

ENGINEERING AND ENVIRONMENTAL GEOLOGICAL INVESTIGATION OF DHARAN AREA USING RS AND GIS TECHNIQUES

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ABSTRACT

Dharan area lies in a precarious location with main settlements sitting on Fan Deposits of Sardu and Seuti Kholas. The area is frequently endangered by floods particularly at Bikashtol in the west by Sardu and at Nirajanbasti in the east by Seuti Kholas during monsoon season. LANDSAT TM (November 1990) and IRS PAN (February 2000) of the area helped to recognise various land use patterns, flood plains and areas susceptible to mass movements. Airphotos of 1992 and 1998 were used to know further information in the field. Digital data (1: 25, 000) of topo maps obtained from Department of Survey is used for preparation of base map for the intended investigation. The area is underlain by Tertiary sediments (Siwaliks) in the north and Quaternary sediments (Terai Plain) in the south. The Main Frontal Thrust (MFT) marking the contact between Siwalik and Terai runs along the break of slope little north of the main settlement of Dharan. Main Boundary Thrust (MBT) separates the rock sequences Middle Mountain and Siwalik. Siwalik rocks show gentle to steep dips due N, NE and NW. Valley floor setting consists of nine units of Quaternary - Recent sediments of alluvial, residual and colluvial types. Three divisions of Siwalik is recognized in Dharan area. Riverbank cutting in Sardu and Seuti Kholas is severe. Badland development due to rapid erosional process in the immediate vicinity of these kholas is enhancing the vulnerability of area to natural hazards. All these information are presented on "Engineering and Environmental Geological Map" at 1 : 25,000 scale with optimum utilization of RS and GIS.

1. INTRODUCTION

The area of field investigation covers nearly 130 km² lying in between latitudes 26° 45' 30" N to 26° 52' 25" N and longitudes between 87° 14' 30" E to 87° 20' 30" E. Urban Geology and Land Use study was mainly focussed on the Dharan Municipality. Dharan town is situated at the foothills of Siwalik (Churia Range) morphotectonic zone within the Bhavar zone represented by coarse gravels, sand and silt. Immediately to the north extend fragile Siwalik foot hills consisting of sandstone and shale while in the south lies Terai plain. Dharan town has good linkage with other urban areas of the country through Mahendra (E - W) and Koshi (N - S) Highways. MFT marking the contact between Siwaliks (Tertiary molasse type sediments deposited during the rising of the Himalayas) in the north and northern marginal part of Indo - Gangetic Plain (Terai) in the south runs along the break of slope (Figure - 1) and is well exposed in eastern part of the area near upper stretches of Khar Khola.

2. OBJECTIVES

Urban geological mapping of the area is carried out with a view to prepare an engineering and environmental geological map required for Dharan municipality for its urban, landuse and infrastructure development planning. Subsequently, present program was formulated by DMG with the objectives of Preparation of Engineering and Environmental Geological Map consisting information on present land use natural and man – induced hazards, settlements, waste disposal sites, probable landfill sites, infrastructures etc.

3. PHYSIOGRAPHY AND CLIMATE

The study area is partly mountainous in the northern part and the plain in the southern side. It is situated on the debris and fan materials derived from the northern hills and deposited by Sardu and Seuti Kholas. The climate of the area is sub – tropical to tropical with hot and humid monsoon type summer followed by cool and fairly dry winter. Monsoon rainfall occurs during the months of June to September.

4. METHODOLOGY

Desk study, field investigation and laboratory study were supported by GIS analysis in course of the preparation of the engineering and environmental geological map. LANDSAT TM Scenes at 1:125,000 scale taken on November, 1990 and aerial photographs at 1:15,000 (taken during 1998) and at 1 : 50, 000 scales (taken during 1992) were studied and interpreted. Lineaments were marked in the TM – Scene that oriented mainly in N – S, NW - SE and NE – SW directions. These lineaments could be the deep seated faults or fracture zones, the lithological and in most cases represent the tectonically weak zones. IRS PAN/LISS Indian satellite data of the area at 1:12, 500 scale (taken in 16th February, 2000) has been used in incorporating the latest changing information in the map. Topo maps (at 1 : 25,000 scale of 1995) of the investigated area were also acquired. The digital data base of topo map received from Topographical Survey Branch has been useful to prepare the base map of the area.

