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APPLICATION OF GIS TO LANDSLIDE PRONE AREA

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ABSTRACT

The geographic information system (GIS) is a computer-based tool for mapping and analyzing geographic phenomenon that exist, and events that occur, on Earth. GIS has facility to integrates common database. It involves operations such as query and statistical analysis. This function distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and planning strategies. GIS has various applications to Civil Engineering like landslide, watershed management, town planning, water resource engineering, etc. Landslide is one of the natural disasters involving the movement of rock mass / debris / soil due to slope failure, under the influence of gravity. The intensity and magnitude of landslide events may vary and is purely governed by inherent causative factor. Water is invariably involved in the mass movements. Besides natural factors, anthropogenic activity is often involved in slope failure. It causes damage to structures, property and loss of life. In this paper the applications of GIS for landslide is discussed. The preventive measures are also be suggested to avoid landslides.

Keywords: GIS, landslide, civil, engineering, slope, failure.

I. INTRODUCTION

Civil engineering is the basic branch of engineering which have various uses in day to day life of people. The GIS (Geographic Information System) is the computer based tool useful in various fields. It has the capacity of storing data, analyze the data to get the output.GIS has various applications in the field of Civil Engineering like Geotechnical Engineering, Watershed Management, Pollution Monitoring, Transportation Management, Architectural Planning, etc. Landslide is one of the natural disasters involving the movement of rock mass / debris / soil due to slope failure, under the influence of gravity. The intensity and magnitude of landslide events may vary and is purely governed by inherent causative factor. Water is invariably involved in the mass movements. Besides natural factors, anthropogenic activity is often involved in slope failure. It causes damage to structures, property and loss of life. These are generally isolated processes which individually may not be very large in size but can occur with high frequency (Van Westen et al. 2006).

II. LITERATURE REVIEW

Landslide hazard is defined as the probability of occurrence of landslides within a specific period of time and within a given area (Varnes, 1984). According to Cruden (1991) landslide is the movement of a mass of rock, debris or earth down a slope. According to Scheidegger (1994), it is the probability that a reasonably stable condition may change abruptly. Guzzetti et al. (1999) preferred the definition to include the area, volume and velocity of the expected landslide. Sharma (1996) emphasized that a complete hazard assessment and mapping should be based on where and how large a landslide will occur.

The landslide is the downward and outward movement of the materials composed of rocks, soils, artificial fills or combination of all these materials along surfaces of separation by different actions like falling, sliding and flowing from one place to another. Although the landslides are primarily connected with mountainous terrains, these can also occur in areas where an activity such as surface excavations for highways, buildings and open pit mines takes place. The materials may shift by falling, toppling, sliding, spreading, or flowing. Some landslides are rapid, occurring in seconds, whereas others may take hours, weeks, or even may take longer time to develop. The factors that contribute to landslides are rainfall, earthquake, geology, gravity, weather, groundwater, wave action, and human activities. Although landslides frequently occur on steep slopes, they also can take place in areas of low relief. Landslides can occur as ground failure of river bluffs, cut and-fill failures that may go along with highway and building excavations, and slope failures associated with quarries and open-pit mines.

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The term "landslide" describes a wide variety of process that result in the downward and outward movement of slope-forming material including rock, soil, artificial fill, or a combination of these. The materials may travel by falling, toppling, sliding, spreading, or flowing. The various types of landslides can be identified by the kinds of material involved and the mode of movement. A classification system based on these parameters is shown in Table 1. Other classification systems include additional variables, such as the rate of movement and the water, air, or ice content of the landslide material.

Table 1: Types of landslides and the Abbreviated version of Varnes' classification of slope movements (Varnes 1978)

Type of movement		**Type of materials**		
		Bedrock	**Engineering soils**	
			Predominantly coarse	**Predominantly Fine**
Falls		Rock Fall	Debris fall	Earth fall
Topples		Rock Topple	Debris topple	Earth topple
Slides	Rotational Translational	Rock slide	Debris slide	Earth slide
Lateral spreads		Rock spread	Debris spread	Earth spread
Flows		Rock flows (deep creep)	Debris flows	Earth flow
			(soil creep)	
Complex movements		Combination of two or more principal types of movement		

The mountainous area of India is frequently undergoing the landslides. The causes of landslide may be gravity, rainfall, earthquake, human interference, etc. landslide prone area. The area of India is divided into different zones based on landslide.

