

Geological, Lineament and Landslide Studies of the Reservoir and its Vicinity of Bunakha Hydroelectric Project, Bhutan Himalaya

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Abstract

For a careful evaluation of a major river valley projects, precise geological, major lineament / fault pattern, land use & land cover and landslide inventory maps of reservoir/catchment area are required as input maps to ascertain the feasibility of construction of dam and other appurtenant structures and also for the stability of reservoir. The present work was carried out for the reservoir area of Bunakha hydroelectric project, to map geological formations, land use & land cover, landslide inventory and lineaments with input of remote sensing and field studies. Indian Remote Sensing Satellite data Cartosat-I, dated 2nd January 2010, sensor PAN Force (Max $\pm 26^\circ$) & Aft (Max $\pm 5^\circ$), spectral band width 0.50–0.85 μm (Pan) having the resolution of 2.5m was used to identify and delineate structural and drainage features and for the preparation of landslide inventory, lineament, drainage and land use & land cover maps of the reservoir area. For the image processing ERDAS Imagine 9.3 was used and for the digitization and analysis Arc GIS 9.3 was used. Landslide inventory with lineaments and land use and land cover maps were generated on 1:10,000 scale with the help of topomaps and Cartosat imagery, while the geological map was generated from published literature and author's traverses. Ground features available on the topomaps on 1:50,000 scale have been used on the base map for facilitating quick ground referencing. The objectives of the study were to provide the above mentioned maps for the assessment of their impact on project structures and reservoirs areas. These studies will also be useful for forecasting of slope stability in the event of reservoir filling and later fluctuation.

The reservoir impounded by Bunakha dam is bounded between latitude of N27°07'57" to 27°15'52" and longitude E 89°30'57.364" to 89°32'41.891", would

be spread in 6.82 sq km area (at FRL 2006m) with a length (linear) of 17.25 km has been studied. The stability of this area depends on the combined effect of lithology, slope, structures, landuse & land cover and hydro-geological condition. The reservoir would as linear bay excepting 700 wide spread near village Bunakha in a declivity occupied by taluswash / drift material and river terrace deposits. The reservoir envisages a gross storage capacity of 329.16 Mcum between the Dobji Dzong and the proposed dam. The Minimum Draw Down Level (MDDL) is at El 1950.00 m and Full Reservoir Level (FRL) level is at El 2006.0 m.

The rocks of the Bunakha hydroelectric project reservoir area are falling under the Central Crystalline belt of Bhutan Himalaya trending in E-W direction. The Central Crystalline consists of Thimphu Gneissic Complex and Paro Formations and MCT-I forming the contact between these two Formations in the reservoir area. In the catchment area the Paro Formation is a lenticular shape separated from upper high-grade metamorphosed migmatitic gneisses by thrust and low grade gneisses with gradational contact. The reservoir on the either sides of Wang Chhu is surrounded by steep slopes and in general slopes are thickly vegetated. The rocks are thinly to thickly bedded and joints are mostly tight to open in nature. The bedrock encountered at the proposed dam site at Bunakha and its appurtenant structures is represented largely by crystalline rocks of Thimphu Gneissic Complex belonging to upper amphibolite facies of metamorphism. These litho-units at site are characterized by heterogeneous lithology consisting of foliated gneisses, streaky and banded ganiess, amphibolite gneisses with large boudins and bands of quartzite and thin interlayer of mica schists/foliated gneisses with large porphyroblasts of garnet and bands of calc-silicate gneisses.

The area is traversed by series of lineaments; which have four major trends having distinct structural relationship with N-S trending antiform: N-S, axis parallel longitudinal lineaments; NW-SE, diagonal lineaments; NE-SW, diagonal lineaments and E-W, trending transverse lineaments (parallel to fold axis of second generation). In the study area 129 lineaments (L-1 to L-129) were identified from the images and most of the lineaments which are falling in the reservoir area were checked in the field. Based on the strike length, lineaments of this area are classified into three

types viz. mega (length >1500 m), major (500 – 1500 m) and minor (0 – 500 m) lineaments.

In the Bunakha project area, on the right and left bank of Wang Chhu river, the 3400 m elevation has been taken into consideration for landslide inventory, because landslide above this elevation will not affect the project area. Geomorphologically project area is characterized by deep, steep and narrow valleys with long convex slopes descending from the ridgeline ending in near vertical and steeply convex gorges or V-shaped valley. Landslide is the area have been classified based on status of activity (active, old/ dormant/ stabilized), material involved (debris avalanches, rock-slide etc.), morphometric character and scale. Based on crown height, landslide are classified into three types viz. large (crown height >10 m), medium (5-10 m) and minor (< 5 m) landslide. Total 51, minor, medium and major landslides have been identified from the reservoir area and its vicinity.

Broadly, the landuse pattern of the area are grouped into five categories: agricultural land/ populated flat land, thickly vegetated forest area, moderately vegetated forest area, open scrub area with lesser ground cover and barren land. More than 50.83 percent of the area is come under the thickly vegetated forest followed by moderately vegetated forest area (22.55%), agricultural / populated flat land (11.67%), open scrub area (9.27%) and barren land (3.42%). In the Bunakha HEP area about 79% of the population's main source of livelihood is agriculture. For the reservoir total about 3.745 sq km land will be required, and the area comprises agricultural land including orchards, forest area, water bodies and barren rocky outcrop. No village, no road and no archaeological monument are coming under submergence zone of the reservoir area.