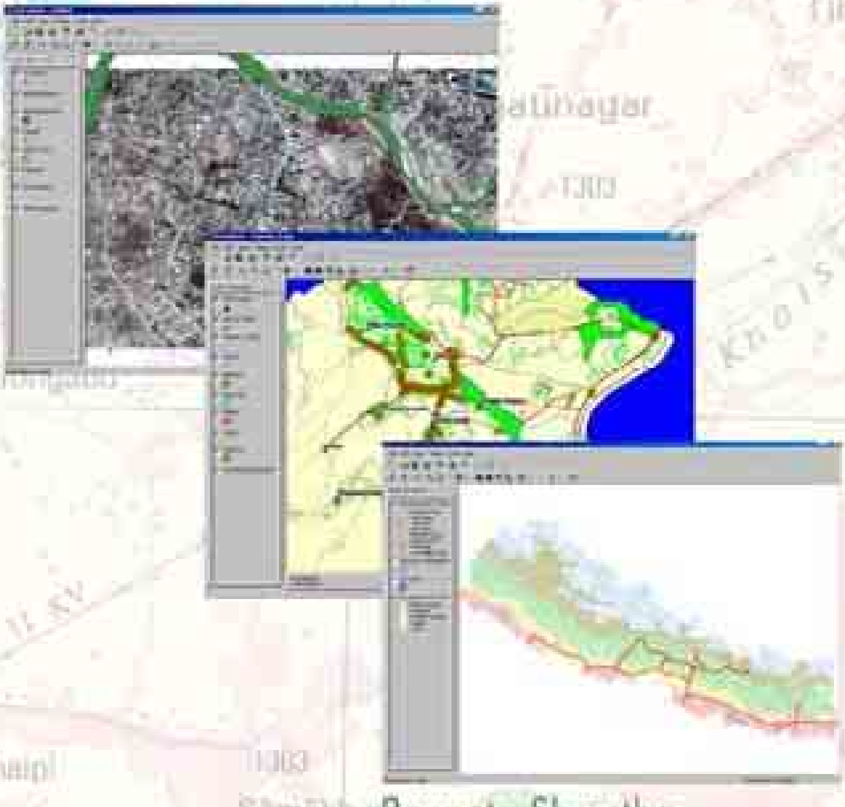
GIS FOR BEGINNERS

Introductory GIS Concepts and Hands-on Exercises



Basanta Shrestha
Birendra Bajracharya
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Released on the occasion of GIS Day 2006, Nepal

GIS DAY NEPAL
Promoting Geographic Literacy Through GIS

ICIMOD

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Introductory GIS Concepts and
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Foreword

Geographic information systems (GIS) are computer-based tools for mapping and analysing things that exist and events that happen around us. Our everyday decisions are dependent on this type of analysis. With the rapid growth of GIS and related technologies over the last two decades, GIS has become a vital element in maintaining and integrating geographic-based information. In today's information society, GIS technology is moving into the mainstream of the Information Technology (IT) industry and virtually influencing the way we deal with many of our problems. It helps us to solve problems such as locating a hospital or a facility, solid waste management, emergency vehicle routing, earthquake disaster mapping, real state business and many more.

Also, GIS software and the hardware required to operate it have become much more affordable and easy to use. This has resulted in the ability to develop GIS without making huge investments in software, hardware, and support staff; items that were once needed to implement them. GIS technology is rapidly reaching the public and their use is changing the way we access information and use it.

As GIS technology is taking hold in our society, it is important to create an awareness of the technology and educate the public. With ICIMOD's experience in the Hindu Kush-Himalayan (HKH) region, it has been observed that the popularity of GIS is growing rapidly. Through the Mountain Environment and Natural Resources' Information Systems (MENRIS) programme, the International Centre for Integrated Mountain Development (ICIMOD) is playing a catalytic role in promoting the use of GIS technology.

The demand for GIS training and education is continually on the rise. It is important not only to train and educate scientists, professionals, and technicians but also to bring about awareness and educate policy makers, decision makers, school/college students, and the public. The manuscript of this introductory text 'GIS for Beginners' with hands-on exercises was released on the occasion of GIS Day 2000 Nepal to bring about awareness of GIS technology and its applications. Encouraged by the welcome given to this document at this very important event, ICIMOD is now publishing it. An interactive CD-Rom for wider circulation with special emphasis on school and college students will be available at a later date.

This publication is intended to serve as introductory reading material on GIS to a wide-ranging audience. The publication introduces a collection of everyday problems from a spatial perspective and provides an overview of basic mapping concepts. It introduces basic GIS concepts and gives a brief overview of GIS and related technologies. It also introduces how GIS can be used to analyse complex problems and briefly discusses how to establish GIS. The hands-on exercises provide an interactive introduction to GIS, which is drawn along similar lines to the book 'GIS for Everyone' published by Environmental Systems Research Institute (ESRI). The hands-on exercises provide a basic understanding of digital maps and how to interact with them. The exercises will help readers to answer basic geographic questions such as *what, where, how far,* and *what's it like*. The reader will learn to distinguish the difference between the dynamic nature of digital maps and static paper maps. All the exercises are based on ESRI-ArcExplorer freeware software with local datasets

This publication with the CD-ROM can be used for a short training course. We hope that the materials thus developed will be useful in promoting GIS technology in the region. Furthermore, the publication can be used as supplementary material in schools and colleges as an extension of geography and related courses.

We hope that the publication is of value to beginners and in promoting the understanding and use of GIS in Nepal and in the region.

J. Gabriel Campbell PhD.
Director General, ICIMOD

Acknowledgements

The authors would like thank all the enthusiastic Participants of the introductory GIS training course 'GIS for Beginners' (more than 120 participants from schools and colleges) held for the first time on the occasion of GIS Day 2000 Nepal. Their valuable feedback and enquiries about the training course has led us to publish this document. We would like to express our gratitude to the Hon'l Member of the National Planning Commission, Dr. Jagadish Chandra Pokharel, for formally launching the manuscript and the CD-Rom. Also, we would like to acknowledge the presence of three prominent geographers of Nepal, Professor Mangal Raj Joshi, Professor Upendra Man Malla, and Professor Mangal Siddhi Manandhar on the occasion and their valuable support for the cause of GIS in promoting geographic literacy.

We are grateful for the support of the former division head of MENRIS, Mr. Pramod Pradhan, and other MENRIS staff Mr. Sushil Pandey, Mr. Pradeep Mool, Mr. Saisab Pradhan, Mr. Govinda Joshi, Mr. Anirudra Shrestha, and Ms. Monica Moktan. The help and assistance provided by Dr. Pushkar Pradhan, Mr. Rajesh Thapa, Mr. Pawan Ghimire, Mr. Sagar Chapagain have been very much appreciated.

More importantly, we would like to express our sincere gratitude to Mr Jack and Mrs Laura Dangermond, who visited Nepal in late April 2001 and their encouraging words and support to the GIS Day event and the 'GIS for Beginners' manuscript. Mr. Jack Dangermond, ESRI President has been one of the founder members of International GIS Day and his genuine efforts and dedication for the cause of GIS Day and its promotion among the younger generation have inspired us immensely.

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Part 1 Concepts

"The most incomprehensible thing about the world is that it is comprehensible."
Albert Einstein

Chapter 1 Thinking Spatially

What's going around you?

Floods in Kathmandu. It's been raining too much!

This year's monsoon has brought more rain than usual to the country and even in Kathmandu there have been a number of floods (Figure 1.1). The effects of haphazard urban growth are revealed in the form of loss of public property and poor quality of life in areas where residential housing has been built without consideration of the area's suitability. The increasing population and the scarcity of land mean that people are building houses on farms and lowland.


Source: Nepalnews.com

Figure 1.1
Flooded streets in Kathmandu

Although the Bagmati and the Bishnumati are the two major rivers flowing through the Kathmandu valley, it is the Tukucha and Samakhusi rivers that give trouble more frequently since their banks have been heavily encroached by large buildings and squatter settlements.

Seeing this story, a person, who is familiar with Kathmandu, can visualise the scenario. He knows these problem areas, how these localities look and the types of houses that are prevalent in these areas. This is called a mental map. It is generated from information stored consciously or unconsciously in a person's brain over the years. However, mental maps are not sufficient if we want to understand the problem in more detail or if we want to carry out remedial work in these areas. Therefore, planners, engineers and construction workers make use of maps and drawings to guide them around the area.

To find the areas that are most likely to be effected by floods, let's demarcate the area within 150 metres of these rivers (Figures 1.2 and 1.3). This buffer area can be considered as the flood-prone zone. Now, if we want to make plans to improve the situation, we need to involve local bodies such as the ward offices. We should identify the stakeholders; these are the wards falling in these flood-prone areas and the households that are likely to be affected by flooding. For this, we need to identify the wards and then the households that lie within the buffer zone (Figures 1.4 and 1.5).

What we have done is to look at rivers, wards and households, and relate them based on their locations. This is called spatial reasoning. For this, we use maps or spatial information.

Figure 1.2
Kathmandu valley from space with rivers overlay

Figure 1.3
Area within 150 m of Tukucha and Samakhusi rivers

Figure 1.4
Wards that are intersected by the buffer zone

Figure 1.5
List of households within the buffer zone

Figure 1.6
Kathmandu valley

Buying a new house

People from all over Nepal migrate to Kathmandu valley looking for jobs (Figure 1.6). After some time, they think of buying a piece of land and building a house; after all, everyone has a dream of making a beautiful house. However, there are many constraints to overcome before this dream can come true.

The first thing is to find a suitable land. With the rapid urban expansion in the valley, it is becoming more difficult to find good places for living. People have their preferences but there are common issues that need to be considered.

The land should be close enough to basic infrastructure such as roads, water and electricity supplies. In Kathmandu, facilities such as water and electricity are dependent on accessibility to roads. Figure 1.7 shows the area within 500 m of major roads.

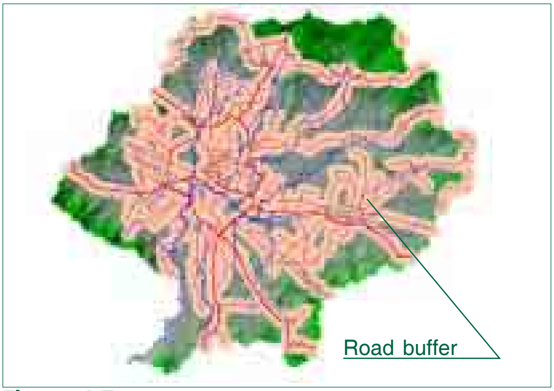


Figure 1.7
Area within 500 m of major roads

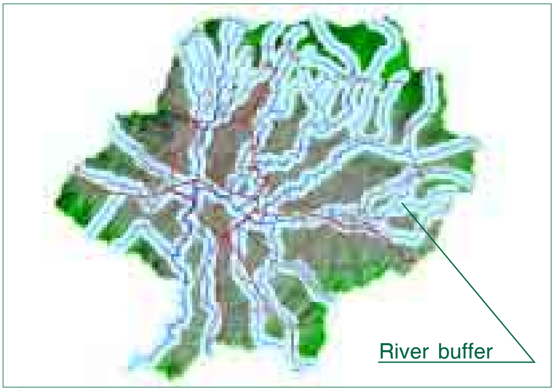


Figure 1.8
Area at least 500 m from major rivers

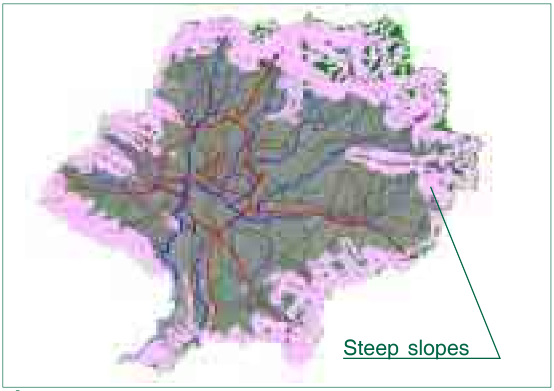


Figure 1.9
Areas with steep slopes

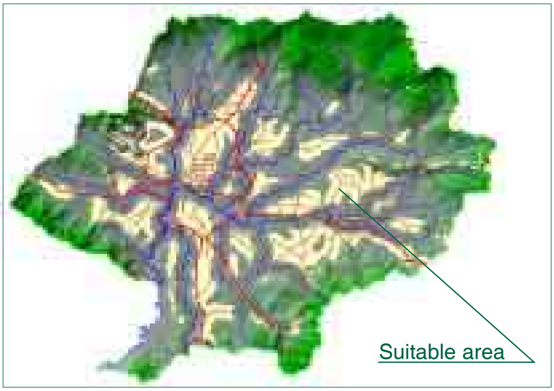


Figure 1.10
Area suitable for building

We have already seen that there are places in the heart of the Kathmandu valley that are frequently affected by floods. Figure 1.8 shows the area at least 500 m from major rivers.

Also, the land should be safe from natural hazards such as landslides that occur on steep slopes. The area that has a slope greater than 10 degrees is shown in Figure 1.9. This land would not be suitable for building purposes.

Excluding all land that is not suitable because of road, river or slope criteria, we find the area that is suitable for residence building (Figure 1.10).

We have used information based on geographic features—rivers, roads and slope—and their relationships to solve our problem.

Let's have a broader outlook

So far, we have discussed our desire to build a house and the need for improvements in the urban environment of Kathmandu valley. However, what is the scenario if we look at the country as a whole? We know that there is a lot to be done in all sectors and all regions of the country to improve the livelihoods of the people. However, with our limited resources it is not possible to meet all the needs at once. Then, how do we identify the most pressing needs?

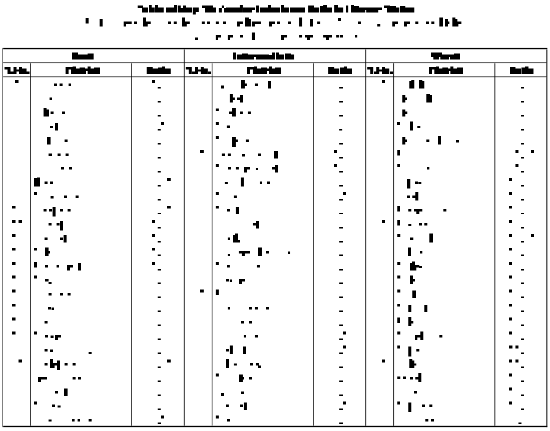


Figure 1.11
Data in tables

To make decisions for national priorities and plans, many data are collected and presented in tables. There are huge volumes of such publications. For example, the ratio of females to males among the literate population of 15 years and above looks like Figure 1.11.

Now, let us plot these figures on a map and see how it looks (Figure 1.12).

Similarly, we can look at the indices for poverty and deprivation, women's empowerment, socioeconomic and infrastructural development in Nepal on a map (Figures 1.13, 1.14 and 1.15).

Figure 1.12
Gender imbalance ratio in literacy status

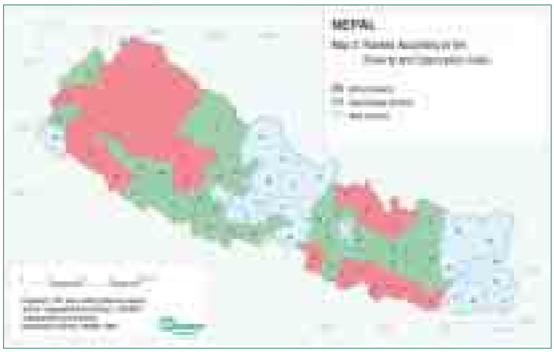


Figure 1.13
Poverty and deprivation index

Source: ICIMOD 1997

Figure 1.14
Women's empowerment index

Figure 1.15
Socioeconomic and infrastructural development index

Source: ICIMOD 1997

We can see that when we plot values on a map, things become clearer and it is easier to make decisions. In this example, we can see that the situation in the far western region is the poorest in all indices. Therefore, greater focus is needed on development in this region.

What we see here is that when we add a spatial or geographic component to our analysis, we have a better picture of the real-world scenario. This is often called spatial thinking. It gives us better insight of our problems and allows us to make better decisions.

The use of computerised information systems is a growing part of our everyday life. GIS is one such system that uses the power of computers to answer questions related to location by arranging and displaying data about places in a variety of ways such as maps, charts and tables. In the following chapters, we will discuss more about maps, mapping and GIS.

"A journey *of* a thousand miles starts in front of your feet."
Lao Tzu

Chapter 2 You and Maps

Understanding the world better

After going through the examples in the previous section, you have probably noticed one thing—we used lots of maps to give a clear picture of the areas discussed. We have seen that maps are powerful means of conveying messages related to places or location. Now let us look at maps in more detail.

A map is a picture of a place. It gives you a better understanding of that place. It is a two dimensional representation of a particular place. Maps are made for many reasons and, therefore, they vary in content and context. Different maps show different information. Different symbols are used to represent the features of the environment on a map. They are explained in the legend for each map.

Some examples

A photograph

A photograph shows a place as our eyes see it. However, the area that is viewed on the ground is limited. It is often difficult to see a substantial landscape in one photograph (Figure 2.1).

Aerial photograph

A photograph taken from an aircraft is known as an aerial photo (Figure 2.2). These photographs are normally taken to prepare maps of an area. Aerial photographs give a 'birds-eye' view of the earth's surface. Features on earth look different from above; consequently, field experience is needed to make correct interpretations of these photographs.

Figure 2.1
A photograph of a landscape

Figure 2.2
Aerial photograph

Shaded relief map

A shaded relief map shows how an area looks when sunlight is shining on it from a particular direction (Figure 2.3). It gives an impression of the nature of the terrain. We can visualise whether an area is plain or rugged by looking at these maps.

Topographic map

A topographic map (Figure 2.4) shows the shape of the earth's surface by contour (elevation) lines. Contours are the imaginary lines that join points of equal elevation on the surface of land above or below a reference surface such as mean sea level. These maps include symbols that represent features such as streets, buildings, rivers and forests. Topographic maps are used by most applications as the base map on which other features or phenomena are referenced.

Road/tourist map

Road maps show people the route for travelling from one place to another. They show some physical features such as rivers and forests, and political features such as cities and towns. Normally, tourist maps emphasise the location of monuments and tourist spots.

3-D map

3-D maps show a phenomenon in three dimensions (Figure 2.6). They help us visualise an area as a continuous surface that rises and falls showing the high and low values of the phenomenon.

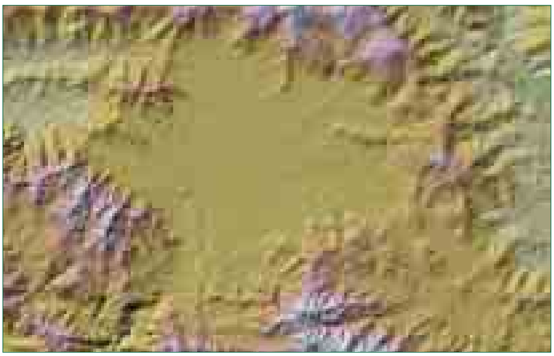


Figure 2.3
Shaded relief map

Figure 2.4
Topographic map

Figure 2.5
Tourist map

Figure 2.6
3-D map

Use of maps

Maps give us a better understanding of a place. The information they contain depends on the type of map. However, maps are used to obtain answers to the following fundamental questions.

Location: where are we?

We sense our surroundings visually and attempt to locate ourselves with relation to visible features in the surroundings. We use rivers, mountains, buildings, trees and other landmarks to make a reference to where we stand. Similarly, we also think of places in terms of other places. For example, you know where you live relative to your friends' houses, your school and the supermarket you visit.

Since these features are depicted on a map with their positions relative to each other, we can locate ourselves by relating these features on the map and these features in our surroundings. To know exactly where we stand in a more scientific way, maps also provide information on latitude and longitude, the co-ordinate system to measure all places on the earth.

Navigation: where are we going?

Travelling is a part of our daily life, whether it is going from our house to school or going from one city to another. Travel depends on skills of navigation; this is the ability to find a route from one place to another and back. Maps have been used as an aid for navigation since ancient times. From a tourist in a new town to a captain of an aeroplane, everybody uses maps and navigation charts as a guide to reach to their destinations.

Information: what else is here?

Apart from road maps and topographic maps that help us locate ourselves and navigate, there are many other types of maps, which are made for conveying information on a specific topic. These are known as thematic maps. They are made for a purpose. Maps of rainfall, temperature, earthquake zones, household incomes or spread of typhoid are thematic maps that give us information on a theme in the area concerned.

Exploring: where do we go from here?

With developments in science and space technology, the making of maps and expansion of their uses have made great progress in the last few decades. Developments in data acquisition techniques—such as remote sensing, digital photogrammetry and global positioning—and the graphic capabilities of computers have greatly changed mapping techniques and practices.

Mapping technologies are being used in many new applications. Biological researchers are exploring the molecular structure of DNA or mapping the genome, geophysicists are mapping the structure of the earth's core, oceanographers are mapping the ocean floor and so on. Mapping techniques are being used to explore the relationships between ideas in what is known as concept mapping.

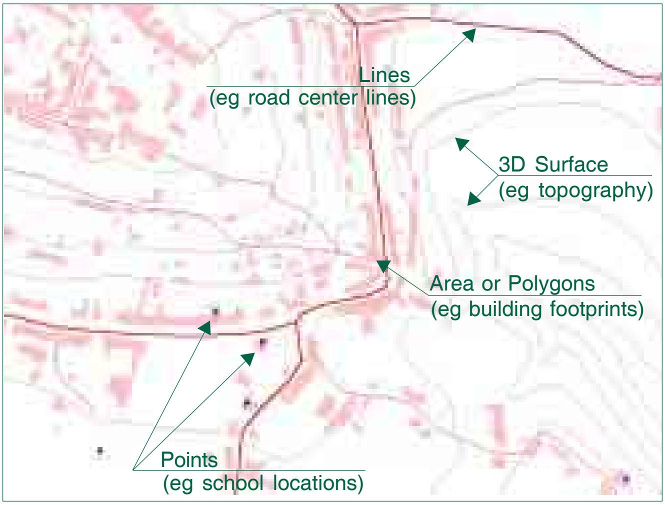


Figure 2.7
Types of map feature

Map reading

Reading a map means interpreting the colours, lines and other symbols. Features are shown as points, lines or areas depending upon their size and extent (Figure 2.7). Besides recognising the features, knowing their locations and distances accurately is also important. Map symbols and map scale provide this information.

Point features

Point features or geographically defined occurrences are features whose location can be represented by a single x, y or x, y, z location. Points have no linear or area dimensions but simply define the location of a physical feature (e.g. control point monument, sign, utility pole) or an occurrence (e.g. accident).

Line features

Lines represent features that have a linear extent but no area dimensions. Centrelines of roads, water mains and sewer mains are examples of line features.

Area features

Area features, also called polygons, have a defined two-dimensional extent and are delimited by boundary lines that encompass an area. Typical area features are maintenance districts and soil types.

Three-dimensional surfaces

Some geographic phenomena are best suited to representation in three-dimensional form covering an area. The most frequent example is surface terrain often represented by contour lines that have an elevation value. This concept can be applied to other spatially continuous data as well. For instance, population density or income levels could be mapped as a third dimension to support demographic analysis or water consumption statistics.

Scale

Map scale describes the relationship between mapped size and actual size. It is expressed as a relationship between linear distances on the map and corresponding ground distance. Two methods of notating scale are commonly used.

Inch–foot equivalent. The scale relationship is expressed as '1 inch = x feet' where the map distance of 1 inch equates to its corresponding ground distance.

Representative fraction (RF). This is a pure fraction that represents the ratio of map distance to ground distance without specifying any measurement unit. The inch–foot equivalent of 1 inch = 100 foot is represented in RF form as 1:1200 or 1/1200.

Large-scale maps cover small areas and usually include a greater level of detail than small-scale maps that depict larger areas in lesser detail. There are no precise definitions for large or small scale but, for most map users, the following general scale categories apply.

Large scale: 1"	= 50' to 1"	= 200' (1:240 to 1:1200)
Medium scale: 1"	= 100' to 1"	= 1000' (1:1200 to 1:12,000)
Small scale: 1"	= 1000' to 1"	= 5000' (1:6000 to 1:60,000)
Very small scale: 1"	= 5000' and smaller (1:60,000 and smaller)	

Figure 2.8
Map symbols

Symbols

The meaning of each symbol used in a map is described in the map's legend. However, many symbols in topographic maps have become conventional and can be interpreted without looking at the legend. For example, an area feature shown in green is vegetation, blue is water and a built-up area is grey or red. Similarly, many line symbols such as curved, dashed, dotted or a combination are used to show various features. Usually the contours are brown, streams and canals are blue, roads are red and black, and borders are black dash-dots. Various point symbols are used to show schools, hospitals, temples and so on. Figure 2.8 presents some of the standard symbology used in map making.

Map projection

A globe is the best way to show the relative positions of places but it is neither portable nor practical for large scales (Figure 2.9). The three-dimensional shape of the earth means that it is not possible to depict locations and features directly on to a two-dimensional map space without some distortions. (Try to flatten the skin of an orange on to a piece of paper.) Map projection is a procedure to transform locations and features from the three-dimensional surface of the earth on to two-dimensional paper in a defined and consistent way.

Figure 2.9
A Globe

The transformation of map information from a sphere to a flat sheet can be accomplished in many ways. Mapmakers have invented projections that show distances, directions, shapes or areas as they are on a globe to at least some extent. Each projection has advantages

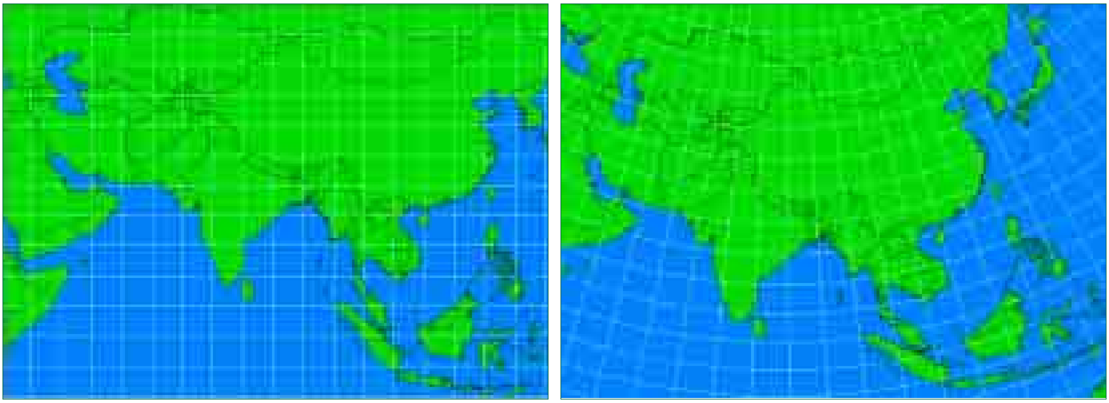
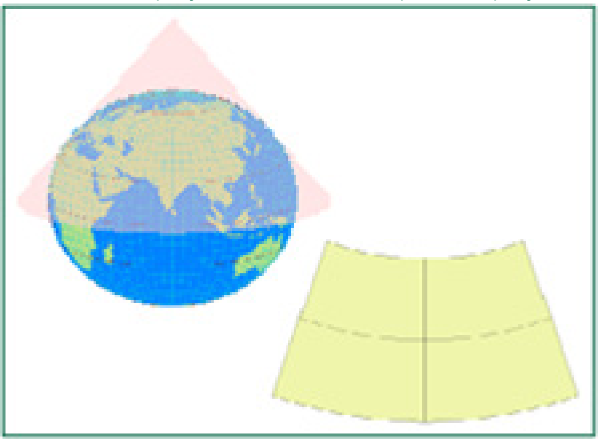
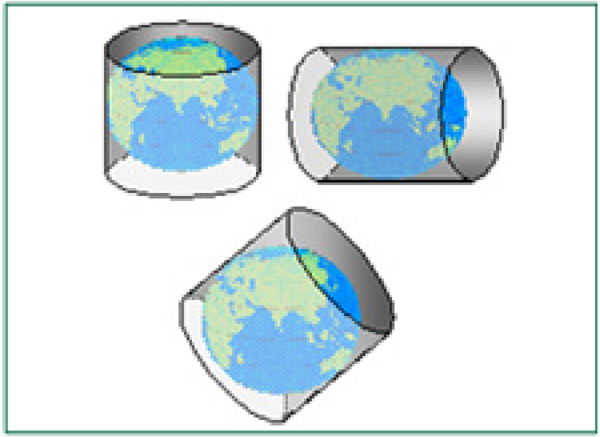


Figure 2.10
Plate carree projection and albers equal area projection



Conical projections



Cylindrical projections

and disadvantages. Orthographic projections, for example, show shapes as they appear when the globe is viewed from space. Equal-area projections do not distort the size of areas but do distort their shape. Conformal projections are those on which the scale is the same in any direction at any point on the map. Many projections retain one geometric quality and a few retain more than one, but no single projection can accurately portray area, shape, scale and direction (Figures 2.10, 2.11 and 2.12).