- The Western Himalayas (in states of Uttar Pradesh, Uttaranchal, Himachal Pradesh and Jammu & Kashmir)
- The Eastern & North-eastern Himalayas (in states of West Bengal, Sikkim and Arunachal Pradesh)
- The Naga-Arakkan Mountain belt (in states of Nagaland, Manipur, Mizoram and Tripura)
- The Western Ghats region including Nilgiris (in states of Maharashtra, Goa, Karnataka, Kerala & Tamil Nadu)
- The Plateau margins of the Peninsular India and Meghalaya plateau in North-east India.

Some of the major landslides that took place in different parts of India are given in Table 2.

Table 2: Major landslides in India

S. N.	**Date**	**Location**	**Impact**
1	July 1984	Kerala	14 Killed
2	June 1985	Kumpanpara, Kerala	9 Killed
3	October 1990	Nilgiris	36 people killed and several injured. Several buildings and communication network damaged
4	July 1991	Kappikalam, Kerala	11 killed
5	July 1991	Assam	300 people killed, road and buildings Damaged
6	November 1992	Nilgiris	Road network and buildings damaged, Rs.5 million damage estimate
7	June 1993	Aizawal	4 persons were buried
8	July 1993	Itanagar	25 people buried alive, 2 km road damaged
9	August 1993	Kalimpong, WB	40 people killed, heavy loss of property

10	August 1993	Kohima, NL	200 houses destroyed, 500 people died, about 5 km road stretch was damaged
11	November 1993	Nilgris	40 people killed, property worth several thousands damaged
12	June 1994	Varandha ghat, Konkan	20 people killed, breaching of ghat road damaged to the extent of 1km. At several places

III. METHODOLOGY AND STUDY AREA

The GIS is a computer-based tool. It is used for mapping and analyzing geographic phenomenon that exist, and events that occur, on Earth. The data required for analysis are toposheets, images and soil properties. GIS has a facility to integrates common database. It includes operations such as query and statistical analysis. Due to this GIS is different from other information systems. It is useful and make valuable to a wide range for public and private enterprises for explaining events, predicting outcomes, and planning strategies.

GIS has main four main functional subsystems. These are:

a. Data input system
b. Data storage and retrieval subsystem
c. Data manipulation and analysis subsystem
d. Data output and display subsystem.

GIS operates on its hardware. Data plays important role in GIS. GIS is useful to integrate spatial data with other existing data resources. The integration of spatial data and tabular data stored in a DBMS is a key functionality afforded by GIS. The role of people is important in GIS who manage the system.

The components of GIS are:

a) Data
b) Software
c) Hardware
d) Methods and Procedures
e) People

The GIS components are shown in Figure 1

Figure 1: GIS Components (Source: www.gisdevelopment.com)

The methodology consists of:

a) Literature review of landslides, causes and mitigations.
b) Collection of geotechnical and geospatial data for required study.
c) To prepare thematic maps using Survey of India (SOI) Toposheets, District Resource Map and satellite image.
d) To collect the sample to determine geotechnical properties.

