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Environmental geological map of the Kathmandu Valley, Nepal

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ABSTRACT

The environmental geological map of the Kathmandu Valley at a scale of 1:50,000 was prepared during a Technical Co-Operation Project of the Department of Mines and Geology (DMG) of Nepal and the Federal Institute for Geosciences and Natural Resources, Germany. This map is meant to draw attention to the natural environmental risks and hazards, as well as to recommend measures for the protection of important natural resources in the Kathmandu Valley. This thematic map is addressed mainly to governmental agencies and consultants, who can use the map as a database for planning purposes, especially for planning new settlement areas and various types of infrastructure.

The map shows the locations of clay, sand, limestone, groundwater, and forest. These resources are very important for the economic development of the Kathmandu Valley. They need protection against the haphazard growth of settlement areas. In the case of mining, environmentally sound methods with monitoring and supervision is recommended. Areas to be considered for agricultural use (rain-fed or irrigation) are also delineated.

The map also shows areas of geological hazards and related environmental problems from floods, landslides, and liquefaction of soils. Pollution caused by human activities, such as river pollution, and areas of uncontrolled landfills are also indicated. Pollution of the Bagmati River and its tributaries and the resulting degradation of water quality is a burning issue in the Kathmandu Valley. Rapid urbanisation and increasing volume of industrial and municipal wastes have drastically changed the sacred river into an open sewer.

The map has already been used for the general assessment of the environmental geological risks in 27 new settlement areas in the Kathmandu region. This study realised that there is a conflict with other competing interests, e.g., the interests of the landowners. The promotion and implementation of environmentally sound recommendations is very complicated and politically sensitive. Nevertheless, these difficulties should not discourage the planners, because the promotion of environmentally sound aspects is for the long-term benefit of the whole population of the area.

INTRODUCTION

The Department of Mines and Geology (DMG) of Nepal implemented an Environmental Geology Project from 1994 to 1998 in collaboration with the Federal Institute for Geosciences and Natural Resources (BGR), Germany. An initial product of this project was the preparation of the Engineering and Environmental Geological Map of the Kathmandu Valley (Shrestha et al. 1998) and the Explanatory Notes (Kaphle and Joshi 1998). This first map was introduced at the Second International Geological Congress in Kathmandu in November 1997 and at the International Symposium on Engineering Geology and Environment in Athens (Hanisch et al. 1997). However, many users have asked for an environmental geological map, which could be easily understood by planners. Therefore, the map presented here (Fig. 1) uses the existing geological database by GIS techniques, but avoids most of the geological and engineering terminology in order to give priority only to the presentation of environmental facts and problems.

OBJECTIVES

Environmental geology is defined as the study of geological processes and their interaction with human activities. Essentially, it deals with geoscientific aspects related to land-use planning, urban development, and natural resource management, for which this information is used to minimise negative impacts on the environment.

The information presented on the map can be very useful for cost-effective, efficient regional and urban development planning. It is a good basis for:

- regional and urban development planning;
- infrastructure and land-use planning;
- identification of sites suitable for industrial areas, new settlement areas, landfill sites, sewage treatment plants, recreation parks, etc;
- identification of quarry sites for construction materials (sand, gravel, limestone); and