Field investigation was carried out in the dry season of 2001. It was planned with an aim to verify the interpreted information (like lineaments) in the field as well as compared with the previously identified thrusts, faults, lithological formations, boundaries, land use and the infrastructures. Field survey enabled to delineate the potential areas of instabilities on the ground (hill slopes, river banks) that endangered the settlements (built up area) in Dharan. Standard Penetration Test (SPT) and augering was simultaneously carried out in the same area by a team of engineering geologists. Laboratory tests and analysis of samples collected from the field were carried out in chemical, mineralogical and geotechnical laboratories. GIS analysis was carried out at the Remote Sensing Section (RSS) of DMG using ARC/INFO software. The process includes the digitizing of the map, input of data and its storage, data processing and plotting of the engineering and environmental geological map.

5. APPLICABILITY AND LIMITATIONS OF THE MAP

The map is expected to deliver the basic geoscientific information that are necessary to the planners, decision – makers, engineers, civil technicians and other users at local level to make use as a base for landuse planning, urban and regional development plannings, disaster mitigation and environment management. General information about present status of landuse, settlement areas, industrial area, ground condition, potential areas for mining, construction materials, ground water extraction, waste disposal sites, degraded and hazardous areas as well as other areas requiring protection measures are indicated in the map (Figure 1). Detailed site investigation is always an essential aspect to be considered for specific engineering design and construction projects.

6. INVESTIGATION RESULTS

The study area (Dharan Municipality and the surroundings) covers partly the Siwalik foothills, Middle Mountain and partly the debris and fan materials derived from northern hills and deposited by Sardu and Seuti Kholas. Further north Mahabharat Thrust (MT) is exposed with rocks of Kunchha Formation lying north of it.

7. GEOLOGICAL SETTINGS

7.1. Bedrock Geology: Bedrock in the area is represented by rocks of **Siwalik Group** (Late Miocene to Pliocene sedimentary rocks), and **Nuwakot Group** (Precambrian low – grade metamorphic rocks like metasandstones, phyllites as well as medium to high grade (schists and gneisses) rocks of the Lesser Himalaya (Rimal and Tuladhar, 2001). These rock sequences are separated by thrust faults. The low – grade metamorphic rocks (**Nuwakot Group**) are sub - divided into two formations as **Bhendetar** and **Kunchha Formations (kn)**. The **Bhendetar Formation** is further sub - divided into two units as Churibas and Sangure Quartzite Units (Sq). The Churibas Unit is further sub - divided into three sub – units as Lower sub – unit(ch1) – Green Grey Metasandstone, Middle sub – unit (ch2) – Green Phyllite and Shale and the Upper sub – unit (ch3) – Grey to Pink Metasandstone and Pink Shale. Sangure Quartzite (Sq) consists mainly the white quartzite with subordinate bands of pink and purple quartzites and marks the northern watershed. **Kunchha Formation (kn)** consists of green grey chloritic phyllites, schists and bands of augen gneiss. These rocks form the highest ridge in the northeast corner of the area and are thrust over the low – grade metamorphic rocks along the Mahabharat Thrust (MT) which acts as the southern border. The **Siwalik Group** comprises the thick piles of fresh water molasse sediments deposited during Mid Miocene to Lower Pleistocene time and later uplifted during the rising of the Himalayas (Duvadi et. al., 1998). The Siwalik rock sequence consists of colourful fine sandstone, shale and mudstone in lower part; medium to coarse grained sandstone and mudstone in the middle part. The Lower Siwalik Formation (ls) is represented by fine to medium grained, hard, light – grey sandstone alternating with colourful mudstone, siltstone and shale. Predominance of mudstone over sandstone is generally observed. Cyclic sedimentation with fining upward sequence is often marked. Approximate thickness of the Lower Siwalik is 500 meters. It shows smooth ridges and landslides are possible on steep slopes. The Middle Siwalik Formation is divided into two parts: Lower Middle Siwalik (ms1) and Upper Middle Siwalik (ms2) Formations. **ms1** is medium to coarse - grained, thick – bedded, grey sandstone alternating with purple, yellow and grey mudstone, calcareous siltstone and grey shale (with plant fossil). Dominance of sandstone over mudstone is observed. The thickness of ms1 is approximately 500 meters. Steep cliff formation, differential erosion forming scarp ridges and blockfall are common. Stabilization measures to control blockfall is needed. **ms2** on the other hand is gravelly / pebbly, coarse – grained, pepper and salt textured sandstone and vari – - coloured mudstone. Predominance of sandstone over mudstone is observed. Approximate thickness is 800 meters. It has high potential for badland development. Slope failure on river banks is common and erosion of incompetent rocks result into toppling of competent rocks. In general the Siwalik rocks show a gentle to steep dipping towards north, northeast and northwest. Repetition of the siwalik rocks sequence occurs due to Central Churia Thrust (CCT).

