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Urban geology and environmental problems of Lahore City, Pakistan

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ABSTRACT

The present study deals with the urban geology and environmental problems of the Lahore City in Pakistan. It is based on a set of the following thematic maps at 1:100, 000 scale: geology, urbanisation, engineering geology, land use, flood hazard, and aquifer drawdown depth. The major hazards of the Lahore metropolitan area are air pollution, water pollution, noise pollution, and deforestation, which are the result of rapid population growth as well as poor planning.

The Lahore metropolitan area comprises the Early Pleistocene to Recent silty loess and silty clay deposits of the Ravi River. The foundation conditions of the Lahore metropolitan area are generally good. The city suffers from periodic floods during the monsoon season. The pavement and drains accelerate and increase the surface runoff and the peak flood. Unplanned groundwater development in the metropolis has caused a rapid lowering of the water table. Subsequently, the sand is dewatered and the water table has dropped to 7–13 m.

INTRODUCTION

The Lahore metropolis (Fig. 1) has a population of about 6.7 million (GoP 1998) and comes under the jurisdiction of the Lahore Development Authority (LDA). The city occupies an area of 1,760 sq km and extends up to the Hudiara drain in the south, the border with India in the East, across the Ravi River up to the Muridkhe distributory and the upper Chenab Canal in the West, and up to the town of Muridkhe along the Grand Trunk Road in the north (Fig. 2).

Owing to the rapidly increasing population and accelerated economic growth, the demands on land and natural resources for housing, industry, road construction, and the like are increasing rapidly. Consequently, the environment of the city is deteriorating to a great extent.

In the developmental planning of the Lahore metropolis, little attention was paid previously to the geoscientific data and geological setting of the area. Therefore, it was felt necessary to collect relevant information on natural hazards and pollution in the metropolitan area. For this purpose, the following thematic maps at 1:100,000 scale were prepared: geology, urbanisation, engineering geology, land use, flood hazard, and aquifer drawdown depth. One of the important outcomes of the study was the environmental assessment

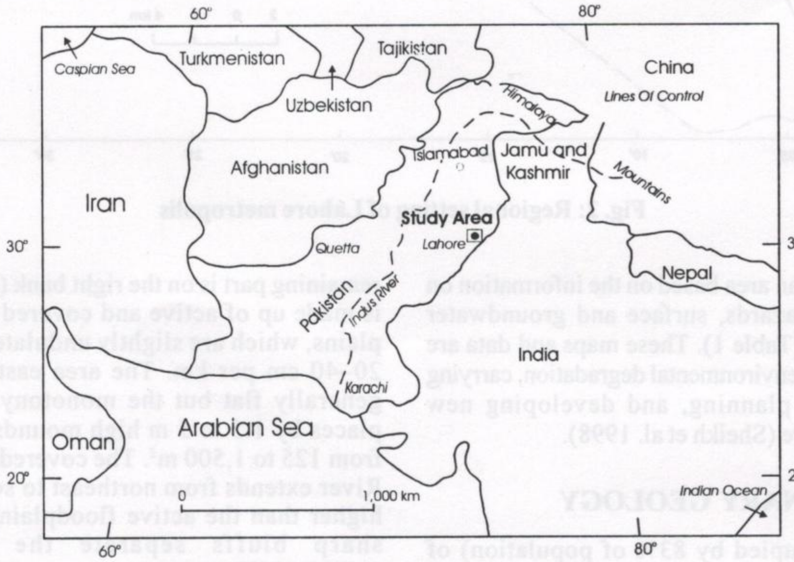

Fig. 1: Location map of Lahore metropolis

Fig. 2: Regional setting of Lahore metropolis

of the Lahore metropolitan area based on the information on lithology, landforms, hazards, surface and groundwater resources, and land use (Table 1). These maps and data are useful for minimising the environmental degradation, carrying out sensible land-use planning, and developing new infrastructure in the future (Sheikh et al. 1998).

QUATERNARY GEOLOGY

The main part (occupied by 83% of population) of the city lies on the left bank of the Ravi River, and the remaining part is on the right bank (Fig. 2). The metropolis is made up of active and covered floodplains and loess plains, which are slightly undulated with the gradient of 20–40 cm per km. The area east of the Ravi River is generally flat but the monotony is broken at several places by 1.5 to 5 m high mounds, which range in area from 125 to 1,500 m^2. The covered floodplain of the Ravi River extends from northeast to southwest and is 1–6 m higher than the active floodplain. In many places, the sharp bluffs separate the active floodplain (APGC 1968).

Table 1: Explanation of environmental geological map units

Unit Name	Formation	Landform	Resources	Hazards	Water resources	Land use planning
Stream channel and Braid, S	Quaternary alluvium	The wide, flat plain	Sand and silt	Flooding	Plenty of water used for agriculture	Not suitable for any purpose
Meander belt plains, M	Quaternary meander plain alluvium	Meander plains	Sand and silt	Flooding	Abundant water	Not suitable for many purpose
Younger flood plain, Fa	Quaternary flood plain alluvium	Active flood plains	Sand and loamy clay	Flooding	Do	Suitable for crops
Older flood plains, Fc	Quaternary older flood alluvium	Covered flood plains	Silt and clay	Urban flooding	Do	Suitable for residential and many other uses
Dissected wind blown silty clay, M1	Quaternary meander belt plains alluvium of ancient streams	Eroded land and gullies	Clay and silt	Do	Do	Suitable for light structure
Undissected wind blown silty clay, L	Loessic clay	Loess plains	Clay and silty clay	Do	Do	Suitable for huge structure and residential uses

Table 2: Quaternary geological units of the Lahore Metropolitan Area

	Period	Epoch	Formation	Description
Top	Quaternary	Recent to Sub-Recent	Recent deposits of Ravi River	Unconsolidated sand, silt, and clay.
			Meander belt deposits	Sand, silt, and clay.
			Younger flood plains deposits	Sand and silt.
			Older flood plain deposits	Silt, silty clay, and sand.
			Meander belt plain of ancient course of Ravi River	Silty clay, silt, and sand.
Bottom		Pleistocene	Loessic clay deposits	Clay, kankers, silty clay, silt, and sand.

