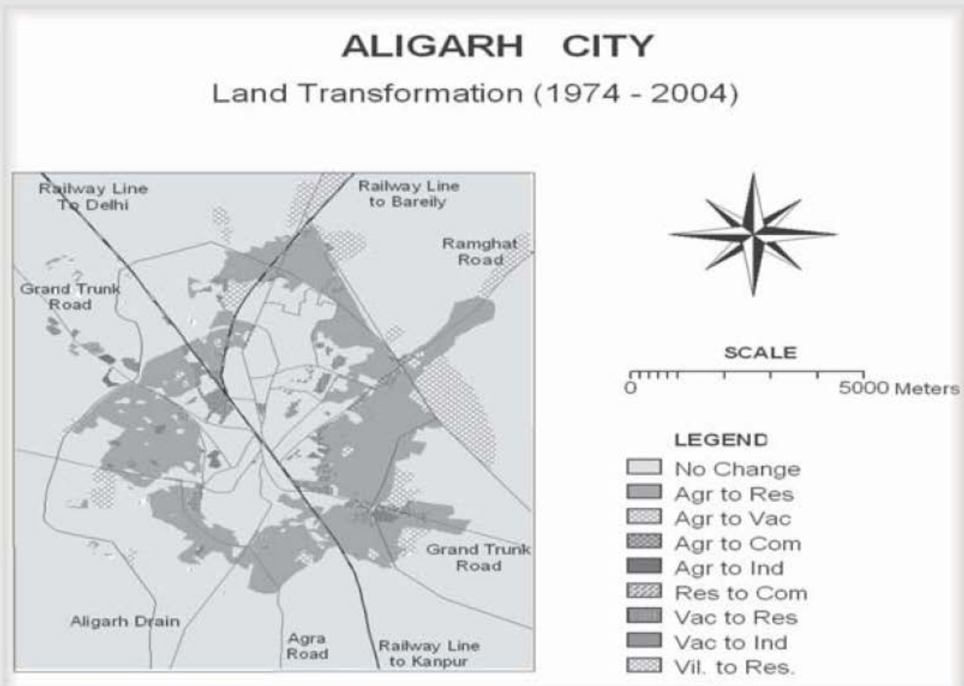
Chapter 12

GIS Project Design and Management



PROBLEM IDENTIFICATION

- Before developing a GIS application the problem that the GIS will address must be identified.
- Two techniques that can be used to assist problem identification:
  - Creating a rich picture (a schematic view of the problem being addressed),
  - Developing a root definition (a statement of an individual's or group's perspective on the problem)
- Both these techniques are drawn from the soft systems approach to system design.

The rich picture

- A rich picture is a schematic view of the problem a project will address.
- It presents the main components of the problem, as well as any interactions that exist.

- The rich picture for the urban sprawl GIS study adopts the conventions of the authors, in particular Reeve (1996) and Avison and Wood-Harper (1991).
  - Crossed swords
    - A crossed swords symbol expresses conflict.
    - It is used to indicate the differences between the urban residents and the fringe area residents.
  - Eyes
    - Eyes are used to represent external observers.
    - Property developers interested in identifying new areas for housing development may be external observers.
  - Speech bubbles
    - Personal or group opinions are indicated in speech bubbles.
    - The different priorities urban land buyers see for the system may be included in the rich picture in this way.
- A rich picture drawn by a project team will represent a consensus view of a problem reached by all the project participants.

Box 21 : *The soft systems approach*

The original soft systems ideas were developed by Checkland (1981) and have been added to more recently by other researchers (Wood-Harper et al., 1995). The soft systems approach to problem identification provides a method for addressing unstructured problems (Skidmore and Wroe, 1988). This is useful in a GIS context because many GIS problems are unstructured and often difficult to define. To formulate a problem users should appreciate the context, or world view, from which the problem is being considered. This is the key to the soft systems approach. From the soft systems perspective it is not models of real-world activities which are created, but models of people's perception of an activity. How people feel about and view the activity are included. Therefore, soft systems models are abstract logical models that help with our unerstanding and structuring of a problem.

- Skidmore and Wroe (1988) suggest that rich pictures are particularly useful when considering the design of computer systems within organizations because:
  - they focus attention on important issues;
  - they help individuals to visualize and discuss the roles they have in the organization;
  - they establish exactly which aspects of the information flows within the organization are going to be covered by the system;
  - they allow individuals to express worries, conflicts and responsibilities.
- The development of a rich picture should not be rushed, particularly if it is trying to reflect an unstructured problem.
  - A poorly defined rich picture may translate into a poor GIS application.

The root definition

- The root definition is a view of a problem from a specific perspective.
    - Land buyers may see the GIS as ‘a system to help identify and rank possible lands’,
    - The estate agents may see it as ‘a system to help identifying high rent lands which are available for sales’.
    - The system developer must get these two groups to agree on a common root definition, for example, ‘a system that identifies land for sale which meet the requirements of individual land buyers’.

- Once rich picture and root definition exist, the main aims and objectives for a project can be identified and a GIS data model can be created.
- As the rich picture is developed and the root definition formulated the resources available to the project must also be considered.
  - It is important to consider, given the resources available, whether to address the whole problem that is unfolding or to break the problem down into smaller parts.

Designing a data model

- The rich picture and root definitions that define a problem must be turned into a GIS data model.
- Data model is used as a collective term for the process of identifying all the design elements used in the construction of a GIS (Peuquet, 1984 and Frank and Mark, 1991).
- Two parts of GIS data model: A conceptual model and a physical model
- The conceptual data model
  - It is a high-level view that is independent of the computer system. This is the user's view of a problem and its elements.
  - It adds spatial detail to the rich picture by including elements of spatial form and spatial process.

- The physical data model
  - It is concerned with how to represent the conceptual model within the computer.
  - Details about the spatial data model, the appropriate data structure and the analysis scheme are included.
- Insufficient attention to data modelling may lead to the failure of the GIS to meet the expectations of users.