7.2. Quaternary Geology: The valley floor in the area consists of Siwalik sediments derived by the rivers that originate within Siwalik Hills except in the depositional sites of **Sardu**, **Seuti** and **Sehara Kholas** where boulders from Middle Mountain are also found (Duvadi and Tuladhar, 2001). Sometimes gneissic boulders are also seen in **Sehara Kholas**. Mainly the alluvial soils of Quaternary – Recent are deposited on the plain and along the river valleys (by fluvial action). The valley floor sediments are classified according to their composition, degree of compaction and segmentation and the types of cementing material based on the Unified Soil Classification System. They are divided into nine units: Active Alluvial Fan (aaf), River Bed Deposit (rbd), Khairani Gravel Deposit (kbd), Colluvial Soil (sco), Residual Soil (srs), Ghopa Formation (gf), Dharan Formation (df), Pindeshwor Formation (pf) and Bijayapur Formation (bf). **aaf** is locally deposited debris as fan derived from landslides and brought down by tributaries to the main stream. **rbd** occurs along the riversides and on the flood plain itself. It has alluvial loose sediments consisting boulder, cobble, gravel mainly of quartzite, sandstone, gneisses with sand and silt, and chert. When mixed with clay it gives rise to the fertile top fine soil usable for the cultivation. The aggregates derived and deposited by river often provide an excellent source of building and construction materials. **kbd** is the river terrace and is locally developed on the both sides of the rivers and streams and is characterized by sub – angular to rounded pebbly and gravelly materials of quartzites, gneiss, schistose phyllite mixed together with fine sand, silt as well as clay giving rise to the fertile top fine soil usable for the cultivation. The exposed thickness is up to 2m. **sco** is the inhomogeneous deposit at base of slopes and consists of clay, silt and sand with sub – angular gravel to boulder size fragments of rocks (shales, phyllites and metasandstones). Most of these deposits are derived from old landslides. **srs** is developed in place on flat to gentle hill slopes in **Patranbari**, **Manwatar**, **Karkichhap**, **Machhamara**, **Gurunchhap**, **Lopsedanda**, **Thulo Khairi** and **Subantar** villages. It generally represents clay, silt and gravel and is reddish brown, dark brown and grey in colour with few cobble size rock fragments. **gf** represents the stratified layers of sub – rounded to rounded cobbles of quartzites, sandstone, gneisses intermixed with

sand and silt and is covered by soil of 1 – 3 m. thick towards the top. **df** is ill – sorted deposit of sub – angular to sub – rounded boulders, gravels, cobbles, pebbles of quartzites, sandstones and gneisses derived from the Siwaliks and Middle Mountains and is intermixed with sand and silt covered by brownish grey humus soil of less than 1m. thickness. **pf** shows sub – angular to rounded boulders, gravels of gneiss, quartzites, phyllite, sandstone, siltstone and mudstone intermixed with clayey silt and is covered by grey soil (up to 1m. thick). It attains the thickness up to 30m. and is characterized by flat surface on the top. Bedrock is generally exposed at the bottom of the formation. **bf** shows sub – angular to rounded boulders, gravels of gneiss, quartzite, phyllite, sandstone, siltstone and shale intermixed with clayey silt and is covered by red soil up to 4m. in thickness on the top.

