"A Study of Geographical Information System (GIS) based computerized framework to enhance the water supply system in Pune city"

A Thesis Submitted to
Tilak Maharashtra Vidyapeeth, Pune

For the Degree in
Doctor of Philosophy (Ph.D.)
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June 2013

Declaration by the Candidate

I hereby declare that the thesis entitled **"A Study of Geographical Information System (GIS) based computerized framework to enhance the water supply system in Pune city"** completed and written by me has not previously formed the basis for the award of any Degree or other similar title upon me of this or any other University or examining body.

I further declare that the material obtained from other sources has been acknowledged in the thesis.

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Place: Pune

Date: 13th June , 2013

Certificate of the Guide

This is to certify that the thesis entitled **"A Study of Geographical Information System (GIS) based computerized framework to enhance the water supply system in Pune city** "which is being submitted herewith for the award of the Degree of Philosophy (Ph.D.) under the faculty of Management of Tilak Maharashtra Vidyapeeth, Pune, is the result of original research work completed by Mrs. Vidya Sunil Gavekar, under my supervision and guidance.

To the best of my knowledge and belief the work incorporated in this thesis has not formed the basis for the award of any Degree or similar title of this or any other University or examining body upon her.

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V. Abbreviations

ADO	Activex Data Object
AFSIRS	Agricultural Field Scale Irrigation Requirements Simulation
AMR	Automatic Meter Reading
AMR	Automatic Meter Reading
ANOVA	Analysis of Variance
ARV	Annual Rate able Value
AutoCAD	Automatic Computer Aided Design
BAU	Business-as-Usual
BCM	Billion cubic meter
BIS	Bureau of Indian Standard
BISON	Bangalore Information System on Networks
BMP	Banglore Mahanagar Palika
BOT	Build Operate and Transfer
BPMC	Bombay Provincial Municipal Corporation
BWSSB	Bangalore Water Supply & Sewerage Board
CAD	Computer Aided Design
CHA	Cis Hindon Area
CPHEEO	Central Public Health and Environmental Engineering Organization
DBMS	Data Base Management System
DEMs	Digital Elevation Models
DMA	District Metered Areas
EPL	Electronic Pipe Locator
ESR	Environment Status Report
ESR	Elevated Service Reservoir
GIS	Geographical Information System
GITA	Geospatial Information and Technology Association
GNN	Ghaziabad Nagar Nigam
GPM	Gallons Per Minute
GPR	Ground Penetration Radar

GPS	Global Positioning System
GSR	Gravity Storage reservoir
GUI	Graphical User Interface
GWRAPPS	GIS-based Water Resources and Agricultural Permitting and Planning System
HLR	High Level Reservoir
HSCs	House Service Connections
IGWR	Integrated Ground Water Resource
IMS	Infrastructure Management Systems
IT	Information Technology
IWA	International Water Association's
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
KL	Kilolitre
LAN	Local Area Network
LLR	Low Level Reservoir
Lpcd	Liters per Capita per Day
Lph	Liters per Hours
LRS	Land records and survey
MFR	Minimum flow requirement
MGD	Million gallon per day
MIS	Management Information System
MJP	Maharashtra Jeevan Pradhikaran
MLD	Million Liter Per Day
MLR	Middle Level Reservoir
MSN	Municipal water supply networks
MWR	Ministry of Water Resources
NCIWRD	National Commission of Integrated Water Resources Development
NGO	Non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
NRSA	National Remote Sensing Agency
NRW	Non revenue water

NSSO	National Sample Survey Organization
NWIP	National Well Inventory Project
NWP	National Water Policy
OLEDB	Object linking and Embedding Data Base
OMP	Optimal management policy
PEST	Political, Economical, Social and Technical
PMC	Pune Municipal Corporation
PRV	Pressure Reducing Valve
PSP	Public stand post
PPP	Public private partnership
SCADA	Supervisory Control and Data Acquisition
SDSS	Spatial Decision Support System
SDTS	Spatial Data Transfer Standard
SLB	Service Level Benchmark
SOI	Survey of India
SQL	Structured Query Language
SRSACs	State Remote Sensing Application Centers
SWAT	Soil and Water Assessment Tools
SWOT	Strength, Weaknesses, Opportunities, Threats
THA	Trans Hindon Area
TMC	Thousand million cubic meters
TWD	Tampa Water Department
UFW	Unaccounted For Water
ULB	Urban Local Body
UTM	Universe Transverse Mereator
WADSOP	Water Distribution System Optimizer
WAN	Wide Area Network
WDM	Water District Metering
WGS	World Geodetic System
WHO	World Health Organization
WQI	Water Quality Index

CHAPTER 1
INTRODUCTION

"Life Started From Water, Nature Flourishes with Water,
Seasons Caused By Water, Development Progresses with Water,
Energy Formed Of Water, Health Depends On Water ,
Religion Imbibes Water ,History Made Of Water,
Trade Rides On Water ,Bio-Diversity Needs Water,
Water Sustains Life, It Brings Prosperity and Happiness"

1.1. Introduction

Water is life. It is the commonest liquid on our planet and vital to all life forms.No life form can be sustained without water on the planet. It is essential for all the important activities like drinking, food production, and industries like energy, production and manufacturing. It plays an important role in economic development and the general well being of the country.

Water is a fundamental need and an essential resource for economic activities with strong cultural and symbolic value for millions of people in developing countries. A domestic water supply is universally acknowledged as not only a basic right, but also a key development indicator. It is also widely recognized that water is vital for multiple and universally agreed-upon aspects of human well-being, such as health, economic security and freedom from drudger.