"The new source of power is not money in the hands of a few but information in the hands of man."
John Naisbitt

Chapter 3 GIS

A tool for decision-making

Every day you wake at 6 o'clock in the morning. At 8 o'clock you go to school which is four kilometres south of your house. You return home at 4 o'clock in the afternoon travelling along the same route. Then at 5 o'clock you call your friends and go for a game of football at the nearby playground that is 10 minutes walk from your house. Many of our activities are related to place and time in one way or the other. Planning and decision-making—whether it is planning a new road or finding a suitable location for a health centre—are influenced or dictated by location or a geographic component. The major challenges we face in the world today—over-population, deforestation, natural disasters—have a critical geographic dimension.

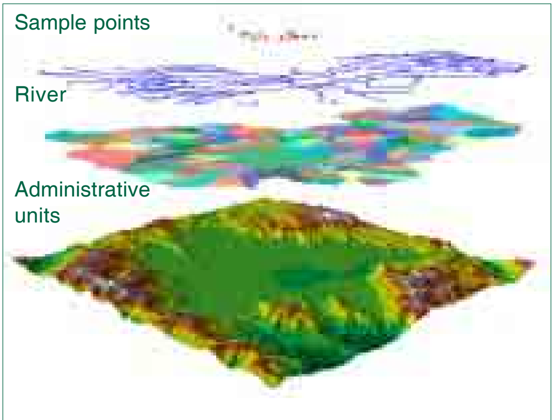


Figure 3.1
Geography in layers

Our geography can be considered as a number of related data layers as illustrated in Figure 3.1. GIS combine layers of information about a place to give an understanding of that place. Which layers of information are combined depends on a purpose: for example, finding the best location for a new supermarket, assessing environmental damage, tracking delivery vehicles or modelling the global environment. A GIS stores information about the world as a collection of thematic layers that can be linked together by geography. This simple but extremely powerful and versatile concept has proven invaluable for solving many real-world problems.

In the strictest sense, GIS are computer systems for collecting, storing, manipulating and displaying geographic information. There are many definitions for GIS. However, their major characteristic is geographic (spatial) analysis functions that provide a means for deriving new information based on location.

GIS functions

There are four basic functions of GIS: data capture, data management, spatial analysis and presenting results.

Data capture

Data used in GIS come from many sources, are of many types and are stored in different ways. A GIS provides tools and methods for the integration of data into a format so that data can be compared and analysed. Data sources are mainly manual digitisation/scanning of aerial photographs, paper maps and existing digital data. Remote-sensing satellite imagery and GPS are also data input sources.

Data management

After data are collected and integrated, a GIS provides facilities that can contain and maintain data. Effective data management includes the following aspects: data security, data integrity, data storage and retrieval, and data maintenance.

Spatial analysis

Spatial analysis is the most important function of a GIS that makes it distinct from other systems such as computer aided design and drafting (CADD). The spatial analysis provides functions such as spatial interpolation, buffering and overlay operations.

Presenting results

One of the most exciting aspects of GIS is the variety of ways in which information can be presented once it has been processed. Traditional methods of tabulating and graphing data can be supplemented by maps and three-dimensional images. These capabilities have given rise to new fields such as exploratory cartography and scientific visualisation. Visual presentation is one of the most remarkable capabilities of GIS that allows for effective communication of results.

Questions GIS can answer

GIS can be distinguished by listing the types of questions it can answer.

Location: What is at…?

This question seeks to find what exists at a particular location. A location can be described in many ways using, for example, a place name, postcode or geographic reference such as longitude/latitude or x and y.

Condition: Where is it…?

This question is the converse of the first and requires spatial data to answer. Instead of identifying what exists at a given location, one may wish to find locations where certain conditions are satisfied (e.g. a non-forest area of at least 2000 m^2 within 100 m of a road and with soils suitable for supporting buildings).

Trends: What has changed since…?

This question might involve both of the first two and seeks to find the differences within an area over time, e.g., changes in forest cover or the extent of urbanisation over the last ten years.

Patterns: What spatial pattern exists…?

This question is more sophisticated. It might be asked to determine whether landslides are occurring mostly near streams or to find out at which traffic points accidents are occurring most frequently. It might be just as important to know how many anomalies there are and where they are located.

Modelling: What if…?

This question is posed to determine what happens if, for example, a new road is added to a network or a toxic substance seeps into the local groundwater supply. Answering this type of question requires both geographic and other information (as well as specific models).

Geographic data

There are two important components of geographic data: geographic position and attributes or properties. In other words, spatial data (where is it?) and attribute data (what is it?). Geographic position specifies the location of a feature or phenomenon by using a coordinate system. The attributes refer to the properties of spatial entities such as identity (e.g. maize, granite, lake), ordinal (e.g. ranking such as class 1, class 2, class 3) and scale (e.g. value such as water depth, elevation, erosion rate). They are often referred to as non-spatial data since they do not in themselves represent location information.

Raster and vector data

Spatial features in a GIS database are stored in either vector or raster form. GIS data structures adhering to a vector format store the position of map features as pairs of x, y (and sometimes z) coordinates. A point is described by a single x-y coordinate pair and by its name or label. A line is described by a set of co-ordinate pairs and by its name or label. In theory, a line is described by an infinite number of points. In practice, this is not feasible. Therefore, a line is built up of straight-line segments. An area, also called a polygon, is described by a set of coordinate pairs and by its name or label with the difference that the coordinate pairs at the beginning and end are the same (Figure 3.2).

A vector format represents the location and shape of features and boundaries precisely. Only the accuracy and scale of the map compilation process, the resolution of input devices and the skill of the data-inputter limit precision.

In contrast, the raster or grid-based format generalises map features as cells or pixels in a grid matrix (Figure 3.3). The space is defined by a matrix of points

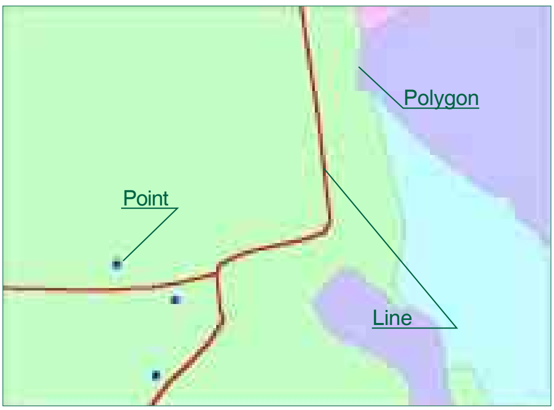


Figure 3.2
Vector format

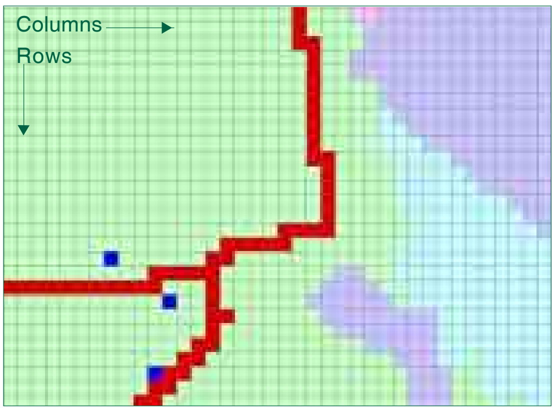


Figure 3.3
Raster format

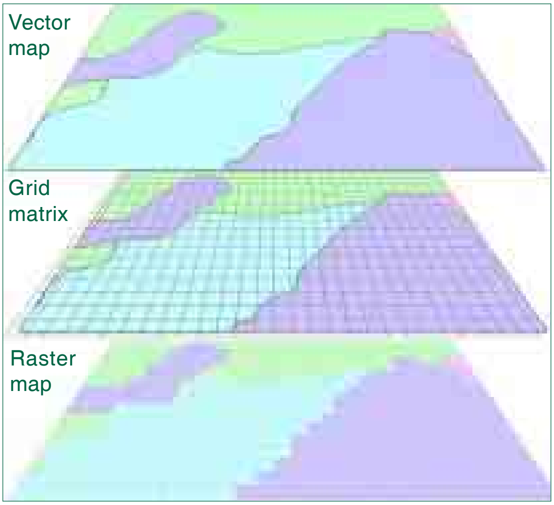


Figure 3.4
Vector–raster relationship

or cells organised into rows and columns. If the rows and columns are numbered, the position of each element can be specified by using column number and row number. These can be linked to coordinate positions through the introduction of a coordinate system. Each cell has an attribute value (a number) that represents a geographic phenomenon or nominal data such as land-use class, rainfall or elevation. The fineness of the grid (in other words, the size of the cells in the grid matrix) will determine the level of detail in which map features can be represented. There are advantages to the raster format for storing and processing some types of data in GIS. The vector–raster relationship is shown in Figure 3.4.

Organising attribute data

GIS use raster and vector representations to model earth features or phenomena. Apart from locations, GIS must also record information about them. For example, the centre line that represents a road on a map does not tell you much about the road except its location. To determine the road's width or pavement type or condition, such information should be stored so that it can be accessed by the system as needed. This means that the GIS must provide a linkage between spatial and non-spatial data. These linkages make the GIS 'intelligent' as the user can store and examine information about where things are and what they are like. The linkage between a map feature and its attributes is established by giving each feature at least one unique means of identification—a name or number usually called its ID. Non-spatial attributes of the feature are then stored, usually in one or more separate files, under this ID number (Figure 3.5)

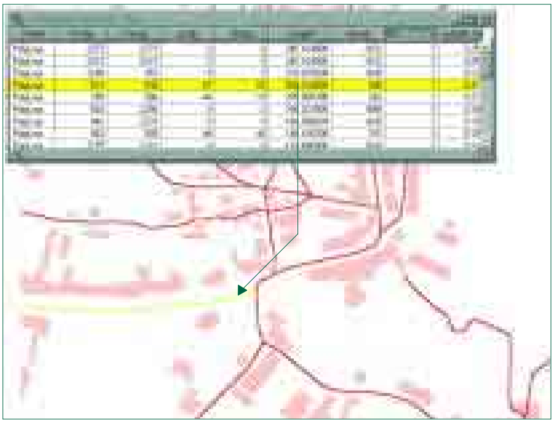


Figure 3.5
Linking attribute data

This non-spatial data can be filed in several forms depending on how it needs to be used and accessed. Many GIS software use the relational database management systems (RDBMS) to handle attribute data.

A relational database is the perception of data as series of tables that are logically associated with each other by shared attributes (Figure 3.6). Any data element in a relationship can be found by knowing the table name, the attribute (column) name and the value of the primary key. The advantage of these systems is that they are flexible and can answer any question formulated with logical and mathematical operators.

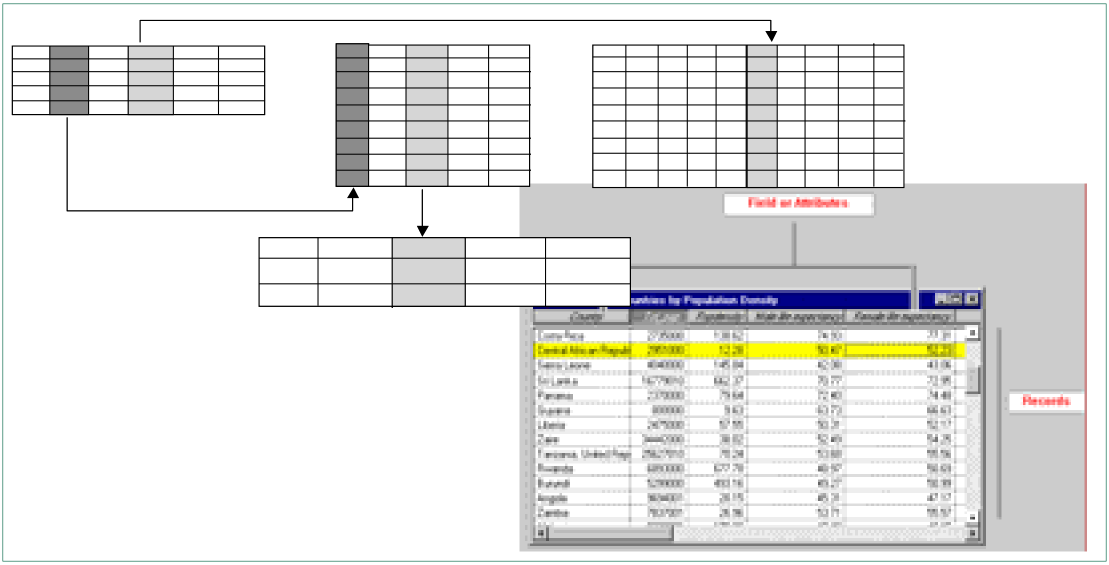


Figure 3.6
Relational database management system

Metadata

Metadata are simply defined as 'data about data'. It gives the information about the content, source, quality, condition and other relevant characteristics of the data (Figure 3.7). For instance, it may describe the content as road or land-use data, the source as where the data have come from, the quality as the level of accuracy, the condition as whether the data are outdated or partial and so on.

Figure 3.7
Metadata

"A decision is as good as the information that goes into it."
John F. Bookout, Jr.

Chapter 4 Data Capture

How to feed maps into your computer

Data: the fuel

The geographic data are information about the earth's surface and the objects found on it. Data are fuel to a GIS. How can we feed data such as a map into a GIS? Data capture is the process of putting information into the system. A wide variety of sources can be used for creating geographic data.

Types and sources of geographic data

Geographic data are generally available in two forms: analogue data and digital data. Analogue data are a physical product displaying information visually on paper, e.g. maps. Digital data are information in a computer-readable form, e.g. satellite data (Figure 4.1).

There are various sources for obtaining these types of data. For example, as shown in Figure 4.2, the sources are maps, aerial photographs, satellite images, existing tabular data (in analogue and digital format) and field data (GPS). A GIS is able to capture these different types of data from various sources. Creating a database, i.e. capturing the data, is the initial and time-consuming stage of a GIS project.

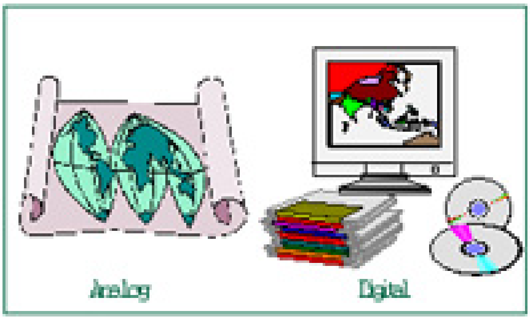


Figure 4.1
Analogue and digital data

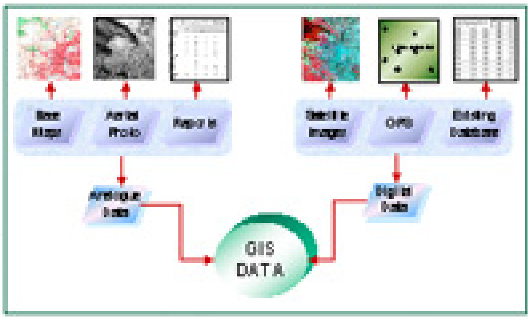
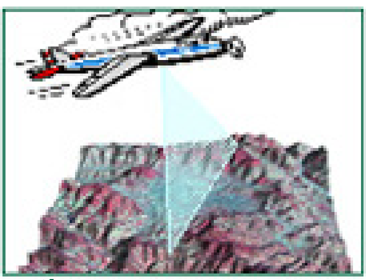


Figure 4.2
Data sources



Arial photography

Data capturing methods

Data capturing methods from various sources commonly used in a GIS are briefly discussed below (Figure 4.3).

Photogrammetric compilation

The primary source used in the process of photogrammetric compilation is aerial photography. Generally, the process involves using specialised equipment (a stereoplotter) to project overlapping aerial photos so that a viewer can see a three-dimensional picture of the terrain. This is known as a photogrammetric model. The current technological trend in photogrammetry is toward a greater use of digital procedures for map compilation.

Figure 4.3b
Digitiser

Digitising

A digitising workstation with a digitising tablet and cursor is typically used to trace digitise. Both the tablet and cursor are connected to a computer that controls their functions. Most digitising tablets come in standard sizes that relate to engineering drawing sizes (A through E and larger). Digitising involves tracing with a precise cross hair in the digitising cursor features on a source map that is taped to the digitising tablet and instructing the computer to accept the location and type of the feature. The person performing the digitising may input separate features into map layers or attach an attribute to identify the feature.

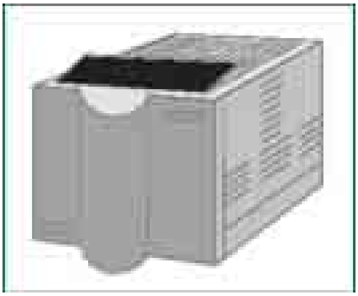


Figure 4.3c
Map scanner

Map scanning

Optical scanning systems automatically capture map features, text and symbols as individual cells or pixels and produce an automated product in raster format. Scanning outputs files in raster form, usually in one of several compressed formats to save storage space (e.g. TIFF 4, JPEG). Most scanning systems provide software to convert raster data to vector format that differentiates point, line and area features. Scanning systems and software are becoming more sophisticated with some ability to interpret symbols and text, and store this information in databases. Creating an intelligent GIS database from a scanned map will require vectorising the raster data and manual entry of attribute data from a scanned annotation.

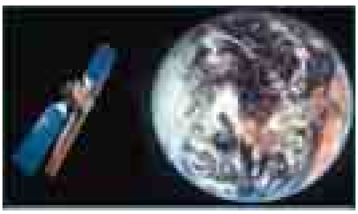


Figure 4.3d
Satellite data

Satellite data

Earth resources satellites have become a source of huge amounts of data for GIS applications. The data obtained from satellites are in digital form and can be imported directly into a GIS. There are numerous satellite data sources such as LANDSAT or SPOT. A new generation of high-resolution satellite data, that will increase opportunities and options for GIS database development, are becoming available from private sources and national governments. These satellite systems will provide panchromatic (black and white) or multi-spectral data in the 1-m to 3-m ranges as compared to the 10-m to 30-m range available from traditional remote sensing satellites.

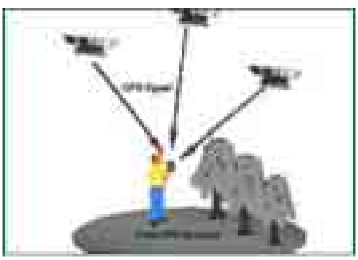


Figure 4.3e
GPS

Field data collection

Advances in hardware and software have greatly increased opportunities for capture of GIS data in the field (e.g. utility sign inventory, property surveys, land-use inventories). In particular, electronic survey systems and the global positioning systems

(GPS) have revolutionised surveying and field data collection. Electronic distance measurement services allow for survey data to be gathered quickly in an automated form for uploading to a GIS. Sophisticated GPS collection units provide a quick means of capturing the coordinates and attributes of features in the field.

Tabular data entry

Some of the tabular attribute data that are normally in a GIS database exist on maps as annotation or can be found in paper files. Information from these sources that is required for GIS applications has to be converted to a digital form through keyboard entry. This kind of data entry is commonplace and relatively easy to accomplish.

Document scanning

Smaller format scanners can also be used to create raster files of documents such as permit forms, service cards, site photographs, etc. These documents can be indexed in a relational database by number, type, date, engineering drawings, etc., and queried and displayed by users. GIS applications can be built that allow users to point to and retrieve for display a scanned document (e.g., tax parcel) interactively.

Translation of existing digital data

Existing automated data may be available from existing tabular files maintained by outside sources. Many programmes are available that perform this translation. In fact, there are many GIS packages with programmes that translate data to and from several 'standard' formats that are accepted widely by the mapping industry. They have been used as intermediate 'exchange' formats for moving data between platforms (e.g. Intergraph SIF, TIGER, Shapefile and AutoCAD DXF).

"To envision information—and what bright and splendid visions can result—is to work at the intersection of image, word, number, art."
Edward R. Tufte

Chapter 5 Remote Sensing

Big Brother is watching you ...

What is remote sensing?

We perceive the surrounding world through our five senses. Some senses (touch and taste) require contact of our sensing organs with the objects. However, we acquire much information about our surrounding through the senses of sight and hearing that do not require close contact between the sensing organs and the external objects. In other words, we are performing remote sensing all the time.

Figure 5.1
Earth from space

Generally, remote sensing refers to the activities of recording/observing/perceiving (sensing) objects or events at distant (remote) places.

Remote sensing is defined as the science and technology by which the characteristics of objects of interest can be identified, measured or analysed without direct contact. Remote sensing deals with gathering information about the Earth from a distance. This can be done a few metres from the Earth's surface, from an aircraft flying hundreds thousands of metres above the surface or by a satellite orbiting hundreds of kilometres above the Earth.

Figure 5.2
Remote sensing satellite

Remote-sensing satellite

Remote-sensing satellites are equipped with sensors that look down at the earth. They are 'eyes in the sky' constantly observing the earth (Figure 5.2).

Why remote sensing?

Remote-sensing satellite images gives a synoptic (bird's eye) view of any place on the Earth's surface. This allows us to study, map and monitor the Earth's surface at local and/or regional/global scales. It is cost effective and gives better spatial coverage compared to ground sampling.

How does remote sensing work?

Electro-magnetic radiation reflected or emitted from an object is the usual source of remote sensing data. A device to detect the electro-magnetic radiation reflected or emitted is called a remote sensor or sensor. Cameras or scanners are examples of remote sensors. A vehicle to carry the sensor is called a platform. Aircraft or satellites are used as platforms.

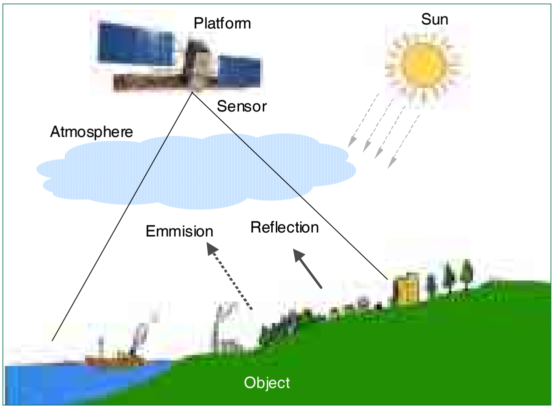


Figure 5.3
Remote-sensing

The characteristics of an object can be determined using its reflected or emitted electro-magnetic radiation. That is 'each object has a unique characteristic of reflection or emission if the object type or environmental conditions are different'. Remote sensing is a technology to identify and understand the object or the environmental conditions through the uniqueness of its electro-magnetic reflection or emission. This concept is illustrated in Figure 5.3.

Types of remote-sensing images

Presently there are several remote-sensing satellite series in operation. Different satellite systems have different characteristics—e.g. resolutions, number of bands—and have their own importance for different applications. Some major satellite systems and their major characteristics are given in the table below.

Remote-sensing images

Remote-sensing images are normally digital images (Figure 5.4). In order to extract useful information, image processing techniques are applied to enhance the image to help visual interpretation, and to correct or restore the image if the image has been subjected to geometric distortion, blurring or degradation by other factors. There are many image analysis techniques available and the method used depends upon the requirements of the specific problem concerned.

Use of remote-sensing data in GIS

Remote-sensing data can be integrated with various other geographic data. There has been an increasing trend in integration of remote-sensing data into

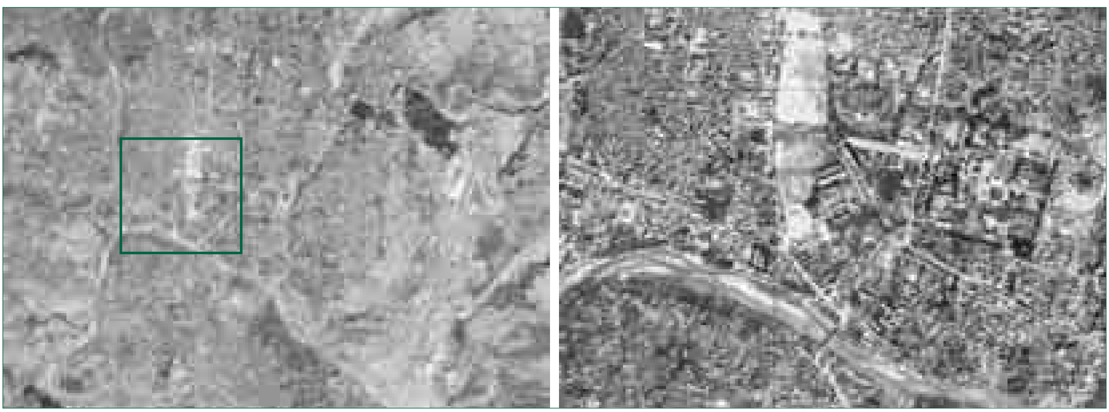


Figure 5.4
Satellite Image of Kathmandu

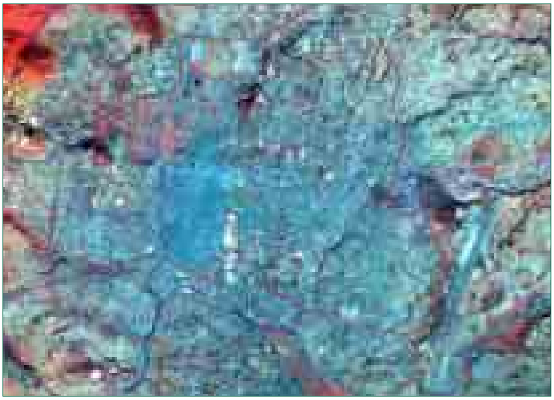


Figure 5.5
Kathmandu urban area observed from an ADEOS-AVNIR M Japanese satellite image, 1997, and overlaid with road and river features

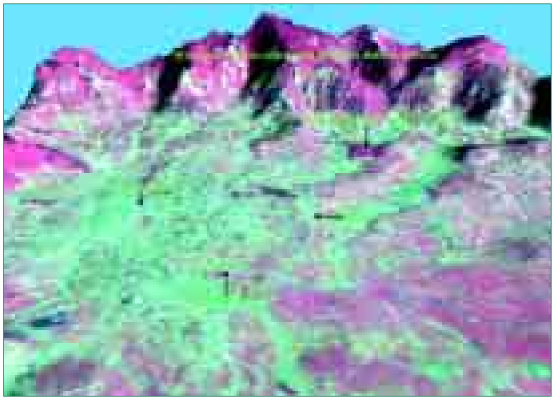


Figure 5.6
3-D perspective of the Kathmandu valley generated by draping a LANDSAT-TM, 1988, satellite image over a DEM

GIS for analytical purposes. There are many ways to use remote-sensing data; some examples are illustrated as below.

Land cover maps or vegetation maps classified from remote-sensing data can be overlaid on to other geographic data to enable analysis for environmental monitoring and its change.