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Kathmandu 1998

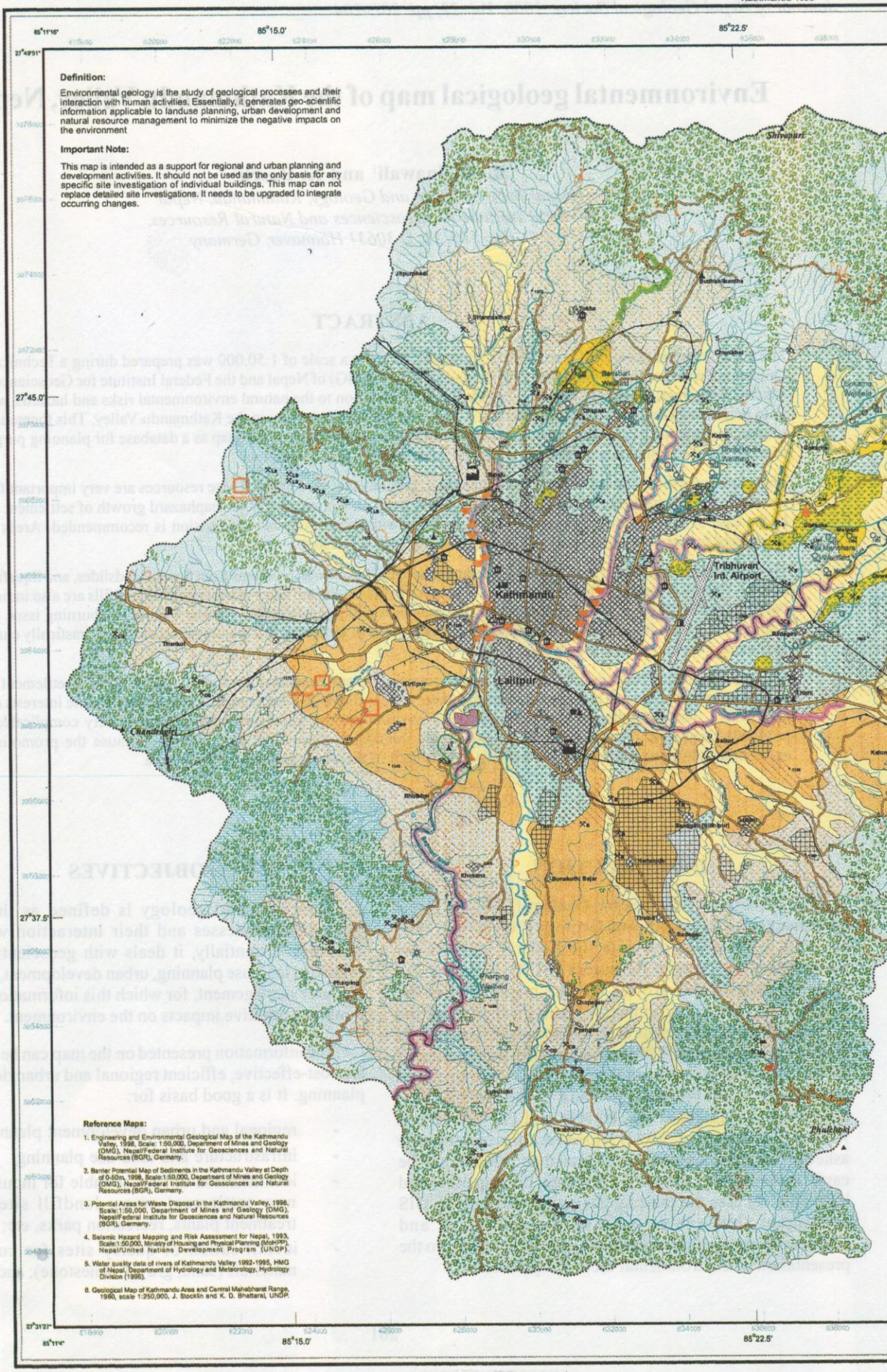

Fig. 1: Environmental Geological map of Kathamandu Valley, Nepal

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- protection of well fields and geological sites of national importance.

This map was prepared at a reconnaissance scale of 1:50,000 with a limited database. Therefore, construction of individual buildings and infrastructure components requires a more detailed site investigation.

NATURAL RESOURCES

The Environmental Geological Map of the Kathmandu Valley (Fig. 1) shows the locations of clay, sand, limestone, groundwater recharge areas, and the location of well fields and a gas field. These resources are very important for the economic development of the Kathmandu Valley. They need protection against the uncoordinated growth of settlements, and in the case of mining of mineral resources, environmentally sound methods with monitoring and supervision are recommended.

Clay and clayey silt

Clay and clayey silt deposits occur mainly in the central and southern parts of the Kathmandu Valley. They belong to the Quaternary Kalimati Formation, which is rich in organic matter and phosphate. The soils are very fertile and suitable for farming (rice, maize, wheat, and many types of vegetable). The silty clay is suitable for bricks. There are many brickyards south of Kirtipur, south of Patan, and around Bhaktapur. The clay pits are marked on the map by the standard hammer symbol with the letter "B". Most of the historical buildings of the three royal cities: Kathmandu, Patan (Lalitpur), and Bhaktapur are built with these bricks, and these deposits are still very important for the current construction industry. Extensive areas of clay deposits south of Patan are in danger of being covered by new settlements. In this case, the mining industry should have a priority. However, environmentally sound mining methods and regular monitoring by the Government are recommended.

Sand

Owing to the strong demand for medium- to coarse-grained sand by the flourishing building and construction industry in the Kathmandu Valley, near-surface sand occurrences are of great interest. Up to now, sand has been mostly obtained from riverbeds, which has resulted in serious riverbed scouring. Such practice has endangered bridges and other types of infrastructure, and triggered off landslides. Since 1995, the exploitation of sand from rivers in the Kathmandu Valley has been prohibited by the Government.

Sand of good quality also occurs in the northern Kathmandu basin as layers in the Quaternary Gokarna and Tokha Formations. The sand deposit of 2 to 10 m thick occurs in palaeo-channels up to 100 m wide. Sand is extracted in small quantities in the area of Jhaukhel and Duwakot in the Bhaktapur District, and in the areas around Mulpani, Gokarna, Bansbari, and Thoka in the Kathmandu District. Sand production from these formations is very limited because of the thick overburden of silt and fine-sand layers (the ratio of depth of overburden and thickness of sand deposit is 4:1). The existing pits are marked on the map by the hammer symbol with the letter "S".