1.1.1. Technology at water Supply through Geographic Information system

A **G**eographic **I**nformation **S**ystem (**GIS**) can be defined as a system for entering, storing, manipulating, analyzing, and displaying geographic or spatial data. These data are represented by **points**, **lines**, and **polygons** along with their associated **attributes** (i.e., characteristics of the features which the points, lines, and polygons represent). For example, the points may represent hazardous waste site locations and their associated attributes may be the specific chemical dumped at the site, the owner, and the date the site was last used. Lines may represent roads, streams, pipelines, or other linear features while polygons may represent vegetation types or land use.

Geographic Information System which links computerized maps i.e. location data to computerized data base which describes attributes of a particular location. By this linkage, one can easily access location and data simultaneously. Further, maps and other data may be updated quickly and accurately with the help of GIS. The spatial data of GIS can provide information to support modelling. The strength of GIS is that it is possible to process the data sets using any type of numerical analysis procedure. The digital procedure to storing and processing spatial or image data is very much useful to analyzing the data.

A Geographic Information System is an effective tool to help protect the water quality. GIS allows us to combine location in formation in the form of longitude and latitude and descriptive tabular information. And these describe the feature being plotted. GIS and engineering design tools have long played a role in water distribution and wastewater management. The physics of water distribution requires details on the third dimension, with water following gravity's pull. The visualization of water in 3D space helps trace our networks and gives us a better handle on the efficiency of our systems. Sophisticated models allow us to discover water loss to be stemmed from ageing and leaking systems.

The GIS technology may be used for the areas in water supply.

a) Planning:-. A water utility's planning group generally performs estimates of future water demands, evaluates the transmission system utilizing these estimates, specifies the required system improvements, and structures a long term capital investment program around these improvements.

b) Engineering: - The engineering group is generally responsible for facility design, construction and mapping. For the design and construction activities, CAD software technology yields an important tool for increasing productivity and aiding the long term maintenance of as-built drawings. GIS systems are not intended to handle the details and nuances of construction documents. However, conversion and import/export of data from GIS to CAD systems and vice versa has become so simple; it can be executed with the click of a button.

c) Operation and Maintenance: - O & M performs work on geographically distributed facilities. The primary need on a daily basis is to manage work crews. The technology

required to satisfy this need is a database application that provides work order management, work scheduling, and work history logging.

d) Administration: - Administrative functions are to integrate administrative data within GIS. However, GIS technology does not give any tangible benefits for water supply administration.

A Geographic Information System[3] can be defined as a system of hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modeling, and display of spatially referenced data for solving complex planning and management problems. The main objective of a GIS is to add value to spatial data by allowing it to be organized and viewed efficiently, by integrating them with other data, by analysis, and by creation of new data.

Geographic Information Systems are designed for data pertaining to real-world features or phenomenon described in terms of location, also known as geographic data. This data must follow several criteria: they must be connected with an accepted geographical coordinate system of the Earth's surface, they must be represented on a geographic scale, and they should describe the spatial interrelations with each other which describe how they are linked together.

Definitions:

A **geographical information system (GIS)** is a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to the earth. In the strictest sense, it is a **computer system** capable of integrating, storing, editing, analyzing, sharing, and displaying geographically-referenced information. In a more generic sense, GIS is a tool that allows users to create interactive queries (user created searches), analyze the spatial information, edit data, maps, and present the results of all these operations of **Geographic Information Science.**

According to Dana Tomlin's definition, from Geographic Information Systems and Cartographic Modelling, "A geographic information system is a facility for preparing, presenting, and interpreting facts that pertain to the surface of the earth." Or

A geographic information system or GIS is a configuration of computer hardware and software specifically designed for the acquisition, maintenance, and use of cartographic data."

A GIS is "an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information".

A **Geographic Information System (GIS)**[12], also known as geospatial information system, is any system for capturing, storing, analyzing, managing and presenting data and associated attributes which are spatially referenced to Earth

A Geographic Information System (GIS) [14] is not one particular component, nor a single analysis, but rather a collection of hardware, software, data, organizations, and professionals that together help people represent and analyze geographic data.

1.2. Nature of Geographic Information

In this heading to study the fundamentals of geographic data and information. The focus is on understanding the basic structure of geographic data, and how issues of accuracy, error, and quality are paramount to properly using GIS technology. The establishment of a robust database is the cornerstone of a successful GIS.

1.2.1 Maps and Spatial Information

The main method of identifying and representing the location of geographic features on the landscape is a **map**. A map is a graphic representation of where features are, explicitly and relative to one another. A map is composed of different geographic features represented as points, lines, and/or areas. Each feature is defined both by its location in space (with reference to a coordinate system), and by its characteristics (typically referred to as attributes).

The **map legend** [6] is the key linking the attributes to the geographic features. Attributes, e.g. such as the species for a forest stand, are typically represented graphically by use of different symbol and /or color. For GIS, attributes need to be coded in a form in which they can be used for data analysis. This implies loading the attribute data into a database system and linking it to the graphic features.

For geographic data, often referred to as spatial data, features are usually referenced in a coordinate system that models a location on the earth's surface. The coordinate system may be of a variety of types. For natural resource applications, the most common are:

- **Geographic coordinates** such as latitude and longitude, e.g. 56°27'40" and 116°11'25". These are usually referred by degrees, minutes, and seconds. Geographic coordinates can also be identified as decimal degrees, e.g. 54.65°.
- **A map projection**, e.g. Universe Transverse Mercator (UTM) where coordinates are measured in meters, e.g. 545,000.000 and 6,453,254.000 normally reference to a central meridian. Easting's refer to X coordinates while Northing refer to Y coordinates.
- **A legal survey description**, e.g. Meridian, Township, Range such as the Alberta Township System, e.g. Township 075 Range 10 West of 4th Meridian.

Maps are the traditional method of storing and displaying geographic information. **A map portrays 3 kinds of information about geographic features.**

- Location and extent of the feature
- Attributes (characteristics) of the feature
- Relationship of the feature to other features.

Geography has often been described as the study of **why what is where**. This description is quite appropriate when considering the three kinds of information that are portrayed by the traditional map.