Image data are sometimes also used as image maps, with an overlay of political boundaries, roads, rivers, etc. Such an image map can be successfully used for visual interpretation (Figure 5.5 and 5.6).

"Knowing where you are is so basic to life."
Jeff Hurn, Trimble Navigation

Chapter 6 Global Positioning System

Where do I stand?

Knowing where you are and where you are going was the most crucial and challenging task faced by explorers in ancient times. Positioning and navigation are extremely important to many activities, and many tools and techniques have been adopted for this purpose. People have used a magnetic compass, sextant or theodolite and measured the positions of the sun, moon and stars to find their own position. More recently, a global positioning system (GPS) has been developed by the US Department of Defence (DoD) for world-wide positioning at a cost of 12 billion US dollars.

GPS is a world-wide radio-navigation system formed from a constellation of 24 satellites and their ground stations. It uses these 'man-made stars' as reference points to calculate positions accurate to a matter of metres. GPS receivers are remarkably economical and have made the technology accessible to virtually everyone. The GPS provides continuous three-dimensional positioning 24 hours a day to military and civilian users throughout the world. These days, GPS is finding its way into cars, boats, planes, construction equipment, farm machinery and even laptop computers. It has tremendous scope for use in GIS data collection, surveying and mapping. GPS is increasingly used for precise positioning of geospatial data and collection of data in the field.

Components of the GPS

The global positioning system is divided into three major components: the control segment, the space segment and the user segment. All three segments are required to perform positional determination.

Control segment

The Control Segment consists of five monitoring stations—Colorado Springs, Ascension Island, Diego Garcia, Hawaii and Kwajalein Island (Figure 6.1). Colorado Springs serves as the master control station. The control segment is the sole responsibility of the DoD who undertakes its construction, launching, maintenance and constant monitoring of all GPS satellites. The monitoring stations track all GPS signals for use in controlling the satellites and predicting their orbits.

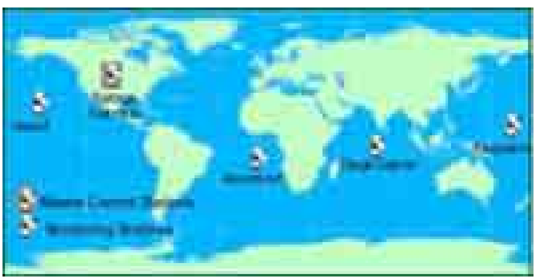


Figure 6.1
Control segment

Space segment

The space segment consists of the constellation of Earth-orbiting satellites. The satellites are arrayed in six orbital planes inclined 55 degrees to the equator (Figure 6.2). They orbit at an altitude of about 12,000 miles. Each satellite contains four precise atomic clocks (Rubidium and Cesium standards) and has a microprocessor on board for limited self-monitoring and data processing. The satellites are equipped with thrusters that can be used to maintain or modify their orbits.

User segment

The user segment consists of all Earth-based GPS receivers (Figure 6.3). Receivers vary greatly in size and complexity although the basic design is rather simple. The typical receiver is composed of an antenna and preamplifier, radio-signal microprocessor, control and display device, data recording unit and power supply. The GPS receiver decodes the timing signals from the 'visible' satellites (four or more) and, having calculated their distances, computes its own latitude, longitude, elevation and time. This is a continuous process and generally the position is updated on a second-by-second basis. It is output to the receiver display device and, if the receiver provides data capture capabilities, stored by the receiver logging unit.

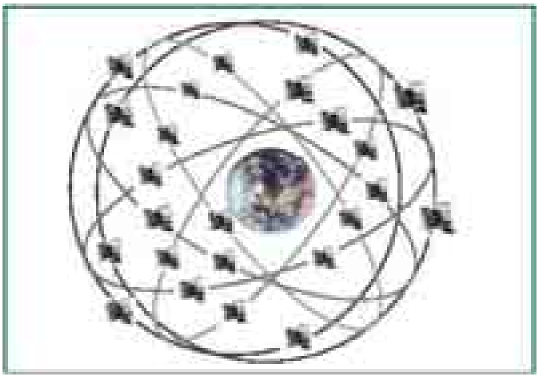


Figure 6.2
Space segment

Figure 6.3
GPS receiver

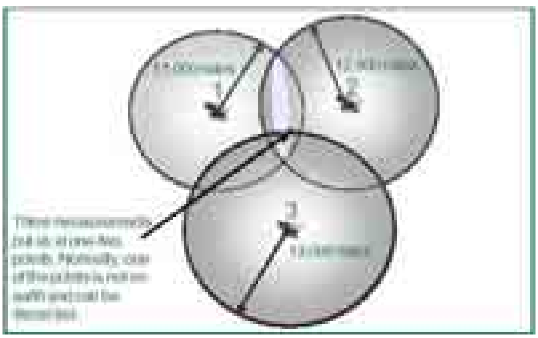


Figure 6.4
GPS triangulation

How GPS works?

The GPS uses satellites and computers to calculate positions anywhere on earth based on satellite ranging. This means that a position on Earth is determined by measuring its distance from a group of satellites in space. The GPS measures the time it takes for a radio message to travel from each satellite to the position on Earth. For this, it needs an extremely accurate clock. It then converts this time into a distance and, using triangulation, calculates each satellite's distance from Earth. It then needs to know where each satellite is in space. To compute a satellite's position in three dimensions, the GPS needs to have four satellite measurements. It uses a trigonometric approach to calculate these positions (Figure 6.4). The satellites are so high that their orbits are very predictable.

GPS errors

Although the GPS looks like a perfect system, there are a number of sources of errors that are difficult to eliminate (Figure 6.5). The ultimate accuracy of GPS is determined by some of these several sources of error.

Satellite errors

Slight inaccuracies in time-keeping by satellites can cause errors in calculating positions on Earth. Also, the satellite's position in space is important because it is used for the starting point of the calculations. Although GPS satellites are at extremely high orbits and are relatively free from the perturbing effects of atmosphere, they still drift slightly from their predicted orbits. This contributes to errors.

The atmosphere

The GPS signals have to travel through charged particles and water vapour in the atmosphere. This slows their transmission. Since the atmosphere varies in different places and times, it is not possible to compensate accurately for the delays that occur.

Multipath error

As the GPS signal arrives on the Earth's surface, it may be reflected by local obstructions before it reaches the receiver's antenna. This is called multipath error because the signal reaches the antenna along multiple paths.

Receiver error

Receivers are also not perfect. They introduce errors that usually occur from their clocks or internal noise.

Selective availability

Selective availability (SA) was the intentional error introduced by the DoD to make sure that hostile forces could not use the accuracy of the GPS against the US or its allies. Some noise was introduced into the GPS satellite clocks that reduced their accuracy. The satellites were also given erroneous orbital data that were transmitted as part of each satellite's status message. These two factors significantly reduced the accuracy of GPS for civilian uses. On 1 May 2000, the US Government announced a decision to discontinue the intentional degradation of the GPS signals to the public. Civilian users of GPS are now able to pinpoint locations up to ten times more accurately. The decision to discontinue SA is the latest measure in an on-going effort to make GPS more responsive to civil and commercial uses world-wide.

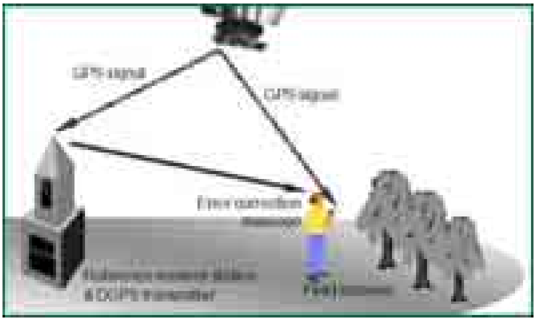


Figure 6.6
Differential positioning

Differential positioning

To eliminate most of the errors discussed above, the technique of differential positioning is applied. Differential GPS carries the triangulation principle one step further, with a second receiver at a known reference point. The reference station is placed on the control point—a triangulated position or the control point coordinate. This allows for a correction factor to be calculated and applied to other roving GPS units used in the same area and in the same time series. This error correction allows for a considerable amount of error to be negated—potentially as much as 90 per cent. The error correction can either be post-processed or in real time (Figure 6.6).

Integration of GPS and GIS

It is possible to integrate GPS positioning in GIS for field data collection. GPS is also used in remote-sensing methods such as photogrammetry, aerial scanning and video technology. GPS is an effective tool for GIS data capture. The GIS user community benefits from the use of GPS for locational data capture in various GIS applications. The GPS can easily be linked to a laptop computer in the field and, with appropriate software, users can place all their data on a common base with little distortion. Thus, GPS can help in several aspects of the construction of accurate and timely GIS databases.

"Knowing where things are and why is essential to rational decision-making."
Jack Dangermond

Chapter 7 Spatial Analysis

Playing with places

When you think of a name and address database, you probably visualise a table of data in rows and columns. What you might miss is that each of these records represents a person or family that lives in a particular place (location). Furthermore, that particular place (location) can tell us something about a person's standard of living, neighbourhood, access to schools, access to hospital, distance to the main market, vulnerability to local crime, exposure to pollution levels and so on. Through GIS analysis, it allows us to visualise the 'bigger picture' by allowing us to see patterns and relationships within the geographic data. The results of analysis give insight into a place, help focus actions or select an appropriate option. The beauty of GIS is its ability to perform spatial analysis.

What is spatial analysis?

Spatial analysis is a process for looking at geographic patterns in data and relationships between features. The actual methods used can be simple—just a map of the theme being analysed—or more complex involving models that mimic the world by combining many data layers.

Spatial analysis allows us to study real-world processes. It gives information about the real world that may be the present situation of specific areas and features or the changes or trends in a situation. For instance, it may be able to answer 'where and by how much are forest areas decreasing or increasing?' or 'where are urban areas growing in the Kathmandu valley?' and so on.

Spatial analysis functions

Spatial analysis functions range from simple database query to arithmetic and logical operation to complicated model analysis. Each of these functions is briefly described below.

Database query

Database query is used to retrieve attribute data without altering the existing data. The function can be performed by simply clicking on the feature or by means of a conditional statement for complex queries. The conditional statement can involved Boolean (logical) operators—and, or, not, xor (exclusive of or)—or relational (conditional) operators—=, >, <, <> (not equal to). An example of Boolean operators that combine more than two conditions is shown in Figure 7.1.

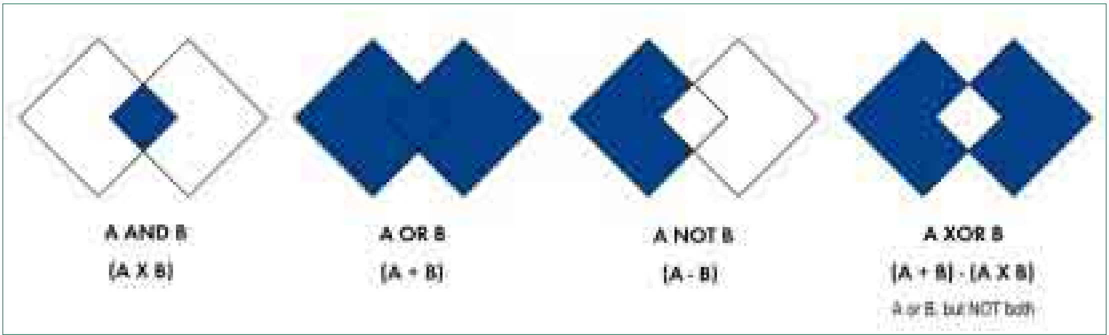


Figure 7.1
Boolean operations

For example, in Figure 7.2, the Boolean operator used is ([LandUse] = 'Agriculture') OR ([LandUse] = 'Shrub').

Reclassification

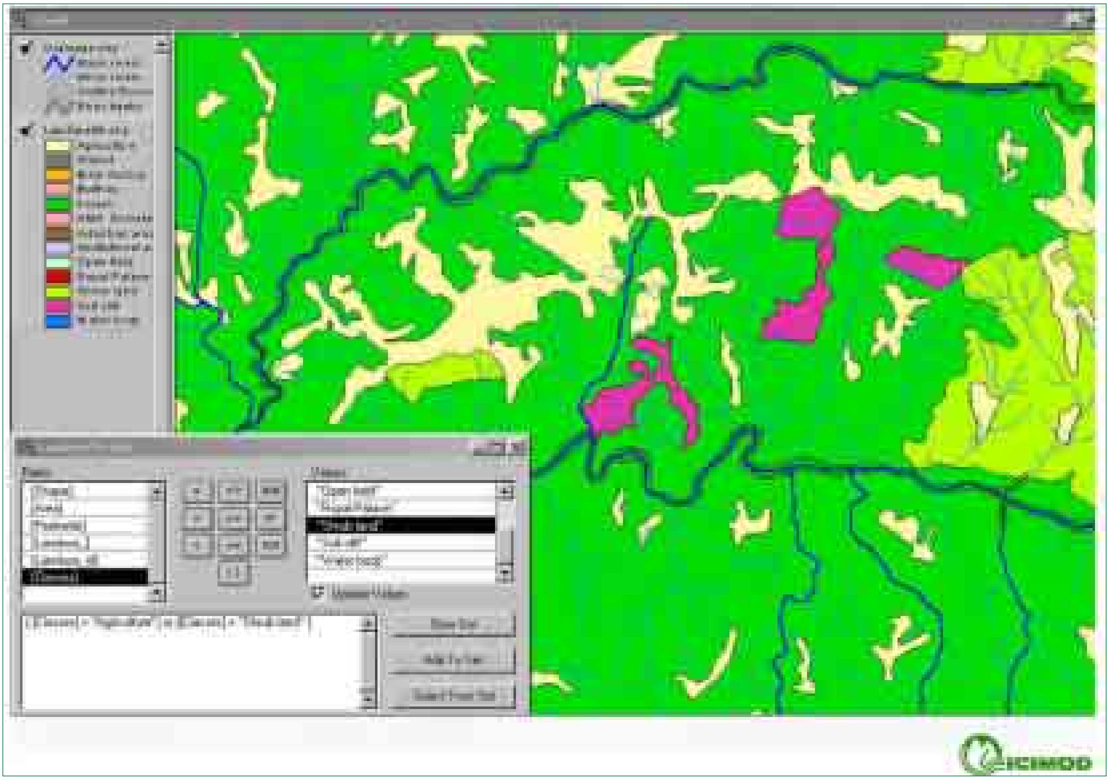
(Re)classification operations involve the reassignment of thematic values to categories of an existing map. The following are examples.

- Classify an elevation map into classes with intervals of 500 m (Figure 7.3).
- Reclassify a VDC (village development committee) map based on population density (Figure 7.4).

Overlay

Overlay is at the core of GIS analysis operations. It combines several spatial features to generate new spatial elements. Overlay can be defined as a spatial

Figure 7.2
Selection using Boolean operators



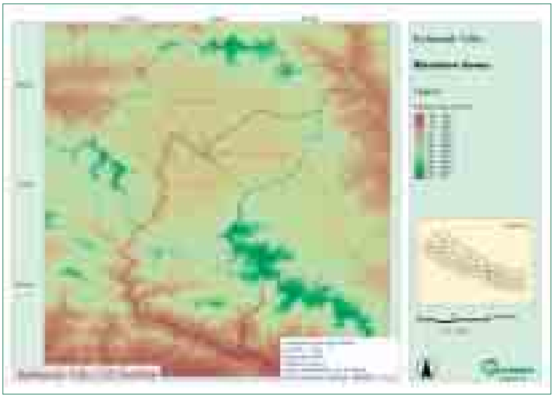


Figure 7.3
Classification of an elevation map of Kathmandu valley into different intervals

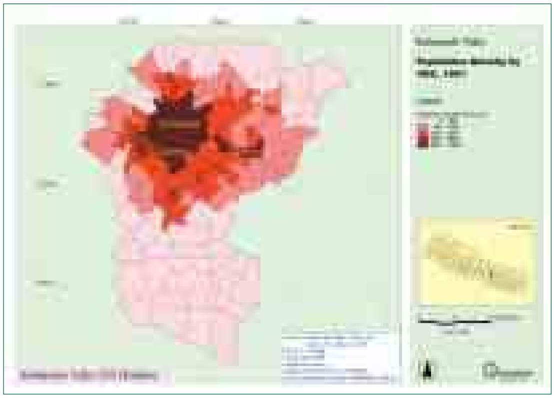


Figure 7.4
Classification of a VDC map of Kathmandu valley based on population density, 1991

operation that combines various geographic layers to generate new information. Overlay is done using arithmetic, Boolean and relational operators, and is performed in both vector and raster domains.

Vector overlay

During vector overlay, map features and their associated attributes are integrated to produce a new composite map. Logical rules can be applied to determine how the maps are combined. Vector overlay can be performed on various types of map feature: polygon-on-polygon, line-on-polygon, point-on-polygon (Figure 7.5). During the process of overlay, the attribute data associated with each feature type are merged. The resulting table will contain all the attribute data.

Figure 7.5
Vector overlay

Raster overlay

In raster overlay, the pixel or grid cell values in each map are combined using arithmetic and Boolean operators to produce a new value in the composite map. The maps can be treated as arithmetic variables and perform complex algebraic functions. The method is often described as map algebra (Figure 7.6). The raster GIS provides the ability to perform map layers mathematically. The map algebraic function uses mathematical expressions to create new raster layers by comparing them.

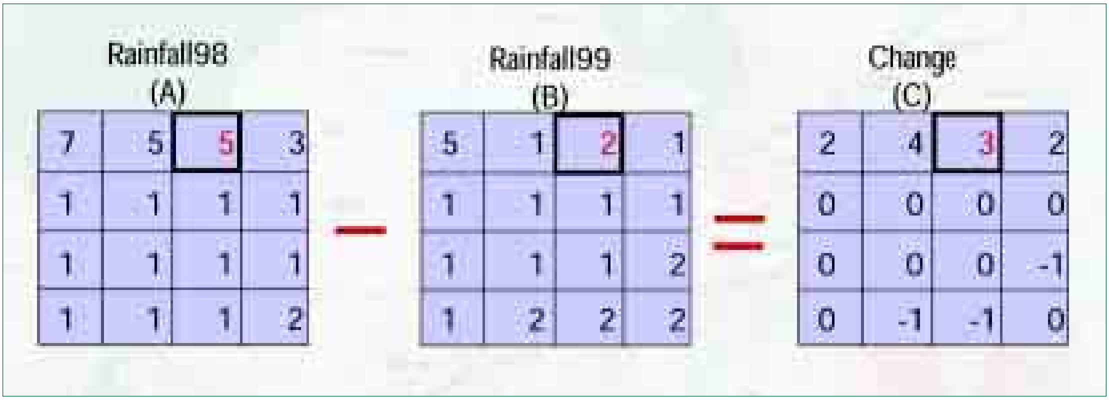


Figure 7.6
Map algebra

There are three groups of mathematical operators in the map calculator: arithmetic, Boolean, and relational.

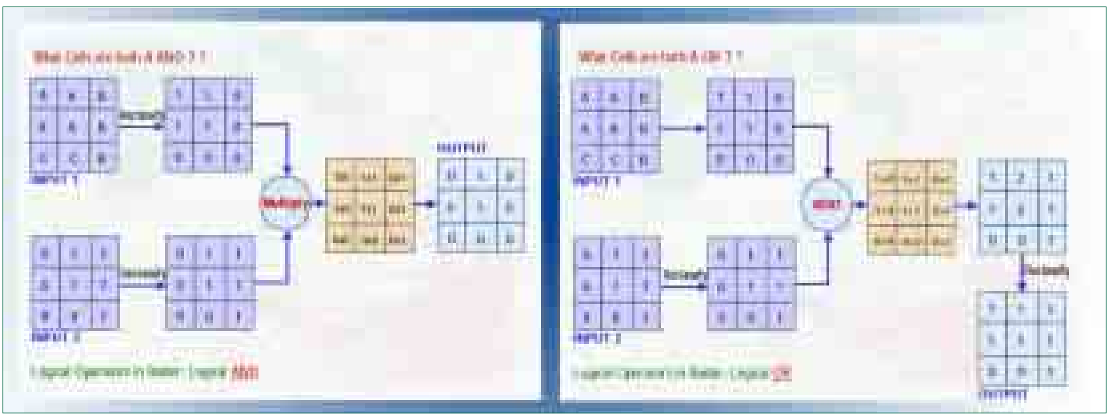
- **Arithmetic operators** (+, -, *, /) allow for the addition, subtraction, multiplication and division of two raster maps or numbers or a combination of the two.
- **Boolean operators** (and, not, or, xor) use Boolean logic (true or false) on the input values. Output values of true are written as 1 and false as 0.
- **Relational operators** (<=, <>, =, >, >=) evaluate specific relational conditions. If the condition is true, the output is assigned 1; if the condition is false, the output is assigned 0.

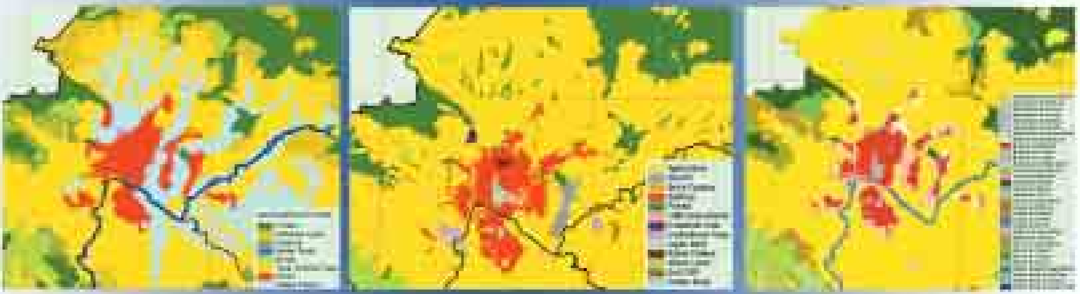
Figure 7.7 shows examples of simple raster overlay using different logical operators.

The following GIS application illustrates land-use and land-cover changes over time in the Kathmandu Valley (Figure 7.8). The analysis is done by overlaying land-use/land-cover data from different dates. The figure shows the land-use/land-cover data for 1978 and 1995, and the changes between 1978 and 1995 derived from these data.

This is the analysis of connectivity between points, lines and polygons in terms of distance, area, travel time, optimum paths, etc. Connectivity analysis consists of the following analyses.

Figure 7.7
Raster overlay using 'and' and 'or' logical operators





Land use/cover of Kathmandu Valley, 1978

Land use/cover of Kathmandu Valley, 1995

Land use/cover of Kathmandu Valley, 1978-1995

Figure 7.8
Land-cover change in the Kathmandu valley between 1978 and 1995

Proximity analysis

Proximity analysis is the measurement of distances from points, lines and boundaries of polygons. One of the most popular types of proximity analysis is 'buffering' by which a buffer zone with a given distance is generated around a point, line or area as shown in Figure 7.9. Buffering is easier to generate for raster data than for vector data.

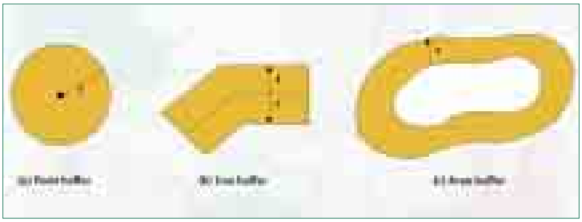
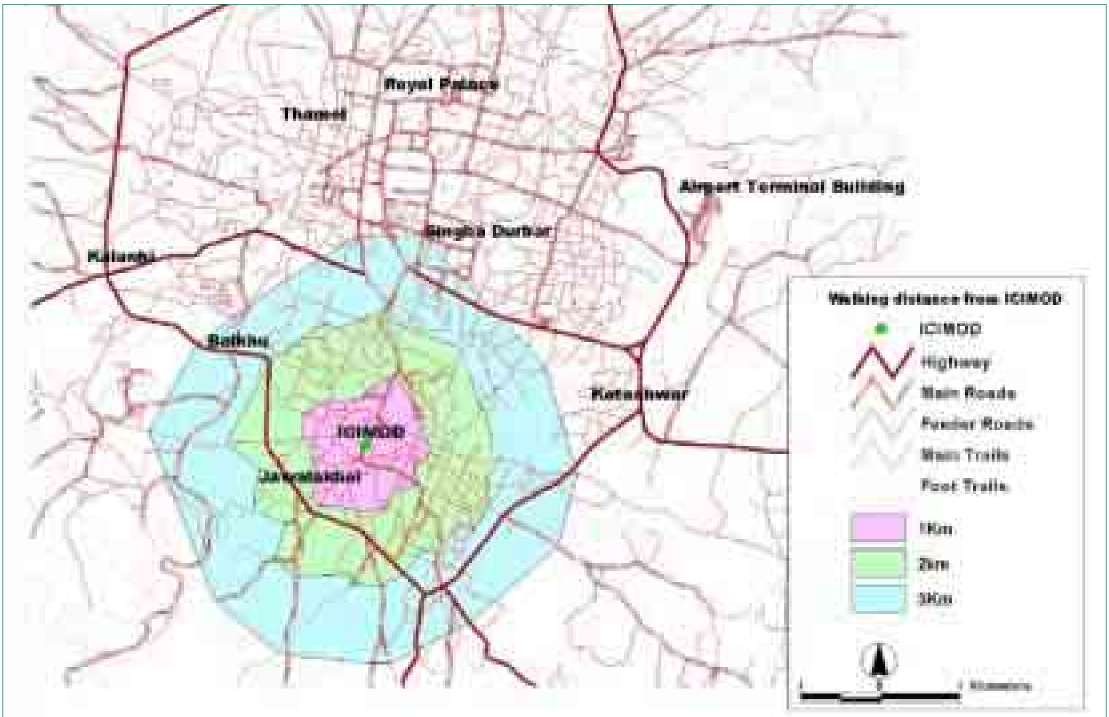


Figure 7.9
Buffer operations

Figure 7.10 shows walking distance from the ICIMOD building.

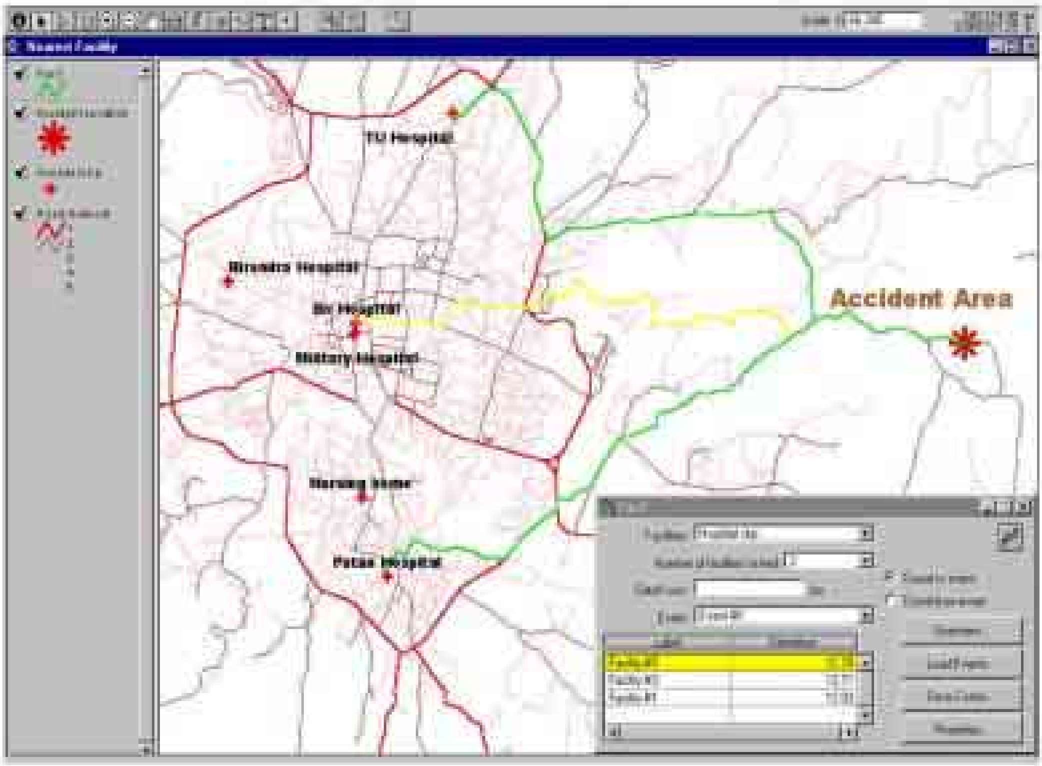
Figure 7.10
Walking distances from ICIMOD



Network analysis

Network analysis is commonly used for analysing the movement of resources from one location to another through a set of interconnected features. It includes determination of optimum paths using specified decision rules. The decision rules are likely to be based on minimum time or distance, and so on. Figure 7.11 demonstrates an example of optimum paths based on minimum distance. The figure shows the locations of a number of hospitals within the ring road of Kathmandu. If there has been an accident outside the ring road (e.g. at Bhaktapur) it may be important to know which is the closest hospital and what is the shortest route to that hospital for an ambulance. Network analysis identifies the closest hospital as Bir Hospital and indicates how to go there.

