within 14 months period.

Surge Shaft – Excavation & Concreting

It is proposed to excavate the pilot hole of the Surge Shaft with a Raise Climber. The diameter of the pilot hole is proposed to be 2.5 metres to 3.0 metres. Once the pilot hole of the Shaft has been raised completely, enlargement of the shaft will be done from the top down. Drilling, blasting, scaling, rock support will be done from the top and the pilot hole will be used for mucking. The blasted material will be pushed through the pilot hole into the headrace tunnel from where it would be mucked out and transported to dumping site using loaders and dumpers. Once the excavation of the surge shaft has been completed concreting lining will be done from bottom towards the top.

Pressure Shaft – Excavation, Lining and Concreting

It is planned to excavate the shaft using a raise climber, which will be capable of excavating the full section of the shaft in a single operation starting at the bottom bend. Mucking out will be from the bottom. The horizontal part of the penstock from the top bend to the surge shaft will be excavated together with the headrace tunnel. Installation of the steel liner will start at the bottom bend and work up the shaft. Following installation of the steel lining cavity, the consolidation grouting will be carried out from a platform suspended from the hoist in the valve chamber.

Powerhouse – Excavation & Concreting

Excavation for the underground caverns for the powerhouse and transformers will be carried out initially through construction adits leading to the arches of the caverns. The first heading will be along the crown of the arch followed by headings on either side to excavate the full width of the cavern. The short crete and rock anchor supports for the arch will be installed progressively as the headings advance. After completion of excavation and support for the arch is complete the cavern shall be excavated by benching downwards. Spoil will be removed through the main access tunnel. The shotcrete and rock anchor supports for the walls will be installed progressively from each bench as the excavation proceeds.

Tailrace tunnel

The tailrace tunnel involves around 65000 cum of underground excavation, the entire work shall take about 30 months to complete. The TRT tunnel will be excavated by drilling and blasting method. The excavation will be carried out from out fall end of TRT.

17.13 Environmental Monitoring Programme

Based on the findings of the Environmental Impact Assessment study various Environmental Management Plans *viz*. Catchment Area Treatment, Biodiversity Conservation & Management, Public Health Delivery System, Fisheries Development, Relocation & Rehabilitation of Dumping Sites, Landscaping and Restoration of Construction Area, Creation of Green Belt, etc. have been proposed. In order to monitor and impact and efficacy of these plans a number of parameters have been proposed during and after the completion of the management plans.

A sum of **Rs.50.00 lacs** (**Rupees Fifty lacs only**) has been proposed for environmental studies to monitor the various environmental parameters as described above. For this, an Environmental Monitoring Laboratory would be setup at a cost of **Rs. 25.00 lakhs**, which would monitor various water quality parameters as well as air quality environment. Therefore, total cost of Environmental Monitoring Programme would be **Rs. 75.00 lakhs**.

17.14 Summary of cost estimates

An amount of **Rs. 3193.31 lacs** has been allocated for the implementation of different environment management plans. The summary of total cost estimates for the execution of different plans is given in Table 2 below:

Table 2. Cost estimates for the implementation of EMP*

Sl.No.	Plans	Amount (Rs. in lacs)
1.	Biodiversity Conservation & Management Plan	585.00
2.	Action Plan for Catchment Area Treatment	545.86

3.	Fishery Management	59.00
4.	Public Health Delivery System	297.22
5.	Solid Waste and Sewage Management	90.85
6.	Provision for Fuel and Energy conservation Measures	20.80
7.	Muck Disposal Plan	750.00
8.	Landscaping and Restoration of Construction Areas & Quarry Sites	342.20
9.	Creation of Green Belt around Reservoir	4.00
10.	Resettlement and Rehabilitation Plan	203.38
11.	Disaster and Hazard Management Plan	220.00
12.	Environmental Monitoring Programme	75.00
	Total	**3193.31**

* This does not include the cost for Compensatory Afforestation and cost of land to be acquired and NPV

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