The **location and extent** of a feature is identified explicitly by reference to a coordinate system representing the earth's surface. This is **where** a feature is the **attributes** of a feature describe or characterize the feature. This is **what** the feature is.

The relationship of a feature to other features is implied from the location and attributes of all features. Relationships can be defined explicitly, e.g. roads connecting towns, regions adjacent to one another, or implicitly, e.g. close to, far from, similar to, etc. Implicit relationships are interpreted according to the knowledge that we have about the natural world. Relationships are described as **how** or **why** a feature is.

The geographic information system distinguishes between the spatial and attributes aspect of geographic features.

1.2.2. Characterizing geographic features

All geographic features on the earth's surface can be characterized and defined as one of three basic feature types. These are **points, lines,** and **areas**.

- **Point** data exists when a feature is associated with a single location in space. Examples of point features include a fire lookout tower, an oil well or gas activity site, and a weather station.
- **Linear** data exists when a feature's location is described by a string of spatial coordinates. Examples of linear data include rivers, roads, pipelines, etc.
- **Areal** data exists when a feature is described by a closed string of spatial coordinates. An area feature is commonly referred to as a **polygon**. Polygonal data is the commonest type of data in natural resource applications. Examples of polygonal data include forest stands, soil classification areas, administrative boundaries, and climate zones. Most polygon data is considered to be homogeneous in nature and thus is consistent throughout.

1.3. Data Accuracy and Quality of Geographic Information

The quality of data sources for GIS processing is becoming an ever increasing concern among GIS application specialists. With the influx of GIS software on the commercial market and the accelerating application of GIS technology to problem solving and decision making roles, the quality and reliability of GIS products is coming under closer scrutiny. Much concern has been raised as to the relative error that may be inherent in GIS processing methodologies. While research is ongoing, and no finite standards have yet been adopted in the commercial GIS marketplace, several practical recommendations have been identified which help to locate possible error sources, and define the quality of data. The following review of data quality focuses on three distinct components, data accuracy, quality, and error.

1.3.1. Accuracy

The fundamental issue with respect to data is accuracy. **Accuracy is the closeness of results of observations to the true values or values accepted as being true**.

There are two types of accuracy existing. These are **positional** and **attribute** accuracy.

- **Positional accuracy** is the expected deviation in the geographic location of an object from its true ground position. There are two components to positional accuracy. These are **relative** and **absolute** accuracy. **Absolute accuracy** concerns the accuracy of data elements with respect to a coordinate scheme. **Relative accuracy** concerns the positioning of map features relative to one another.

  Often relative accuracy is of greater concern than absolute accuracy. For example, most GIS users can live with the fact that their survey township coordinates do not coincide exactly with the survey fabric, however, the absence of one or two parcels from a tax map can have immediate and costly consequences.
- Attribute accuracy is equally as important as positional accuracy. It also reflects estimates of the truth. Interpreting and depicting boundaries and characteristics for forest stands or soil polygons can be exceedingly difficult and subjective

1.3.2. Quality

Quality can simply be defined as the fitness for use for a specific data set. Data that is appropriate for use with one application may not be fit for use with another. It is fully dependant on the scale, accuracy, and extent of the data set, as well as the quality of other data sets to be used. The recent U.S. Spatial Data Transfer Standard (SDTS) identifies five components to data quality definitions. These are as follows

- **Lineage**

The lineage of data is concerned with historical and compilation aspects of the data such as source of the data, content of the data, data capture specifications, geographic coverage of the data, compilation method of the data, transformation methods applied to the data and the use of pertinent algorithms during compilation, e.g. linear simplification, feature generalization.

- **Positional Accuracy**

The identification of positional accuracy is important. This includes consideration of inherent error (source error) and operational error (introduced error).

- **Attribute Accuracy**

Consideration of the accuracy of attributes also helps to define the quality of the data. This quality component concerns the identification of the reliability, or level of purity (homogeneity), in a data set.

- **Logical Consistency**

This component is concerned with determining the faithfulness of the data structure for a data set. This typically involves spatial data inconsistencies such as incorrect line intersections, duplicate lines or boundaries, or gaps in lines. These are referred to as spatial or topological errors.

- **Completeness**

The final quality component involves a statement about the completeness of the data set. This includes consideration of holes in the data, unclassified areas, and any compilation procedures that may have caused data to be eliminated.

1.4. Component of GIS

A GIS can be divided into five components [4]: People, Data, Hardware, Software, and Procedures. All of these components need to be in balance for the system to be successful. No one part can run without the other.

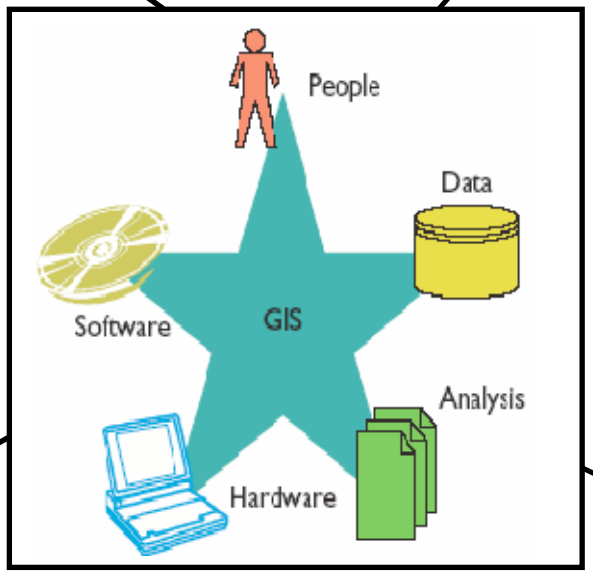
An application supported on a spatially-enabled object-relational database management systems that facilitates viewing, querying, analysis, editing of alphanumeric as well as cartographic data in a multi-user/single-user environment that has, in addition to the traditional features of an RDBMS features including, but not limited to, the following

- Maintains topological relationships between different geographical features
- Defines layers of data and links attributes with these
- Spatial Indexing
- Geographic relationships such as proximity, adjacency etc
- Spatial Querying/Overlaying
- Interfacing with other applications
- Defines layers of data and links attributes with these
- Spatial Indexing
- Geographic relationships such as proximity, adjacency etc

Software

Map user: the end consumer of a GIS.
Map builder: use map layers, make a custom map.
Map publisher: print maps
Analyst: solve geographic problems, viz. finding nearest Zonal Office.
Database administrator manage GIS databases
Database designer: build logical data models, implement physical database designs.
Developer: customize GIS software to serve the specific needs of DWB.