Figure 7.11
Network analysis



"A picture is worth a thousand words."
Chinese proverb

Chapter 8 Presenting Your Results

How do I say what to whom?

Visualisation

Visualisation is defined as the translation or conversion of spatial data from a database into graphics. These graphics are in the form of maps that enable the user to perceive the structure of the phenomenon or the area represented. The visualisation process is guided by the saying 'How do I say what to whom, and is it effective?' 'How' refers to the cartographic methods that are used for making the graphics or map. ' I' refers to the cartographer or GIS user who is preparing the map. ' Say' refers to the semantics that represent the spatial data. 'What' refers to the spatial data and its characteristics, and the purpose of the map. 'Whom' refers to the map's audience. The usefulness of a map depends upon the following factors.

Who is going to use it?

The map's audience or users will influence how a map should look. A map made for school children will be different from one made for scientists. Similarly, tourist maps and topographic maps of the same area are different in content and look as if they are made for different users.

What is its purpose?

The purpose of a map determines what features are included and how they are represented. Different purposes such as orientation and navigation, physical planning, management and education lead to different categories of map.

What is its content?

Its usefulness also depends upon the contents of the map. Contents can be seen as primary content (main theme), secondary content (base-map information) and supporting content (legends, scale, etc).

What is the scale of the map?

The map scale is the ratio between a distance on a map and the corresponding distance in the terrain. Scale controls the amount of detail and extent of area that can be shown. Scale of the output map is based upon considerations such as the purpose of the map, needs of the map user, map content, size of the area mapped, accuracy required etc.

What is the projection of the map?

Every flat map of a curved surface is distorted. The choice of map projection determines how, where and how much the map is distorted. Normally, the selected map projection is that which is also used for topographic maps in a certain country.

Accuracy

GIS has simplified the process of information extraction and communication. Combining or integrating data sets has become possible. However, this has created the possibility of integrating irrelevant or inconsistent data. The user should be aware of aspects of data quality or accuracy such as 'What is the source of data? Are the places at correct locations? Are the attribute values correct? Are the themes correctly labelled? Are the data complete?'

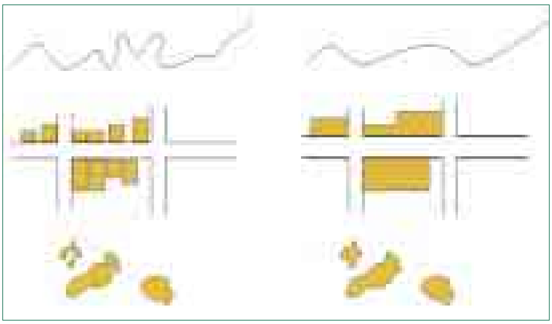
Map design

Map-making is both a science and an art. A beautiful map may be more popular than a plain map even if it is less accurate. Maps influence people's perception of space. This influence is partly as a result of convention and partly as a result of the graphics used. People understand the world differently: they express this understanding differently in maps and also gain different understandings from maps.

Generalisation

Maps contain a certain level of detail depending upon its scale and purpose. Large-scale maps usually contain more detail than small-scale maps. Cartographers often generalise the data by simplifying the information so that the map is easier to read (Figure 8.1). The process of reducing the amount of detail on a map in a meaningful way is called generalisation. Generalisation is normally done when the map scale has to be reduced. However, the essence of the contents of original map should be maintained. This implies maintaining geometric and attribute accuracy as well as the aesthetic quality of the map. There are two types of generalisation—graphic and conceptual. Graphic generalisation involves simplification, enlargement, displacement or merging of geometric symbols. Conceptual generalisation mainly deals with the attributes and requires knowledge of the map contents and the principles of the themes mapped.

Figure 8.1
Generalisation



Graphic variables

Differences in the graphic character of symbols convey different perceptions to the map reader. These graphic characteristics are termed graphic variables and can be summarised as size, lightness or grey value, grain or texture, colour, orientation and shape or form (Figure 8.2). Knowledge of graphic variables and their perceptual characteristics helps map designers to select those variables that provide a sensation that matches the data or the objective of the map.

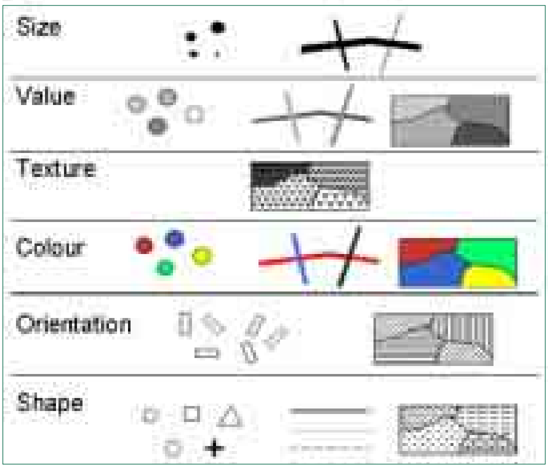


Figure 8.2
Graphic variables

Use of colour

Colour perception has psychological, physiological and conventional aspects. It has been noted that it is difficult to perceive colour in small areas, and greater contrast is perceived between some colours than others. In addition to distinguishing nominal categories, colour differences are also used to show deviations or gradation.

Data analysis, adjustment and classification

Data need to be analysed before they are mapped so that they represent information in correct form. Data are either qualitative—roads, rivers, districts—or quantitative—elevation, temperature, population density, etc. Representation will also depend on the measurement scale of the data such as nominal, ordinal, interval and ratio scales.

For nominal scale, the differences in data are only of a qualitative nature, e.g., differences in gender, language, land use or geology.

For ordinal scale, only the order of the attribute values is known and a hierarchy can be established such as 'more than or less than', 'small, medium, large' or 'cool, tepid, hot'.

For interval scale, both the hierarchy and the exact difference are known but it is not possible to make a ratio between the measurements, e.g. temperature or altitude values. A temperature of 8 °C is not twice as warm as 4 °C; it is only the difference between two temperatures.

For ratio scale, data can be measured on a ratio measurement scale, e.g. the number of children in a family or an income.

Grouping of data can also be done in different ways. Ranges of values may be grouped according to natural breaks, at round numbers, at statistical means or standard deviations. Different grouping or classification schemes give different perception of the phenomena.

Mapping methods

Mapping methods are standardised ways of applying graphic variables based on measurement scale and the nature of the distribution of objects. Various map types are given below.

Figure 8.3(a)
Chorochromatic map

Chorochromatic maps: This method renders nominal values for areas with different colours (in Greek, choros = area, chroma = colour). The term is also used when patterns are used to render nominal area values. Only the nominal qualities are rendered and there is no suggestion of hierarchy or order conveyed (Figure 8.3a).

Choropleth maps: In this method, the values are rendered for areas (in Greek, choros = area, plethos = value). Values are calculated for area and expressed as stepped surface showing a series of discrete values. The differences in grey value or in intensity of a colour denote the differences in the phenomenon. A hierarchy or order between the classes can be perceived (Figure 8.3b).

Isoline maps: Isoline maps are based on the assumption that the phenomenon to be represented has a continuous distribution and smoothly changes in value in all directions of the plane. Isolines connect the points with an equal value, e.g. equal height above sea level or equal amounts of precipitation. Isoline maps show the trends of the phenomenon, i.e. in which direction it is increasing or decreasing (Figure 8.3c).

Nominal point data maps: Nominal data for point locations are represented by symbols that are different in shape, orientation or colour. Geometric or figurative symbols are more common in maps for tourists and schools (Figure 8.3d).

Absolute proportional maps: Discrete absolute values for points or areas are represented by proportional symbols. Different values are represented by symbols differing in size. The primary considerations for these symbols are legibility and comparability (Figure 8.3e).

Diagram maps: Diagrams are used in the maps to allow comparisons between figures or to visualise temporal trends. Line diagrams, bar graphs, histograms or

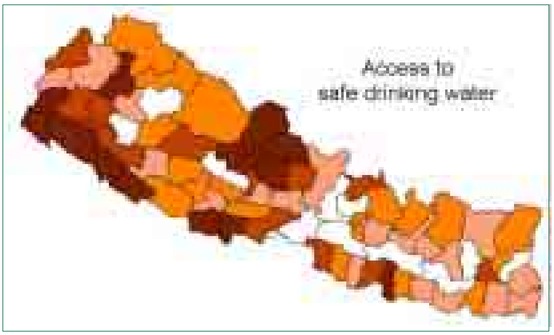


Figure 8.3 (b)
Choropleth map

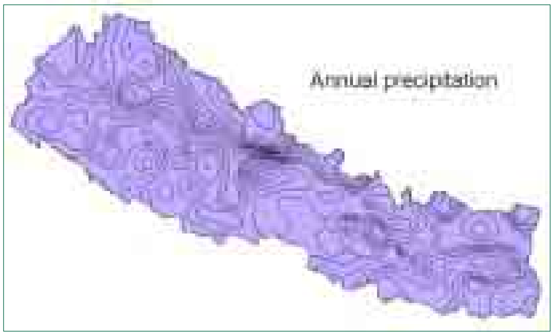


Figure 8.3 (c)
Isoline map

Figure 8.3 (d)
Nominal point data map

Figure 8.3 (e)
Absolute proportional map

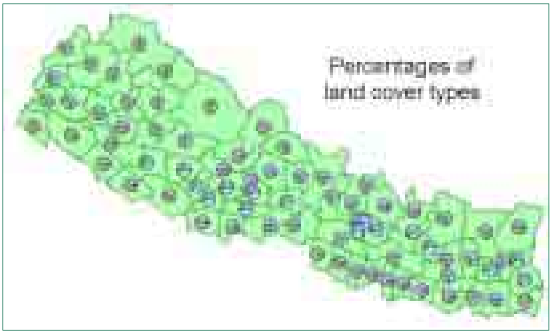


Figure 83(f)
Diagram map

Figure 8.3 (g)
Dot map

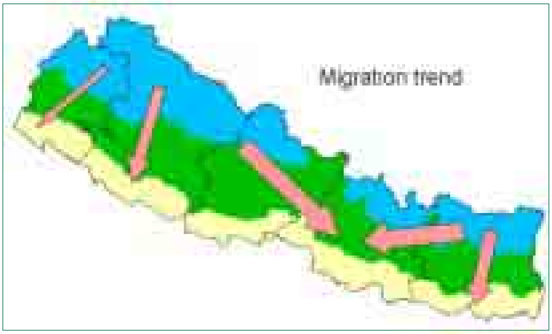


Figure 8.3 (h)
Flowline map

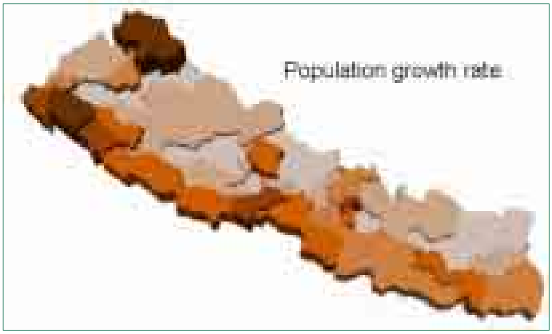


Figure 8.3 (i)
Statistical surface map

pie graphs are normally used on maps. However, care has to be taken that there are not too many distracting features so the image becomes complicated rather than conveying the information clearly (Figure 8.3f).

Dot maps: Dot maps are special case of proportional symbol maps as they represent point data through symbols that each denote the same quantity, and that are located as closely as possible in the locations where the phenomenon occurs (Figure 8.3g).

Flowline maps: Flowline maps simulate movement using arrow symbols. Arrows indicate both route and direction of flows. The volume transported along the route is shown by the relative thickness of the arrow shaft (Figure 8.3h).

Statistical surfaces: Statistical surfaces are the three-dimensional representation of qualitative data such as used in choropleth and isoline maps (Figure 8.3i).

New map output types

With the added potential of computers, new ways of visualisation and using spatial information are being developed. New products such as electronic atlases, cartographic animations and multimedia systems are appearing in the field of spatial information.

Multimedia allows for interactive integration of sound, animation, text and video. In a GIS environment, this new technology offers a link to other kinds of information of geographic nature. These could be text documents describing a parcel, photographs of objects that exist in a GIS database, or a video clip of the landscape of the study area.

Maps on the internet

With new interactive tools and facilities offered by the internet, maps are being used extensively online for various purposes. Apart from their traditional role of representing spatial data, maps can now function as an index of spatial data, a preview of data, and a search engine to locate spatial data. The internet is becoming a major form of map distribution. With the new functions offered by map servers for interactive mapping, the user can define the content and design of maps. This is changing the way visualisation applications are developed, delivered and used.

Figure 8.4
Maps on the internet (Source: www.mapquest.com)

"Few things are harder to put up with than the annoyance of a good example."
Mark Twain

Chapter 9 Implementing GIS

How can I make GIS work for me?

A geographic information system is an information management tool that helps us to store, organise and utilise spatial information in a form that will enable everyday tasks to be completed more efficiently. Since its rapid growth over the last two decades, GIS technology has become a vital element for us to maintain and integrate information. GIS software, and the hardware required to operate it, has become much more affordable and easy to use. This has resulted in the ability to develop a GIS without making large investments in software, hardware and the support staff that were once needed to implement it. With the implementation of GIS, we see dramatic improvements in the way we access information, execute responsibilities and respond to requests from citizens, potential developers and other clients.

Figure 9.1
A working GIS

A working GIS

A working GIS integrates five key components: hardware, software, data, people, and policy and procedures (Figure 9.1).

Hardware and software

Hardware is the computer on which a GIS operates. Today, GIS software runs on a wide range of hardware types from centralised computer servers to desktop computers used in standalone or networked configurations.

GIS software provides the functions and tools needed to store, analyse and display geographic information. Key software components are as follow.

- Tools for the input and manipulation of geographic information
- A database management system (DBMS)
- Tools that support geographic query, analysis and visualisation
- A graphical user interface (GUI) for easy access to tools

The affordability of desktop computers with increasing computing power and decreasing cost of software has resulted in widespread use of desktop GIS.

Data

Data are one of the most important and costly components in implementing GIS. The database is the longest existing part of any GIS implementation. Building the database takes the most time, costs the most money and requires the most effort in terms of planning and management. Implementing a GIS requires adequate emphasis on database planning and choosing the right information base for the particular applications of an organisation.

Figure 9.2
Data and GIS applications

Most GIS applications in a particular area require a common set of spatial data (Figure 9.2). However, these data are often possessed by different organisations. A lack of adequate data-sharing mechanisms means that different organisations are involved in collecting the same data; thus, wasting resources and time. This duplication of effort is also a result of insufficient or inappropriate standards in data collection. The major obstacle in the re-use of data is the lack of awareness or willingness among organisations to share data. GIS as a technology will only be viable and cost-effective if data are readily available at an affordable cost.

People

GIS technology is of limited value without people to manage the system and develop plans for applying to real-world problems. GIS users range from technical specialists, who design and maintain the system, to those who use it to help them perform their everyday work. GIS is a truly interdisciplinary field; it requires varied backgrounds of expertise depending upon the applications. It requires input from computer and information technology experts for the system support and from domain specialists for application-specific models and analyses.

Policies and procedures

A successful GIS operates according to a well-designed plan and business rules that are the models and operating practices unique to each organisation. GIS exist in the context of application within an organisation. For example, in the case of municipal applications, the GIS will have different functional requirements from a GIS required for agriculture or land-use planning.

Besides the technical components such as hardware, software and databases, the institutional framework and policies are also important for a functional GIS. The interest and willingness of decision-makers to exploit GIS technology, and the organisational set-up for collecting spatial data, analysing it and using the results for planning and implementation form an important component in a GIS.

Choosing the right GIS for a particular implementation involves matching the GIS needs to the functionality demanded by the type of application required by an organisation.

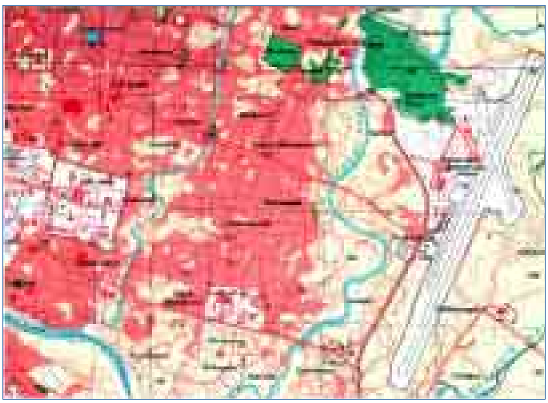
Part 2 Hands-on Exercises

Chapter 1 Understanding Digital Maps

When you want to use a paper map, first you need to unfold it. You need a large space, probably an entire table, to do this. On the map you will find a careful representation of cities, roads, rivers, mountains, administrative boundaries, etc. The cities are represented by little dots or circles, the roads by black lines, the mountain peaks by tiny triangles and the lakes by small blue areas similar in shape to the real lakes.

A digital map is not much more difficult to use than a paper map, and takes much less space. As on the paper map, there are dots or points that represent features such as cities, lines that represent roads, and areas that represent lakes. A digital map takes less space because all the information—where the Dharahara is (point information), how long the road from Lagankhel to Jawalakhel is (line information), and how many square metres the Kamal Pokhari occupies (area information)—is stored in digital format.

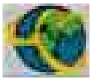
Different digital geographic data in the form of layers, also called themes, can be laid on top of one another. This creates a stack of information about the same geographic area. Each layer can be turned on and off. You can control the amount of information that you want see about an area. If you turn off all the themes, you will have a blank screen. If you turn on the school theme, roads theme, lakes theme and so on you will have a map on your computer screen that pretty well matches a paper map.



We will use ArcExplorer—software used to create maps—to explore some themes in the Kathmandu area.

Exploration 1-Look at Kathmandu

In this first exploration you see a paper map from the Survey Department of the Government of Nepal that has been scanned into the computer. On this map, you can find the Pashupati forest, Bhandarkhal forest, Singha Durbar, Kamal Pokhari, part of the ring road, Bagmati Nadi (river), and the airport. You will look at the same area on a digital map to see how these things are represented as layers of digital geographic data.

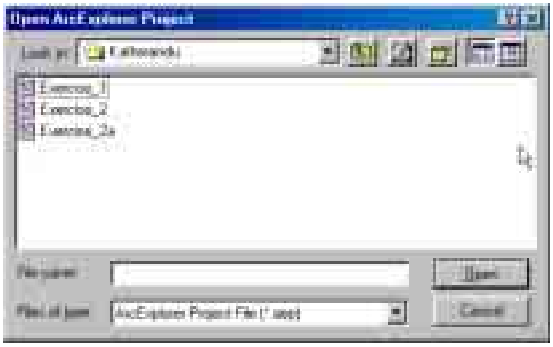


Step 1

Start ArcExplorer either by double clicking the shortcut on your desktop or by selecting Programs, ESRI, ArcExplorer from the Start menu.

Step 2

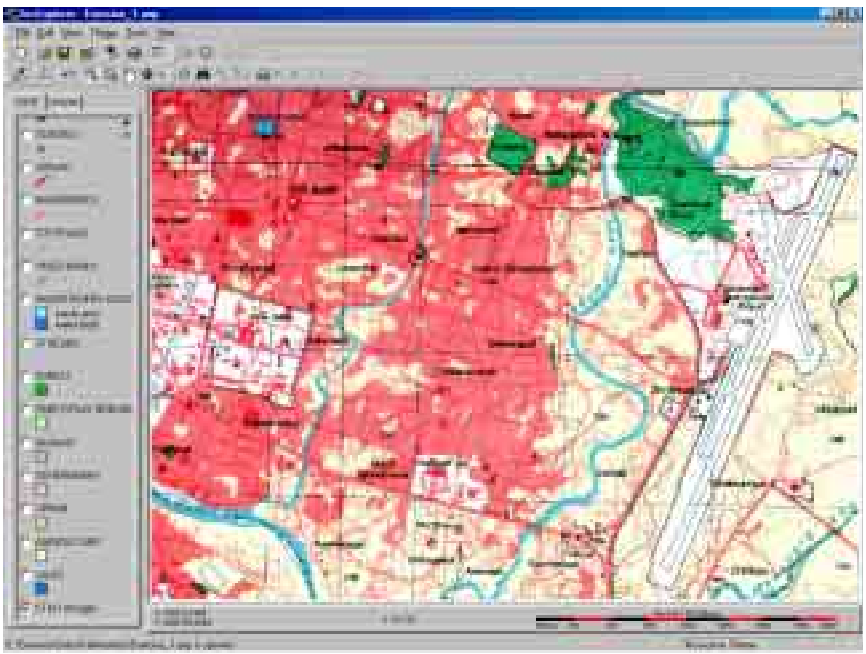
Click the Open Project button. In the dialogue box displayed, navigate to the *GIS Basics\Exercise\Data\Kathmandu* directory.



Step 3

Select the project file called Exercise_1.AEP and click Open. The AEP extension stands for ArcExplorer Project.

In the map view is the scanned paper map of Kathmandu. It shows features such as forest, built-up areas, ring road, city roads, rivers, settlements, airport,

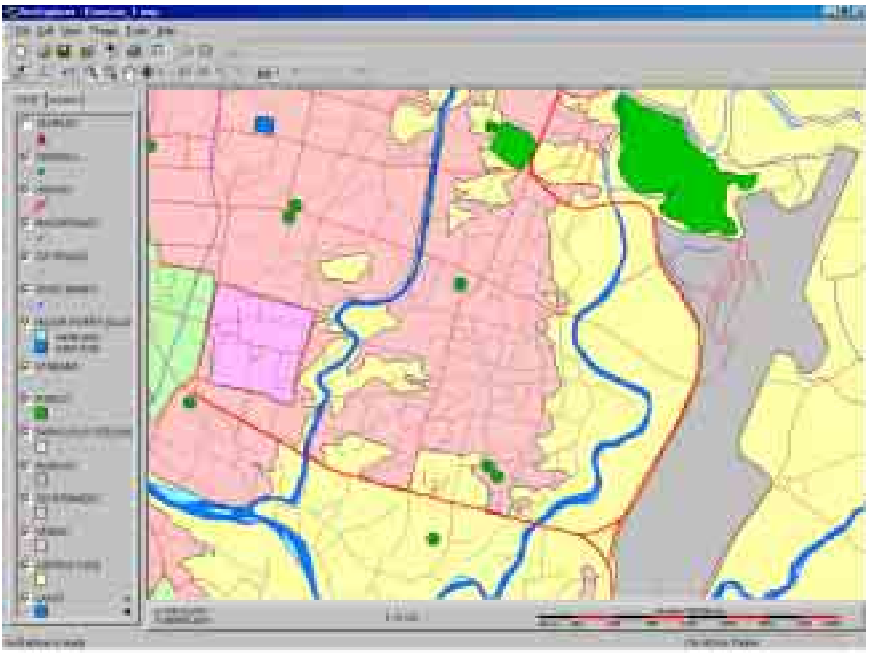


water bodies, etc. Although you can learn a lot from a paper map, the amount of information you can obtain is limited. You cannot exclude features that you do not want to see.

In ArcExplorer, each layer of digital data—the theme—is listed to the left of the map view; this is called the legend. The map view of Kathmandu contains a theme on highways, major roads, city roads, schools, temples, rivers, forests, urban areas, airport and other features.

Step 4

Use the down arrow at the bottom of the legend to scroll down. In the legend, turn off the KTM-1 (scanned image) map by unchecking the box next to the KTM-1 theme. This turns off the view of the scanned paper map. Turn on the HIGHWAY, MAJOR ROADS, CITY ROADS, RIVER BANKS, MAJOR RIVERS, STREAMS, AGRICUL TURE, FOREST, PARK/PLAYGROUND, GOVERNMENT, URBAN, LAKES and RUNWAY themes by checking the appropriate boxes.



This digital map of the Kathmandu looks similar to the scanned paper map. In the digital map, you can look at the different features by turning themes on and off, whereas with the scanned paper maps, what you see is what you get.

Step 5

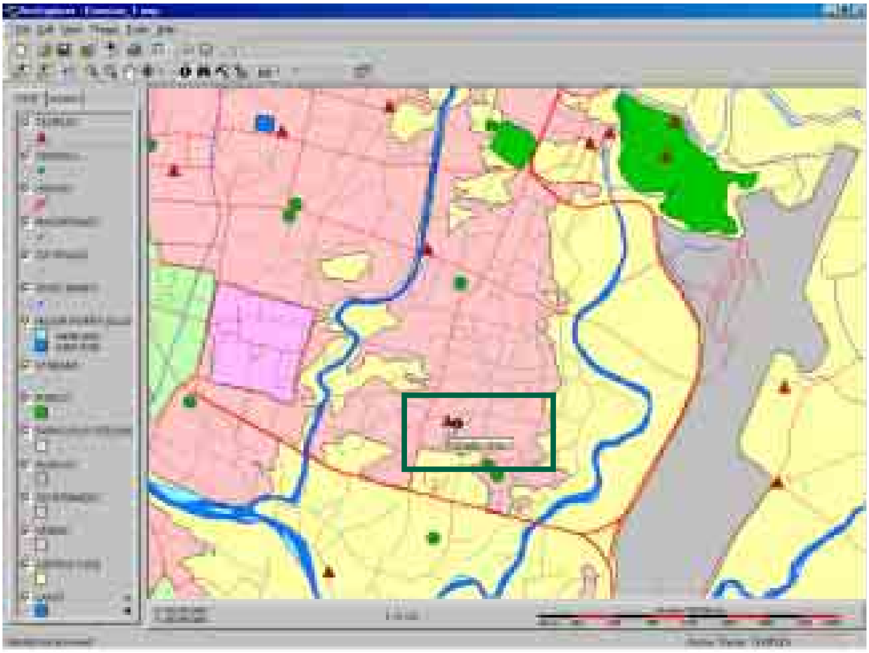
Turn on the TEMPLES and SCHOOLS themes by checking their boxes. Suddenly, several triangles and circles appear, each representing a different theme.

Step 6

Click on the theme TEMPLES in the legend to make the theme active. When the theme is active, it will appear raised above the surface of the legend.

Step 7

Move your mouse pointer over one of the red triangles (temples). Since the theme is active, the name of the temples (or the name of the location where the temple is situated) will appear above the triangle. See if you can find Pashupati Nath and Guhyeshwari temples.



Try to explore some other themes by activating them.

You have identified some features. Now it is time to move around the map. First you will explore Kathmandu with the Direction button.

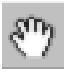
Step 8

Choose a direction using the down arrow at the right of the Direction button. An arrow appears on the button to indicate the direction you selected. Click the Direction button to move in that direction. Try other directions as well.

Direction	Choose panning directional
Pan North	Pans the map view to the north.
Pan South	Pans the map view to the south.
Pan East	Pans the map view to the east.
Pan West	Pans the map view to the west.