Limestone and marble

Limestone and marble (Chandragiri Formation) occur as bedrock near Chapagaon and Godavari in the southern part of the valley and west of Swayambu in the western part of the valley. Limestone is mostly quarried for crushed rock aggregate for road and building construction. The quarry sites are indicated on the map with the hammer symbol with the letters "CG" (crushed rock) and "Ls" (limestone). The marble (MA) quarried at Godavari is of very high quality.

Surface water and groundwater resources

Water of good quality is a very important natural resource. It is used for drinking and irrigation purposes. Its protection from pollution is a considerable problem, especially in the dens population centres of Kathmandu, Patan, and Bhaktapur, where untreated sewage is discharged into the rivers. Another source of pollution is the dumping of waste on the riverbanks.

Groundwater is the source of about 40 % of the Kathmandu water supply. The Bansbari, Dhobi Khola, Gokarna, and Manohara well fields in the northern part of valley take water from the sandy layers of the Gokarna and Thoka Formations. In the Pharping well field in the southern part of the Kathmandu Valley, groundwater is abstracted from the sand and gravel of the Lukundol and Kobgaon Formations. All these well fields need protection from pollution. It is recommended to establish a protection zone around the wells with a radius of 1 km, and it should not contain any landfills, untreated sewage, or industrial waste.

Areas of groundwater recharge are coloured blue on the map. These areas are underlain by geological formations with a high infiltration capacity. Though the detailed data on the groundwater potential in the Kathmandu Valley are not available, a high potential for groundwater recharge is expected in the sandy formations of the northern part of the Kathmandu basin. Groundwater recharge is also possible through the surrounding mountain ranges.

Gas field

There is a gas field, containing mostly methane (CH_4), in the central part of the Kathmandu basin, at a depth of 300 to 550 m. The gas is in a confined aquifer in Quaternary sediments covered by clay layers of the Kalimati Formation. The Department of Mines and Geology drilled 14 boreholes at various locations in a 26 km^2 of prospective area from 1988 to 1992. The maximum depth of the holes was 570 m at Bhrikuti Mandap. This borehole encountered bedrock at a depth of 549 m. On the basis of the data, DMG identified the area of the gas field and calculated a reserves potential of about 300 million m^3 of methane. Techno-economic feasibility study carried out in 1996 indicated 15.5 % IRR. However, commercialisation of the gas reserve is still awaited.

LAND USE

One of the most important items of information on an environmental geological map is land use, such as for forestry and agriculture. The forest in the mountain areas protects the soil on steep slopes from erosion and landslides, and enhances groundwater recharge. Forest areas are indicated by a green bush symbol, and the "protected forests" are additionally outlined by a green chain symbol.

Land use for agricultural purposes is recommended only on the basin plain and not on the steep mountain slopes. Areas with a gradient of less than 5° are generally suitable for irrigated crops (indicated by a green grass symbol). However, proper irrigation and a drainage system is necessary to avoid soil erosion. Controlled use of chemical fertilisers and pesticides is recommended. The areas with a gradient of more than 5° are suitable only for rain-fed crops (brown grass symbol).

NATURAL HAZARDS AND RELATED ENVIRONMENTAL PROBLEMS

Areas endangered and affected by natural hazards have risks for human life and property. The Kathmandu Valley is often affected by floods, landslides, and earthquakes.

Flood prone areas

Almost all the lowlands along the Bagmati River and its tributaries are prone to flooding. On the map, the floodplains are indicated by light brown colour. The land in this category is not recommended for settlements. For construction projects, further investigation must be carried out, for example, to determine bearing capacity of the foundation soil. However, such areas can be used for rain-fed or irrigated crops, green belts, and development of open spaces for recreation. These areas have a high groundwater potential, but they are highly vulnerable to pollution. For this reason, waste disposal and storage of chemicals, oil and gas should be prohibited in such areas.

Landslide and erosion

A large number of active and dormant landslides are recorded in the hilly areas, especially in the Shivapuri Range on the north side of the Kathmandu Valley. Erosion of soil is also a common problem in these areas. Improper land use, haphazard exploitation of natural resources (e.g., aggregate, clay, and sand), irrigation agriculture in the steep slope areas, and deforestation are basic causes of landslide and soil erosion.

Only some of the areas have been studied in detail for landslides. Areas of active and dormant landslides and gully erosion are delineated on the map. Proper maintenance of internal and external drainage, and construction of check dams to control flooding and soil erosion are strongly recommended.