The Lahore metropolitan area comprises the Early Pleistocene to Recent silty loess, silty clay, and most recent deposits of the Ravi River (Fig. 3). A short description of the geological units (Table 2) of the Lahore metropolitan area is given below (Akhtar et al. 1996).

Silty Loess Deposits (Qlc)

This unit comprises clay, silty clay, and sand. The colour of clay is brownish khaki to yellow-brown, and it is fine in texture, calcareous, and hard on fresh surfaces. It also contains shells and calcretes. The unit is divisible into two parts. The upper part is thick-bedded, brownish khaki coloured silty clay with minor (5–7 m thick) salt layers. At places, the calcareous clay beds form low terraces under the recent floodplain deposits of the Ravi River. The lower part constitutes red and grey clay and silty clay having thin beds of sand and silt. These beds are made up of calcretes, and are hared and compact. Some layers are soft and consist of silty clay with gravel or calcretes.

Palaeo-Meander Belt Deposits of Ravi (Qcu)

The Palaeo-Meander Belt Deposits of the Ravi River comprise dominantly earthy brown clay, silt, and medium-grained sand. Channel fills and clay plugs of ancient streams are characteristics of this unit and they are well exposed in southern and partly northern parts of the area.

Older Floodplain Deposits (QSS2)

The Older Floodplain Deposits exposed along the floodplain channel deposits of the Ravi River, are well marked in the extreme northern part of the Lahore City, i.e. along the Grand Trunk Road towards Gujranwala up to Muridkae and the Shekhupura Road. This unit comprises medium- to fine-grained sand, silt, and clay. The sand, silt, and clay were deposited on the old floodplain as back swamp deposits and cut fillings in old cut-off meanders and oxbows.

Younger Floodplain Deposits (Qss1)

The Younger Floodplain Deposits are composed of a thin veneer of clay having very fine- to medium-grained sand and silty clay. The Ravi River has meandered over to respective course in recent geological time and does not obliterate the old features such as channel fills, meander scars, and levees.

New Meander Belt Deposits (Qsb)

The New Meander Belt Deposits are developed in a relatively narrow (3–5 km wide) zone along the riverbanks.