Notice that your map view changes in easy, controlled steps.

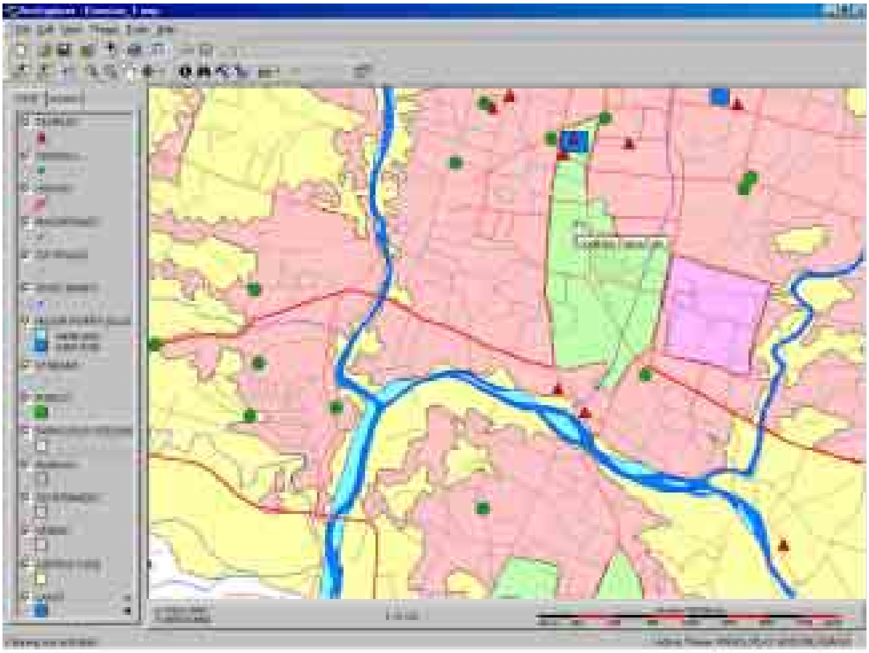
Now, you will try to move around the map with the Pan button. With it, you grab the display and drag it in any direction.



Step 9

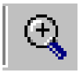
Click the Pan button. Move your mouse pointer into the map view, hold down the mouse button and drag. When you get to where you want to be, release the button.

Go ahead and move in any direction you want.



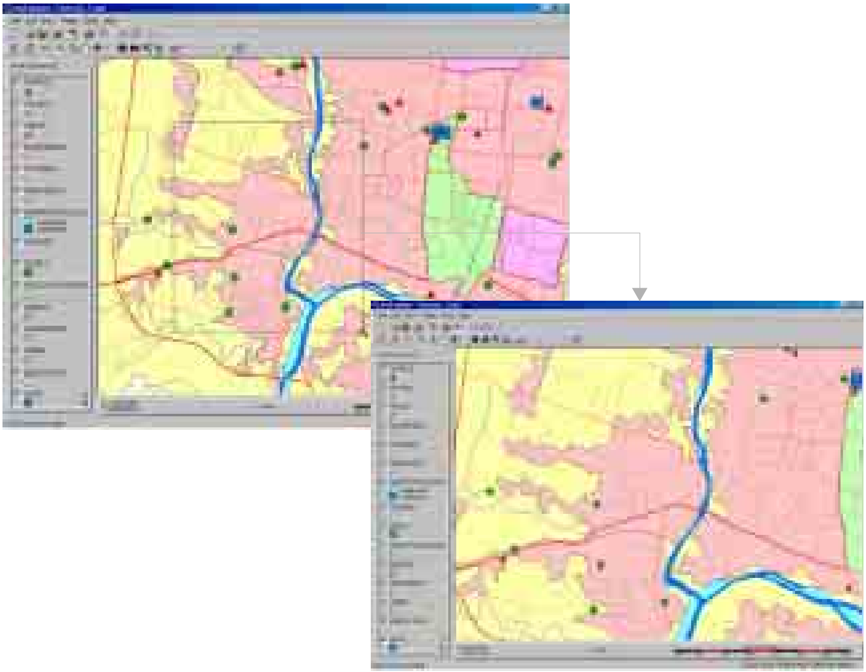
Some themes represent features located all over the map; some represent features located in one area. In either case, you can zoom to the area covered by a particular feature. To see the whole map—the area covered by all the themes—you can click the Zoom to Full Extent button. Or you can zoom to the active theme with the Zoom to Active Theme button. Also, you can zoom in and out. Don't worry if you become lost; the Zoom to Full Extent button will bring you back to a view of the entire map.

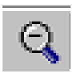
Zoom to Full Extent	Zooms to the extent of all themes.
Zoom to Active Theme	Zooms to the extent of the active theme. (Local mode only.)
Zoom to Previous Extent	Zooms to the last previous extent. (Local mode only.)
Zoom In	Zooms in on the position you click or the box you drag on the map view.
Zoom Out	Zooms out from the position you click or the box you drag on the map view.



Step 10

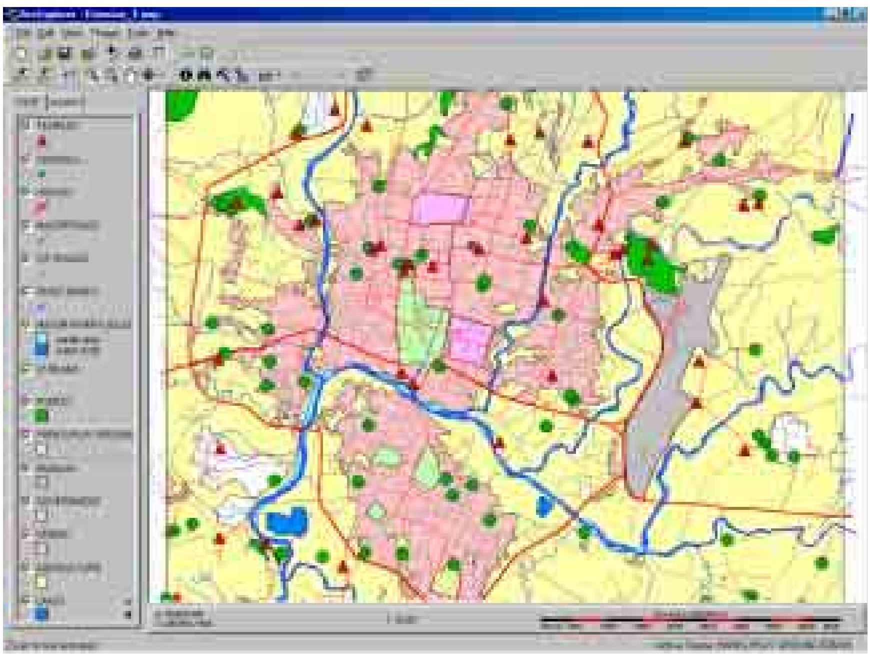
Click the Zoom In button. Click once somewhere in the map view to zoom in on that area. Click again to zoom in even more. You can also drag a box over an area to zoom in on it, as shown below.





Step 11

Click the Zoom Out button. Click once somewhere in the map view to zoom out from that location. Click the Zoom Out button once more.



Step 12

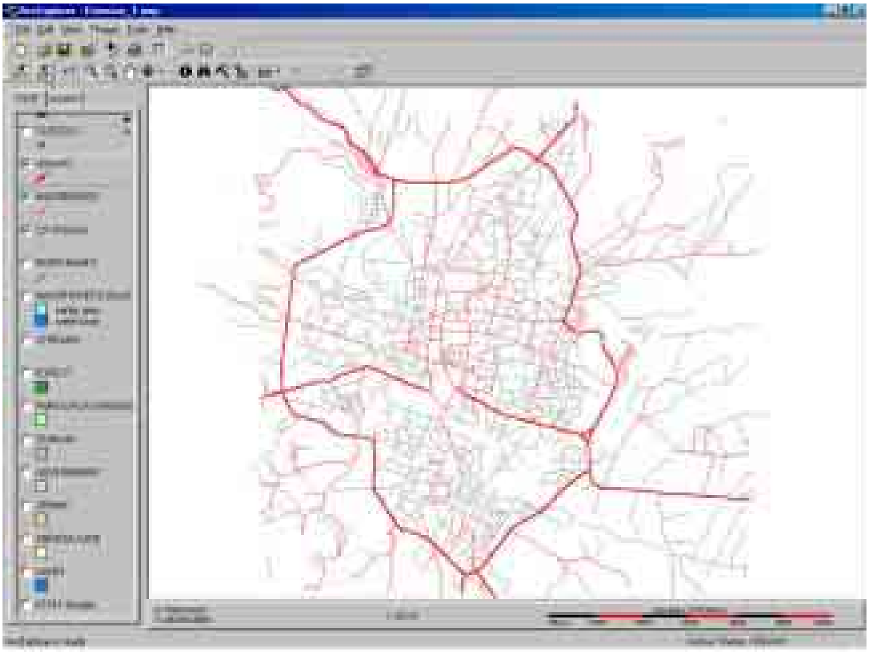
Turn off all the themes except HIGHWAY.

Step 13

Zoom to the extent of the HIGHWAY theme. (Activate the theme HIGHWAY and click Zoom to Active Theme button.)

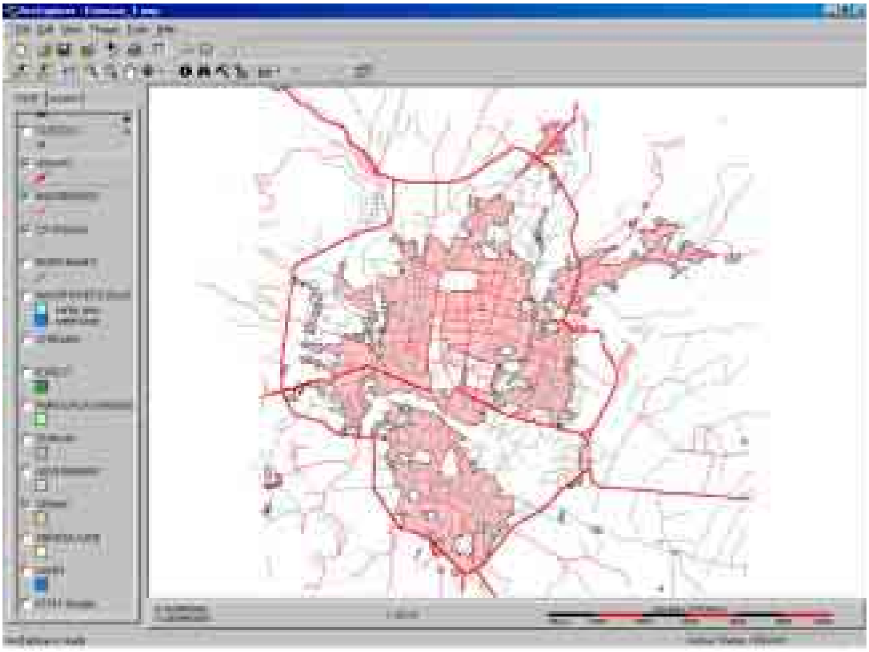
Step 14

Turn on the themes CITY ROADS and MAJOR ROADS. With this, you have just changed the subject of your map to road map showing different types of road within the Kathmandu area.



Step 15

Turn on the theme URBAN. You can see that most of the people live within the ring road. The land and housing prices reflect this although this is not a theme here.



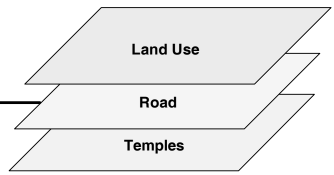
Step 16

Click the Close Project button. Choose No when asked if you want to save any changes.

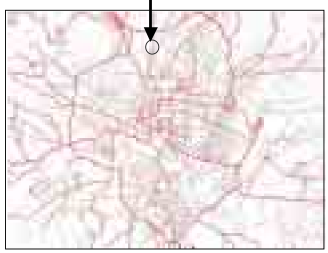
Chapter 2 Finding Answers with Digital Maps

Imagine that you are new to Kathmandu city and you have just arrived at the Tribhuvan International Airport to spend a few days of vacation in Nepal. You did not know where to stay but, with the help of a taxi driver, you have managed to find the Hotel Himalaya in Kopundole. After settling in, some questions have come to mind. Where are the Pashupati Nath and Swayambhu Nath temples that you have read about in a book on holy places? How far are these temples from the Hotel Himalaya? While roaming around Kathmandu city, you saw a tall tower: what is it?

Pulling out a paper map of the new town might give an answer to your questions, but might need a lot of space to unfold your map. With a GIS map of the new town on your computer screen, you can also answer your queries. Answering questions is one of the things a GIS does best.



Road_ID	Type	Surface Materials
1	Highway	Concrete
2	Major Road	Asphalt
3	City Road	Asphalt/Gravel



Exploration 2–What is that?

In exercise 1, you swept your mouse pointer over various features and saw their names pop up on your screen. The tool that does this is called the Map Tips tool. You can set the Map Tips tool to read any of the attributes of a feature.

Step 1

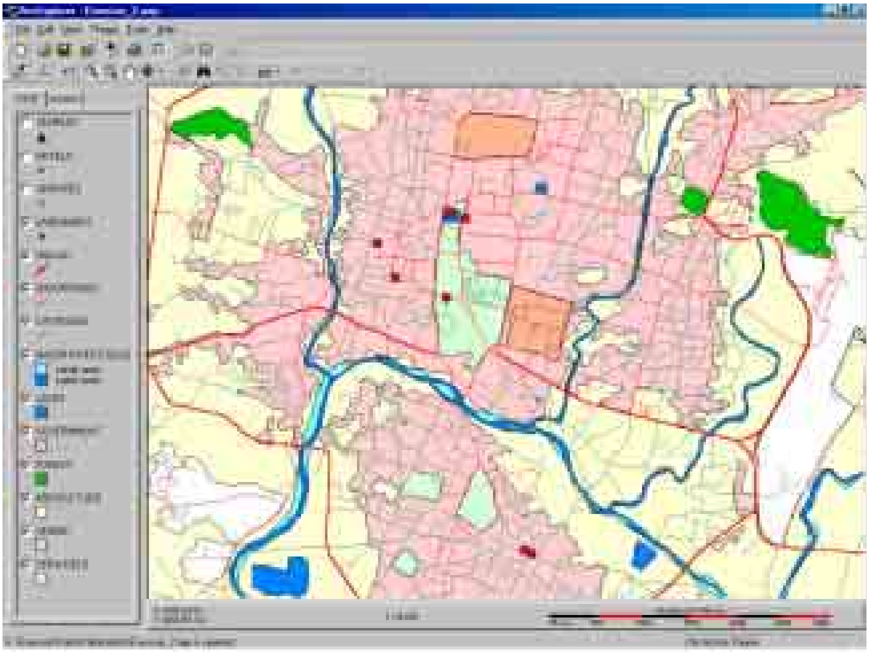
Start ArcExplorer, if necessary.

Step 2

Click the Open Project button. Navigate to the *GIS Basics\Exercise\Data\Kathmandu* directory.

Step 3

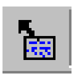
Select the project file called Exercise_2.AEP and click Open. When you open the project, you see a map view of downtown Kathmandu and Lalitpur city with the themes roads, land use, water body, landmarks, services and hotels.



Step 4

Make the LANDMARKS theme active.

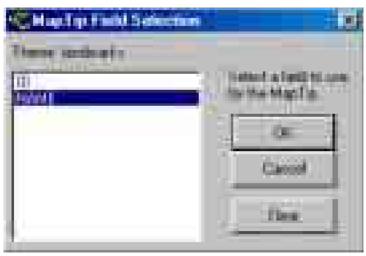
Step 5



Click the Map Tips tool. The Map Tip Field Selection dialogue box appears. This allows you to choose which attribute you want to pop up when you pass the mouse pointer over a particular element.

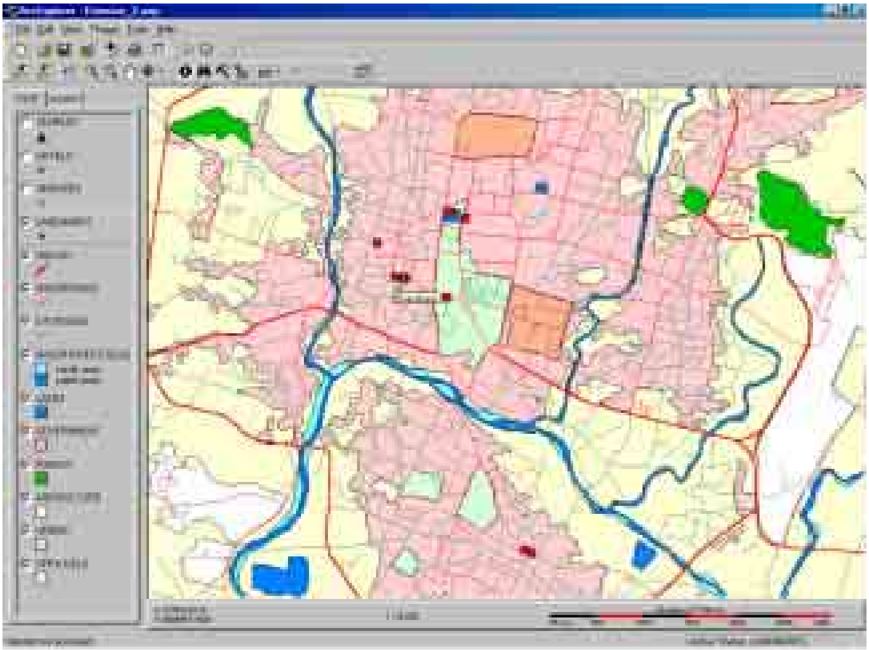
Step 6

Choose the NAME field and then click OK. The name of a particular landmark will appear when you pass your mouse pointer over it.



Step 7

Drag the mouse pointer over all the landmarks and read their names.

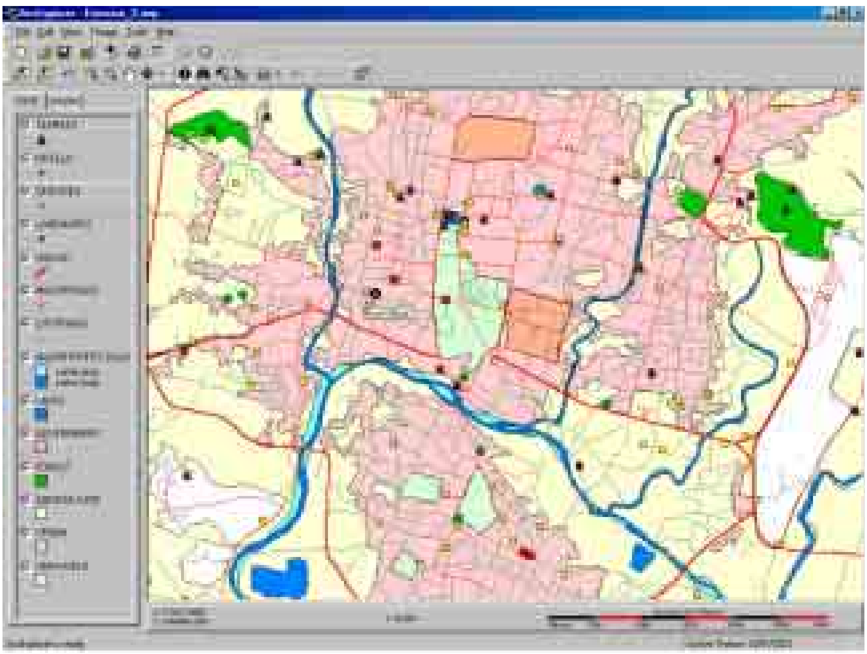


Step 8

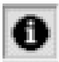
Turn on the SERVICES, TEMPLES and HOTELS themes.

Step 9

Make the SERVICES theme active. Use the Map Tip tool to identify different types of services.



Step 10



You can also use the Identify button to learn about the features. Make the HOTELS theme active. Click the Identify button and move your mouse pointer into the map view and click randomly on some hotels.

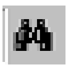
The Identify Results dialogue box will appear and list all attributes of the hotel you clicked.

Close the Identify Results dialogue box by clicking the 'x' in its upper right-hand corner.

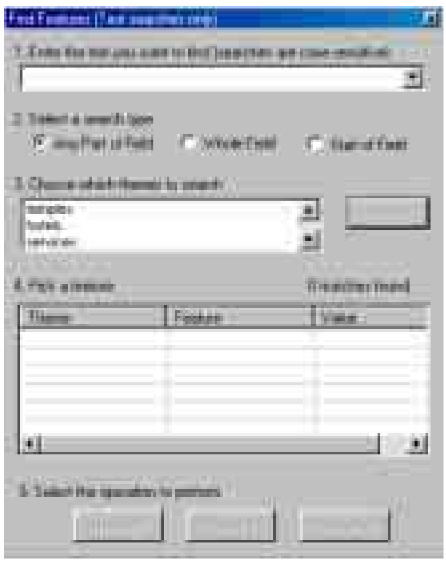
Exploration 3-Where is it?

Map Tips and Identify tools give you information about places you point to on the map. However, sometimes you will already have information about a place, and you want to find it on the map. For instance, as we assumed earlier, you are staying at the Himalaya Hotel and you want to visit to Pashupati Nath and Swayambhu Nath temples. So, you want to see on the map where the Himalaya Hotel, Pashupati Nath and Swayambhu Nath temples are located. To do this you will use the Find tool.

Step 1



Click the Find button. The Find Features dialogue box displays.



Step 2

Type Himalaya into the text box. Note that the Find tool is case sensitive, so make sure you enter the text exactly as shown.

Step 3

Since we did not enter the full name of the hotel, select Any Part of Field in section 2 of the dialogue box.

Step 4

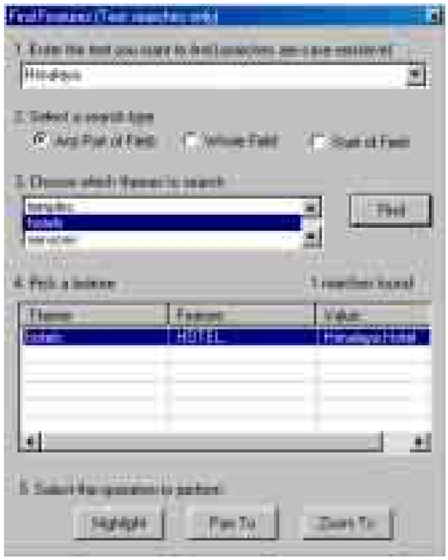
Choose HOTELS as the theme to search in section 3.

Step 5

Click the Find button. ArcExplorer searches the features in the HOTELS theme and gives a list of matches.

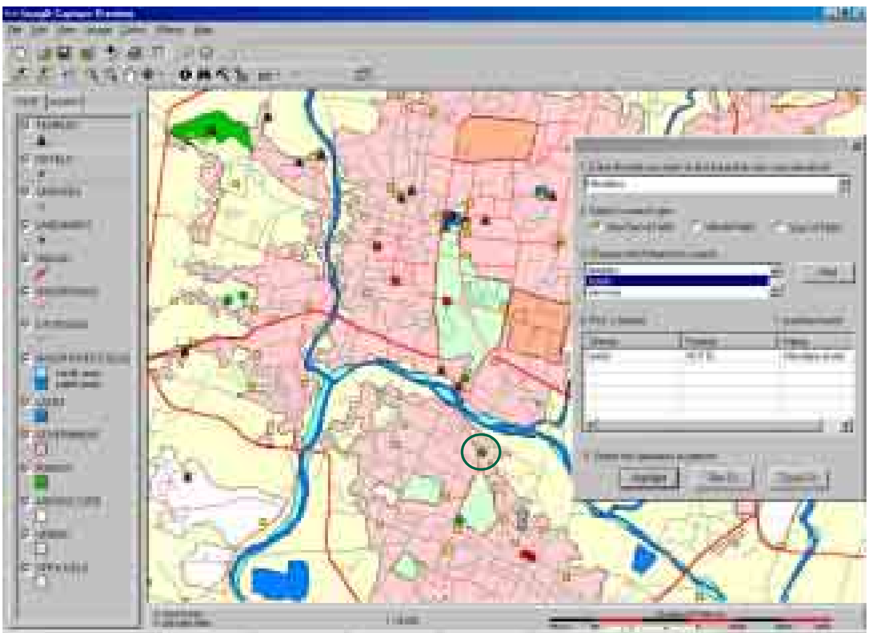
Step 6

Click on the match for Himalaya Hotel to highlight it. You will see that the Highlight, Pan To and Zoom To buttons are darkened now.



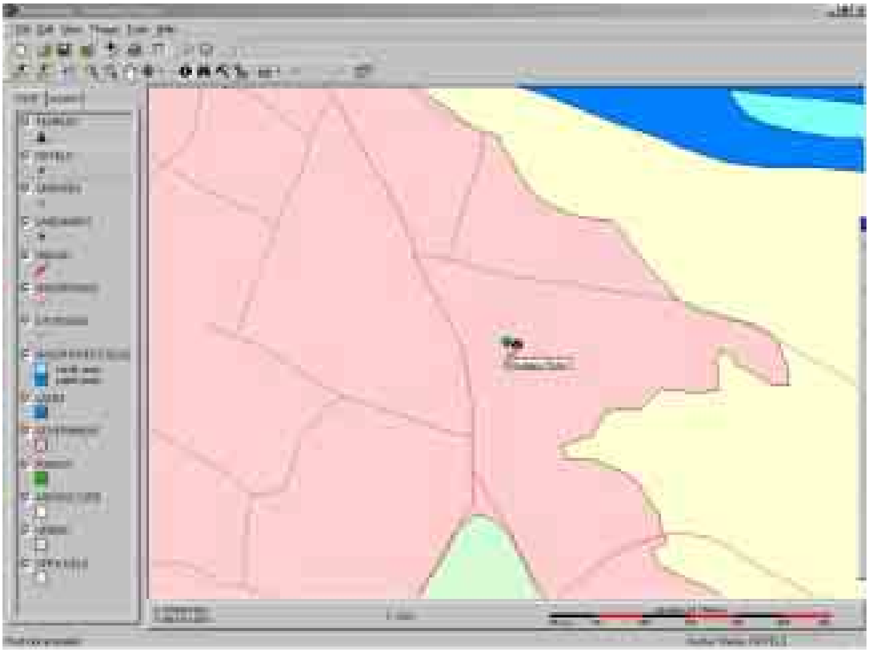
Step 7

Click the Highlight button. The point representing the Himalaya Hotel on the map will flash.

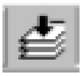


Step 8

Click the Zoom To button in the Find Features dialogue box. You are zoomed in to the Himalaya Hotel. Its location flashes and it is now in the centre of the map view.



Step 9



Click the Zoom to Full Extent button. You will see the entire map—that is the area covered by all the themes in the legend. Like all the tools you have used so far, the Find tool works with any theme. Now, you will locate the Pashupati Nath temple.

Step 10

Use the Find tool and type Pashupati as the text you want to find in the Find dialogue box.

Step 11

Choose Any Part of Field as the search type.

Step 12

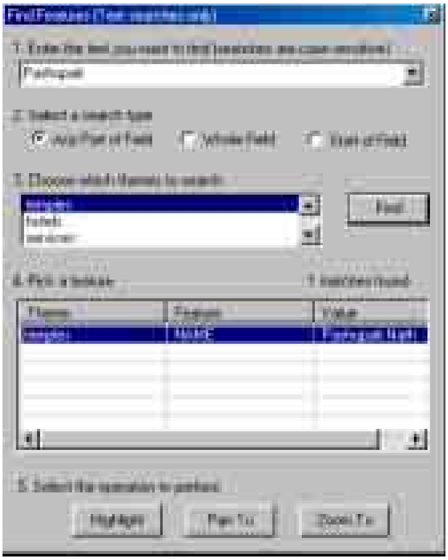
This time choose the theme TEMPLES as the theme to search.