People Profiles



Aerial Photographs
• Satellite Imagery
• Paper/Departmental Maps
• Survey of India Maps
• Legal Records

Data Sources

All kinds of hardware equipment like digitizer, plotter, heavy duty GIS servers, GPS, workstations etc
• All networking facilities depending upon the applications deployed and

Hardware

Analytical Functions to attain the objectives desired by the DWB of the GIS such as
• Principles of Hydrology (including modeling etc)
• Geographical analysis (nearest point, distance calculation, buffering, overlaying etc for complex decision-making
• Map presentation
• Quality Assurance
• Spatially-aided functional queries of the system

Analysis

Fig.1.1.Components of GIS

1.4.1 People: GIS technology has limited value without the people who manage and develop plans for applying it 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. The identification of GIS specialists vs. end users is often critical to the proper implementation of GIS technology. This is called 'brain ware' which is equally important as the Hardware and software. Brain ware refers to the purpose and objectives, and provides the reason and justification, for using GIS.

People associated with a GIS can be categorized into: viewers, general users, and GIS specialists.

General Users are people who use GIS for conducting business, performing professional services, and making decisions. They include facility managers, resource managers, planners, scientists, engineers, lawyers, business entrepreneurs, etc.

GIS specialists are the people who make the GIS work. They include GIS managers, database administrators, application specialists, system analysts, and programmers. They are responsible for the maintenance of the geographic database and the provision of technical support to the other two classes of users.

1.4.2. Procedures

Procedures include how the data will be retrieved, input into the system, stored, managed, transformed, analyzed, and finally presented in a final output. The procedures are the steps taken to answer the question need to be resolved. The ability of a GIS to perform spatial analysis and answer these questions is what differentiates this type of system from any other information system. The transformation processes include such tasks as adjusting the coordinate system, setting a projection, correcting any digitized errors in a data set, and converting data from vector to raster or raster to vector.

1.4.3. Hardware

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

1.4.4. Software

GIS software provides the functions and tools needed to store, analyze, and display geographic information. A review of the key GIS software subsystems is provided above.

1.4.5. Data

Geographic data and related tabular data can be collected in-house, compiled to custom specifications and requirements, or occasionally purchased from a commercial data provider. A GIS can integrate spatial data with other existing data resources, often stored in a corporate Data Base Management System (DBMS). The integration of spatial data (often proprietary to the GIS software), and tabular data stored in a DBMS is a key functionality afforded by GIS.

1.5. GIS Data Types

The basic data type in a GIS reflects traditional data found on a map. Accordingly, GIS technology utilizes two basic types of data. These are:

- **Spatial Data**: Describes the absolute and relative location of geographic features. The coordinate location of a forestry stand would be spatial data. Depending on the specific content of the data, image data may be considered either spatial, e.g. photographs, animation, movies, etc.
- **Attribute Data:** Describes characteristics of the spatial features. These characteristics can be quantitative and/or qualitative in nature. Attribute data is often referred to as tabular data. the characteristics of that forestry stand, e.g. cover group, dominant species, crown closure, height, etc., would be attribute data.

1.5.1. Spatial Data Models

Traditionally spatial data has been stored and presented in the form of a map. Three basic types of spatial data models have evolved for storing geographic data digitally. These are referred to as:

- Vector: It represents features as discrete points, lines, and polygons.
- Raster: It represents the landscape as a rectangular matrix of square cells.
- Image : Images reflect pictures or photographs of the landscape.

The following fig.1.2. reflects the two primary spatial data encoding techniques. These are vector and raster. Image data utilizes techniques very similar to raster data, however typically lacks the internal formats required for analysis and modelling of the data.

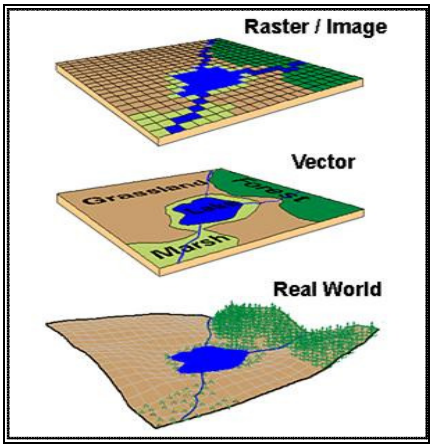


Fig 1.2: Spatial Data Model of GIS

(Source: http://bgis.sanbi.org/gis-primer/page_15.htm)

1.5.2. Attribute Data Models

A separate data model is used to store and maintain attribute data for GIS software. These data models may exist internally within the GIS software, or may be reflected in external commercial Database Management Software (DBMS). A variety of different data models exist for the storage and management of attribute data. The most common are:

- Tabular
- Hierarchical
- Network
- Relational
- Object Oriented

The tabular model is the manner in which most early GIS software packages stored their attribute data. The next three models are those most commonly implemented in database management systems (DBMS). The object oriented is newer but rapidly gaining in popularity for some applications. A brief review of each model is as follows-

- **Tabular Model**

The simple tabular model stores attribute data as sequential data files with fixed formats (or comma delimited for ASCII data), for the location of attribute values in a predefined record structure. This type of data model is outdated in the GIS arena. It lacks any method of checking data integrity, as well as being inefficient with respect to data storage, e.g. limited indexing capability for attributes or records, etc.