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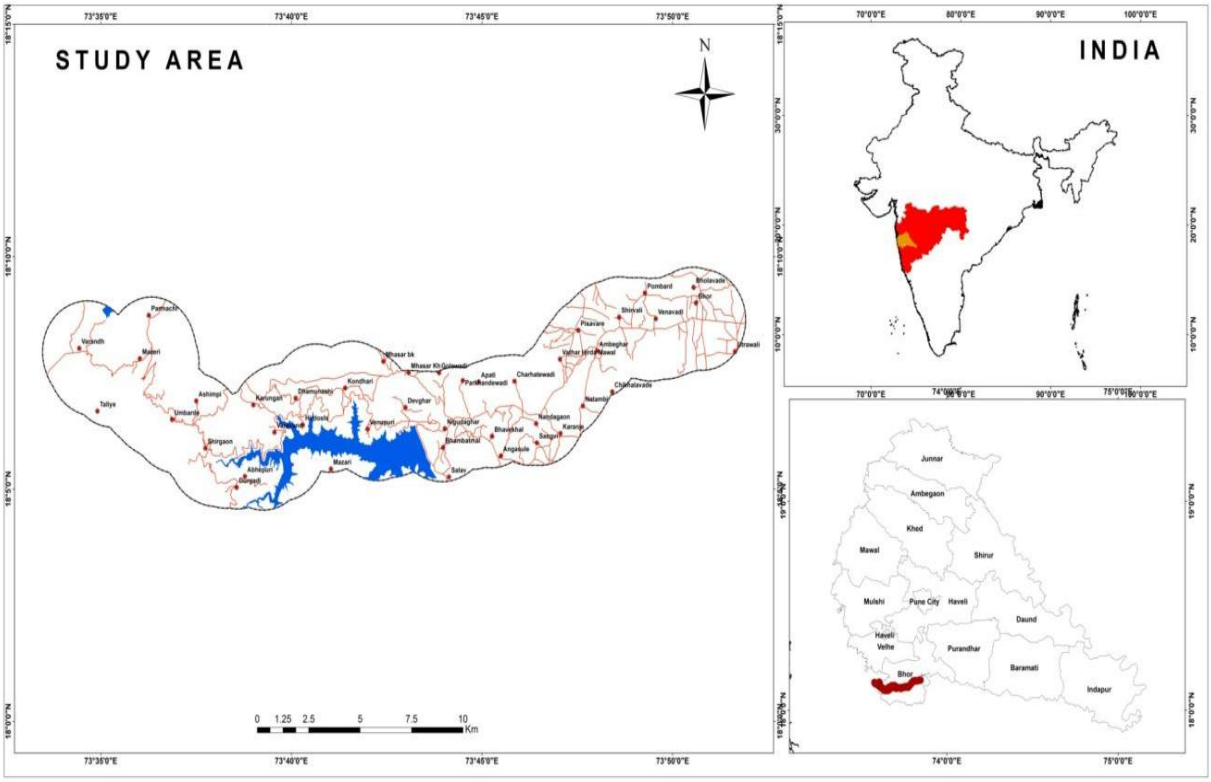

Figure 2: Location Map of the study area- Varandha Ghat

The Varandha Ghat section area consists of hills, valleys, forests, farming, settlements, etc. It is located in Bhor and Velha taluka of Pune district having latitude 18° 04′ 34.77″N to 18° 09′ 46.37″ N and longitude 73° 33′ 29.13″E to 73° 51′ 54.81″E. The Location map of the study area is generated from Survey of India toposheet E 43 H/12 and E43 H/16 of scale 1:50,000 shown in Figure 2.

IV. RESULT AND DISCUSSION

The remote sensing data and base map are used for preparing different thematic maps. The catchment area boundary contours, drainage is digitized on the base map and contour and drainage maps are generated. The Satellite data was georeferenced. The geo-referencing of scanned maps was carried out in QGIS using controlled points which are already established on the base map. The four control points located on top left, top right bottom left and bottom right corners of map were assigned corresponding latitude and longitude values and later converted into polyconic projection system using QGIS software after rectification. On screen digitization of scanned maps were performed by QGIS software and appropriate editing was done to remove errors occurred during digitization. After finalizing the error free coverage attributes were assigned belonging to different categories of the land use, drainage and soils, etc.

The information of altitude can be represented in digital system in GIS. This system is called as DEM. Thus it is a computerized representation of the earth`s relief. DEM is a three dimensional representation of the surface of terrain. The different formats are triangulated irregular networks, contour lines, regular grids, and scattered data points (Gopi et al., 2007). It can be used as an primary input in different studies like geology, geomorphology, landscape, education, health, etc. The topographic maps with contour are required for the DEM. In the process of scanning the topographic map is converted into a digital format. It is usually integrated into the GIS database. The DEM of the study area is shown in Figure 3.