Step 13

Click the Find button.

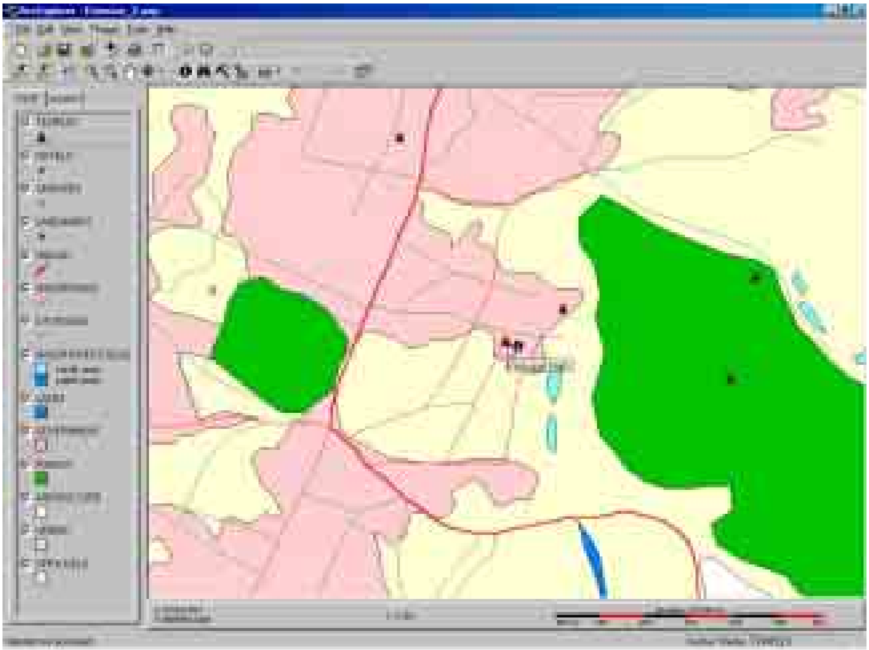
Step 14

Click on the match for Pashupati.



Step 15

Use the Highlight button to flash the location of Pashupati Nath temple. Click the Zoom To button in the Find Features dialogue box to zoom in on the temple.



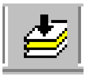
Step 16

Close the Find Features dialogue box.

Self exercise: Find the location of Swayambhu Nath temple.

Exploration 4-How far is it?

Now that you have some idea about the data, you are ready to perform a real geographic analysis such as using the data to measure distances.



Step 1

Close the Find Features dialogue box.

Step 2

Activate the TEMPLES theme and click the Zoom to Active Theme button.

Finding distance is a two-step process. Firstly, you must tell the GIS about the kind of measurement units of your stored map data: decimal degrees, feet, metres. Secondly, you need to tell the GIS which kind of measurement units you want it to use to tell you the distance from one place to another, e.g. feet, metres, kilometres.

Step 3

From the View menu, select Scale Bar Properties, Map Units, Meters as shown below.

Step 4

You want to know how far Pashupati Nath is from the Himalaya Hotel. You have already located places using Find tool, so locate Himalaya Hotel and Pashupati Nath temple again (if you need to).

Step 5

Click on the Measure tool down arrow, then choose Meters from the list. These are your distance units. You can either measure distance between two points in a straight line or you can click several points along a route (at each turn) to obtain a total distance.

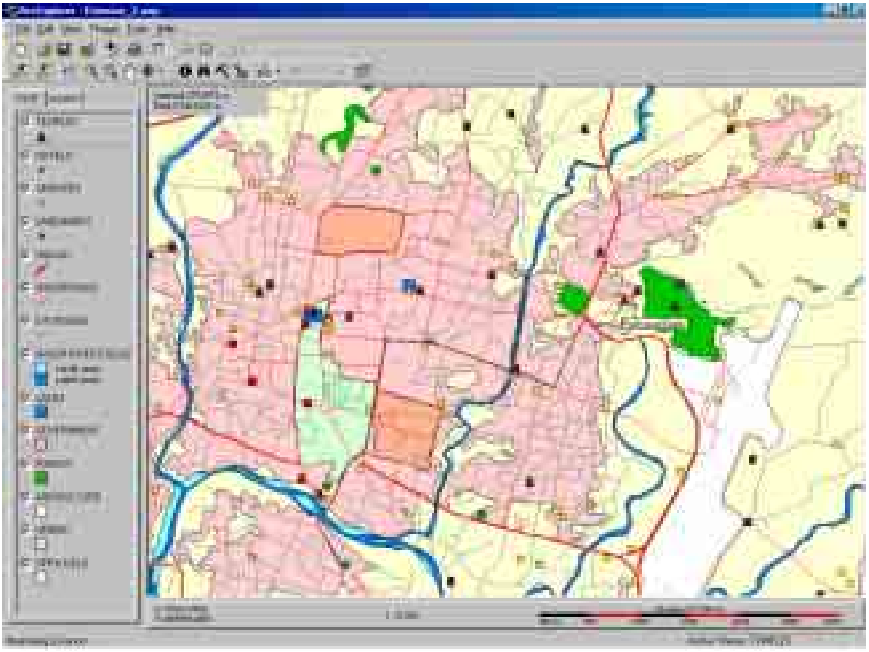
First, you will measure the distance between the Himalaya Hotel and the Pashupati Nath temple.

Step 6

Click on the Measure tool. The pointer changes to a crosshair. Since there is no straight path from the Himalaya Hotel to Pashupati Nath, you will need to measure the path in several segments. Click and hold the mouse as you drag a line segment from the Himalaya Hotel toward Pashupati Nath following the main roads and avoiding water bodies. Release the mouse button at the end of each segment. Follow the path as shown below.

Step 7

The segment and the total length you measured are displayed in the status panel at the top of the map view. The total distance is about 5738 m, i.e., 5.7 km.



If you want to re-measure the distance, double-click anywhere in your map view to begin a new measurement. After you double-click, the total length of your previous measurement appears in the lower left corner on the status bar.

Self-exercise: Find the distance from the Himalaya Hotel to Swayambhu Nath temple.

Step 8

Click the Close Project button. Choose No when asked if you want to save any changes.

Exploration 5–What's it like?

Another way of answering questions about an area is by using the Query Builder. This gives answers to queries that begin 'Where is…?'

Step 1

Start ArcExplorer, if necessary.

Step 2

Click the Open Project button. Navigate to the *GIS Basics\Exercise\Data\Kathmandu* directory.

Step 3

Select the project file called Exercise_2a.AEP and click Open. When you open the project, you see a map view of the VDCs (village development committees) around the Kathmandu and Lalitpur municipalities, with the themes VDC, MAJOR ROADS, HIGHWAYS, CITY ROADS and SCHOOLS.

In the legend, you see the name of a number of VDCs under VDC theme. You see different colours for different VDCs, and the same colour for different VDCs. While looking at the VDC names, you found one VDC name called Lokanthali and you became curious about this VDC. Where is it located? You can use the Query Builder to solve your problem.

Step 4

Make sure the VDC theme is active and click the Query Builder bottom or select Query Builder from the Tools menu.

The Query Builder dialogue box displays. At the top of the dialogue box you see the name of the active theme, VDC. The dialogue box contains a list of field names (at the left) that gives information about population and socioeconomic data for all the VDCs; a set of operators (in the centre) that will do the actual query work; and a list of sample values (at the right).

Step 5

In the Query Builder dialogue box, scroll down through the list of field names. Click on NAME (represents name of VDC). You see the values for this field displayed in the Sample Values list.

Step 6

Click the equal to (=) operator. It displays in the query text box.

Step 7

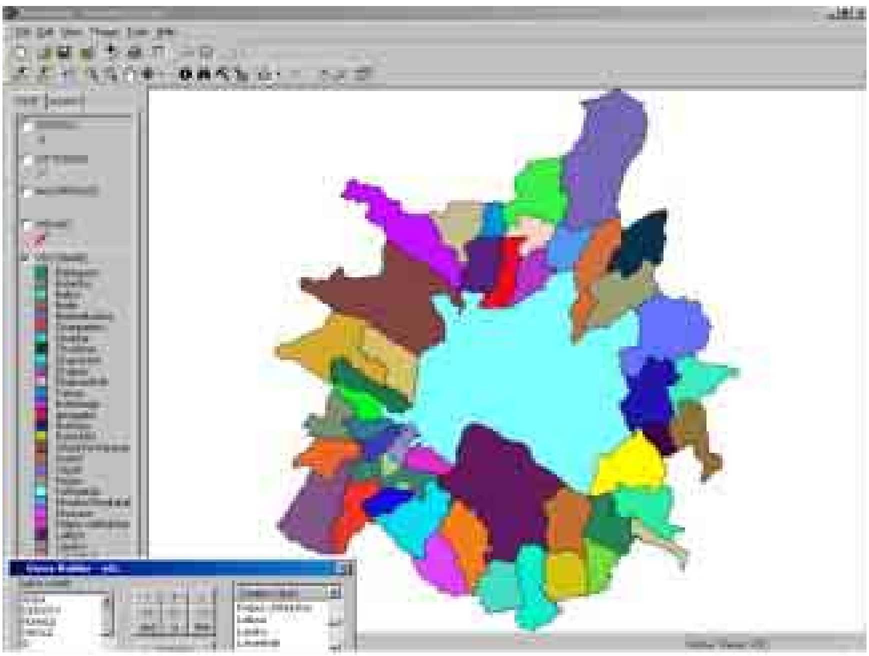
Click Lokanthali from the Sample Values list. Now, in the query text box you should read NAME = 'Lokanthali'.

Step 8

Click the EXECUTE button. ArcExplorer searches the attribute table for all records that match your request.

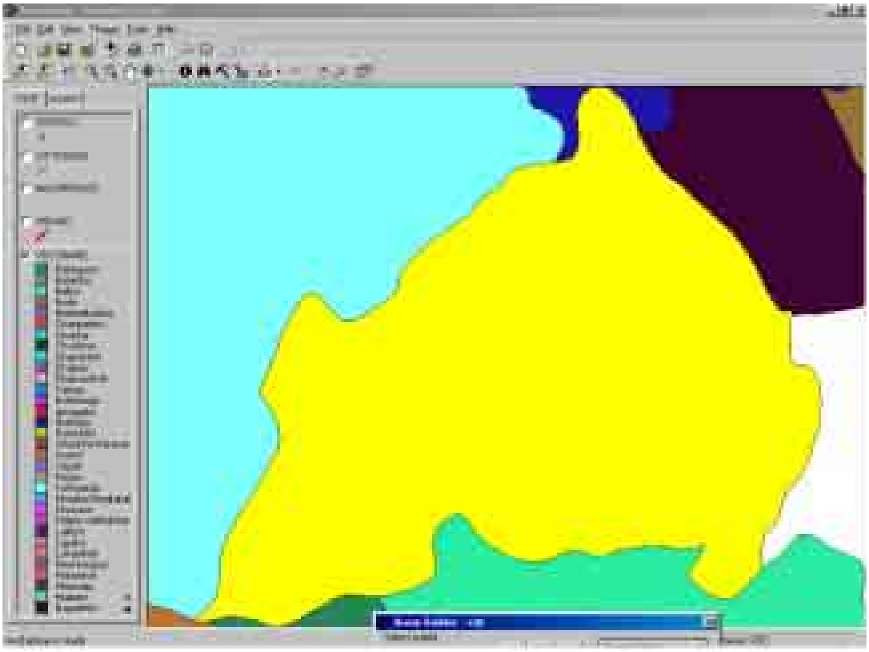
Step 9

Click the Highlight Results button. The Lokanthali VDC is highlighted in your map view in yellow. Move the dialogue window to the side so you can see your map view.



Step 10

Click the Zoom to Results button in the Query Builder dialogue box. You will see the Lokanthali VDC in detail.



Close the Query Builder dialogue box by clicking the ‘x’ in the top right-hand corner of the box.

Step 11

Now click on the themes SCHOOLS and CITY ROADS to obtain a general idea about the status of the roads and number of schools in Lokanthali VDC. There are only four schools and little road accessibility.

Step 12

Click off all the themes except VDC.

Step 13

Make the VDC theme active and click the Zoom to Active Theme button.

Step 14

Use the identify tool and click on any VDC. You will see stored information about that VDC. In this case, you have the information about its area, total population, male population, female population, household numbers and population density represented by the fields AREA, TPOPU, FEMALE, MALE, HHOLD and DENSITY respectively.

You can fulfil many queries using different fields. For the moment, maybe you want to know how many VDCs have a population of less than 5,000.

Step 15

Click the Query Builder button. The Query Builder dialogue box displays.

Step 16

In the Query Builder dialogue box, scroll down through the list of field names. Click on TPOPU (for total population). You can see the values for this field displayed in the Sample Values list.

Step 17

Click the less than (<) operator. It displays in the query text box.

Step 18

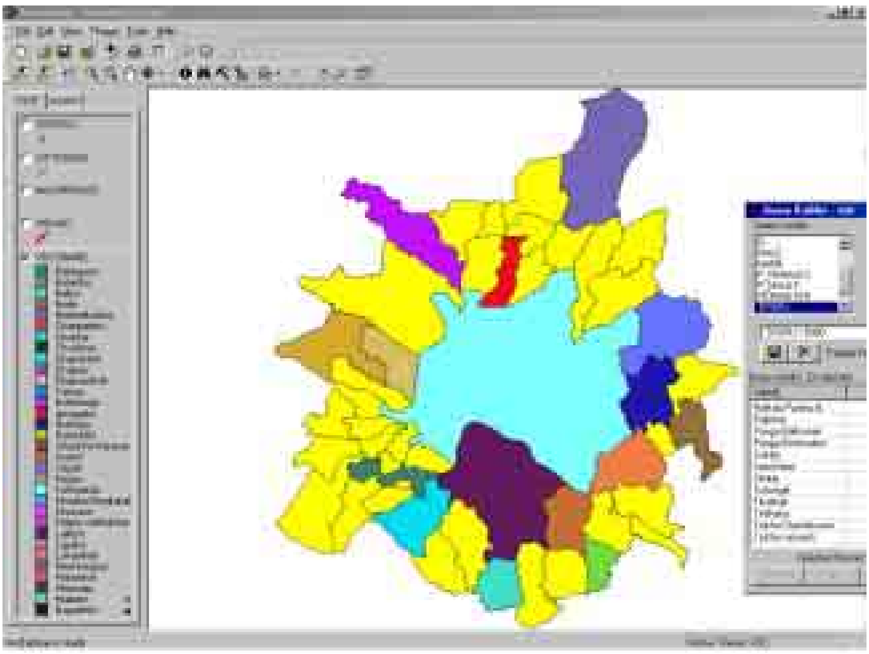
Type 5000 in the query text box. Now, you should read TPOPU < 5000.

Step 19

Select NAME from the Display Field list and click the Execute button. You will see there are 33 VDCs that match your request (i.e. have a population of less than 5,000). The names of the VDCs are also listed.

Step 20

Click the Highlight Results button to see these VDCs. Move the dialogue window to the side so you can see your map view.



Step 21

When you have finished, close the Map Query dialogue box by clicking the 'x' in the upper right-hand corner.

Step 22

Click the Close Project button. Choose No when asked if you want to save any changes.

Chapter 3 Telling Stories with Digital Maps

One of the first things you will learn is that the appearance of a map makes a big difference to its perception. Each dot, line or area on a map represents something in the real world—a city, a road, a district. You can draw them any way you like but there are some traditions in map symbology that you probably already know about without thinking about them: a bold red line is usually a major highway, etc. Even colours are traditional: green denotes vegetation, blue denotes water, etc. These symbols need to be consistent throughout the map. If you keep these principles in mind, your maps will communicate effectively.

Exploration 6–A trip to Kirtipur municipality

Imagine you are participating in a training programme. Your training coordinator announces that there will be an excursion on the coming Sunday around Kirtipur municipality. The object of the excursion will be to visit some important cultural heritage sites within the municipality. There will be a car but, if the roads are not good, you might have to walk to visit each of the sites.

For proper planning for the excursion, you will need to create a map of the Kirtipur municipality that shows the cultural heritage sites, roads, parks and other relevant features. When finished, you will print the map.

Step 1

Start ArcExplorer, if necessary.

Step 2

Click the Open Project button. Navigate to the *GIS Basics\Exercise\Data\Kirtipur* directory.

Step 3

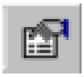
Select the project file called Exercise_3.AEP and click Open. When you open the project, you see a map view of the Kirtipur municipality with the themes HERITAGES, METAL ROAD, GRAVEL ROAD, RIVER, MARKET, BUILTUP, PONDS, PARKS, FOREST and OUTLINE BOUNDARY. The colours assigned to each theme are not really attractive. ArcExplorer assigns colours at random. So, you will pick a colour for each theme that is more attractive and natural.

First, you will change the FOREST theme to green.

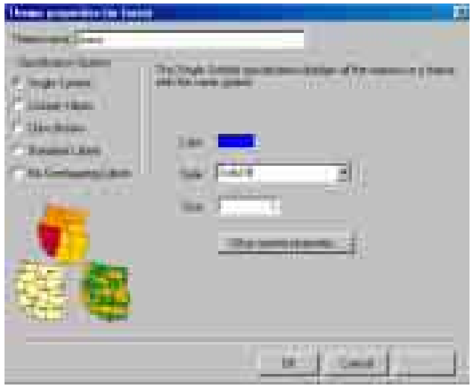
Step 4

Make the FOREST theme active in the legend.

Step 5



Click the Theme Properties button or double-click on the name FOREST in the legend.



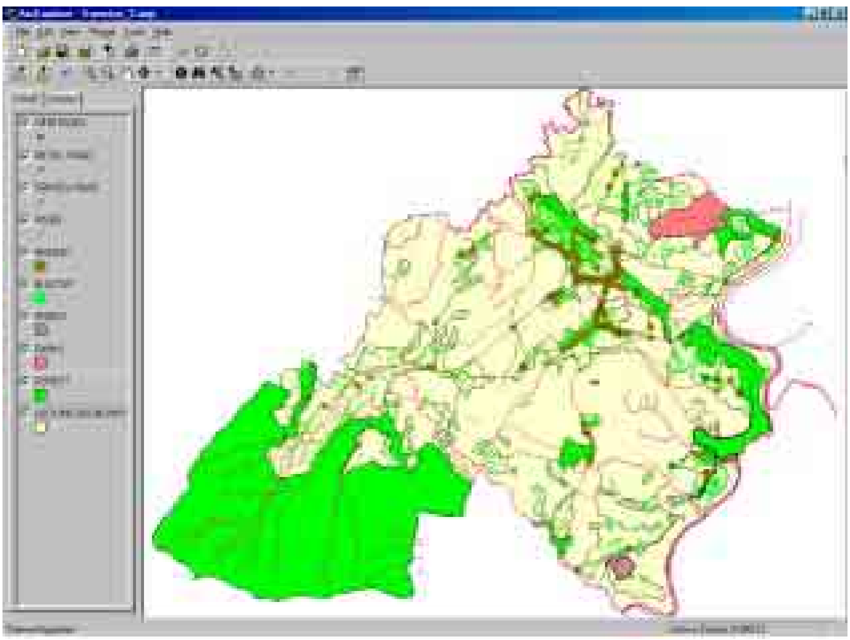
The theme name box in the Theme Properties dialogue box shows which theme you are working with. Classification Options shows you the way in which the features of this theme are displayed. In this case, the classification option is *Single Symbol,* which means that all the features in the theme are currently symbolised as shown in the dialogue box.

Step 6

Click the Color box to display the Color dialogue box. Choose light green and click OK.

Step 7

Click OK in the Theme Properties dialogue box to apply your change.

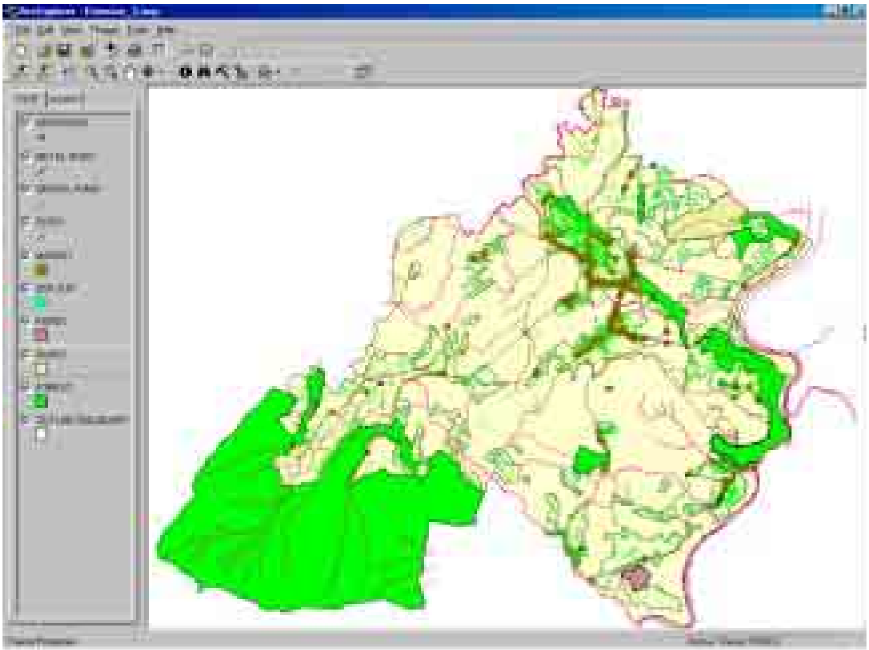


Do the same for the PARKS theme.

Step 8

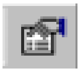
Make the PARKS theme active and use Theme Properties to make parks light yellowish green.

Similarly, change PONDS to blue, BUILTUP to light red and MARKET to light green. You can customise the colours by clicking on *Define Custom Colors* » from the Color dialogue box.

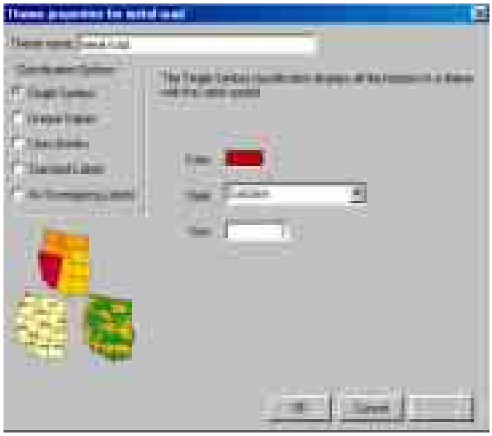


Now you will select an appropriate colour and symbols for roads and rivers.

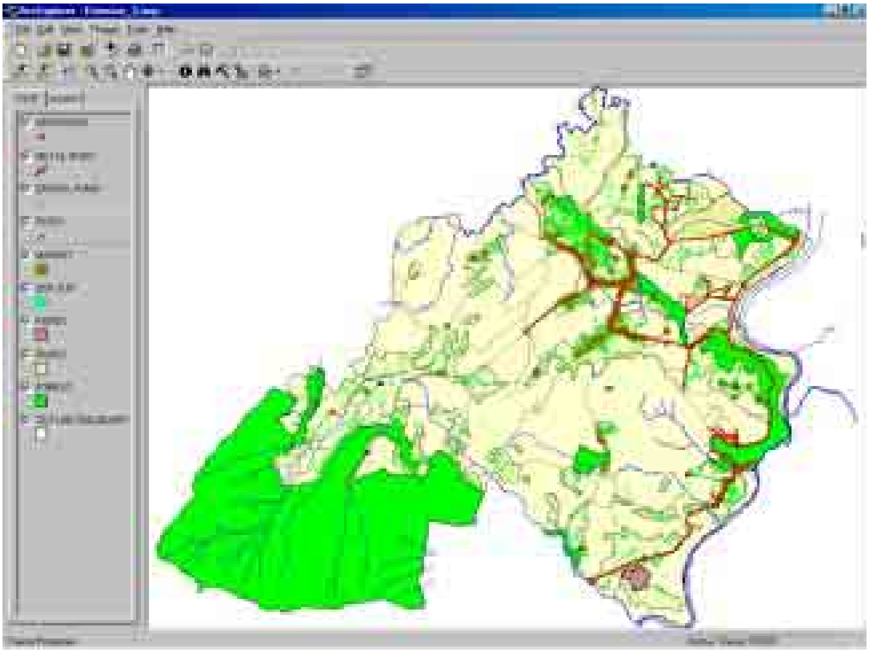
Step 9



Make the METAL ROAD theme active and click the Theme Properties button. Select the colour red and specify the size as 2.



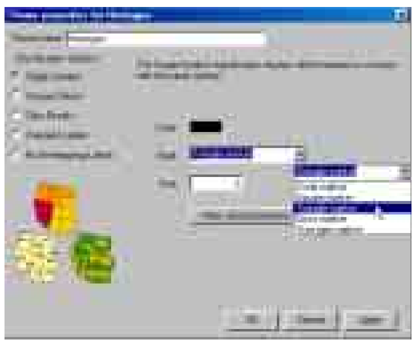
Similarly make the GRAVEL ROAD dark grey and the RIVER blue with size 1.



Now you will change the heritages symbols.

Step 10

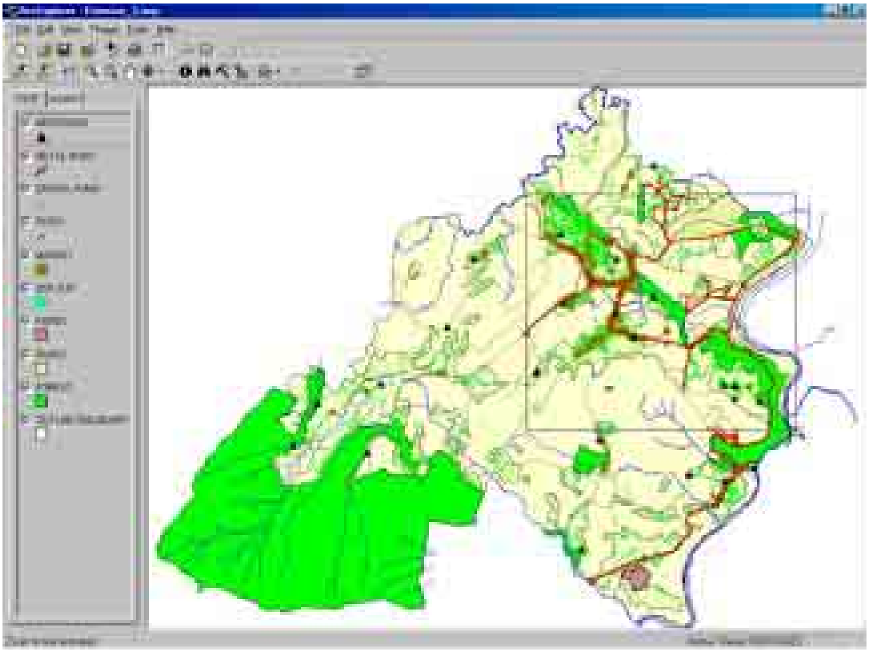
Make the HERITAGES theme active and use the Theme Properties to make heritage sites black. Use the Style pull-down menu to choose Triangle marker. Specify size 6.



Now zoom in on the central part of the municipality where most of the cultural heritage sites are located.

Step 11

Click the Zoom In tool and create a box as shown below.



Now, you will create labels for each of the cultural heritage sites on your map so that the group will know their names.

Step 12

Make sure that the HERITAGES theme is active. Click the Theme Properties button to display the Theme Properties dialogue box.

Step 13

Choose No Overlapping Labels under Classification Options.

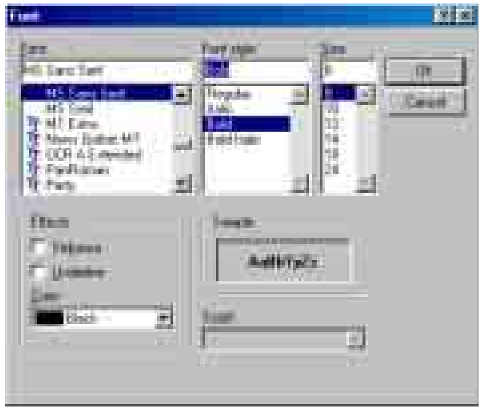
Choose Name as the text field. In the label placement box, choose Place on. Click on the Mask labels option.