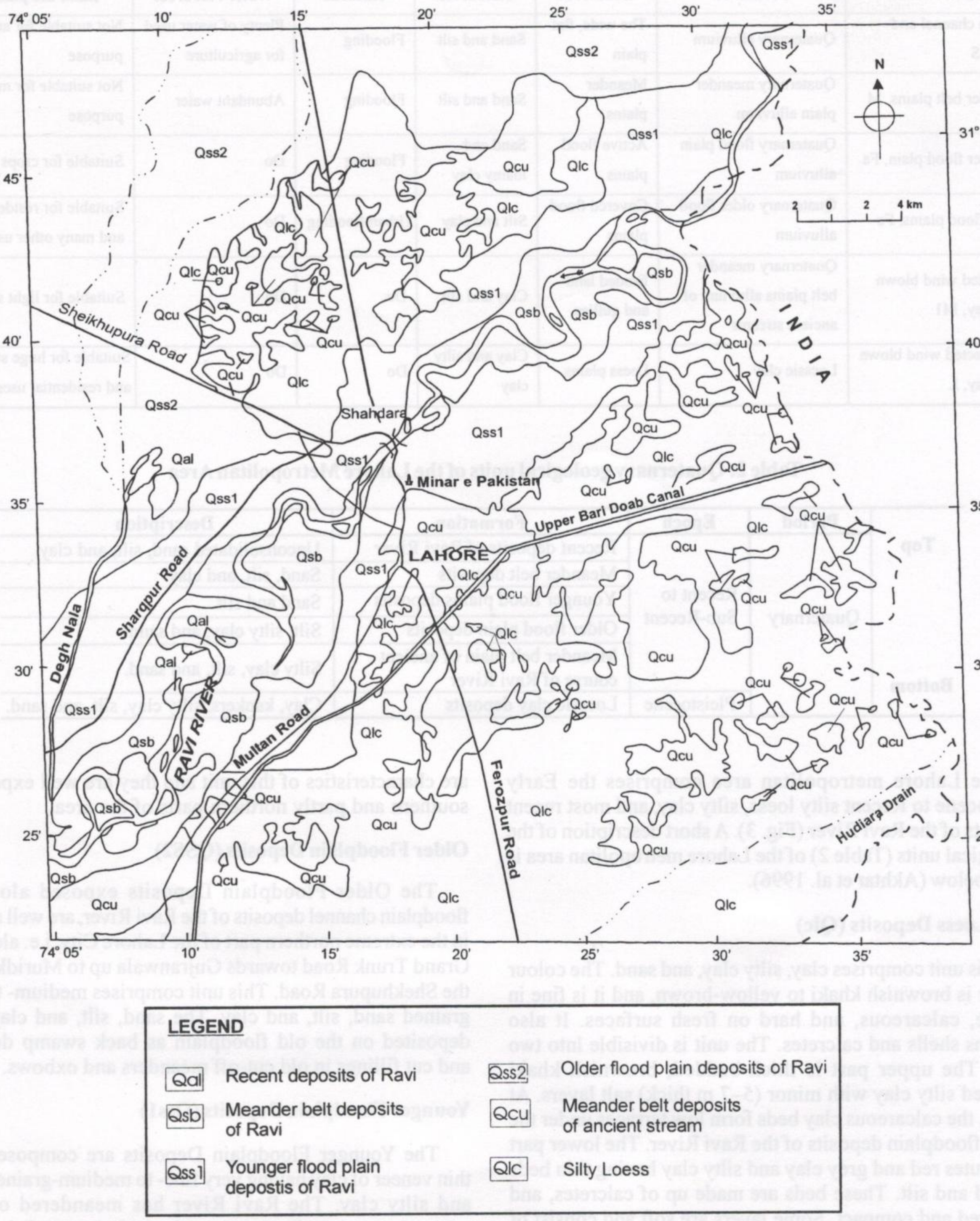

Fig. 3: Geological map of Lahore metropolitan area

They are represented by bars, swales, cut-off meanders, and oxbows.

Recent deposits of Ravi River (Qal)

The Recent Ravi River Deposits consist of unconsolidated sand, silt, and clay that are subjected to stream transportation each year. These are generally without vegetation and are confined to the present channel of the Ravi River.

SUBSURFACE STRATA

Most of the Lahore metropolis lies on floodplain and loessic clay deposits formed as a result of contemporaneous filling of a subsiding trough of foredeep adjacent to the rising Himalayan Ranges. The contemporaneous filling and subsidence have given rise to an extensive sedimentary complex, which is more than 400 m thick (Fig. 4). The present and ancestral tributaries of the Indus River deposited the sediments during the Pleistocene and Recent Epochs (NESPAK and BPCE 1991).

URBANISATION

The entire land development in the Lahore metropolis is carried out by the public sector. The LDA is the main development authority, whereas the Lahore Cantonment Board (LCB), Lahore Municipal Corporation, and other relevant departments as well as federal and provincial governments play a minor role. Housing estates were developed on the southern Silty Loess Deposits overlooking abandoned channels and depressions. At places, the undulating plains of Silty Loess Deposits and the Palaeo-Meander Belt Deposits in the north and south of the Ravi River are also used for new housing by the LDA. The levelled low-lying areas have also become important sites of urbanisation. At present, the city is rapidly expanding southwards (Fig. 5)

ENGINEERING GEOLOGY

The Lahore metropolitan area is divisible into the following three engineering units (Fig. 6).