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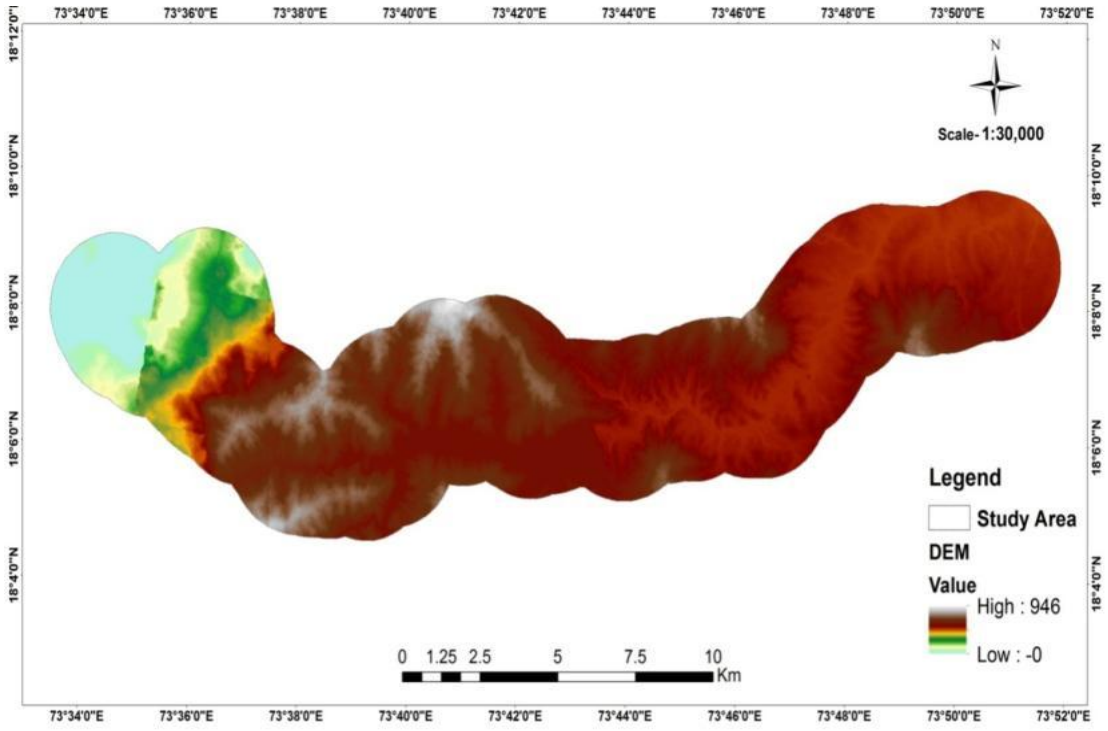

Figure 3: Digital Elevation Model of study area

Extensive field survey was conducted in the Varandha Ghat using GPS to know the location of settlements, landslides, type of soil, type of rocks, land-use and land-cover. We met to people residing in these settlements and got the information regarding landslides. Predominant rocks, minerals and geologic formations were identified. The presence of rivers, streams, water bodies, vegetation, etc. was noted. Old records of rainfall, land use, and landslide occurrence were consulted. The information is also collected from residents and local administrative bodies.

During the field visits the soil samples were observed and we have concluded type of soil. We have observed vegetation, type of rock, erosion, the safety actions provided to avoid landslide, etc.

Table 3: Field Observations of the Varandha Ghat

S. N.	Location	Latitude/ Longitude/ Elevation	Slope/ Height/ Length	Type of Vegetation	Previous landslide	Weathering condition of soil/rock
1	Apti	18° 10' 48" N 73° 40' 08"E 740 m	S-80° H-10m L-35m	Scanty	Yes	Moderate
2	Venupuri Bus Stop	18°06' 24" N 73° 42' 11"E 740 m	S-80° H-8m L-17m	Moderate	Yes	Moderately weathered
3	Venupri bridge	18°06' 46" N 73° 42' 01"E 720 m	S-75° H-10m L-22m	Moderate	Yes	Highly weathered
4	Ayush Garden	18°06' 43" N 73° 40' 55"E 742 m	S-80° H-18m L-90m	Moderate	Yes	Highly weathered
5	Hirdoshi Bridge	18°07' 02" N 73° 40' 39"E 704 m	S-85° H-14m L-23m	Moderate	Yes	Fresh

The soil samples were collected from site and their properties are determined in the laboratory. These properties are used to calculate the stability of slope. From factor of safety the remedial measures can be suggested.

Table 4: Typical Properties of soil mass and Factor of Safety at different locations for Varandha Ghat

S. N.	Description	Location-1	Location -2	Location -3	Location -4	Location -5
1	Dry (kN/m^3)	13.20	12.08	12.62	12.13	12.25
2	Bulk (kN/m^3)	15.70	13.80	14.10	14.25	14.35
3	Specific Gravity	2.30	2.30	2.55	2.35	2.35
4	O.M.C. (%)	18.10	17.20	16.20	16.10	18.20
5	M.D.D. (kN/m^3)	15.00	14.10	13.90	13.65	13.95
6	Coefficient of Curvature	2.85	2.80	2.06	2.62	1.62
7	Uniformity Coefficient	7.60	6.65	17.55	10.10	8.70
8	Direct Shear Test - ϕ°	33.99	35.60	38.80	34.20	33.25
9	Direct Shear Test-C kPa	26.50	26.35	35.85	25.45	26.20
10	Angle in degrees	80°	80°	75°	80°	85°
11	Factor of Safety	1.57	2.22	2.37	1.04	1.18

V. CONCLUSION

The thematic maps were prepared for the study area. The certain locations are identified along the State Highway connecting Bhor to Mahad having danger as far as landslide is concerned. The GIS is a tool to cover the larger area for the analysis. Figure 4 shows the locations prone to landslide along the Bhor to Mahad State Highway. The remedial measures also suggested to avoid live and property losses due to landslide.