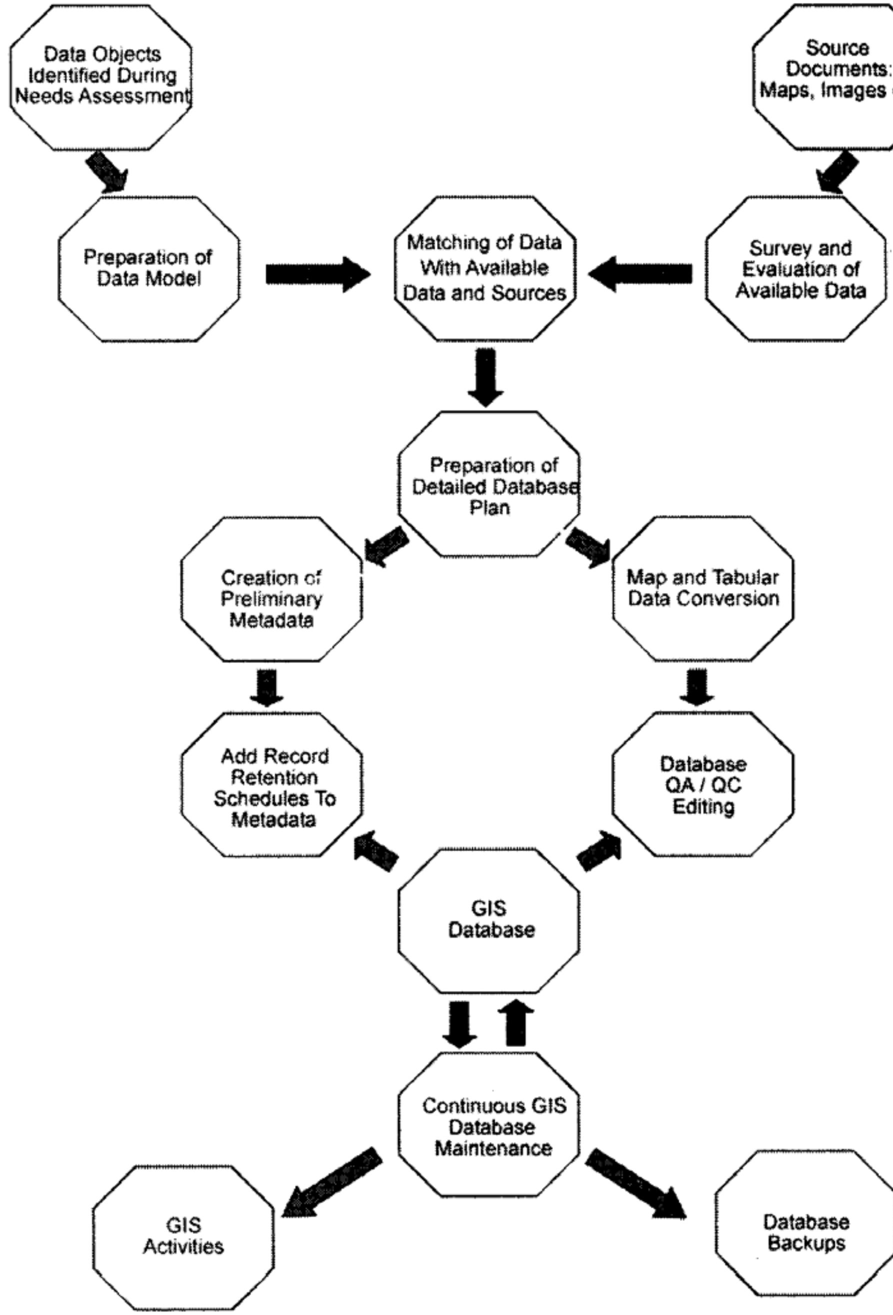


Figure 12.1: Conceptual design of GIS. It includes formal modelling of GIS database and its planning activity.

Conceptual and physical data model

- The conceptual data model
  - One way to create a conceptual data model is to borrow heavily from the ideas of hard systems analysis.
    - Hard systems analysis advocates the clear identification of the elements of the data model: the entities, their states and their relationships to each other.
  - One method of presenting this is using a flowchart.

The GIS Paradigm

Data Management Principles: The logical structuring of databases that contain geographic information and other related data.
Technology: The effective combination of hardware and software components that enables the automation of numerous geographic data handling functions.
Organizational Setting: A management environment that provides resources and enables changes to be made for incorporating GIS utilization within the organization.

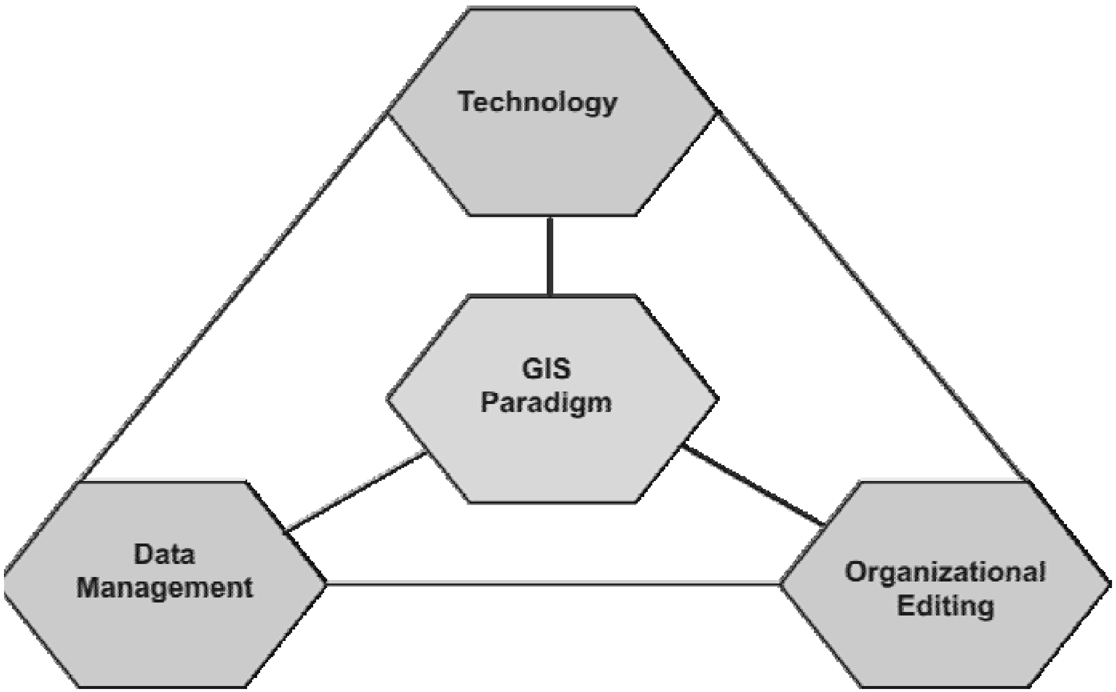


Figure 12.2: GIS paradigm.

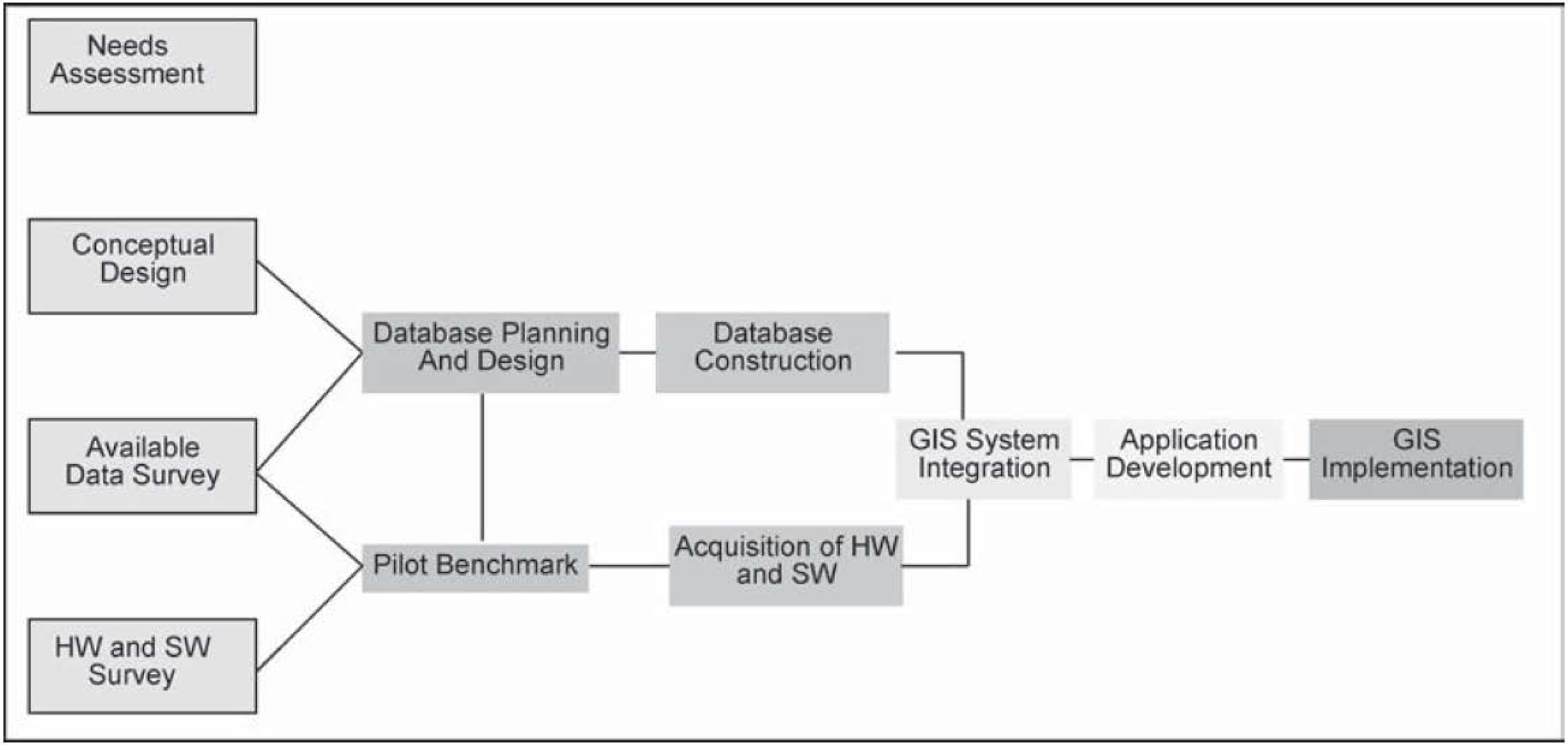


Figure 12.3: GIS development cycle.