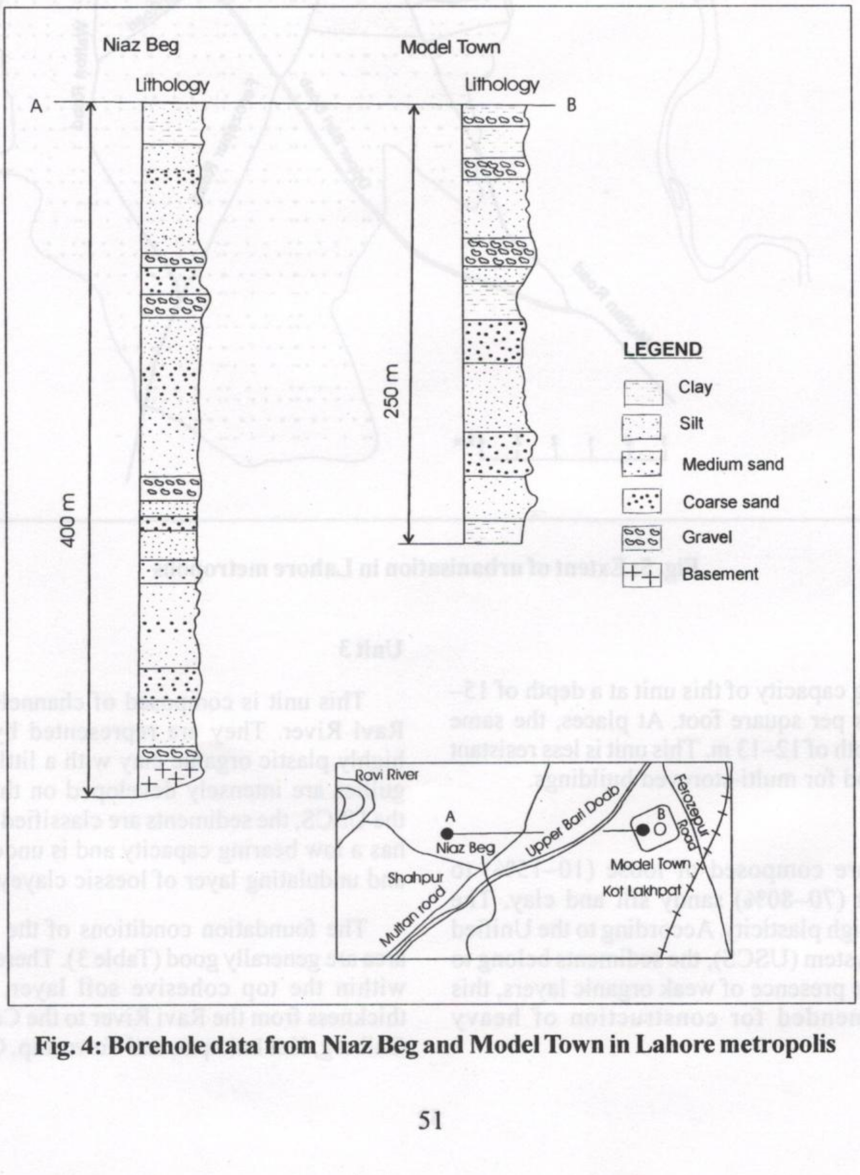

Fig. 4: Borehole data from Niaz Beg and Model Town in Lahore metropolis

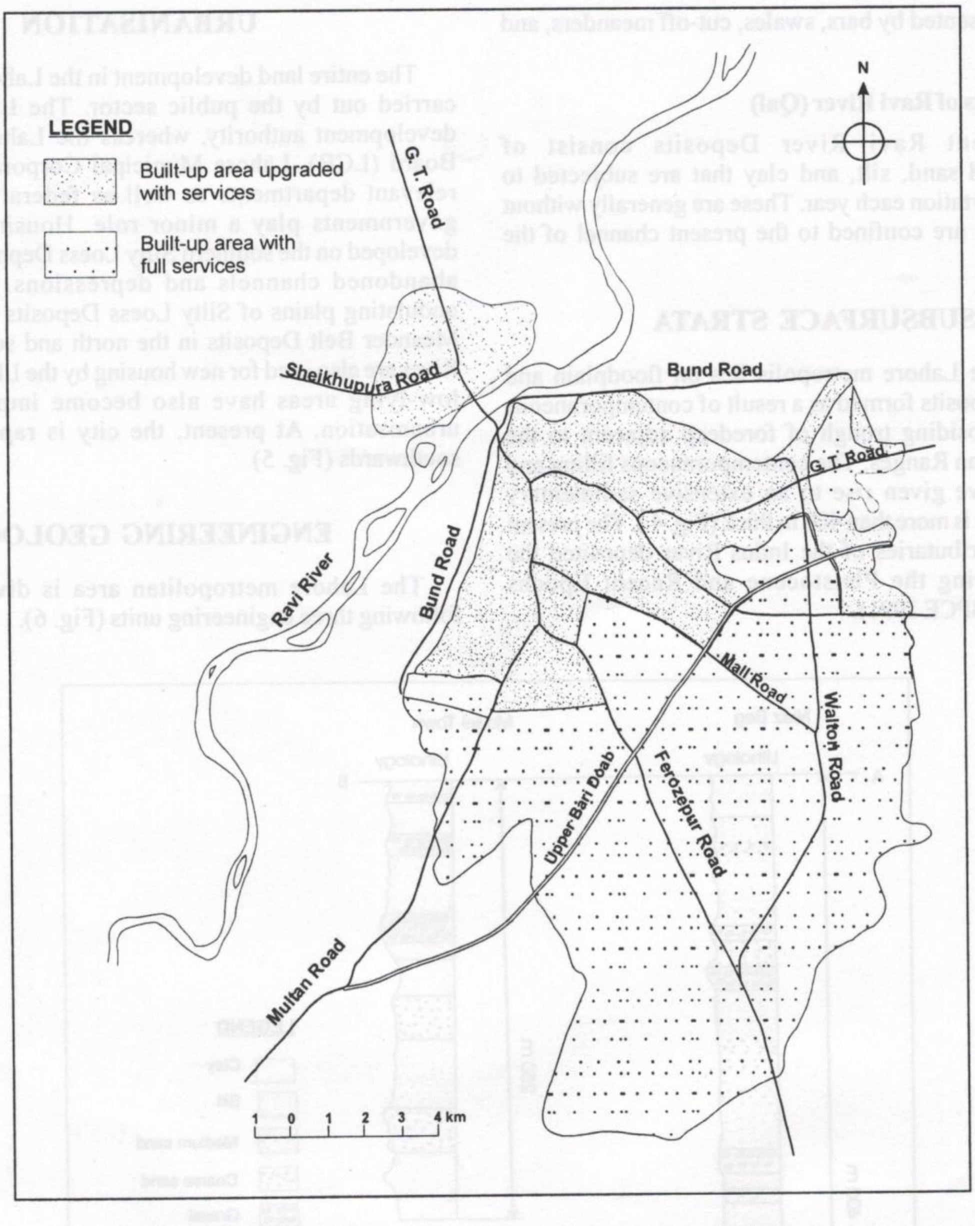

Fig. 5: Extent of urbanisation in Lahore metropolis

Unit 1

The gross bearing capacity of this unit at a depth of 15–17 m is 1.3–1.7 tons per square foot. At places, the same value is found at a depth of 12–13 m. This unit is less resistant to erosion and is good for multi-storeyed buildings.

Unit 2

The sediments are composed of loose (10–15%) to moderately compact (70–80%) sandy silt and clay. The organic layers have high plasticity. According to the Unified Soil Classification System (USCS), the sediments belong to ML–SP. Owing to the presence of weak organic layers, this unit is not recommended for construction of heavy structures.

Unit 3

This unit is composed of channel-fill sediments of the Ravi River. They are represented by poorly compacted, highly plastic organic clay with a little peat. Badlands and gullies are intensely developed on this unit. According to the USCS, the sediments are classified as OH–CH. This unit has a low bearing capacity and is underlain by a very weak and undulating layer of loessic clayey silt and sand.