Click in the Mask Color box and choose White.

Click Apply to check the labels. They may appear too large on the map. If so, adjust the label size slider and then click Apply to check the size. Repeat this procedure until you are satisfied with the size of your labels.

You can change the style of fonts by clicking the Font pull-down menu in Theme Properties dialogue box.

Click OK in the Theme Properties dialogue box when you are finished.



Now change the background colour of the map.

Step 14

Select the Map Display properties from the View menu. The Map Display Properties dialogue box displays.

Step 15

Under Map Colors, click Background to display the Color dialogue box. Choose blue and then click OK to close the dialogue box.

Step 16

Click OK to close the Map Display Properties dialogue box.

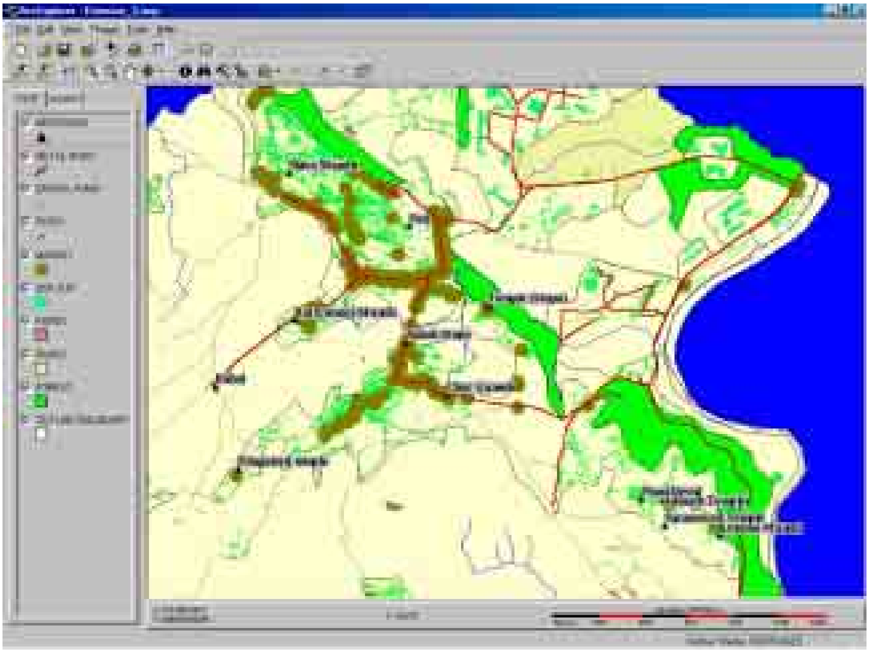
Now add a scale bar so the group can see how large this area is.

Step 17

Choose Display Scale Bar from the View menu. A scale bar appears below the map view.

Step 18

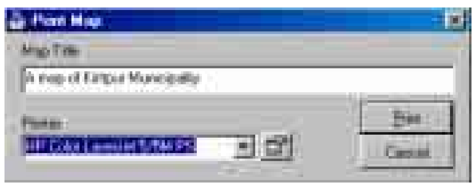
Right click the scale bar and set the map units to Meters. Set scale units to Meters and the screen units to Inches.



Your map is now ready to print.

Step 19

Click the Print tool. The Print Map dialogue box displays. This is where you choose a printer and where you give your map a title.



Step 20

Type 'A map of Kirtipur municipality' in the Print Map dialogue box as the title of your map. Click Print.

Step 21

After you have finished printing your map, close the project without saving.

Exploration 7–Symbolise a map of Nepal based on attributes

Nepal is a mountainous country. Its landscape varies widely from place to place and it is difficult to travel from one place to another. There are many districts that have no access to roads. In the present context, access to roads is one of the major factors in the development of any area. You will create a map of Nepal showing the districts with different types of roads, so that you can distinguish which districts have good accessibility and poor accessibility to roads.

Step 1

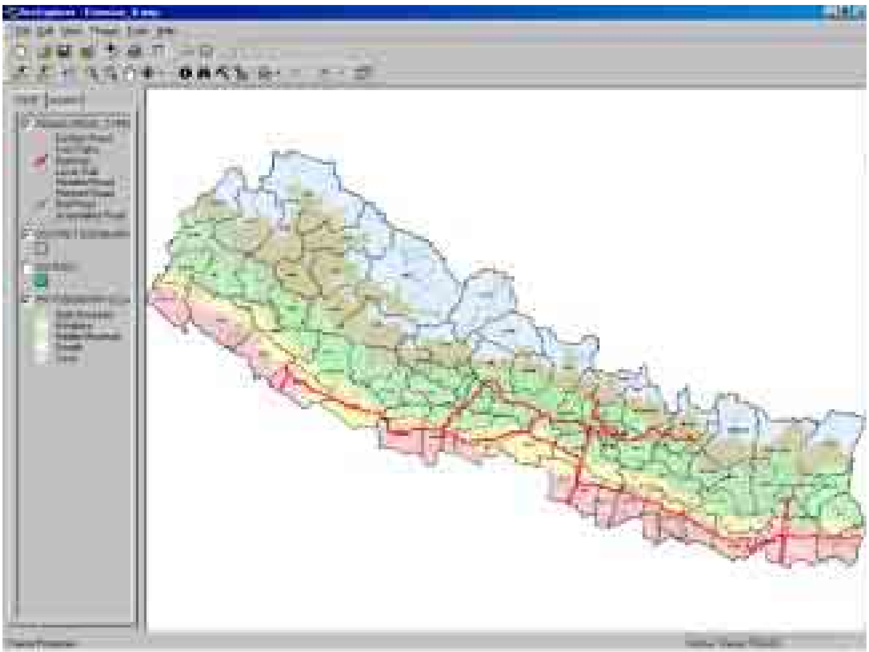
Start Arc Explorer, if necessary.

Step 2

Click the Open Project button. Navigate to the *GIS Basics\Exercise\Data\Nepal* directory.

Step 3

Select the project file called Exercise_4.AEP and click Open. When you open the project, you see the themes PHYSIOGRAPHY, DISTRICT, DISTRICT BOUNDARY and ROADS. You see all types of roads by physiographic region in your map view.



Step 4

Make the ROADS themes active. Use the identify tool to click some of the roads.

Notice that each area you click on has road attributes that specifies the road ID and the type of road.

Step 5

Dismiss the Identify Results dialogue box by clicking 'x' in the upper right-hand corner.

You will assign different symbols to each type of road.

Step 6

Click the Theme Properties button to display the Theme Properties dialogue box.

Step 7

To apply a different colour and symbol to each road, choose Unique Values under the Classification options heading.

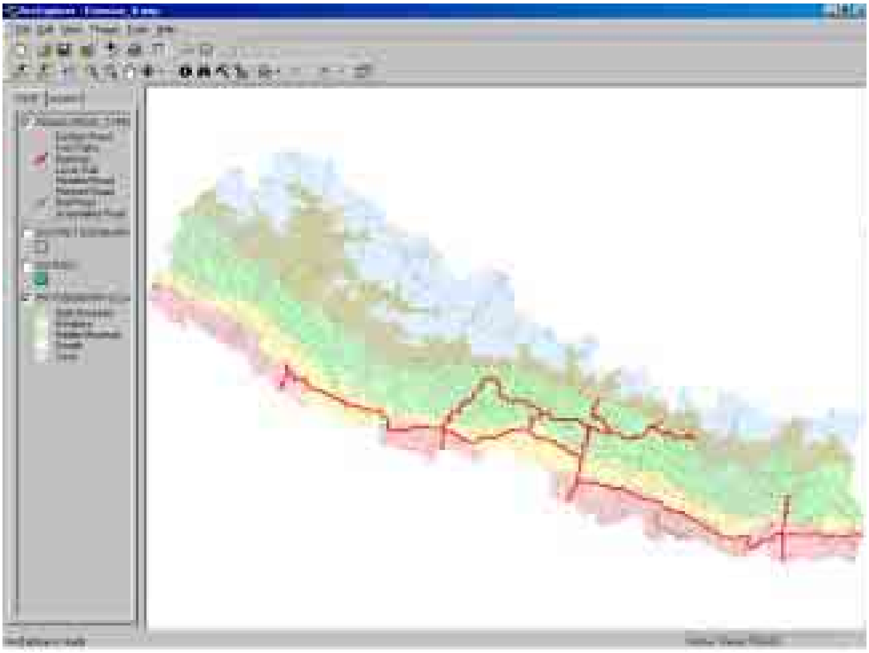
Choose Road_Type as the field in the Field pull-down menu.

The default colours and symbols are probably not appropriate and attractive.

Step 8

In the Theme Properties dialogue box, click on the colour to the left of the word Highway. The Symbol Properties dialogue box displays. Choose dark red as the colour and click OK. Since highway roads are generally wider and bigger, assign the line size 2 and click OK.

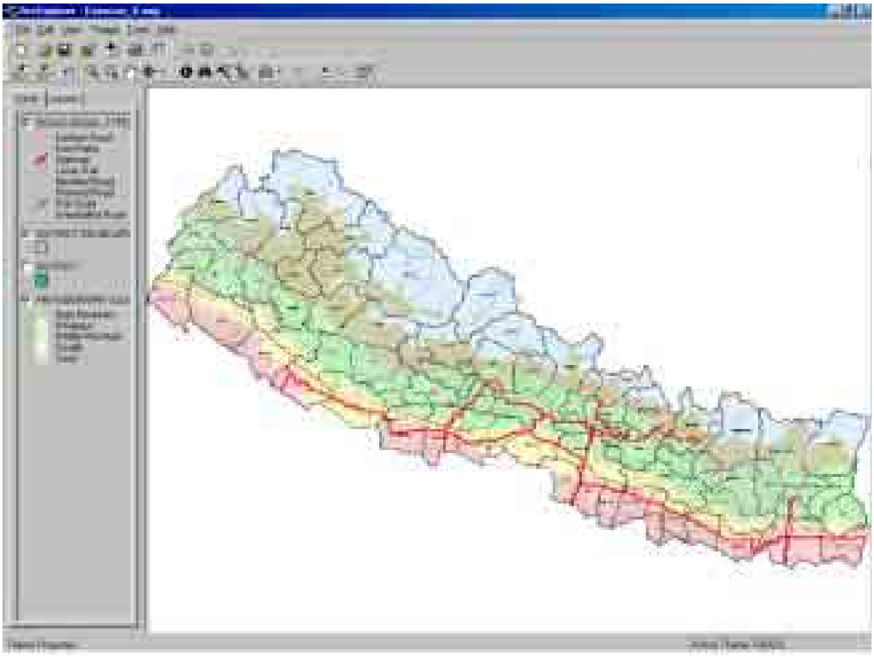
Repeat this procedure for the remaining roads and assign different colours and symbols as shown below. You can distinguish the routes of highways and other roads.



To see which districts have good accessibility to highways, you will draw the district boundaries.

Step 9

Click on the DISTRICT BOUNDARY theme.



You will see that the east-west highway passes through most of the districts in the Terai region. The districts in the middle mountain and the Himalayan region have less accessibility to roads. Zoom in on the Kathmandu valley area. You will see that Kathmandu, Lalitpur and Bhaktapur districts have good accessibility to roads. So, based on this, planners can prioritise districts for development of road infrastructure.

Exploration 8–Share your map of Nepal

Suppose you work for the National Planning Commission that plans the budgetary activities for the development of each district of Nepal. From experience, the Planning Commission has realised that many districts have few educated people. After evaluation, the commission has identified that the main reason for this is that there are either no schools or few schools in these districts. This is mainly because of a lack of budget. So, the Planning Commission wants to reserve more of the budget to establish schools in these districts next year. You will create a map showing the literacy rates in each district and so that planners can identify which districts should be prioritised for more of the budget to establish schools.

Step 1

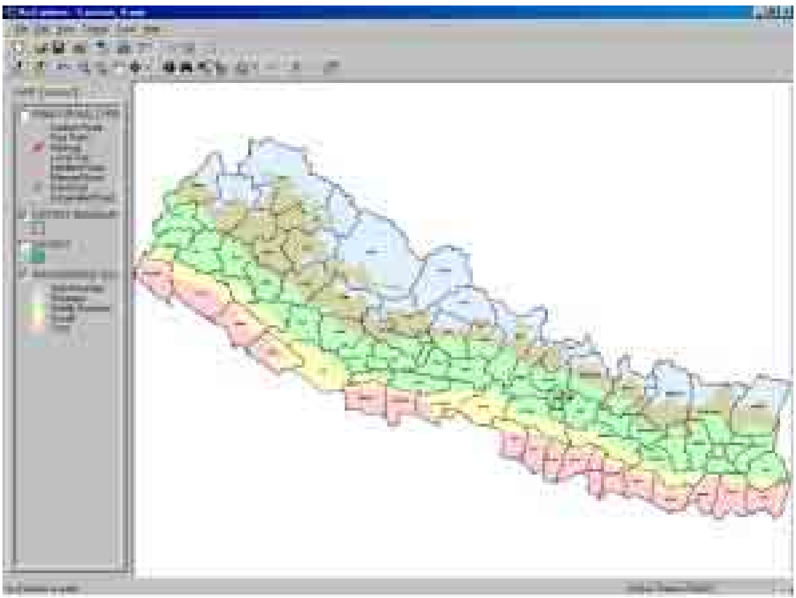
Start ArcExplorer, if necessary.

Step 2

Click the Open Project button. Navigate to the *GIS Basics\Exercise\Data\Nepal* directory.

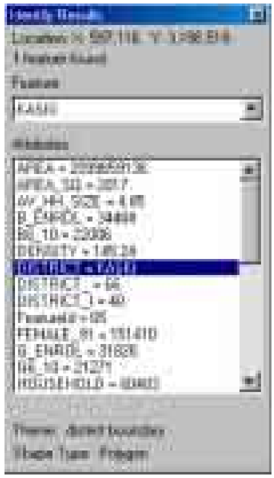
Step 3

Select the project file called Exercise_4.AEP and click Open. When you open the project, you see the themes PHYSIOGRAPHY, DISTRICT, DISTRICT BOUNDARY and ROADS. You see all the districts of Nepal by physiographic region.



Step 4

Make the DISTRICT theme active. Use the identify tool to click on some of the districts.



Notice each district has information about its population, household numbers, number of schools, and literacy.

You will first use the literacy information (defined by the field LITERAC_T) to show the level of literacy in each district.

Step 5

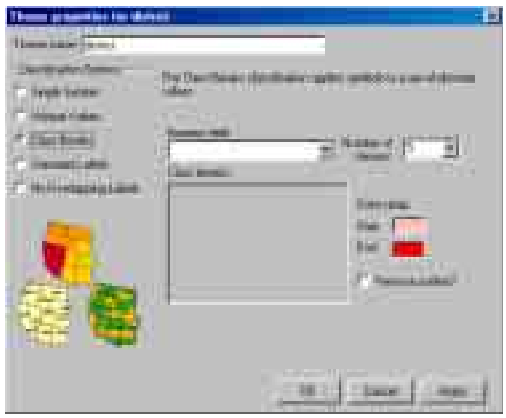
Dismiss the Identify Results dialogue box by clicking the 'x' in the upper right-hand corner.

Step 6

Click on the DISTRICT theme to display it and switch off the PHYSIOGRAPHY theme. Make the DISTRICT theme active.

Step 7

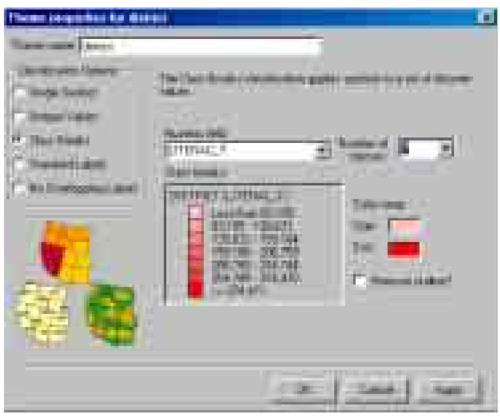
Click the Theme Properties button to display the Theme Properties dialogue box. Choose Class Breaks under Classification Options.



The Class Breaks option is used to create a graduated colour map, such as this one, from numeric data. The numeric values are grouped together as ranges or classes. A different colour is applied to each range.

Step 8

In the Numeric field pull-down menu, scroll down and choose the field LITERAC- T.



Step 9

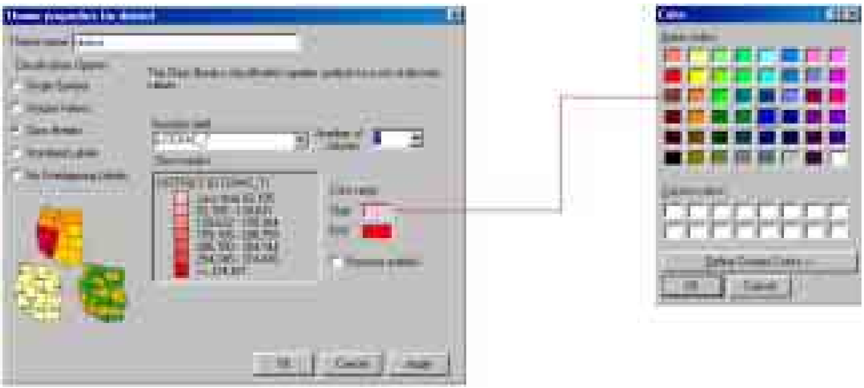
In the Number of Classes pull-down menu, choose 7.

The more classes you choose, the more you can visually distinguish classes. However, five classes are usually the most practical limit.

Now you will create a colour ramp to represent the literate population. A colour ramp uses colours to indicate rank or order among classes. The colours progress from light to dark. With numeric data, lower values should use lighter colours and higher values should use darker colours.

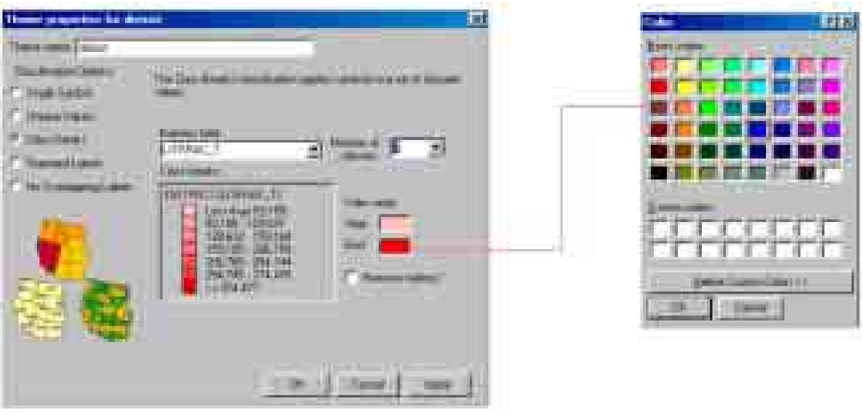
Step 10

Click the Start colour box to select a starting colour for your colour ramp. The Color dialogue box will display.



Step 11

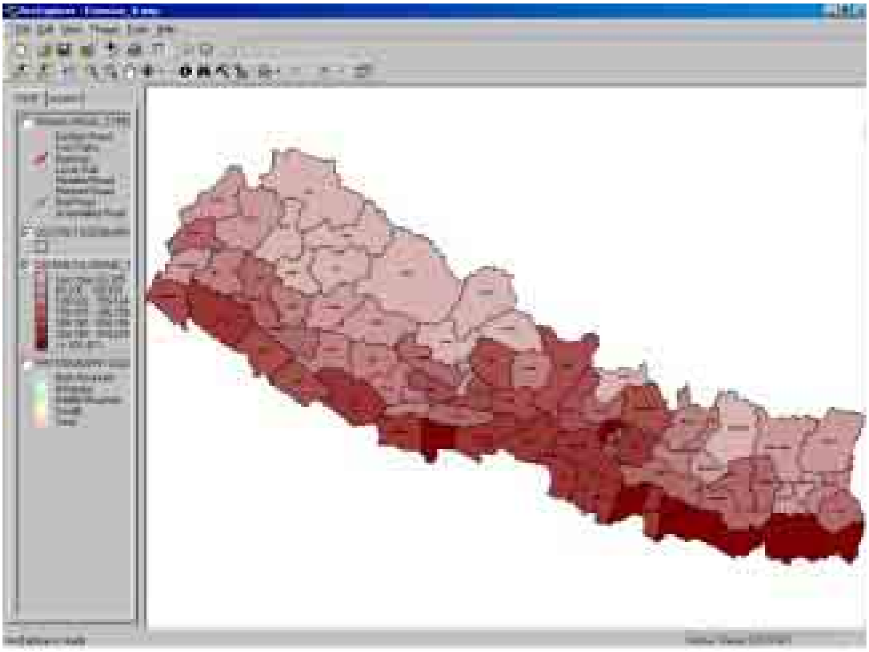
Click the End colour box to select the ending colour for your colour ramp. This time, select a shade of dark red and click OK.



Step 12

Your map shows the districts with a lower literate population in lighter colours and districts with a higher literate population in darker colours.

Notice that the Kathmandu district and other districts, mostly in the eastern Terai region, have a higher literate population. You can also see that most of the districts in the north-western part of the country have lower literate

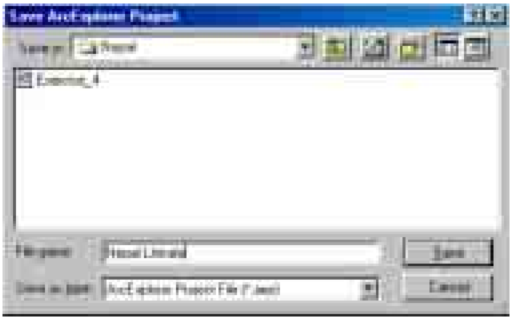


populations. So, based on this map, the National Planning Commission can decide which districts should be prioritised in terms of educational development.

You will save this map as an ArcExplorer project. With this, not only can you view the map quickly later, but you can also distribute your map digitally for others to see.

Step 13

Choose Save As from the File menu. The Save ArcExplorer Project dialogue box is displayed. Specify the file name 'Nepal_Literate' in the File Name box. Click Save.



Chapter 4 Building a Digital Map

So far, you have been provided with the appropriate data files for cities such as Kathmandu, Kirtipur, so you could start working with a GIS without worrying about other issues. However, in practice, geographic data comes in different formats. This chapter introduces you to some of them, then helps you to put these diverse formats together to make an even more powerful map.

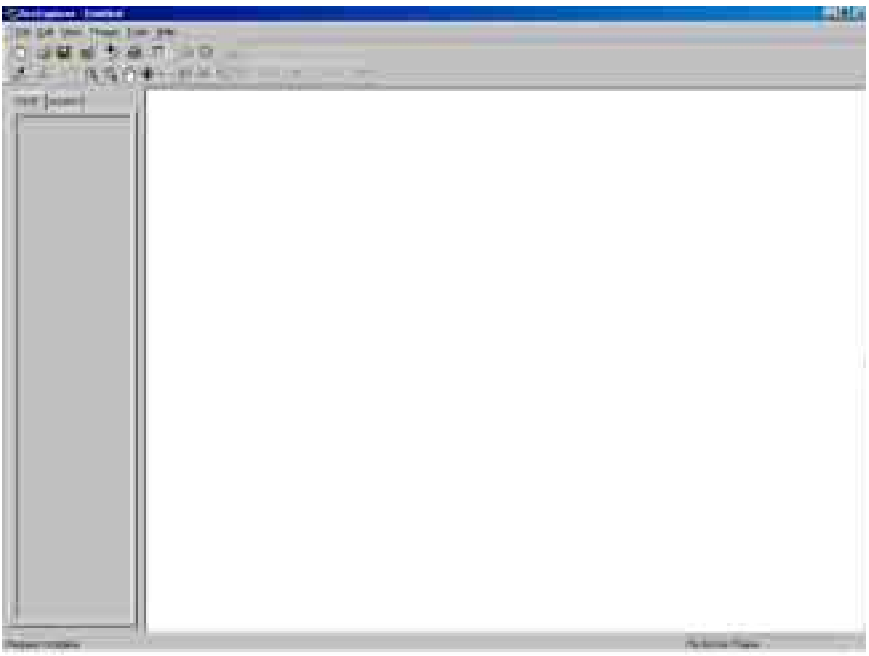
Exploration 9–Make a map of Kathmandu from digital data

Your new boss from the USA is coming to Kathmandu to work at ICIMOD. You have to find a place for him to live. Your new boss wants a house that is close to ICIMOD, not located in a highly air-polluted zone, and near to a hospital. After he arrives in Kathmandu, you have to present him with a map, so that he can decide where to stay.

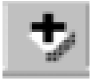
You have several shape files such as location of ICIMOD, highways, major roads, city roads, hospitals and rivers. You have a satellite image that will make an interesting background. You also have an Arc/Info coverage of air pollution zones.

Step 1

Start ArcExplorer, if necessary.

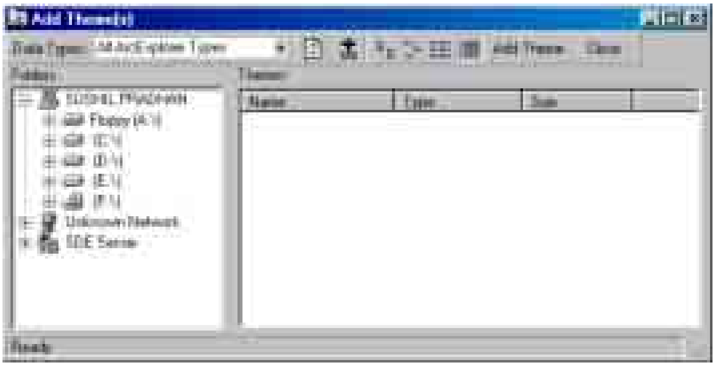


You see a blank map view and a blank legend.



Step 2

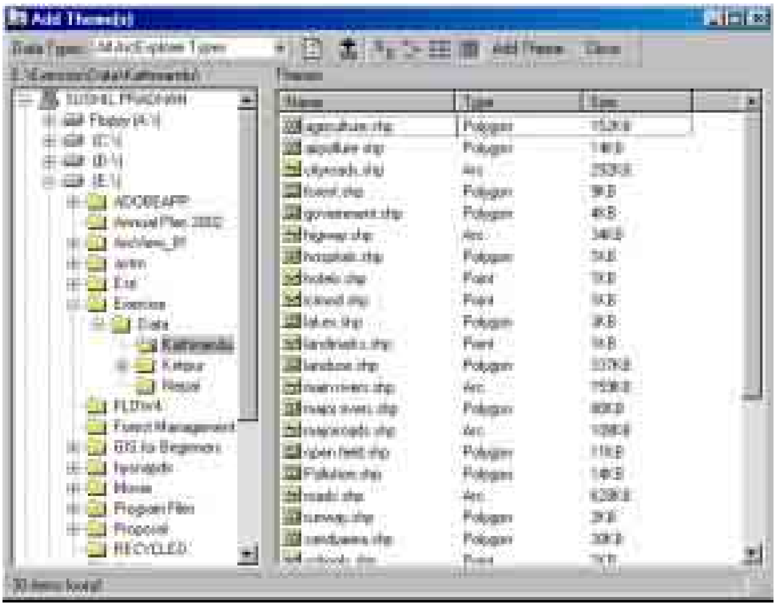
Click the Add Theme button. The Add Theme(s) dialogue box is displayed.



In this box, there are two windows. On the left is a list of all the drives and directories on your computer. This is where you find your data.