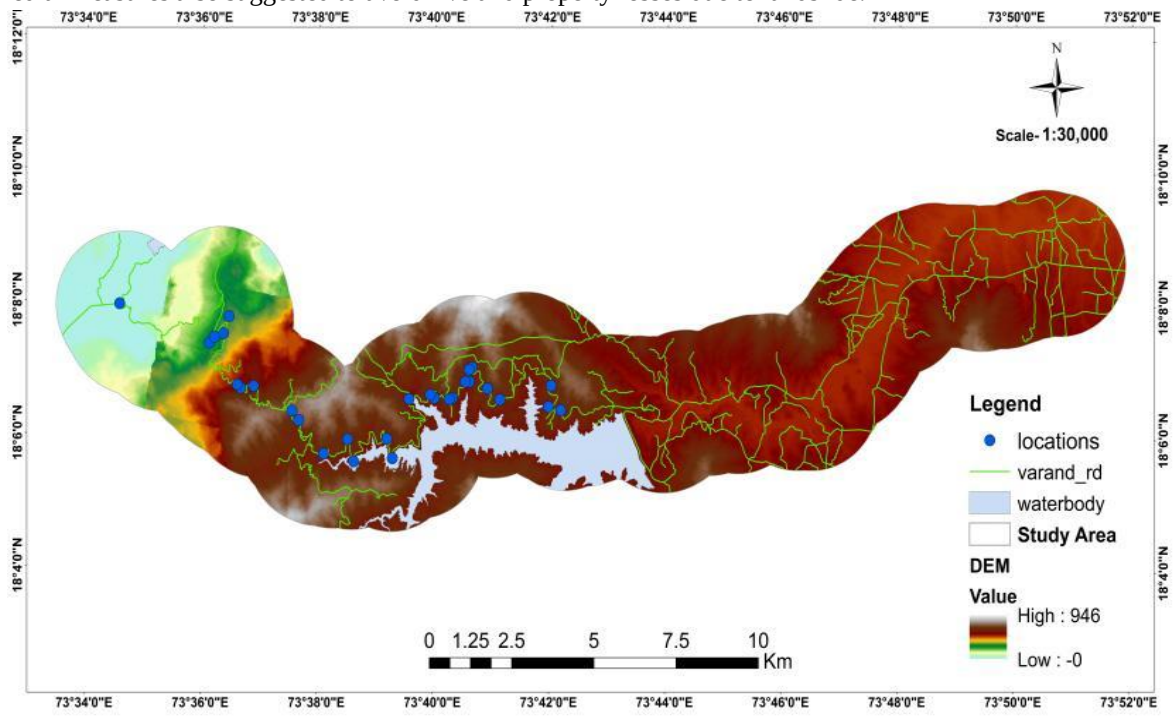

Figure 4: Location of the study points of Varandha Ghat

Landslide Prevention Measures:

Different methods are used to prevent landslide. As far as possible the landslide prone area should be avoided.

The concern of geologist or geotechnical engineer should be taken before purchasing of land or any structure. Following are some of the remedial measures to avoid the landslides.

a) Improving surface and subsurface drainage:

Water is the key factor landslides so improving surface and subsurface drainage at the site can increase the stability of a landslide-prone slope. Surface water should be drained away from the landslide-prone area by channeling water in a drainage ditch to the base of the slope. The water should be drained in such a way as to avoid triggering a landslide adjacent to the site. Surface water should not be allowed to store on the landslide-prone slope.

b) Slope Vegetation:

One of the easiest method to avoid a landslide along the slope is to vegetate the slope. This landslide prevention method can be applied on slopes that are not too steep or if the movement hasn't already begun. This can be be done by oneself by planting a groundcover or hire a landscaper to vegetate the slope.

c) Retaining Walls:

A solid, well-designed retaining should be made of sturdy materials such as masonry, brick, stone or steel to resist the lateral pressure of soil. Proper drainage system behind the wall help increase the stability of the wall.

d) Diverting Debris Pathways:

Landslides on your property can be prevented by building pathways to divert debris . You can create these pathways with the help of retaining walls. However, due to construction of walls if this debris flow lands on neighbor's property you are liable for damage.

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