Box 22: Hard systems analysis and GIS

Hard systems analysis advocates trying to understand reality by rebuilding part of it. The link to GIS is clear, as GIS data models attempt to reconstruct parts of reality for specific purposes. During the 1970s and early 1980s the hard systems approach was the dominant methodology used for the design of computer systems. It is possible that the early developers of GIS software used a hard systems approach to design.

There are four phases in hard systems analysis. These are outlined below (after Huggett, 1980). There are three important terminology of the hard systems approach. These are entities, states and relationships. The *entities, or elements* of a system, are either physical objects or concepts. In GIS terms entities are points, lines, areas, surfaces and networks. Entities also possess properties known in hard systems terms as states. The states associated with an entity give its character. In GIS terms states are attributes. In addition, relationships exist between entities. In GIS this relationship could be the topological links between features.

The four stages in hard systems analysis, in a GIS context, are:

- **The lexical phase-**The objectives of the lexical phase are:
  - to define the problem;
  - to define the boundaries of the problem;
  - to choose the entities that define the components of the problem;
  - to establish the states of these entities.

Contd....

In GIS this involves:

- identifying the nature of the application;
- selecting the study area;
- defining the real-world features of interest;
- identifying associated attributes.

- **The parsing phase**-In the parsing phase the relationship between entities and groups of entities are defined. The entities and knowledge about their states are used to create a computer model.
- **The modelling phase**-In this phase the GIS is used to address the problems identified during the lexical phase. The way in which entities and their states will interact and respond under differing situations is expressed. This may involve linking GIS software to other software.
- **The analysis phase**-This phase is the validation of the modelling phase. Testing occurs to find out how closely the GIS model (of both form and process) fits what is observed in reality.

- Bell and Wood-Harper (1992) provide a useful checklist for the development of a conceptual model:
  - i. Develop a rich picture and root definition:
    - Everyone associated with the problem should agree upon these. They are used to focus the aims and direction for the project.
  - ii. Create a list of actions the system must be able to perform:
    - These actions are known as activities.
  - iii. Identify a list of system inputs and outputs:
    - In GIS terms system inputs are data sources and outputs are products such as maps.
  - iv. Group activities, inputs and outputs into a logical, chronological order:
    - Arrows symbolizing some form of action are used to join activities together.

- The physical data model
  - It requires additional detail that describes how to model the spatial entities, their associated attributes and the relationships between entities in the computer.
  - The emphasis here is on developing a model of the relationships between entities.
  - This is frequently referred to as an analysis scheme.
    - There are a number of different techniques for designing an analysis scheme.
    - Here we describe an approach known as cartographic modelling.

Cartographic modelling

- Cartographic modelling, at its simplest, is a generic way of expressing and organizing the methods by which spatial variables, and spatial operations, are selected and used to develop a GIS data model.
- Cartographic modelling is a geographic data processing methodology that views maps (or any spatial data layer) as variables in algebraic equations.
- In map algebra, maps are transformed or combined into new maps by the use of specific spatial operations.

- There are four stages in the development of a cartographic model:
  - i. Identify the map layers or spatial data sets required.
  - ii. Use natural language to explain the process of moving from the data available to a solution.
  - iii. Draw a flowchart to represent graphically the process in step 2. In the context of map algebra this flowchart represents a series of equations one must solve in order to produce the answer to the spatial query.
  - iv. Annotate this flowchart with the commands necessary to perform these operations within the GIS one is using.

Algebraic Equation for a Simple Overlay Operation

A + B = C

Where A = Map showing river,
B = Map showing canals,
C = Map showing sources of irrigation

Graphical Representation

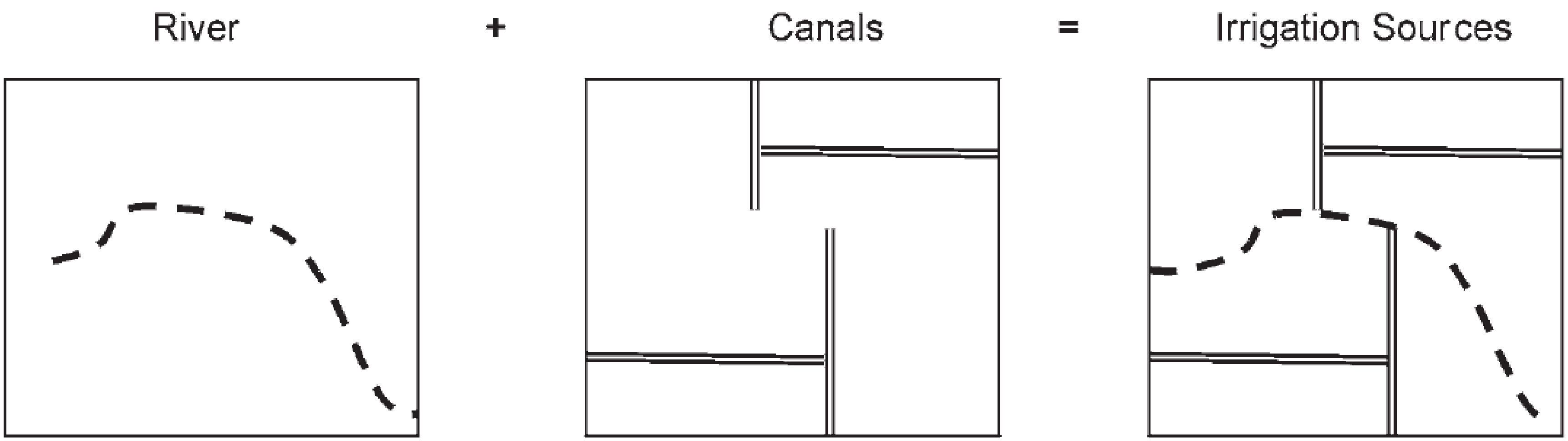


Figure 12.4: A simple map algebra equation.

Box 23 : Examples of natural language keywords

Keyword – **Spread**

Operation – to create a corridor from a linear data set or a zone of influence around a point.

Description – calculate the distance of all geographical positions in the data set from a given point or line.

Example – to create a buffer zones along the main roads and analyze the urban land use.

Keyword – **Overlay**

Operation – to find the intersection of two different sets of area entities covering the same geographical area.

Description – lay two different sets of area entities over each other to produce a new complex set of areas.

Example – to create a map to analyze the influence of accessibility on urban land transformation along the roads.

Keyword – **Extract**

Operation – to extract a new data set from an existing data set.

Description – select specified values or class from one overlay to make a new map.

Example – to create a new data layer showing agricultural land which is transformed in buffer zones along the main roads.

Example of simple equation for GIS analysis:

Equation 1 – EXTRACT from a land use map

$A - B = C$ here, A = land use, B = Kharif cropped area, C = area under rice.

Equation 2 – SPREAD from irrigation potential map

$(D - E) + F = G$ here, D = canal, E = areas which are not canals, F = potential canal irrigated area, G = actual canal irrigated area.