8. GEOLOGICAL HAZARDS AND ENVIRONMENTAL DEGRADATION

Areas susceptible to landslides, rock/block falls, mass movements, debris flows hazards are demarcated in the map. Many places in Siwalik rocks in this area have been encountered with a number of tension cracks, active and old landslides. It is wise to overcome the possible risks caused by each type of hazards before planning and implementation of any civil construction works. Side cutting in Sardu east bank is caused by riverbank scouring and rain water resulting into gully erosion with badland development (in and around Raitol area). Here a buffer zone of 30 m. is desirable not to have any settlements and construction works to allow natural stabilization. Slope failures causing landslides are common in western bank of Sardu Khola. Similarly there are a number of active landslides within Seuti Khola catchment. At places MBT is located at the crown part of slide. Quite a number of landslides are developed at vicinity of MFT suggesting that the thrust is still active.

8.1. Bearing Capacity Areas: Low Bearing Capacity Areas are concentrated in the areas where **aaf**, **rbd** and **ch2** occur. **aaf** and **rbd** have high permeability and loose density whereas landslides are common in **ch2** (Sikrikar, 2001).

8.2. Flood Prone Areas: Low lands adjacent to Dudhpani, Sardu, Seuti, Khar and Sehara Kholas and at the streams in the area are likely to be affected by floods as they are prone to flood hazards. Hence, these areas are not suitable for human settlements but can be utilized for agricultural field. A risk of flash flood can always be a threat in these areas in future.

8.3. Landslide, Erosion and Flood Hazards: Various small and large, active, old and dormant landslides are marked in the area along hill side slopes. Wide open cracks are marked on the crown part of the landslides. Slope with angle of 40° – 60° is unstable and can create further sliding. In addition to these areas with gully erosion and tension cracks are also marked on the map. Soil erosion and rock fall is also quite common in hill slope area because of soft and fast weathering nature of rock/soil, deforestation as well as haphazard exploitation of construction materials. Area in **ms1** and **ms2** is very much likely to suffer from rock/block fall and soil erosion as well as landslides due to steep slope. High density of joints and differential erosion between soft mudstones and hard sandstones of Middle Siwalik are promoting to the rock blocks to be detached creating landslide and block fall hazards. Riverbank cutting in Sardu Khola near Raitol is another threat that needs to be taken care of. Low land area that gets flooded during heavy rain is covered with sediment deposited by streams and are left barren during the dry season. These areas are suitable for both dry and wet cultivation but not for the construction of buildings. They have high groundwater potential and should be avoided for dumping of chemicals and petroleum, municipal, industrial and hospital wastes.

8.4. Industrial, Construction Material Mining Hazards: Industrial district and other industries (like brick factories, stone crushing plants) located near the settlements and the river banks could create health hazards. Several locations of construction materials quarry sites are seen in Sardu and Seuti Kholas. Improper mining of the construction materials have helped to trigger the landslides and river bank scouring.

9. NATURAL RESOURCES

Surface as well as groundwater, non metallic minerals like building stones and natural forests are the main natural resources one can count on in the study area. Proper management and utilization of these resources for the livelihood of the people is highly desirable.

9.1. Surface and Groundwater resources: Both Sardu and Seuti Kholas as they originate from the Middle Mountain have water throughout the year. Other streams originated from the Siwaliks have very less amount of water or not at all during the dry season. Level of groundwater is very deep in the area. However a pond and a well with water level at 10 feet is marked near the Pindeshwor temple in Siwaliks where the bedrock (ms2) is found.

9.2. Mineral Resources: Area does not have any potential economic metallic mineral resources. However the non - metallic minerals resources like construction materials (building stones, sand, gravel, boulders, cobbles and pebbles) are abundant along river beds of Sardu, Seuti, Leduwa, Khar and Sehara Kholas.

9.3. Reserve Forests: Most of the hilly sides and southern part (south of Dharan township) in the area are covered by forests (like protected and community forests). Protected forest in the area is marked at one place south of Ghopa camp. Reserve forests are also seen in the plain area.