Liquefaction

The earthquake catalogue of Nepal shows that several earthquakes greater than 5 on the Richter scale have occurred in the last century in the Kathmandu Valley and in the surrounding regions. Earthquakes can trigger liquefaction, which is the tendency of the sediments to flow under high pore water pressure, e.g., when saturated sand is shaken by an earthquake. The unconsolidated sediments of the floodplains and lower terrace deposits have been classified as highly susceptible to liquefaction on the basis of information provided by HMG/UNDP/HABITAT (1993). In these areas, it is imperative for any construction work of large buildings and infrastructure in the valley to follow the recommendations of the National Building Code of Nepal (BCDP 1994).

POLLUTION BY HUMAN ACTIVITIES

Migration of people to the capital city of Kathmandu and rapid expansion of urban areas without adequate infrastructural development have created serious pollution problems in the Kathmandu Valley. Improper location of industries as well as discharge of municipal waste, sewage, and toxic chemicals directly into the rivers have created the pollution problems in Kathmandu, Patan (Lalitpur) and Bhaktapur. Air pollution is also increasing due to the ever-increasing number of motor vehicles in poor condition and poor quality of fuels.

Pollution of river water

Pollution of Bagmati River and its tributaries, and the resulting degradation of water quality are burning issues in the Kathmandu Valley. Based on the data of HMG/ Department of Hydrology and Meteorology (1996), the degree of pollution of the river water is shown on the map by different colours from green to magenta. The rivers in Kathmandu are shown to have a high degree of pollution (magenta). The use of such polluted water is highly hazardous to human health.

Landfills

Both landfill sites in operation and abandoned ones are shown by red on the map. The landfill sites near the rivers are at high risk to the groundwater as well as surface water. Highly permeable ground, such as unconsolidated riverbeds and floodplains along the Bagmati, Bishnumati and other rivers, are not suitable for disposal of household and industrial wastes. Only the fine-grained sediments with low-permeability, such as clay or clayey silt (e.g., abandoned clay pits) are suitable sites for waste disposal. Preliminary investigation of soil and groundwater and other studies by the Project in the Kathmandu Valley identified five potential areas for waste disposal sites (Kharel et al. 1998). These potential sites are indicated by red squares on the map. A detailed investigation of the specific site is required before a final decision can be made for the waste disposal.

Settlements and industrial areas

Settlement areas, shown by grey colour, are often areas of uncontrolled urbanisation with an accumulation of sewage, solid waste, and emissions, which cause strong environmental impacts. Therefore, especially the newly planned settlement areas should be provided with proper treatment systems for sewage, suitable landfill sites, and emission control.

There are quite a few small- to medium-scale industries in the Kathmandu Valley. Most of them are located in the industrial estates of Balaju, Patan, and Bhaktapur. Major sources of atmospheric, soil, and groundwater pollution are the Himal Cement Industry at Chobhar, various brick kilns, and several factories for dyeing carpets.

PROMOTION OF THE MAP

At a workshop in September 1998, the Project team presented the first draft of this Environmental Geological Map to potential users in the Kathmandu region. Suggested improvements were incorporated as far as possible. Using GIS techniques, further revisions on the basis of users' comments can be easily carried out.

The map has been used for a general assessment of the environmental geological risks in 27 new settlement areas in the Kathmandu region. This study recognised the conflict with other competing interests, e.g., with the economic interests of the landowners. Therefore, the promotion of environmentally sound recommendations is very complicated and politically sensitive. Nevertheless, these difficulties should not discourage the planners, because the promotion of environmental aspects is for the improvement of the general living standards and for the benefit of the whole area.

CONCLUSIONS

Detailed maps of natural resources and geohazards in combination with GIS-based methods are effective ways of providing valuable geoscientific information to planning authorities. The information presented on the map can be very useful for cost-effective as well as efficient regional and urban development planning.

The present map shows the locations of clay (brown), sand (yellow), limestone (blue with limestone symbol), and groundwater recharge (blue). These resources are very important for the economic development of the Kathmandu Valley. They need protection against the uncoordinated expansion of settlement areas. In the case of extraction of mineral resources, environmentally sound methods with monitoring and supervision are recommended.

Areas with geological hazards (e.g., floods and landslides) and environmental problems (e.g., pollution of rivers) are delineated. Strong earthquakes (> 5 on the Richter scale) have frequently occurred in the valley. Therefore, the data from the HMG/UNDP/HABITAT Project (1993) showing a high risk of liquefaction of the soils are included. Land use, such as forestry and agriculture, is also shown on the map.

The Engineering and Environmental Geological Map of the Kathmandu Valley (Shrestha et al. 1998), and the explanatory notes of Kaphle and Joshi (1998) are useful for more basic information on rock and soil, and their engineering properties. These maps and reports are available at the Department of Mines and Geology, Lainchaur, Kathmandu.

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