Equation 3 – EXTRACT good water quality tube wells from all the tube wells

$\mathbf{H - I = J}$ here, H = all the tube wells in the area, I = tube wells with hard water, J = good water quality tube wells.

Equation 4 – OVERLAY identifying good water quality tube wells which can irrigate area under rice

$\mathbf{J + K = L}$ here J = good water quality tube wells, area under rice which is not irrigated by canal, L = tube wells which can irrigate the rice area and that can not be irrigated from canal.

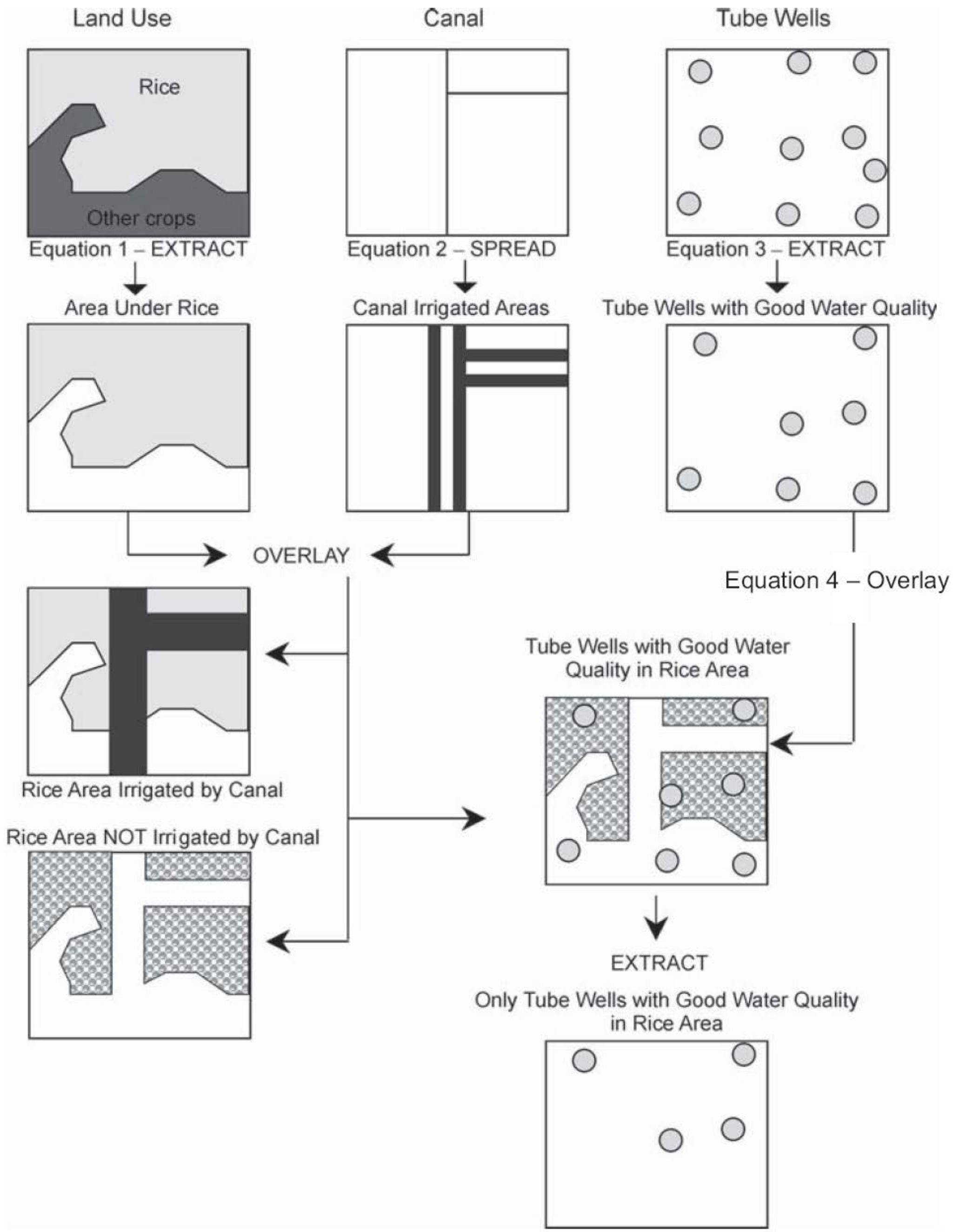


Figure 12.5: An example of GIS analysis for identifying good water quality tube wells which can irrigate area under rice.

Project MANAGEMENT

Systems life cycle approach

- The systems life cycle (SLC) approach advocates a linear approach to managing the development and implementation of an IT system.
- It is also referred to as the ‘waterfall model’ (Skidmore and Wroe, 1988), because the outputs from the first stage of the process inform the second phase, and the outputs from the second phase affect the third phase, and so on.
- There are many variations on the general approach:
  - i. Feasibility study
  - ii. System investigation and system analysis
  - iii. System design
  - iv. Implementation, review and maintenance

- The advantages of the systems life cycle approach
  - It provides a very structured framework for the management of a GIS project.
  - It is often easier to budget for the resources required by a systems life cycle approach because the requirements of the system are established at an early stage in the project.
- The drawbacks of the systems life cycle approach
  - Designers often fail to address the context of the business for which the system is being developed.
  - The timescale and linear nature of the systems life cycle process do not allow for change in the scope and character of the problem.
  - The systems life cycle approach does not put the user at the centre of the system design.
  - The systems life cycle approach is often considered to favour hierarchical and centralized systems of information provision.

The prototyping approach

- The prototyping approach to IT project management developed as a response to the criticisms of the systems life cycle approach, particularly in response to the lack of consideration of users.
- The prototyping approach has a number of advantages over the systems life cycle method:
  - Users have a more direct and regular involvement in the design of the system.
  - It is easier to adapt the system in the face of changing circumstances which were not identified at the outset of the project.
  - The system can be abandoned altogether after the first prototype if it fails to meet the needs of users. This reduces the cost of developing full systems.
  - If money and time are available a number of prototypes can be built until the user is satisfied.

- The drawbacks of prototyping approach are:
  - Prototyping can be difficult to manage. There may be large numbers of users with large numbers of ideas and opinions.
  - The resource implications may change following the development of the first prototype.
  - Knowing when to stop development can also be a problem. However, some GIS designers argue that this is a positive aspect of the approach since few, if any, GIS systems are ever finished.
- There are a wide range of project management techniques and tools which can be used to help with various phases in the systems life cycle and prototyping approaches.

Box 24: Project management techniques

SWOT Analysis (Strength, Weakness, Opportunities and Threats) – This technique is used to establish the SWOT associated with the development of the GIS. It is used as part of the feasibility study in systems life cycle approach.

Rich Picture and Root Definition – These techniques comes from 'soft system' methodology, they are used to help system designers determine the scope of a problem.

Demonstration Systems – These are demonstration GIS applications, designed to help users evaluate systems efficiency. It is used more commonly in prototyping approach is followed for project management.

Interviews and Data Inventories – These techniques are used for problem definition, establishing current information and analysis requirements. Data audits are more structured and valuable in GIS because it evaluates the availability of spatial data.

Organization Charts, System Flowcharts and Decision Trees – These three techniques are all variations on the flowcharting theme. The organization chart maps out the flows of information with in the organization. The system flowchart describes how the system will model these information flows. The decision tree shows the problem from a decision making perspective and focuses on showing how different decisions cause information to be used in different ways within the organization. The technique used will depend on the experience of the system designer and the character of the problem.

Data Flow Diagram and Dictionaries – These techniques are drawn from hard systems analysis and represent a more structured approach to system design. They can be of immense value in GlS for tracking what happens to a data layer through the analysis process. This is extremely valuable in monitoring data quality and providing lineage information.

Cartographic Models and Entity Relationship Diagrams – These techniques are of most valuable in structuring the analysis schemes used in GIS. They help in planning the functional requirements of the analysis.