Step 3

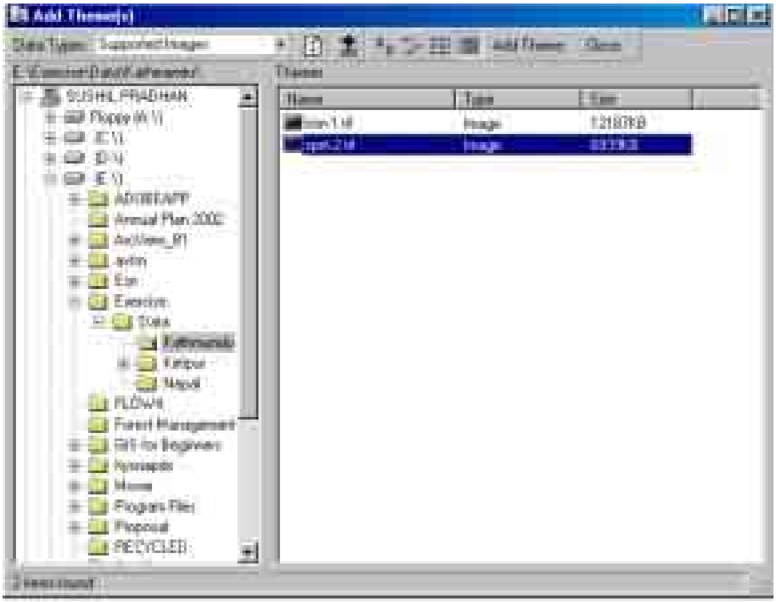
On the left side of the dialogue box, find your local drive where the data is stored. Then go to the *GIS Basics\Exercise\Data\Kathmandu* directory.



When you open the folder, you will see several themes with different formats listed in the right window. At the top of the box, in the Data Types window, All Arc Explorer Types is the default choice. For this selection, the right window shows shape files or image files.

Step 4

Using the Data Types pull-down menu, choose Supported Images.



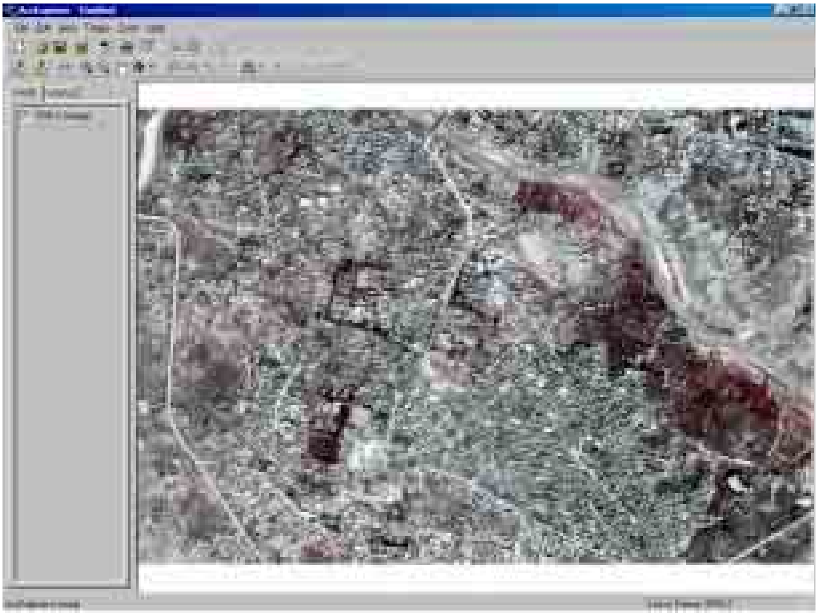
You see an image called spin-2.tif listed. You will add this image to the map view.

Step 5

Click on the file name spin-2.tif. Click Add Theme, then click Close. The theme is added to the legend as SPIN-2 (IMAGE).

Step 6

Turn on the theme SPIN-2.



Now you will add your shape files to the map view.

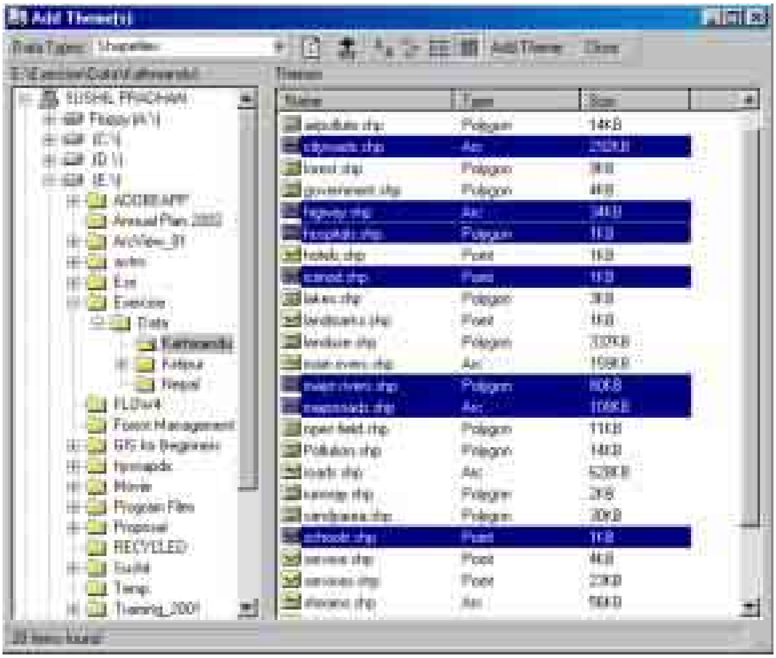
Step 7

Click the Add Theme button. In the Add Theme dialogue box, choose Shapefiles as the data type.

Only shape files appear in the Theme list.

Step 8

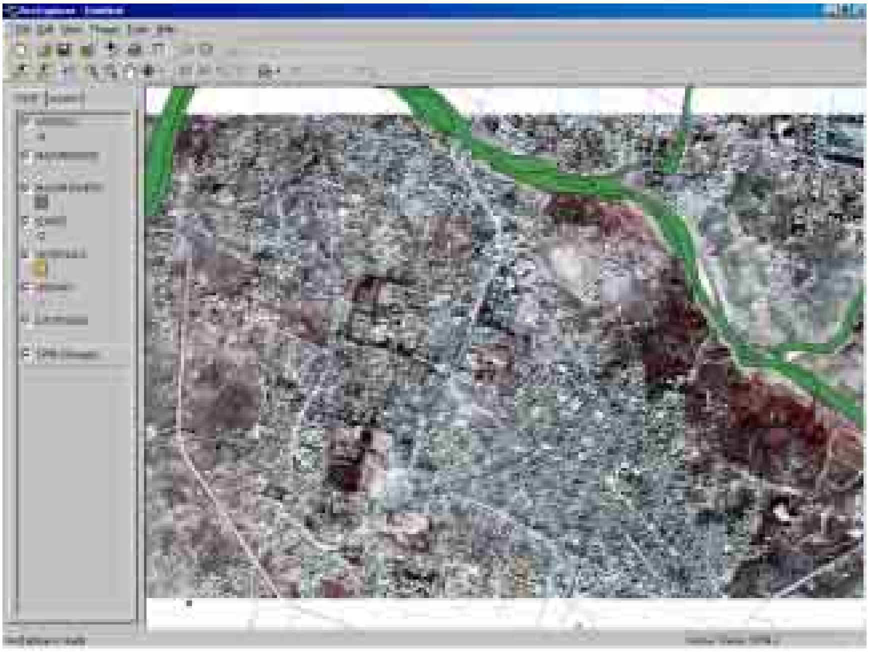
Click on highway.shp and Add Theme. To add more than one theme at a time, hold down the control key, click on cityroads.shp, majorroads.shp, major rivers.shp, icimod.shp and hospitals.shp. Then click Add Theme.



All the selected themes will be added to the legend. Then click Close in the Add Theme dialogue box.

Step 9

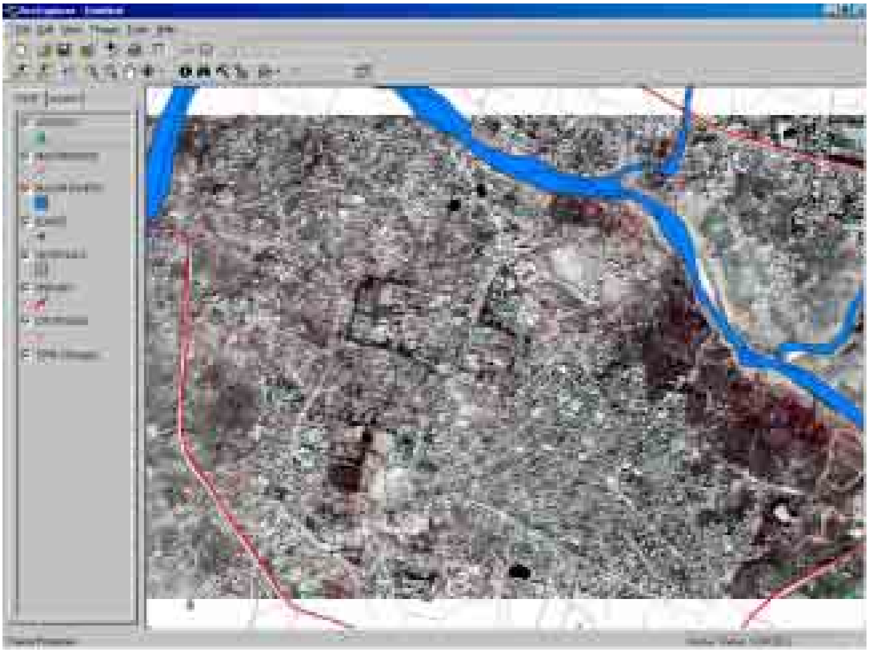
Turn on all new themes in the legend.



Since ArcExplorer assigns random colours to the new themes, you may need to assign more appropriate colours.

Step 10

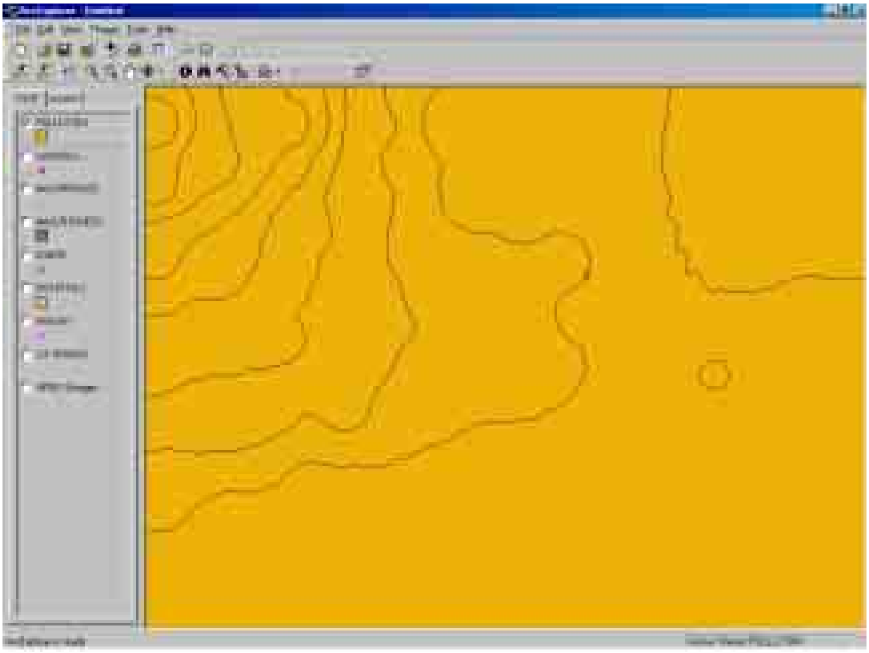
Use Theme Properties in turn for each theme to assign appropriate colours and symbols as shown below.



Your map looks better. All that you need now is the air pollution zone.

Step 11

Use the Add Theme button to add the Pollution.shp. Then turn on the POLLUTION theme.



ArcExplorer displays the themes in the order they appear in the legend from bottom to top. Since the POLLUTION theme is on top of the list, it covers all the other themes. You will move it down the list.

Step 12

Click on the name of the POLLUTION theme in the legend and, holding down the mouse button, drag the mouse pointer until it is above the SPIN-2 (Image), then release the mouse button.

Now you will need to symbolise the POLLUTION theme to show polluted zones.

Step 13

Make the POLLUTION theme active. Click the Theme Properties button.

In the Theme Properties dialogue box, select Unique Values under Classification Options. Select Zone as the field.

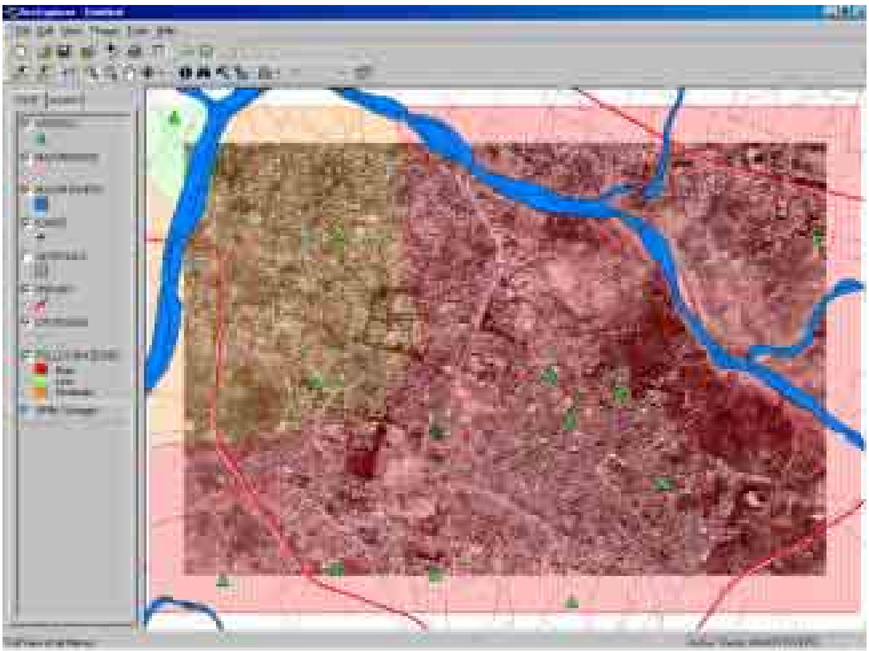
You see that ArcExplorer automatically assigned a random colour to each unique classification—high, moderate, low.

Step 14

Under discrete values and symbols, click on the colour box next to 'High'. In the Symbol Properties dialogue box, select dark red for both the colour and outline colour, and Light Gray Fill as the style. Click OK.

Step 15

Similarly select light orange and light green for 'Moderate' and 'Low' for both the colour and outline colour. Choose Light Gray Fill as the style for both 'Low' and 'Moderate'.



Your map view looks great. With this map, your new boss can decide where to stay. Now go ahead and explore your map. Use the pan and zoom to have a closer look.

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ERDAS Inc. *http://www.erdas.com* ERDAS IMAGINE

ESRI. *http://www.esri.com* ATLAS GIS, Arc/Info, ArcView GIS, ArcCAD

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ITC. *http://www.itc.nl* ILWIS

Maplnfo Corporation. *http://www.mapinfo.com* Maplnfo

PCI Geomatics *http://pcigeomatics.com* SPANS, EASI/PACE, PAMAP GIS

Glossary

Analogue maps	Maps in paper form
Aspect	The compass direction towards which a slope faces; measured clockwise in degrees from North.
Attribute	Non-spatial descriptive characteristic of a real-world phenomenon. Often a measurement or value associated with spatial locations.
Band	One layer of a multispectral image representing data values for a specific range of the electromagnetic spectrum of reflected light or heat (e.g. ultraviolet, blue, green, red, near- infrared, infrared, thermal, radar, etc.). Also, other user-specified values derived by manipulation of original image bands.
Base map	A map containing geographic features used for locational reference. Roads, for example, are commonly found on base maps.
Buffer	A corridor of a specified width defined parallel to lines or around polygons. Buffering is the process of defining the corridor and drawing the new geometry to delimit it.
CAD or Computer-Aided Design	Computer systems for drawing design graphics
Column	The vertical dimension of a table–a column has a name and a data type applied to all values in the column.
Connectivity	Describes whether sets of points (nodes) or lines are connected to each other.
Contour	A line connecting points of equal surface value
Control segment	A world-wide network of GPS monitor and control stations that ensures the accuracy of satellite positions and their clocks.
Co-ordinate pair (X, Y)	A pair of co-ordinates describing the location of a point feature on x and y axes. Sets of co-ordinate pairs are used to define lines and polygons.
Database Management System (DBMS)	A collection of computer software used for organis ing and accessing information in a database.
Data conversion	The translation of data from one format to another

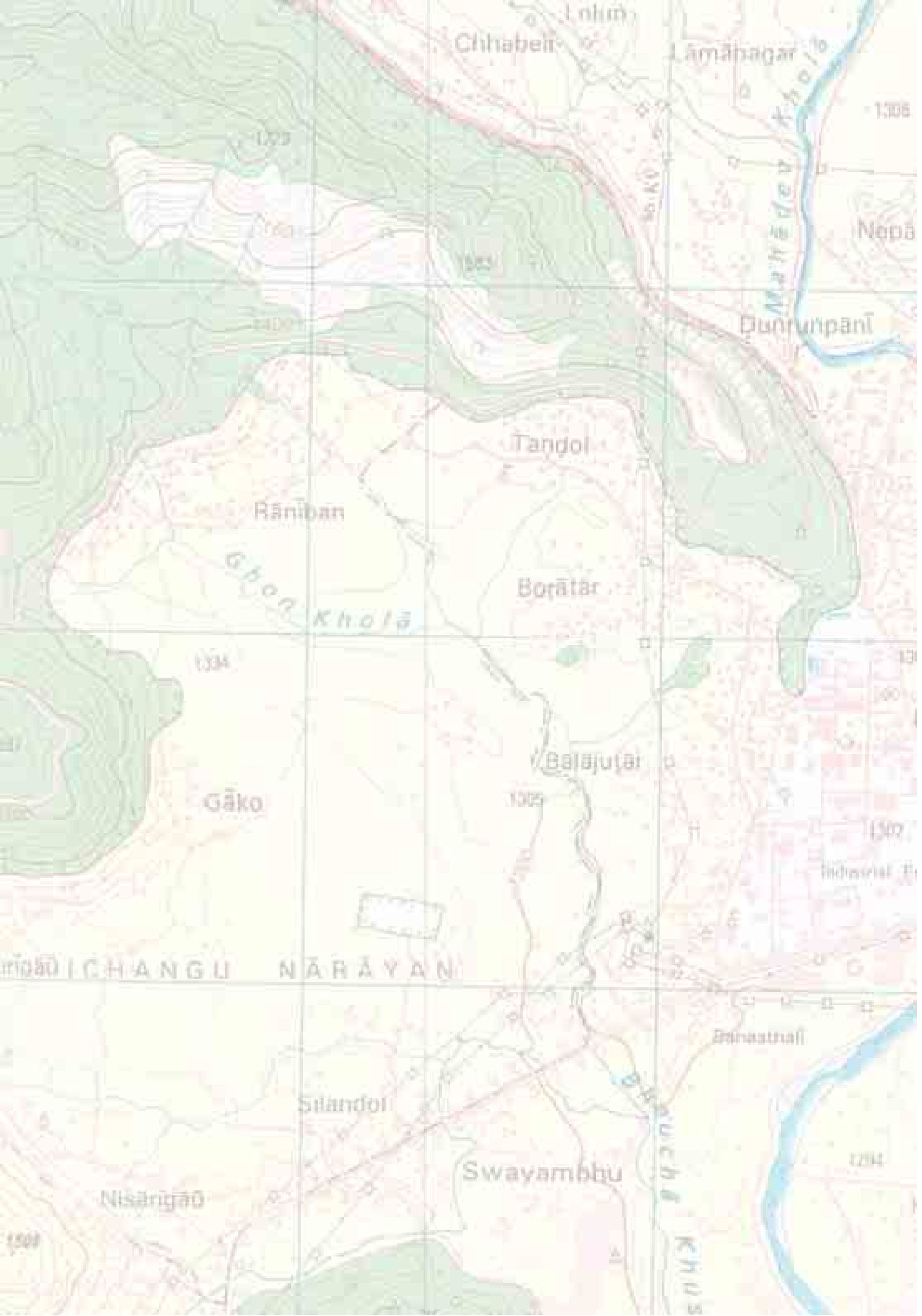
Data dictionary	This contains information about definition, structure and usage of data in a database. No data are actually held here.
Data integrity	Maintenance of data values according to data model and data type, for example, to maintain integrity, numeric columns will not accept alphabetic data.
Data model	An abstraction of the real world that incorporates only those properties thought to be relevant to the application in hand. Also, a set of guidelines for the representation and logical organisation of data in a database, consisting of named logical units of data and the relationships between them.
Data quality	The quality of the data measured in relation to the actual phenomena measured at source
Database	An organised, integrated collection of data related by a common fact or purpose
Differential positioning	Measurement of the relative positions of two receivers tracking the same GPS signals
Digitiser	A device (usually electronic) for coding point locations on a graphic image or map to plane (x, y) coordinates
DTM or Digital Terrain Model	A digital representation of ground surface relief enhanced by the addition of topographic information
Electromagnetic spectrum	The spectrum of wavelengths of electromagnetic radiation (including infrared, visible and ultraviolet light)
Feature	A real-world phenomenon, named and classified– often used in cartography to name classes of elements shown on a map.
File	A collection of records, each of which can be referenced according to its position in the file
Format	The pattern into which data are systematically arranged for use on a computer–a file format is the specific design of how information is organised in the file.
Generalise	Reduce in detail, simplify or resample to change the level of information in a data set. The most common generalisation operation is line-thinning by discarding coordinates.
Geographic information	Information that can be related to a location (defined in terms of point, line and area); particularly information on natural phenomena, cultural or human resources.
Geographical Information System	A set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of circumstances.

Global Positioning System (GPS)	A GPS is a position-fixing system that uses the time taken for signals to travel from at least three GPS satellites in a known orbit to a receiver on the ground.
Grid	A geographic data model representing information as an array of equally sized square cells arranged in rows and columns.
Hardware	The physical device used to process a computer programme and display the results.
Image processing	The various operations that can be are applied to image or raster format data. These include image compression, restoration, enhancement, rectification, pre-processing, quantisation, spatial filtering and other image pattern recognition techniques.
Image	A graphic representation or description of a scene, typically produced by an optical or electronic device. Common examples include remotely sensed data (e.g. satellite data), scanned data and photographs.
Index	Special data structure used in a database to speed searching for records in tables or spatial features in geographic data sets.
Interactive	Describes a process of two-way communication between the user and the computer.
Interpolation	The procedure of estimating the values of unknown points on a surface from the values of a number of points of known value.
Isoline	A line on a surface connecting points of equal value
Latitude–longitude	A spherical reference system used to measure locations on the Earth's surface. Latitude and longitude are angles measured from the Earth's centre to locations on the Earth's surface. Latitude measures angles in a north-south direction. Longitude measures angles in an east-west direction.
Layer	Usually represents a theme or feature type within the database. Layers that are registered to the same co-ordinates as other layers can be integrated in different ways to create a new layer.
Line	The shortest distance between two points (sometimes called a line segment). In some GIS, many connected line segments are also referred to as a line. A one-dimensional object.

Map	An abstract representation of the physical features of a portion of the Earth's surface graphically displayed on a planar surface. Maps display signs, symbols and spatial relationships among the features.
Map algebra	A set of operations for manipulating, filtering and combining raster maps.
Map projection	A transformation from a spheroid to a flat plane representing the parallels of latitude and the meridians of longitude of the Earth.
Map query	The process of selecting information from a GIS by asking spatial or logical questions of the geographic data. Spatial query is the process of selecting features based on location or spatial relationship.
Map scale	The reduction needed to display a representation of the Earth's surface on a map. A statement of a measure on the map and the equivalent measure on the Earth's surface, often expressed as a representative fraction of distance, such as 1:24,000 (one unit of distance on the map represents 24,000 of the same units of distance on the Earth).
Meridian	A line running vertically from the north pole to the south pole along which all locations have the same longitude.
Model	A representation of reality used to simulate a process, understand a situation, predict an outcome or analyse a problem. A model is structured as a set of rules and procedures, including spatial modelling tools available in a geographic information system (GIS).
Multipath error	Errors caused by the interference of a signal that has reached the receiver antenna by two or more different paths. Usually caused by one path being bounced or reflected.
Network analysis	Analytical techniques concerned with the relationships between locations on a network, capacities of network systems and the best location for facilities on a network.
Overlay	The process of integrating digital representations of various spatial data registered to a common coordinate system.
Pixel	Short for picture element, i.e. the smallest discrete element that makes up an image. It may represent either a small square or portion of the Earth's surface, scanned by satellite or aircraft, a portion of a graphics image sensed by an optical scanner or an individual dot on a screen.

Point	The position or location of an object in a spatial reference system. A zero-dimensional object.
Polygon	An area with three or more sides intersecting at the same number of points. A two- dimensional object.
Projection	The procedure for transferring features from the spherical earth to a flat plane using mathematical transformations.
Query	A structured enquiry made on a map or database using a formal language.
Raster	A cellular data structure composed of rows and columns for storing images. Groups of cells with the same value represent features.
RDBMS	A database management system with the ability to access data organised in tabular files that can be related to each other by a common field (item). An RDBMS has the capability to recombine the data items from different files, providing powerful tools for data usage.
Record	A set of observations on a real-world phenomenon as described by attributes.
Remote sensing	The technique of obtaining data about the environment and surface of the earth from a distance, e.g. from an aircraft or satellite.
Resolution	Resolution is the accuracy at which a given map scale can depict the location and shape of geographic features. The larger the map scale, the higher the possible resolution. As map scale decreases, resolution diminishes and feature boundaries must be smoothed, simplified or not shown at all.
Row	A record in an attribute table. The horizontal dimension of a table composed of a set of columns containing one data item each. Also a horizontal group of cells in a grid or pixels in an image.
Satellite constellation	The arrangement of a set of satellites in space.
Scale	The ratio or fraction between the distance on a map, chart or photograph and the corresponding distance on the surface of the Earth.
Scanner	The electronic device used to convert analogue information from maps or images into a digital format usable by a computer.
Selective Availability	A policy adopted by the Department of Defense in the USA to introduce some intentional clock noise

	into the GPS satellite signals thereby degrading their accuracy for civilian users.
Slope	A measure of change in surface value over distance, expressed in degrees or as a percentage.
Software	A system of programmes used to execute tasks written for the computer.
Space segment	The part of the whole GPS system that is in space, i.e. the satellites.
Spatial analysis	Analytical techniques associated with the study of locations of geographical phenomena together with their spatial dimensions.
Spatial resolution	Measure on the ground represented by each pixel in the image.
Table	A set of data elements that have a horizontal dimension (rows) and a vertical dimension (columns) in a relational database system. A table has a specified number of columns but can have any number of rows. A table is often called a relation. Rows stored in a table are structurally equivalent to records from flat files in that they must not contain repeating fields.
Theme	A user-defined perspective on a geographic data set, if applicable, by a name and feature class or data set name, attributes of interest, a data classification scheme and theme-specific symbology for drawing.
Topographic map	A map showing the features that describe the surface of a particular place or region. It contains contours indicating lines of equal surface elevation (relief), often referred to as topo maps.
Transformation	Mathematical conversion of coordinates between alternative referencing systems (e.g. as in map projection).
Triangulation	The interconnection of all points within an area to form a set of reproducible triangles
User segment	The part of the whole GPS system that includes the receivers of GPS signals
Variable	A discrete measurement on a parameter.
Vector data	A description of spatial phenomena based upon geometry (e.g., point, line and area)


Chhabeli
Lāmābagar
Tangol
Rānīban
Ghon Kholā
Borātār
1334
Balajutār
1305
Gāko
CHANGU NĀRĀYAN
Silandol
Swayambhu
1294
1306