10. LAND USE

Existing land use pattern in the area are agricultural, forests, settlements, industrial, recreation centers, infrastructures and land fill / waste disposal sites.

10.1. Agricultural and Forest Lands: Most of the flat, low lands in the plain (in the south) as well as in hilly sides are covered by forest land. Different types of forests like open forest, scrub, orchard, bamboo, bush, grass and swamp forests are categorized in the area. Low angle sloping lands are good for dry cultivation like maize, millet, wheat and cereals.

10.2. Urban Settlement and Industrial Areas: Urban settlement (existing, planned, proposed and expanded) areas are marked in the map. Management of sewerage system in Dharan township is relatively easy as it is situated in slopy land. However proper drainage system in Phusre and east of Bhanuchok is inadequate. Crucial area of manmade pollution is located in east of Bhotepul. Squatters settlements in the banks of Sardu and Seuti Kholas is creating an alarming threat of encroachment of the river banks and flood plain. Cemetery is marked on the northern edge of this forest.

10.3. Recreation Centers and Open Spaces: Bijayapur Danda (hill) is the only existing public and natural park in the area. It has religious and cultural values where most of deities (Bindhabasini, Budhasubba, Dantakali, and Pindeshwor temples) are located from north to south. In addition proposed Saptarangi Park is located west of Sunaulochok between Sardu and Khahare Kholas.

10.4. Landfill / Waste Disposal Sites: Dharan municipality is lacking its own permanent, sanitary landfill site to manage safe disposal of its solid wastes produced from the urban settlement and industries. At present municipality is temporarily dumping its daily wastes into the forests and Seuti flood plain (both at south of Dharan Municipality) without taking any consideration about its environmental impact.

11. GEO – ENVIRONMENT AND POLLUTION

Direct connection of sewage drainage, sewage pipe line, haphazard disposal of industrial and hospital waste in open space and streams and improper dumping of solid wastes into the riverside and forest area are the root causes of river water pollution in Dharan Municipality. Expansion of urban area without adequate infrastructures is another major cause of the environment pollution. Increasing vehicular traffic with their pressure horns causes noise pollution whereas the operation of old vehicles with low quality fuels, industry's chimneys and increasing volume of garbage and industrial wastes cause the air pollution. Analyses of river water, groundwater and tap water from different locations show that water from surface water source and public taps are fairly high in coliform content than the groundwater source. Arsenic value is found to be below WHO limit for potable water. Water samples from different locality are highly polluted biologically but not chemically (Kaphle, 2001).

12. CONCLUSIONS

The study area is situated partly on the Siwalik Hill, Middle Mountain and partly on the debris and fan materials derived from hills in the north as well as sediments deposited by Sardu and Seuti Kholas in the west and east respectively. The area is often endangered by floods particularly at Bikashtol and Raitol in the west by Sardu Khola in its east bank and in Nirajanbasti in the east by Seuti Khola in its west bank. River bank cutting in Sardu (causing badland development) and Seuti Kholas is severe. Siwaliks comprises the thick piles of fresh water molasse sediments while Quaternary sediments in the south are deposited by streams mainly derived from the Siwalik hills and also from Middle Mountains. Middle Mountains on the other hand is represented by Nuwakot Group (low – grade metamorphic rocks like metasandstones, phyllites and medium to high grade (schists and gneisses) rocks of the Lesser Himalaya. These rock sequences are separated by thrust faults.

MFT marks the contact between Siwaliks and Terai and runs along the break of slope. In general the Siwalik rocks show a gentle to steep dipping towards north, northeast and northwest.

River Bed Deposit (rbd) often provide an excellent source of building and construction materials. Proper drainage system in Dharan Municipality area is inadequate. Also the squatter settlements in Sardu and Seuti flood plain are highly vulnerable to flood hazard. There is a need to find a suitable sanitary site for solid waste management in the area. Direct connection of sewage drainage into the Khahare Khola and other streams have caused the pollution of stream water. The map would be a help to urban planners and decision makers at local level particularly in hazard mitigation, sustainable utilization of natural resources and environmental management.

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