Implementation problems

- Three of the most common problems are:
  - i. data in the wrong format for the GIS software;
    - There are two options: to look elsewhere for a supplier, or to convert the data into the desired format.
  - ii. a lack of GIS knowledge imposing technical and conceptual constraints on a project;
    - The solution is to employ an independent expert to undertake application development or specific analysis.
  - iii. users of the GIS frequently changing their mind about what they want the GIS to do.
    - The solution is to gain frequent feedback from the individuals who will be the end-users of the GIS.

Project evaluation

- There are three tests that can be used to check whether a GIS application meets the goals set for it at the start of the design process.
  - First, all the parties involved in the design and development of the GIS can be asked if they are using the application for the purpose for which it was designed.
  - Second, the GIS output can be checked against reality.
    - For example, the flood prediction model.
  - Third, the adaptations and changes that had to be made when moving from the rich picture through the GIS data model to the GIS implementation can be evaluated.

PROJECT DESIGN – AN EXAMPLE (URBAN SPRAWL GIS)

- GIS project design is identical to any plan needed to solve a problem or fill a need.
- Here the author gives an example, where urban – land use, land transformation and sprawl was examined.

1. Objective

- a. Identification of the problem:
  - Examine the land use data of different time period and find the changes in land use over time.
- b. What are the final products:
  - Hard copy maps, digital data base, statistics, reports, decision support system etc.
- c. Who is the audience:
  - Urban development authority, urban administrators, land revenue officials, politicians, environmentalists, researchers etc.
- d. Who else can use this data:
  - State level and national level policy makers and planners etc.

2. Database Design

- a. *Identification of required and optional data layers:*
  - What do we need to map urban land use – the different time period land use data.
- b. *Identification of required and optional attributes:*
  - What type and level of classification will be employed and what other data we need to support our modelling of urban expansion.
- c. *Definition of attributes and codes:*
  - What is the classification system for urban land use and how do we code that into the database.
  - In case of additional data to support the mapping and analysis is used, what would be the nature of the existing attributes and do we need to modify them.

- d. *Registration of map layers to a standard base map:*
  - What are the scales of existing database, and are those scales appropriate to our mapping scale?
  - Are the maps in the same projection and coordinate system?
  - What is the accuracy of the digitizing process that input these data?
- e. *Geographic data encoding schemes (point, line, polygon):*
  - How we will represent urban land use, land ownerships, land values, ground truth locations etc.
- f. *Allocation of storage space:*
  - Given that we will generate a digital data set consisting of many attributes, how large will be the dataset and how we manage, store and preserve these data.

3. Database Automation

- *a. Input data*
- *b. Topology creation*
- *c. Input attributes*
- *d. Building user interface (specific to the needs of users)*

4. Database Management

- *a. Creation of coordinate system:*
  - Putting all the database to a common coordinate system and projection.
- *b. Data tiling:*
  - Joining adjacent areas into database or splitting large database into tiles and develop a management strategy for tiles.
  - Tiles : physical subset of a larger geographic area which contains identical themes. Tiles are essential to reduce data load on computers allowing faster computation.

5. Data Analysis

- *a. Overlay*
- *b. Buffer*
- *c. Merge*
- *d. Recode*
- *e. Network*
- *f. Terrain modelling*
- *g. Spatial adjacency*
- *h. Data transformations*

6. Presentation of Results

- *a. Preparation of hard copy maps*
- *b. Preparation of digital database*
- *c. Preparation of summaries and statistics*
- *d. Final report and recommendations*

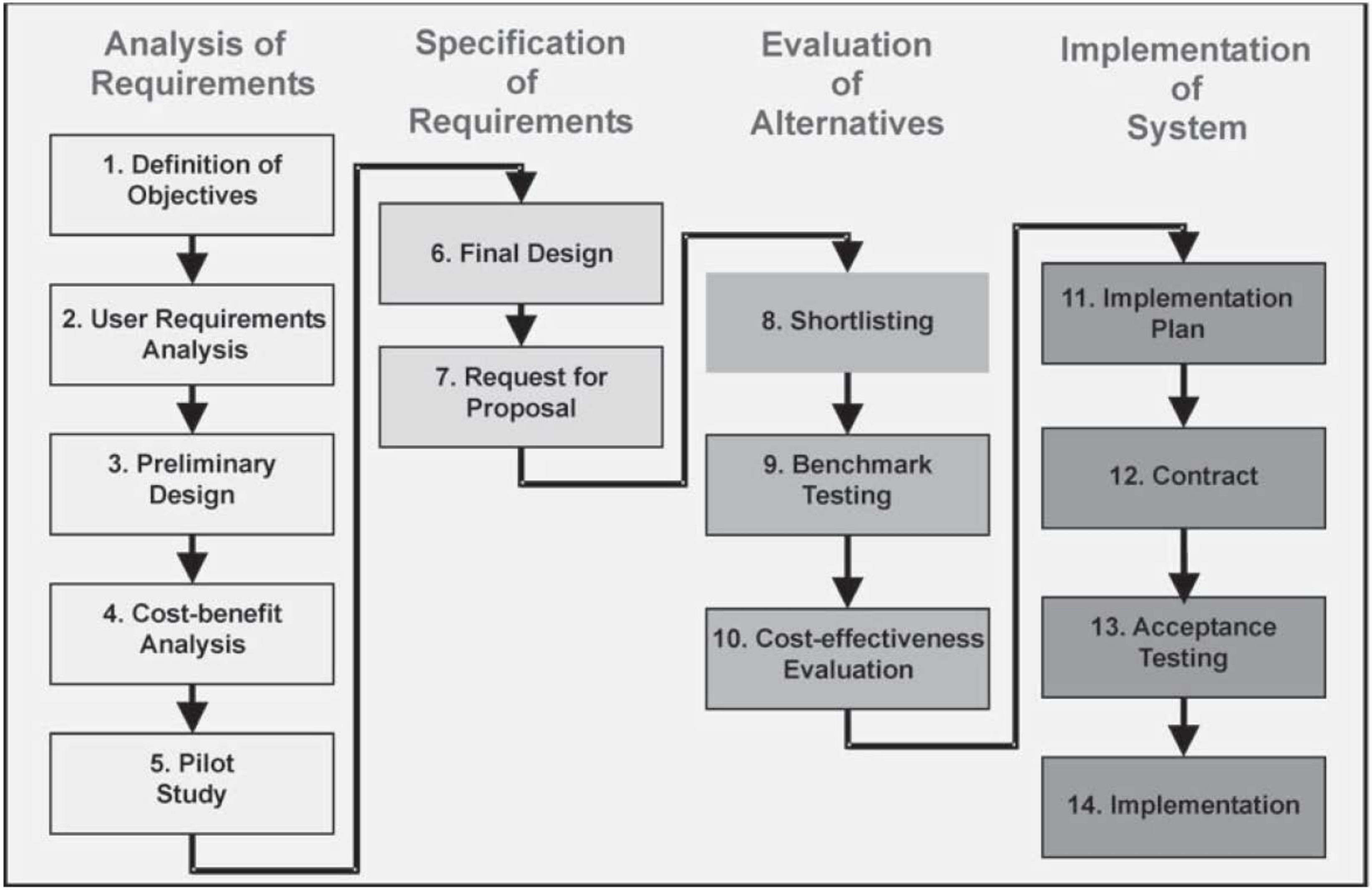


Figure 12.6: GIS acquisition process.