- **Hierarchical Model**

The hierarchical database organizes data in a tree structure. Data is structured downward in a hierarchy of tables. Any level in the hierarchy can have unlimited children, but any child can have only one parent. Hierarchical DBMS have not gained any noticeable acceptance for use within GIS. They are oriented for data sets that are very stable, where primary relationships among the data change infrequently or never at all. Also, the limitation on the number of parents that an element may have is not always conducive to actual geographic phenomenon.

- **Network Model**

The network database organizes data in a network or plex structure. Any column in a plex structure can be linked to any other. Like a tree structure, a plex structure can be described in terms of parents and children. This model allows children to have more than one parent.

Network DBMS have not found much more acceptance in GIS than the hierarchical DBMS. They have the same flexibility limitations as hierarchical databases; however, the more powerful structure for representing data relationships allows a more realistic modelling of geographic phenomenon. However, network databases tend to become overly complex too easily. In this regard, it is easy to lose control and understanding of the relationships between elements.

- **Relational Model**

The relational database organizes data in tables. Each table is identified by a unique table name, and is organized by rows and columns. Each column within a table also has a unique name. Columns store the values for a specific attribute, e.g. cover group, tree height. Rows represent one record in the table. In a GIS, each row is usually linked to a separate spatial feature, e.g. a forestry stand. Accordingly, each row would be comprised of several columns, each column containing a specific value for that geographic feature.

Data is often stored in several tables. Tables can be joined or referenced to each other by common columns (relational fields). Usually, the common column is an identification number for a selected geographic feature, e.g. a forestry stand polygon number. This identification number acts as the primary key for the table.

- **Object-Oriented Model**

The object-oriented database model manages data through objects. An object is a collection of data elements and operations that together are considered a single entity. The object-oriented

database is a relatively new model. This approach has the attraction that quarrying is very natural, as features can be bundled together with attributes at the database administrator's discretion. To date, only a few GIS packages are promoting the use of this attribute data model. However, initial impressions indicate that this approach may hold many operational benefits with respect to geographic data processing.

1.6. Features of GIS

1.6.1. Why GIS is Important?

- GIS technology is to geographical analysis what the microscope, the telescope, and computers have been to other sciences. It could therefore be the catalyst needed to dissolve the regional-systematic and human- physical dichotomies that have long plagued geography and other disciplines which use spatial information.
- GIS integrates spatial and other kind of information within a single system. It offers a consistent framework for analyzing geographical data.
- By putting maps and other kinds of spatial information into digital form, GIS allows us to manipulate and display geographical knowledge in new and exciting ways.
- GIS makes connections between activities based on geographic proximity.
    - Looking at data geographically can often suggest new insights, explanations.
    - These connections are often unrecognized without GIS, but can be vital to understanding and managing activities and resources.
- GIS allows access to administrative records - property ownership, tax files, utility cables and pipes - via their geographical positions

1.6.2. Why GIS is the best choice?

A geographic information system (GIS) is designed to visualize, store and analyze the information about the locations, topology, and attributes of spatial features. In most GIS programmes, data is stored and managed in a relational database embedded in the system. A GIS programme can perform regular database management tasks in addition to its spatial analysis capabilities. For this reason, GIS can be considered as a relational database management system with a map interface for data presentation. In GIS, location data and their map representations are dynamically linked so that any changes made in the databases are reflected immediately on its map presentation. The linkage between the map and databases makes GIS an ideal and strong tool for spatial data visualization and analysis.

1.6.3. GIS Benefits

The specific benefits resulting from using GIS are wide-ranging. Properly constructed, GIS can support for following things:

- **Analysis of spatial data:** By adding a visual component to spatial data, GIS involves the integration of many varying layers of information. This integration then allows in-depth analysis of the data, by showing the relationship between the various layers. The presentation and analysis is repeatable and allows the retention of supporting data, so that the analysis can be viewed as reliable.
- **Decision making:** Companies, elected officials and other public bodies can use GIS to gather and present relevant information for issues on which decisions must be made. Unlike traditional information systems, GIS will allow the graphic presentation of data and provide sound underpinnings for decisions made.
- **Monitoring of projects or any change in the environment:** Through the continuous update of information and the use of aerial imagery, GIS supports the presentation of temporal or time related data. By monitoring the data and imagery, GIS can tell an accurate story of change in land use and the environment; it can also monitor the progress and environmental effects of specific projects, thus leading to a better understanding of feature interrelationships.
- **Return on investment:** GIS can return value for the investment in the system. This may take the form of reduced review time, sustainable decisions which avoid appeal and lawsuits, or the successful analysis which reveals alternative solutions to area problems.

1.6.4. Functions of a Geographic Information System

- **Data Capture**

In a geographical information system data input can be described in, following point:

1. Entering the spatial data (digitizing).
2. Entering the non-spatial associated attributes.
3. Linking the spatial data to the non-spatial data.

At each stage, there should be necessary proper data verification and checking procedures to ensure that the resultant database is as free as possible from error. Entering the spatial data can

be done in numerous ways. Spatial data can be acquired from existing data in digital or paper form, or it can be collected from scratch.

- **Entering the spatial data**

There is no single method of entering the spatial data to a GIS rather there are several mutually compatible methods that can be used singly or in combination. Largely the application, the available budget and the type of data being input govern the choice of method. The type of data encountered is existing map; including field sheets and hand

flat files & spreadsheets.

A flat file or spreadsheet is a simple method for storing data. All records in this database have the same number of 'fields". Individual records have different data in each field with one field serving as a key to locate a particular record. For example, in parcel mapping, house number may be the key field in a record of name, plot size, number of floors, number of families etc. There can be hundreds of fields associated with the record.