The foundation conditions of the Lahore metropolitan area are generally good (Table 3). There are small sand lenses within the top cohesive soil layer, which increases in thickness from the Ravi River to the Cantonment area along Gulberg, Kot Lakhpat, and Township. Generally, the bearing

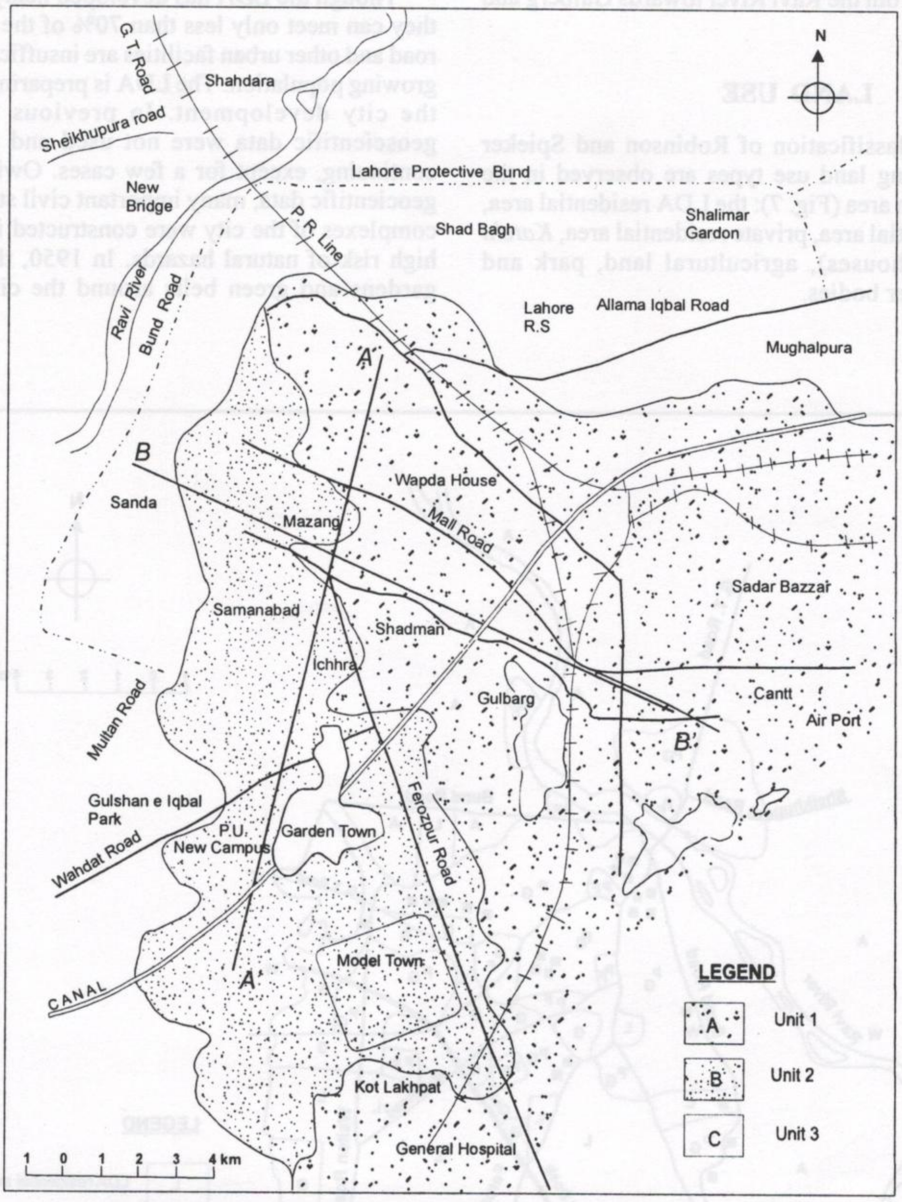

Fig. 6: Engineering geological map of Lahore metropolis

Table 3: Bearing capacity of soils in the Lahore metropolitan area (Farooq and Khan 1985)

Location	Safe bearing capacity range (tons per square foot)	Number of sites (%)
Shahdra, Gulshane Ravi, Allama Iqbal Town, Sanda	<0.7	30
Ichhra, Mozang, Muslim Town, Faisal Town, Jauhar Town, Model Town	0.7–1.0	45
Gulberg, Mall, Walled City, Cantonment, Kot Lakhpat, Township	>1.0	25

capacity increases from the Ravi River towards Gulberg and Cantonment.

LAND USE

Based on the classification of Robinson and Spieker (1978), the following land use types are observed in the Lahore metropolitan area (Fig. 7): the LDA residential area, government residential area, private residential area, *Katchi Abadies* (earthen houses), agricultural land, park and forestland, and water bodies.

Though the LDA has developed many residential areas, they can meet only less than 70% of the demand. The city road and other urban facilities are insufficient for the rapidly growing population. The LDA is preparing a master plan for the city development. In previous urban planning, geoscientific data were not used and that trend is still continuing, except for a few cases. Owing to the missing geocientific data, many important civil structures and other complexes of the city were constructed in the areas with a high risk of natural hazards. In 1950, there were a lot of gardens and green belts around the city, but they were