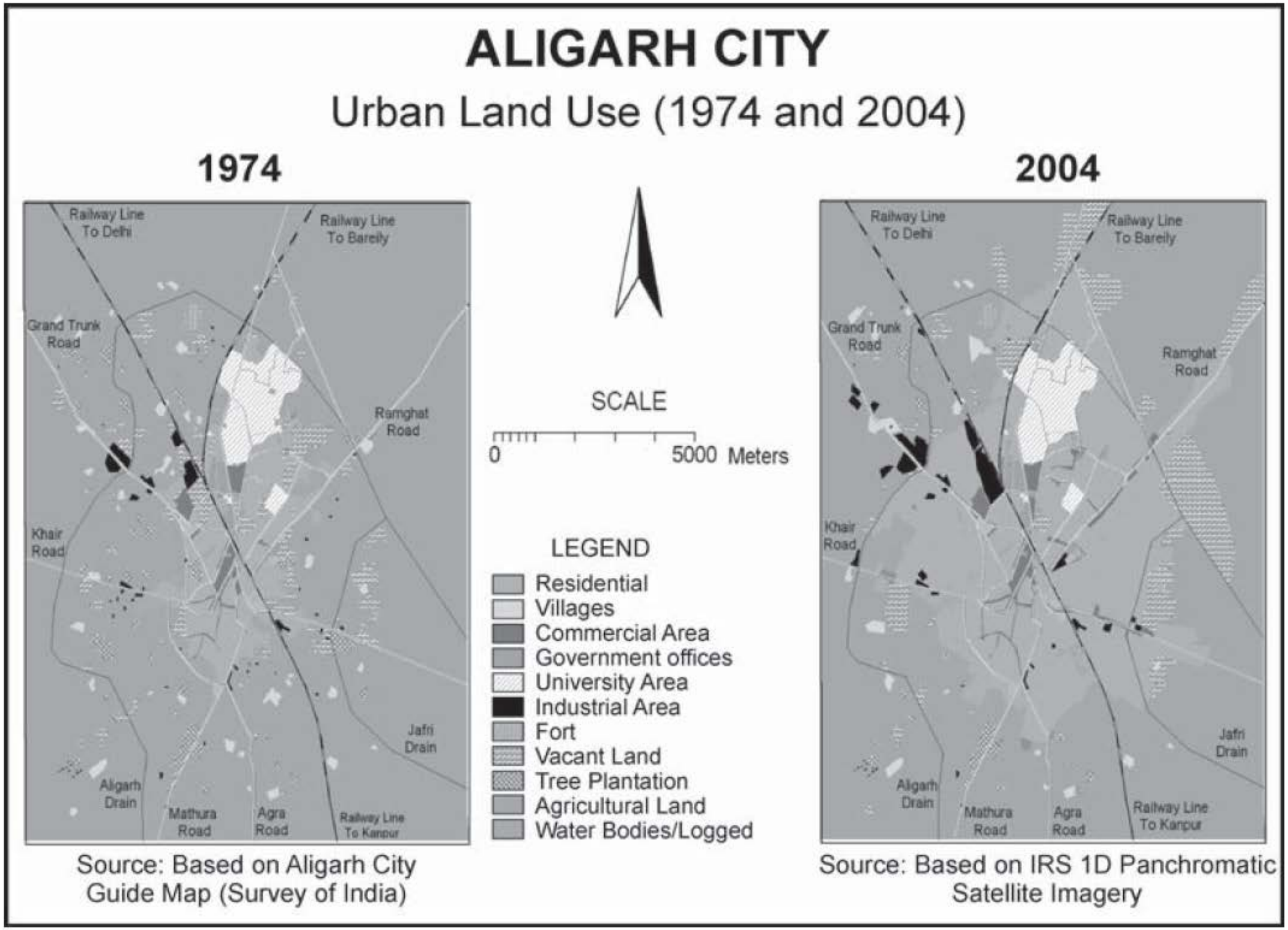


Figure 12.7: The urban sprawl GIS study, we prepared two urban land use map of Aligarh city, the map was prepared by scanning and on screen digitizing the Survey of India, City Guide Map and IRS 1D Panchromatic Satellite Imagery.

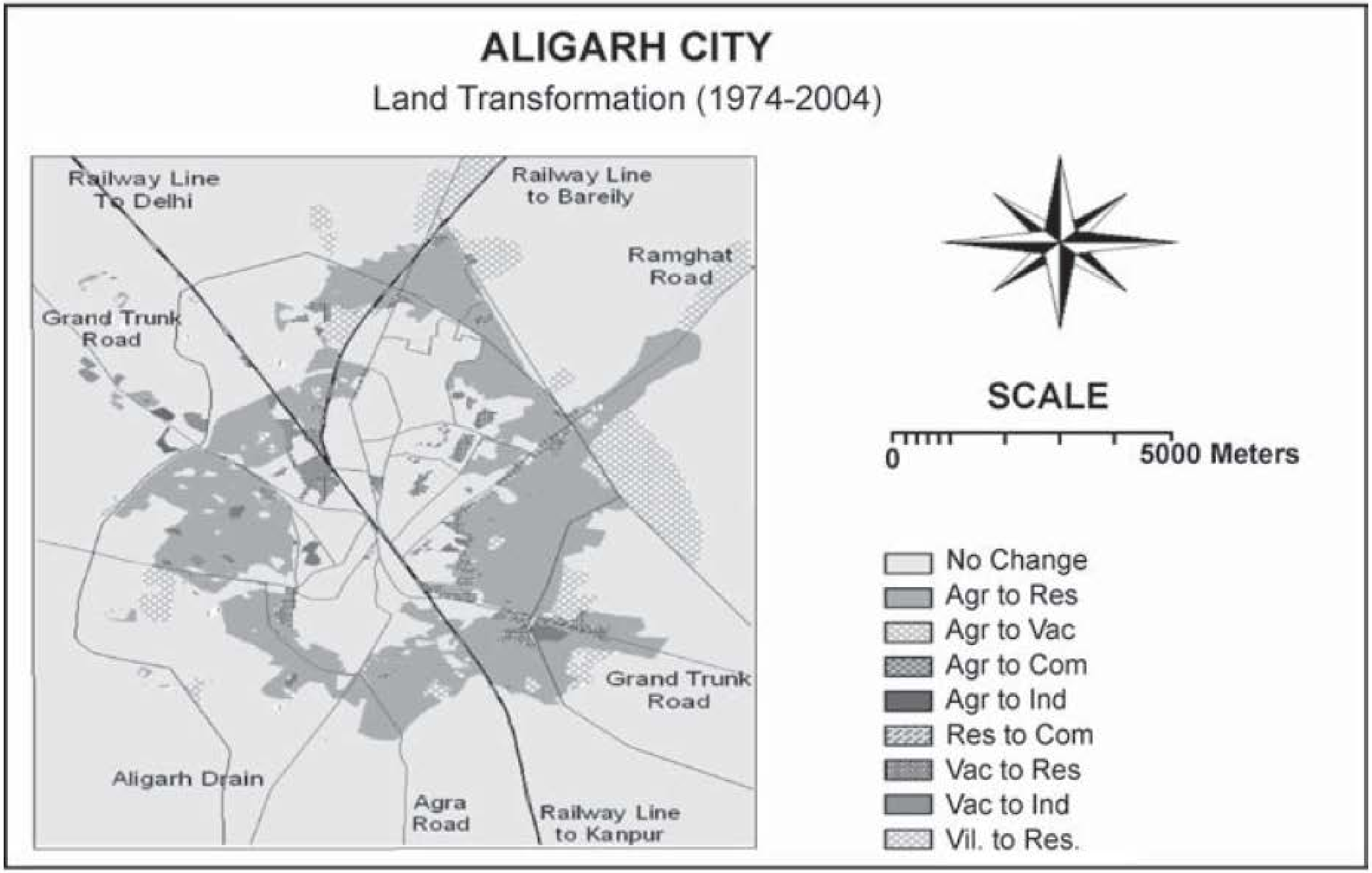


Figure 12.8: Land transformation map was prepared by overlaying the two different period land use map. The areas with no change represent areas where the same land use class exists, while other areas have been transformed from their earlier class.