The actual methods of data input are also dependent on the structure of the database of the geographical information system. Although in an ideal system, the user should not have to worry about whether the data are stored and processed in raster or vector form, such flexibility is still far from generally available, particularly in low budget softwares.

- **Data sources**

Data sources for creating new data include remotely sensed data (Satellite images, Aerial photographs), GPS (Global Positioning System) data, paper maps and so on. Remotely sensed data and GPS data are the primary data sources and paper maps are secondary data sources.

i. **Remotely sensed data: -** Remotely sensed data, such as digital orthophotos and satellite images, is data acquired by a sensor from distance, remotely sensed data are raster data but they are useful for vector data input. Digital orthophotos are digitized aerial photographs that have been differentially rectified or corrected to remove image displacements.

ii. **GPS Data: -** GPS data includes the horizontal location based on the geographic grid or a coordinate system. It has become a useful tool for spatial data input.

iii. **Paper Maps:-** It include all types of hard copy maps.

There are two methods of getting paper maps into the computer: digitizing and scanning. Geocoding is the term used for the conversion of analog spatial information into digital form. Digitizing on a tablet captures map data by tracing lines by hand, using a cursor and an

electronically sensitive tablet, resulting in a string of points with (x,y) values. Scanning involves placing a map on a glass plate while a light beam passes over it, measuring the reflected light intensity. The result is a grid of pixels. Finding data via the Internet can be done by performing a basic search. There are several sources for downloadable data such as:

- The Geography Network
- Data Depot
- Spatial Information Clearinghouse

Finally, if the data available does not meet the needs of the user, it can create by use of GPS, Remote Sensing, Aerial Photography, and field collection techniques.

1.6.5. GIS Capabilities

- Maximize the efficiency of decision making and planning.
- Provide efficient means for data distribution and handling.
- Elimination of redundant database-minimize duplication.
- Capacity to integrate information from many sources.
- Complex analysis/queries involving geographical reference data to generate new information.
- Update data quickly and cheaply.

1.6.6. GIS Tools

There are number of GIS software packages [13] available today. Some of them are listed below.

AGIS	GISIN	SPANS
ARC/INFO	GRAMS	STRINGS
ARCVIEW GIS	GRASS	TIGRIS
ATLAS GRAPHICS	IDRISI	TOPOLOGIC
CARIS-GIS	IGDS/DMRS	TRANSCAD
EPPL 7	IMAGE	UFOSNET
ERPAS	MAPINFO	USEMAP
FMS/AS	MIPS	VANGO
GEO-GRAPHICS	INTERGRAPH	PC ARC/INFO
GEO-MEDIA	GFIS	PMAP
GIMMS	SICAD	

1.7. Applications of GIS in Water Resources

Geographic information system software is becoming a vital tool for managing resources and better understanding of the world. GIS provides a framework for information integration, communication and collaboration, and decision support. It is used today by millions of people in government, business, energy, public safety, education, engineering, health and human services, natural resources, and water resources. Water professionals are increasingly using GIS to help better represent, understand, manage, and communicate hydrologic issues. The management of water resources requires a wide range of spatial data, from hydrographic and water distribution and collection systems, representing the status of water resources, to phenomena influencing the quality and movement of water such as terrain, climate, soils and land use.

1.7.1 Hydrologic and Water Quality Data

The new rising GIS-Hydro science has enabled governments, agencies and organizations related to water resources to change numerical tables' data to maps of spatial data that support any spatial search for relevant data. There are a lot of examples that show this jump in water management. Environmental Protection Agency is a good example, which allows the user to obtain water quality data in the form of maps and tables.

1.7.2. Spatial Interpolation

One of the most powerful aids GIS provided Hydrology [20] is the new tool for creating spatial and spatiotemporal models of land surfaces, climatic phenomena (e.g., precipitation and temperature), soil properties, and water quality from measured data. The inclusion of the ANUDEM elevation gridding procedure in ArcInfo (Versions 7.0 and higher) illustrates these new capabilities. ANUDEM and TOPOGRID (as it is called 14 in ArcInfo) take irregular point or contour data and create square-grid DEMs. The procedure automatically removes spurious pits within user-defined tolerances, calculates stream and ridgelines from points of locally maximum curvature on contour lines, and (most importantly) incorporates a drainage enforcement algorithm to maintain fidelity with a catchment's drainage network

1.7.3. Watershed Delineation

Over the last decade, a number of algorithms for the delineation of watershed and extraction of stream networks from DEMs (Digital Elevation Models) have been developed and implemented in GIS. This development in calculating topographic attributes (such as, slope,

aspect or curvature) has provided the basic required parameters for hydraulic modeling. **1.7.4. Hydrologic Modelling**

Usually as hydrologists, we present watersheds homogeneous units with terrain, soil,and cover conditions. Also, we present these parameters with their average, since considering its actual values and characteristics will consume a lot of time, money and effort. There are a lot of examples showing this efficiency of using GIS such as:

It is used ArcInfo to simulate the drainage system and assess whether the existing drainage system in a portion of the City of Asheville, North Carolina can accommodate 10 and 25 year return period design flows. Their approach used the rational method to examine contributions from surface terrain (i.e., overland flow), manmade structures (i.e., pipes and channels), and storm water intakes. The accomplishments of the Danish Hydraulic Institute [6] are particularly noteworthy in this regard. Since 1998 have embarked on an ambitious program to link their models with the ESRI (Environmental Systems Research Institute) family of GIS products. Many of their modelling systems now support GIS data transfer and one runs inside the ArcView GIS.

It was always difficult for civil engineers (especially water engineers) to divide rainfall into infiltration, runoff and internal distribution flow through watershed. Some models and techniques were made to split total runoff from infiltration, but it was really very difficult and time consuming to split usual runoff from internal runoff flow through watershed.