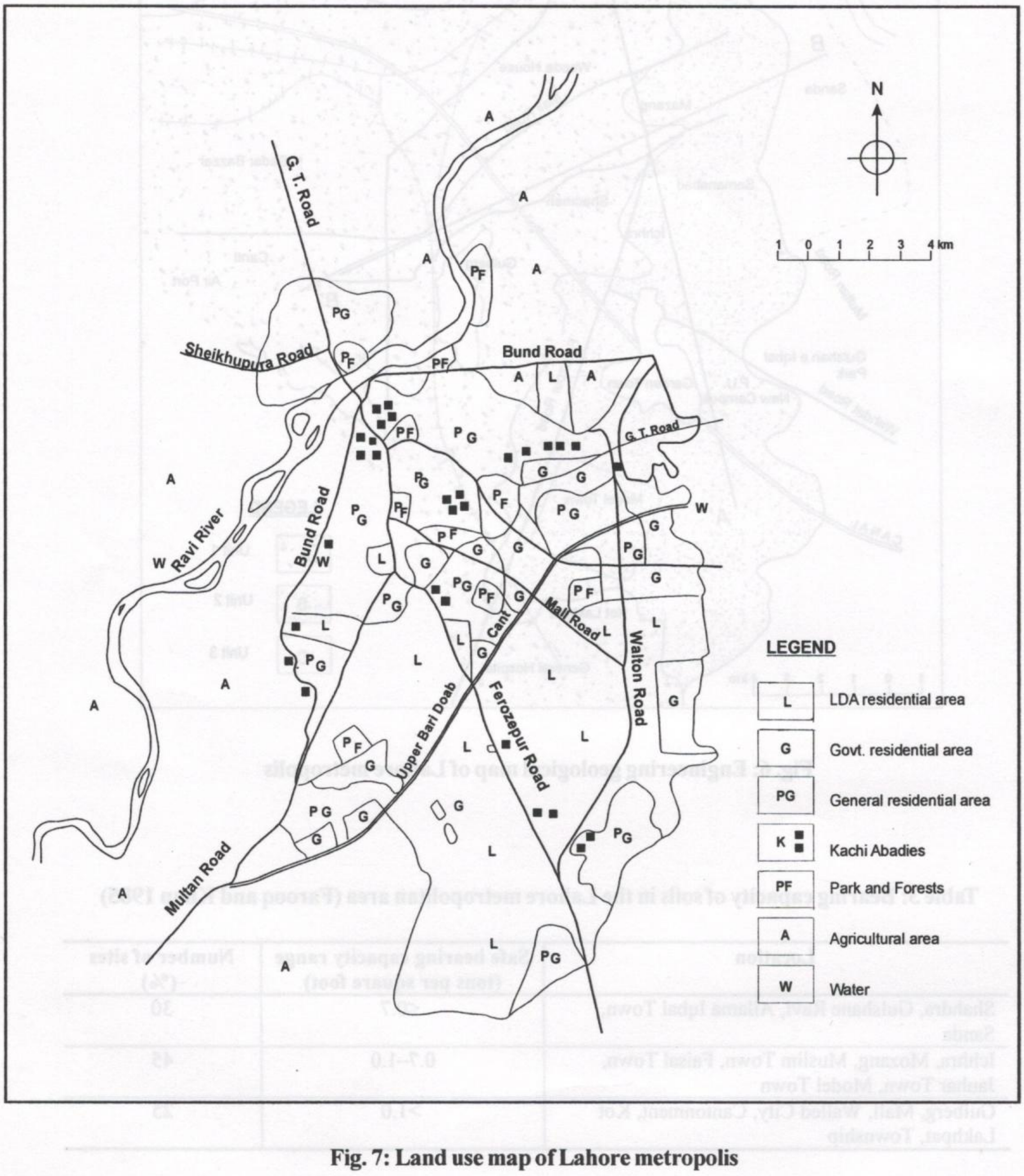

Fig. 7: Land use map of Lahore metropolis

subsequently converted into urban areas. This has resulted in more erosion and sedimentation in the city.

FLOODS

In the Lahore metropolitan area, about 70% of the total rainfall takes place in July, August and September, and the total monsoon rainfall in 1996 and 1997 reached 508–686 mm. Consequently, flooding is almost a regular event (Fig. 8).

Urbanisation tends to replace the natural drainage with gutter, sewer, and confined channels. In the Lahore metropolis, pavement and drains accelerate and increase the surface runoff and the peak flood becomes more intense (Fig. 8). The nature and extent of flood hazard depend on the following factors: land use on floodplain, magnitude of flood, rate of rise and duration of flooding, season, and sediment load. The environmentally sound approach to minimise the flood damage is to control the sediment load. Some of the remedies to the problems could be restructuring the drainage network, installing sucking pumps for sewer water, constructing flood drains, and planting trees to reduce erosion.

WATER SUPPLY

The Water and Sanitation Agency (WASA) of LDA is responsible for overall public water supply. However, in the