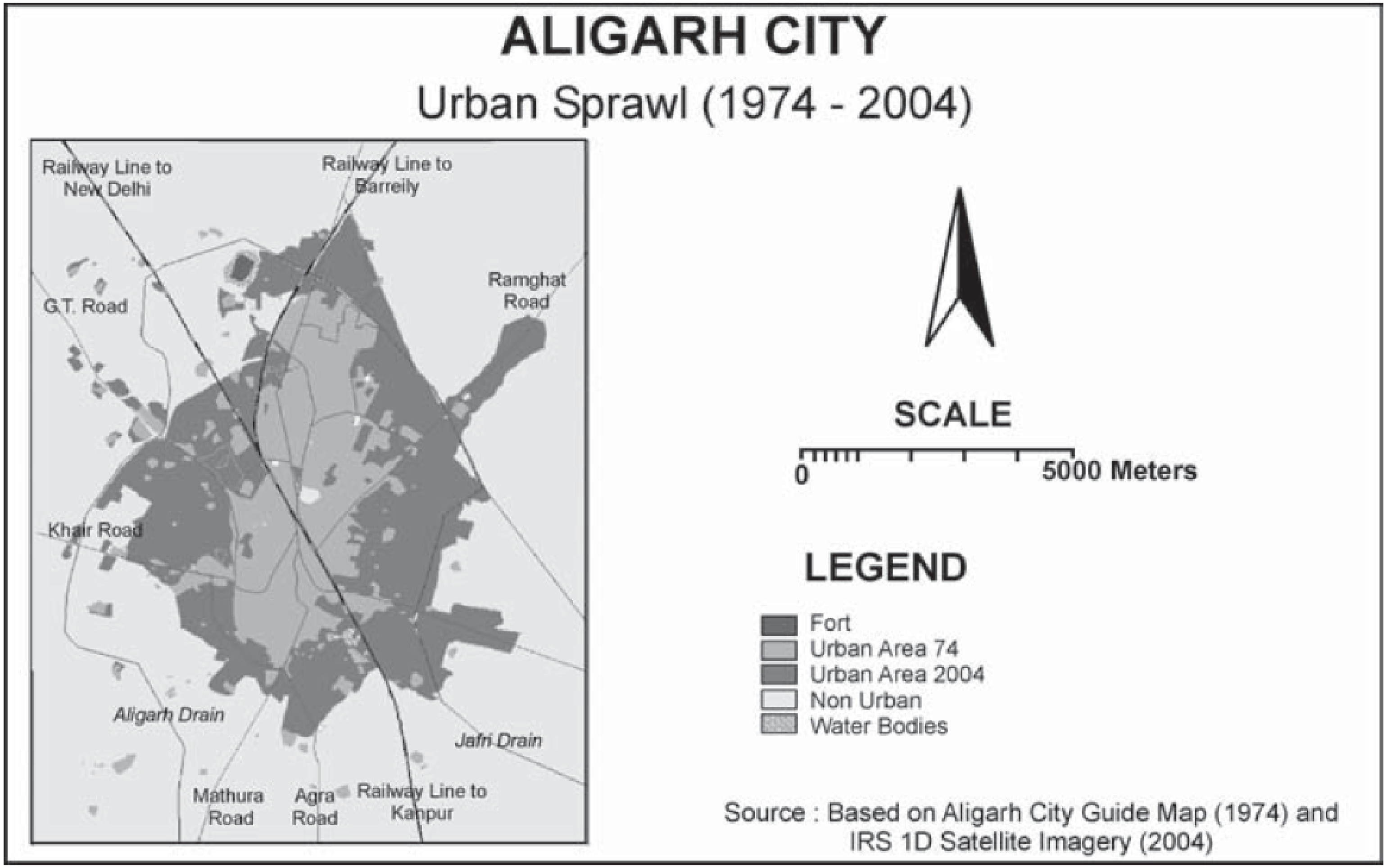


Figure 12.9: Urban sprawl map was prepared by first merging all the urban land use class, such as residential, commercial, institutional, vacant and university area and assigning them a class – 'urban area'. This reclassification of map was done for both time period data. Finally the two maps were overlaid over each other to find urban expansions.

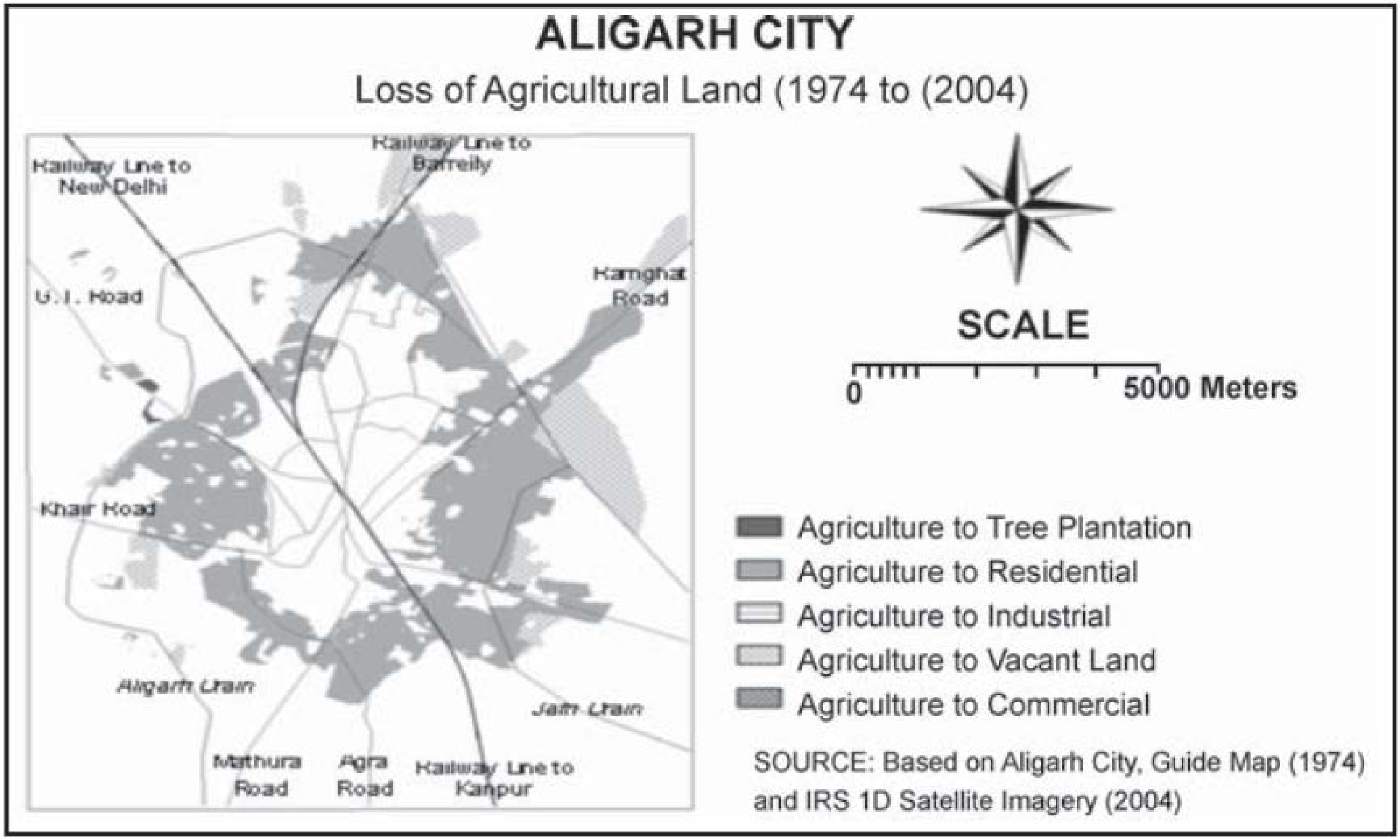


Figure 12.10: Loss of agricultural land was estimated by masking all the land transformation class except where agricultural land was transformed.