1.7.5. Floodplain Management

Computer models play a pivotal role in hydrologic analyses by aiding in the determination of water surface profiles associated with different flow conditions. Unfortunately, a consistent deficiency of these programmes has been their inability to connect the information describing the water profiles with their physical locations on the land surface. Often, the computed water surface elevations are manually plotted on paper maps in order to delineate floodplains. Automating this manual plotting would result in significant savings of both time and resources. Geographic information systems (GIS) offer the ideal environment for this type of work to help improve hydraulic design capabilities.

It also permits GIS to function as an effective planning tool by making hydraulic data easily transferrable to floodplain management, flood insurance rate determination, economic impact analysis, and flood warning systems. Another important application is automating floodplain

mapping to aid in the design of drainage facilities. As GIS entered to the scene, the process was automated and a significant saving of time and resources in the design process. It was an effective tool for representing the spatial variability of the watershed characteristics, integrating hydrologic and hydraulic modeling processes with GIS, and displaying an accurate floodplain map of the project site

1.7.6. Closed Basin Hydrology

Closed basins are a product of a delicate balance between inputs precipitation over the lake and runoff from surrounding land and outputs, such as evaporation and seepage outflows. This dynamic balance makes a closed-basin system extremely sensitive to climate variation. Because of their capability to integrate and analyze data from many sources, geospatial tools such as geographic information systems (GIS) are ideal for unravelling the complex mysteries of closed-basin systems. The versatility of GIS allows researchers to integrate diverse data from many scales from micro climate to regional climate variations.

1.7.7. Water Quality Assessments and Planning

One of the most important subjects in water resources is water quality assessments [15] of river systems. It covers the entire river basin and an evaluation of best management practices to minimize nonpoint source pollution. Hydrologists have linked GIS hydrologic models to facilitate model execution. GIS was preferred because it can store, manipulate, and provide spatial data for a variety of display and analytical tools, and to collect and manage input into the SWAT (Soil and Water Assessment Tool) hydrologic model.

Reservoir planning and management can be undertaken by developing a map-based surface water simulation model of any watershed, which may include rivers, lakes or both of them. There is a need for inexpensive tools that enable planners to accurately quantify the available water supply and its ability to meet the competing demands of projects. There are now some models built using GIS (ArcView) that helped to plan and simulate a model for a watershed and its reservoirs.

1.7.8. Constructing a Groundwater Simulation Model under GIS

Because most groundwater simulation models are self-contained and require a specific input data format, it is not easy to integrate an external groundwater model with a GIS. However, because GIS has the ability to manage and display spatially-referenced data, it is desirable to use GIS to support groundwater simulation models. To achieve this goal, a map-based

groundwater model is constructed within the GIS environment using the concepts of spatial database management and OOP. It is now said that building a regional groundwater flow model without the foundation of a good GIS is unthinkable. GIS has helped to organize and analyze enormous amounts of information, making the models more accurate and useful. Although GIS may not get its deserved attention or credit, a Groundwater Availability Models, or GAMs would be nothing without it. They are useful tools for assessing the possible effects of drought and pumping on water levels and spring flows.

1.7.9. Connecting the Spatially-Referenced Time-Series Data with GIS

Because most hydrologic processes are time dependent, spatially referenced time-series data are frequently encountered in simulating hydrologic events. Therefore, it is important to have an efficient data structure and data management system to handle spatially-referenced time-series data. Data structures designed during this research can be either embedded in or connected to a GIS map to manage the spatially-referenced time series data efficiently and effectively.

A well-planned and well-developed geographic information system (GIS) can significantly improve the decision-making and planning efforts of utility professionals who rely on accurate, readily available data. The use of GIS allows everyday activities, such as asset management, hydraulic modelling and land use planning, to be performed more efficiently, generating substantial savings in time and money. We are experienced in a wide variety of vendor applications, and have the expertise to perform needs assessment studies and develop customized applications to fit our client's needs.

1.8. Applications of GIS in Other Areas

As GIS has special characteristics, which differentiate it from other information system of handling spatial information i.e. information reference by its location and geographical location is central consideration in the planning process of many activities, GIS finds its primarily application as decision support tool useful where spatially referenced data is considered in the decision making process.GIS is now used extensively in government, business, and research for a wide range of applications including environmental resource analysis, land use planning, location analysis, tax appraisal, utility and infrastructure planning, real estate analysis, marketing and demographic analysis, habitat studies, and archaeological analysis. Traditionally, areas of application of GIS [10] have been

- **GIS in Natural resources management**

  Management of wildlife habitat, wild and scenic rivers, recreation resources, floodplains, wetlands, agricultural lands, aquifers, forests.

- **GIS in Central and state Government**

  Development in economy, reforms for legislation, administration, registration for the voters, emergency management.

- **GIS in Facilities management**

  Locating underground pipes and cables, balancing loads in electrical networks, planning facility maintenance, tracking energy use.

- **GIS in Land management**

  Zoning and subdivision planning, land acquisition, environmental impact policy, water quality management, Maintenance of ownership.

- **GIS in street-networks**

  Address matching, location analysis or site selection, development of evacuation plans.

- **GIS in Agriculture**

  GIS is used in a variety of agricultural applications such as managing crop yields, monitoring crop rotation techniques, and projecting soil loss for individual farms or entire agricultural regions.

- **GIS in Business**

  A GIS is a tool for managing business information of any kind according to where it's located. You can keep track of where customers are, site businesses, target marketing campaigns, optimize sales territories, and model retail spending patterns. A GIS gives you that extra advantage to make you and your company more competitive and successful.

- **GIS in the environment**

  GIS is used every day to help protect the environment. As an environmental professional, you can use GIS to produce maps, inventory species, measure environmental impact, or trace pollutants. The environmental applications for GIS are almost endless.

- **GIS in hydrology**

  GIS is used to study drainage systems, assess groundwater, and visualize watersheds, and in many other hydrologic applications.