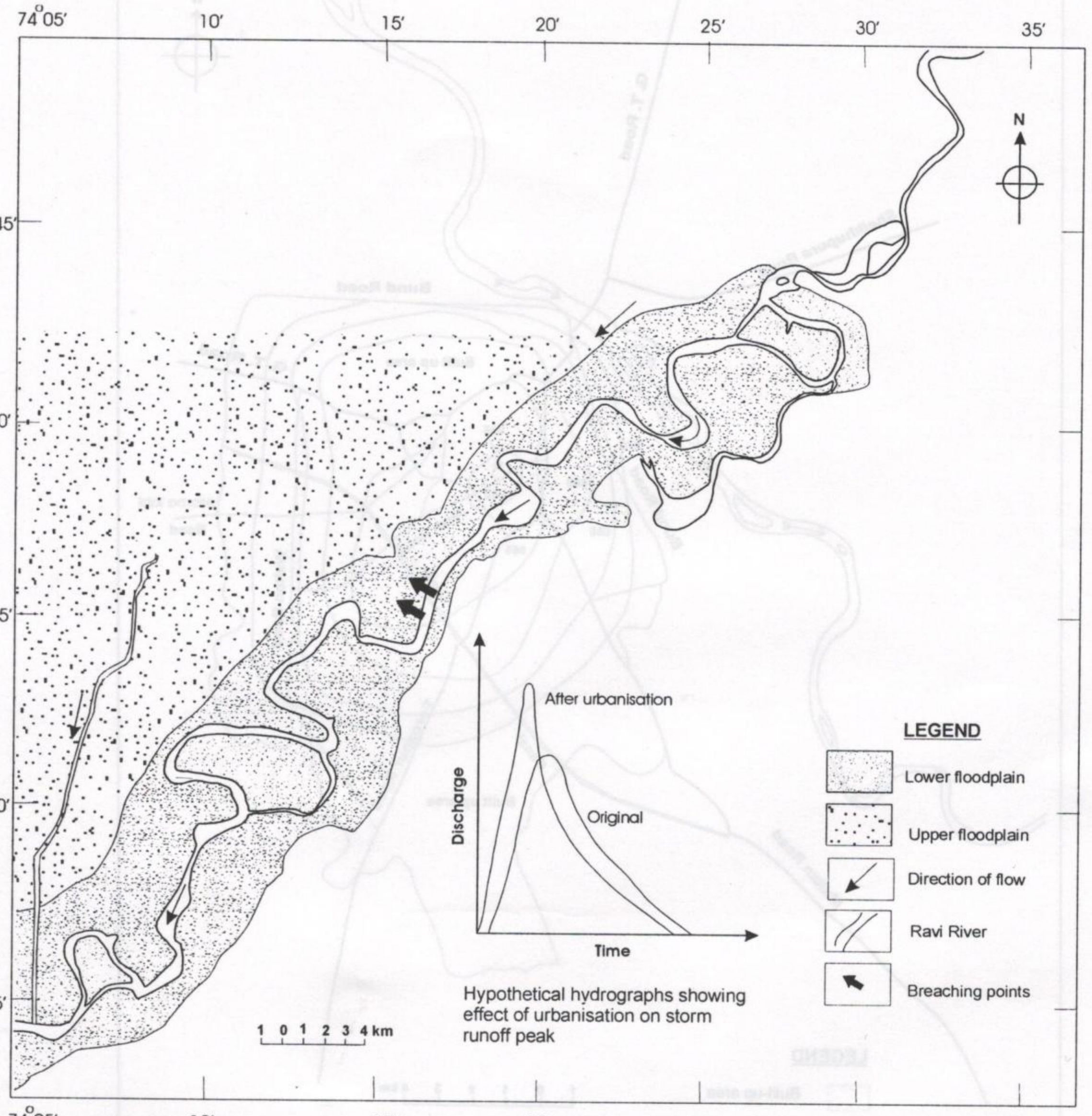

Fig. 8: Flood hazard map of Lahore metropolis

Cantonment area the responsibility is of the LCB, whereas it is the responsibility of the Model Town Society in the Model Town area. The public water supply is entirely based on groundwater resources, and the supply system has the following main elements:

- The aquifer,
- 250–300 scattered tube wells,
- About 100 km of the main distribution pipeline network with 30–35 m high reservoirs and about 1,000 km of sub-distribution network, and
- 150,000–200,000 house connections.

The aquifer is divided into the upper and lower zones. The upper aquifer lies at a depth of 5–80 m, whereas the lower aquifer reaches a depth of 35–40 m. The water in the aquifer is found as a huge underground stream moving slowly towards the south. The aquifer is fed from several sources. The main sources is the melting snow from the Himalayas, but undoubtedly the local sources such as recharge from the Ravi River and rainfall are other important factors. The groundwater supply system with its many tube wells makes a serious impact on local aquifer conditions, as indicated by the formation of a large drawdown cone (Fig. 9). The accelerated groundwater development has caused rapid