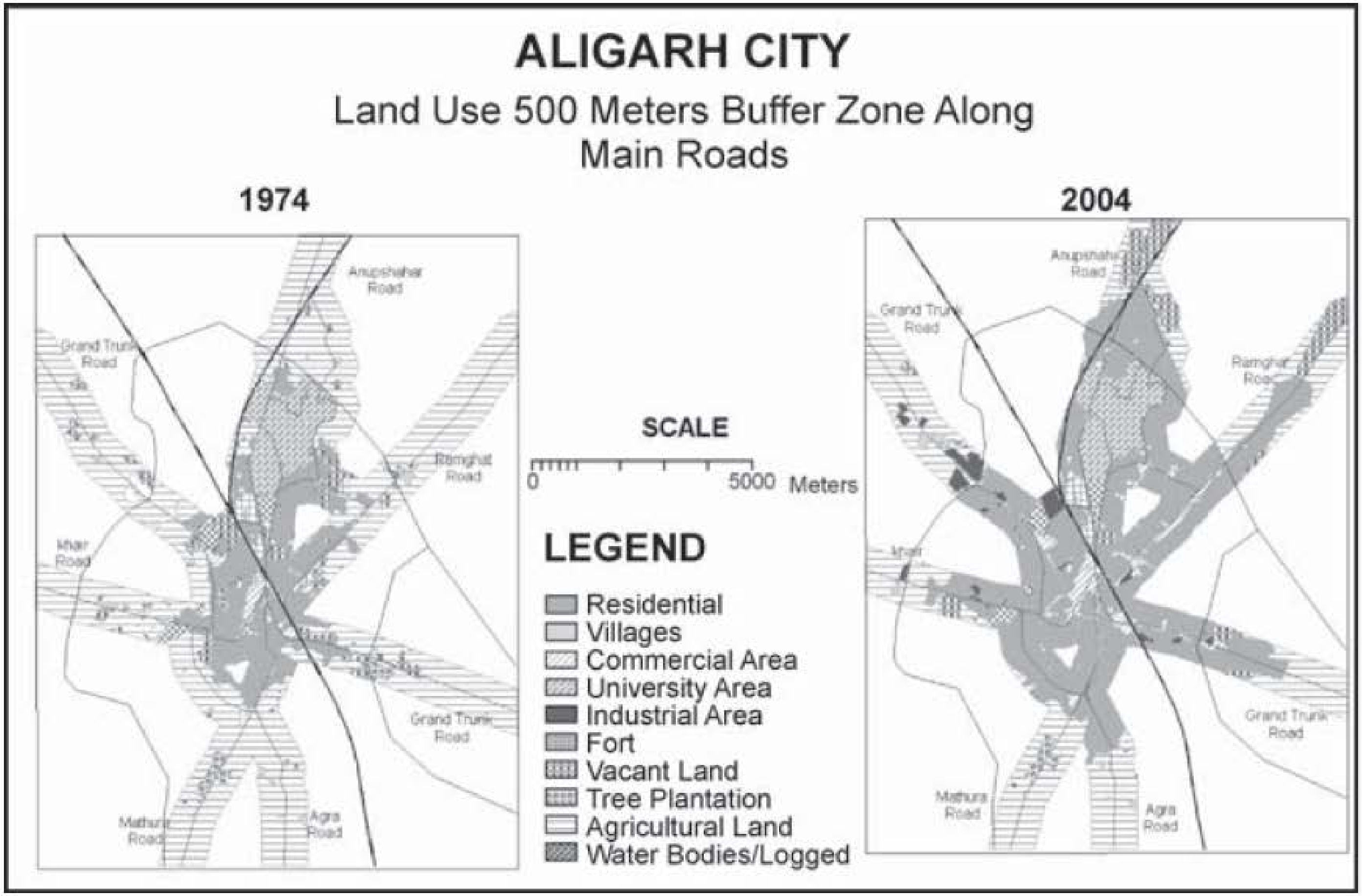


Figure 12.11: Land use buffer along the main roads of Aligarh city for 500 meters on either side of roads was prepared. First, a buffer along the roads was made and then it was overlaid on land use map.

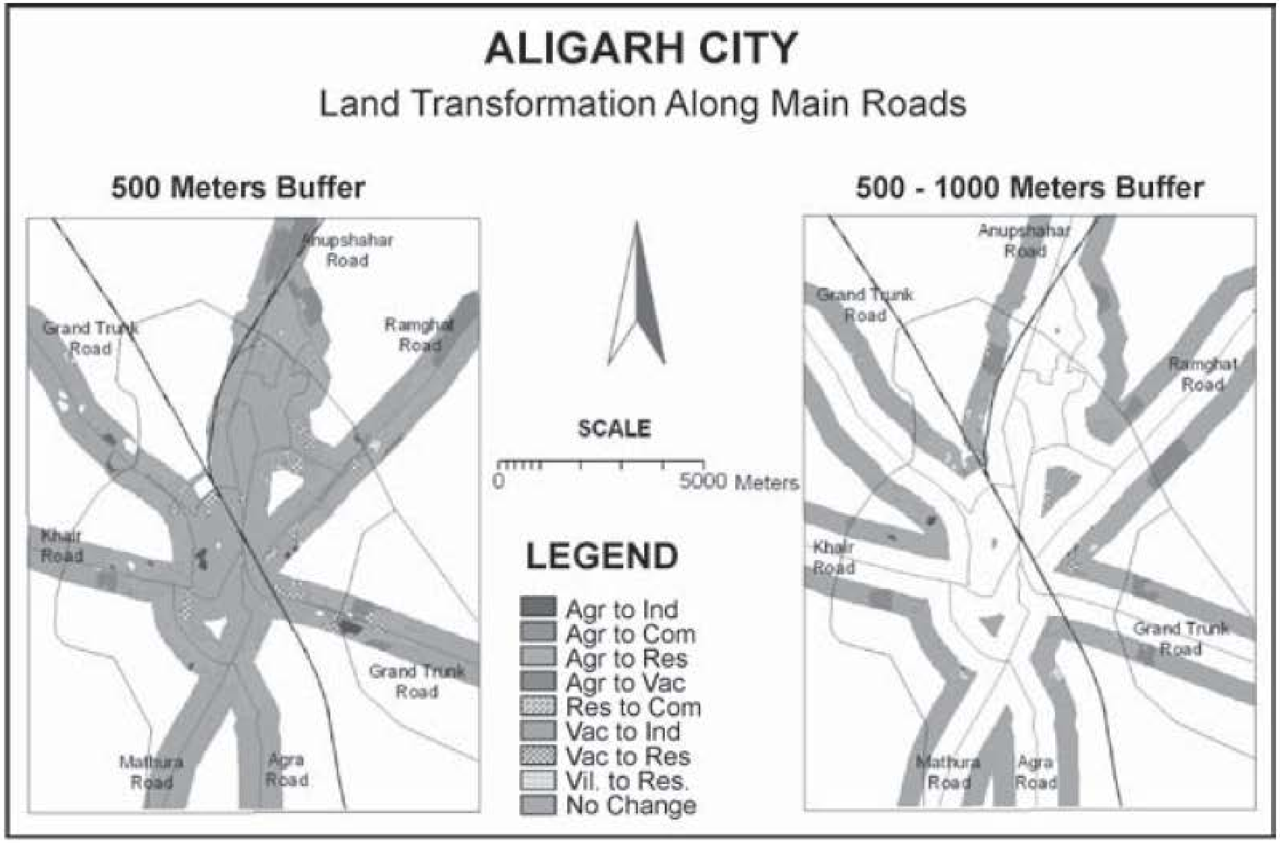


Figure 12.12: Land transformation along the main roads of Aligarh city for two separate buffer zones on either side of roads was prepared. First, two buffers along the roads (one 500 meters from the roads and another 500 to 1000 meters, excluding the first 500 meters) were made and then it was overlaid on land transformation map.