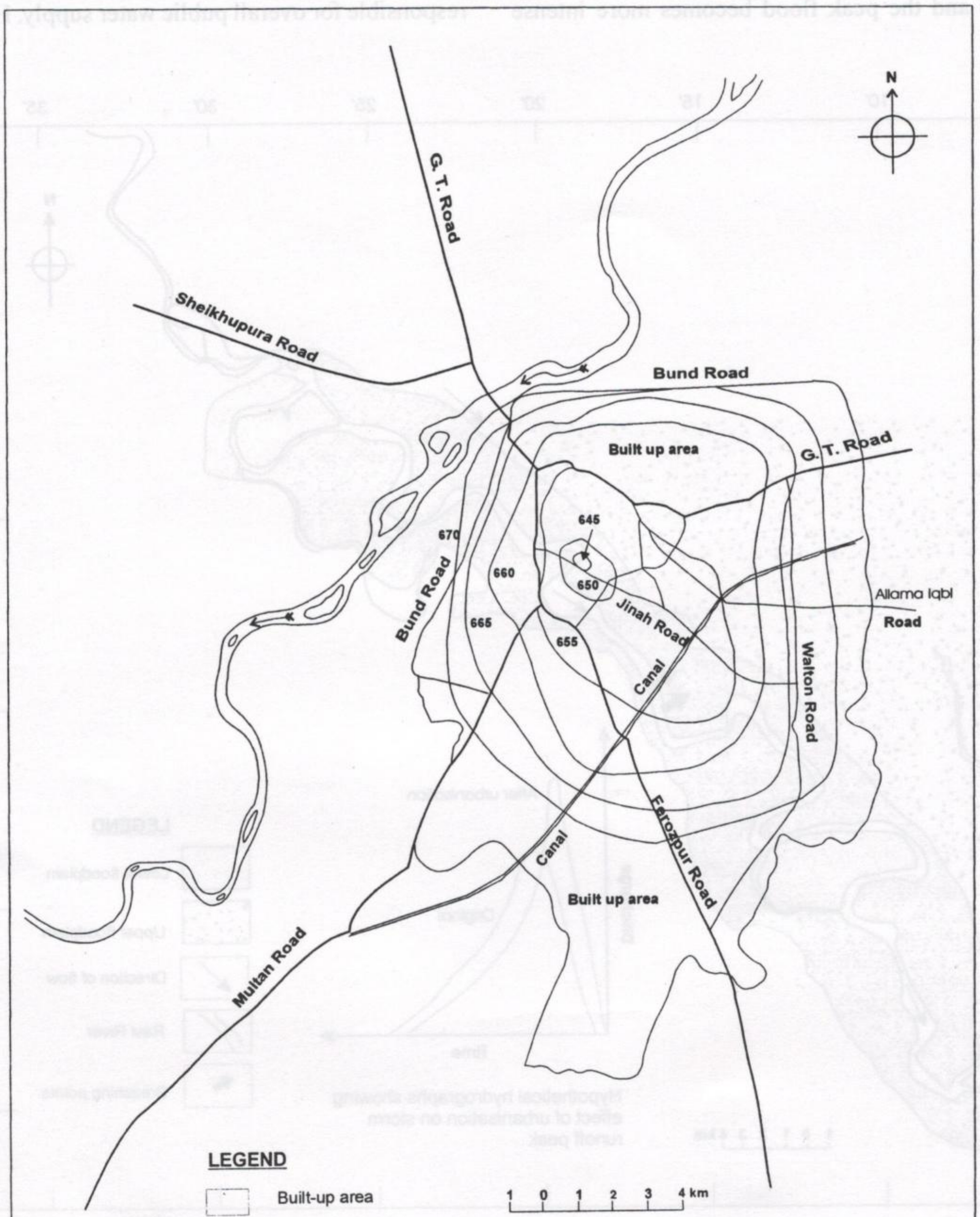

Fig. 9: Aquifer drawdown cone in Lahore metropolis

lowering of the water table. Subsequently, the sand is dewatered and the water table has dropped to 7–13 m.

At present, the water from the lower aquifer is suitable for drinking purposes although it is rather hard, containing dissolved solids up to 400–800 mg/l at the present effective depth.

AIR POLLUTION

Air pollution is another severe problem in big cities. Generally, it is derived from solid waste, toxic smokes, dust, and gases. In the Lahore metropolis, domestic, automobile, and industrial smokes are the main sources of air pollution.

Sheikh et al. (1998) reported that the monoxide concentrations along the Shahrah-é-Quaid-é-Azam Road in the city and around the Walled City were higher than normal whereas maximum concentrations of ozone were well above the permitted level of the Californian Standard. It was revealed that the smoke from diesel engines was the biggest nuisance on the streets and responsible for a lot of inconvenience and discomfort to the citizens. The degree and type of industrial air pollution is not only dependent on the source but also on the climate, weather, and topography. The wind direction and speed can transfer the pollution hazard from one area to another. Likewise, inversion of temperature can cause adverse effects in a heavily polluted area.

The survey of air pollutants in Lahore (GoP 1983) indicates that the gaseous emissions from the *Ithehad Chemicals* are hazardous to human health and they also damage the surrounding rice crops. The sampling carried out at the site indicated the presence of the following pollutants: sulphur dioxide (9 ppm), chlorine (35 ppm), sulphur trioxide (24 ppm), and particulates (32 ppm).

NOISE POLLUTION

The sound that creates sensation on recipient may be described as noise. Noise may also be defined as unwanted, unpleasant, and unreliable sound. Noise affects a person physically, psychologically, and socially. Following are the adverse effects of noise: it reduces the hearing capability, interferes with the communication, creates annoyance, causes tiredness, and reduces the efficiency of performance. The long-term physiological effects of noise on human being are: the noise can damage the hearing permanently; it affects the cardiovascular system (changes have been reported in blood pressure, heart beat, cardiac output and pulse volume); it effects the digestive system by stress and contraction, and may cause diarrhoea and acidity in stomach; and it also affects the respiratory system, reproductive system, and central nervous system.

The noise levels measured at different places on various hours of the day in the Lahore City are given in Table 4. At present there is no legislative control on noise in Pakistan expect on excessive horning or movement of auto rickshaws in certain places.

Table 4: Noise levels at different places of the Lahore City

Place	Noise level (dB)	
	Maximum	**Minimum**
Shah Alam Chowk	90	86
Chowburgi	91	73
Faisal Chowk	94	65
Bhatti Chowk	98	71
GPO Chowk	92	65

CONCLUSIONS

The Lahore metropolitan area comprises Silty Loess Deposits, Palaeo-Meander Belt deposits of the Ravi River, Older Floodplain Deposits, Younger Floodplain Deposits, New Meander Belt Deposits, and the Recent Deposits of the Ravi River. Most of the Lahore metropolis lies on floodplain deposits and loessic clay deposits.

Housing estates were developed on the southern Silty Loess Deposits overlooking abandoned channels and depressions. At places, the undulating plains of Silty Loess Deposits and the Palaeo-Meander Belt Deposits in the north and south of the Ravi River are also used for new housing by the LDA. Though the LDA has developed many residential areas, they cannot meet the growing demands. On the other hand, the city road and other urban facilities are insufficient for the rapidly growing population. Owing to the missing geocientific data, many important civil structures and other complexes of the city were constructed in the areas with a high risk of natural hazards.

Flooding is almost a regular event in the Lahore City, where pavement and drains accelerate and increase the surface runoff and the peak flood. The accelerated groundwater development has caused a rapid lowering of the water table. Subsequently, the sand is dewatered and the water table has dropped to 7–13 m.

In the Lahore metropolis, air pollution is another severe problem. Domestic, automobile, and industrial smokes are the main sources of air pollution. The noise levels measured at different places also indicate an alarming situation.

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