- **GIS in mapping**

  Mapping is an essential function of a GIS. People in a variety of professions are using GIS to help others understand geographic data.

- **GIS in transportation**

  GIS can be used to manage transportation infrastructure or logistical problems, monitoring rail systems and road conditions, finding the best way to deliver your goods or services.

- **GIS in the water/wastewater industry**

  People in the water/wastewater industry use GIS with the planning, engineering, operations, maintenance, finance, and administration functions of their water and Wastewater Networks.

1.9. GIS Services

- GIS System Design and Implementation
- Enterprise Systems
- Internet Mapping Applications
- Water Distribution
- Wastewater Collection
- Storm Drainage
- Natural Gas
- Electric Transmission and Distribution
- Storm Drainage
- Source Water Protection Resource Area Mapping
- Source Water Protection Potential Threat Analysis
- Data Management
- ATV/Snowmobile Trail Mapping
- Multi-Use Trail Mapping
- Roadway Improvement
- Pavement Management Systems

- Environmental Impact Studies
- Regulatory Compliance (GASB34, CMOM)

1.10. Water

United Nations stated that water is a social and cultural good, not merely an economic commodity. Chemically, water is a compound of oxygen and hydrogen with highly distinctive physical and chemical properties. It has chemical formula: H_2O. Water is one of the eminent gifts from the Nature to the humans. Approximately, 70-75% part of Earth is occupied by water out of which merely 1% edible water can be consumed by the humans. Nevertheless, water is synonymous to life, to quench the thirst of continuously growing industrialization its over-utilization should be avoided by all. There is enough freshwater in the world – however, it is not always available in the right place or the right form. The problem is mainly of access, distribution, and optimum utilization.

More than 97 per cent of the world's water resources occur in the form of oceans and only about 2.7 per cent as fresh water bodies including both surface and ground water resources. Thus, fresh water occupies a very small portion of the total water on the Earth in which rivers and lakes do not even get counted as they contribute to a negligible amount (0.014 percent) of all fresh water. Chemically, water is H2O and since it is regarded as a universal solvent, it never exists individually in nature. Nor it is desirable in its purest form as some components like minerals; salts, etc. are required from the health point of view. If any one or more components of water exceed the prescribed limits, it causes water contamination.

1.10.1. Water balance

In its simplest definition, water loss is the difference between the total production and total consumption. However, there is a lot more to it than this, as the International Water Association's [7] (IWA) standard water balance as shown in Fig 1.3.The loss is composed of two main components: commercial (or apparent) and physical (or real). The former comprises inaccurate measurement and illegal use, whilst the latter includes leakage from the reservoirs and from the supply and distribution network, including service pipes.

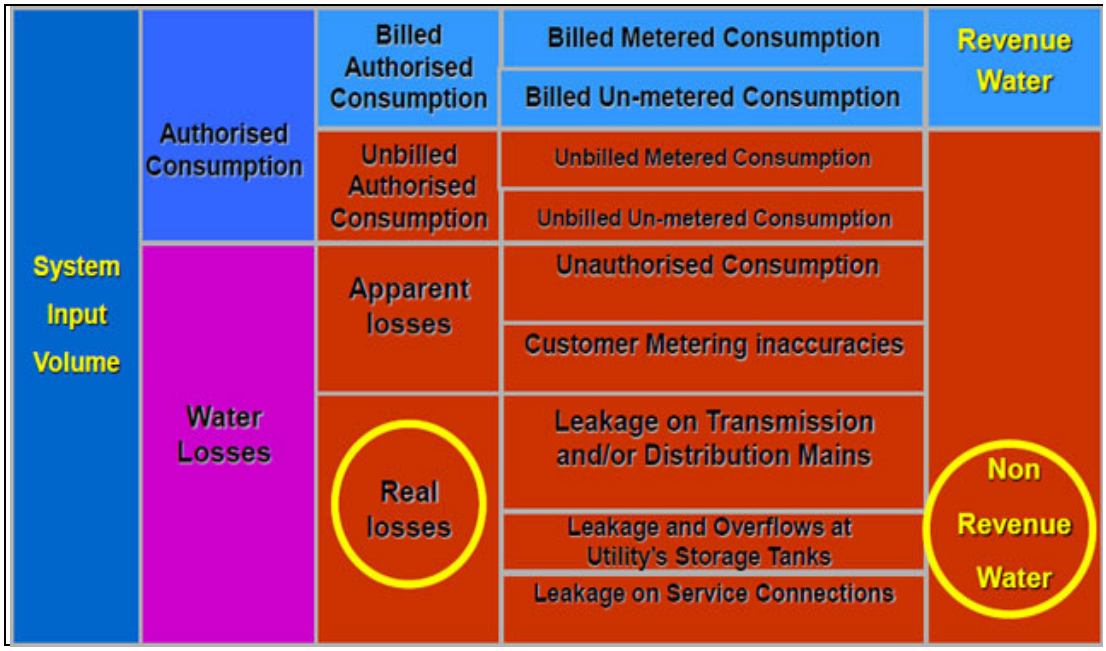


Fig 1.3: International Water Association's (IWA) Water Balance

Water balance is an accounting of all the inputs and outputs in the system under examination. The difference between supply and consumption is attributed to many reasons, whose understanding provides direction on way forward to reduce Non Revenue Water and achieve substantial cost savings.

Sometimes, water is used for authorized purposes but is not billed (e.g. municipal garden irrigation, fountains, firefighting): such consumption is termed as unbilled authorized consumption. In other cases, there might be water losses due to leakages, service reservoirs overflows or illegal withdrawals.

The water audit thus classifies the difference between system input volume and the volume that gets paid for. This brings out the system flaws which can be corrected to improve the overall efficiency and reduce the unit cost of water. This is beneficial to citizens as they get a better service at a lower cost. However, this essentially requires the knowledge of the system input volume and of the quantities received by consumers, which is possible only if we meter our supplies and consumptions.

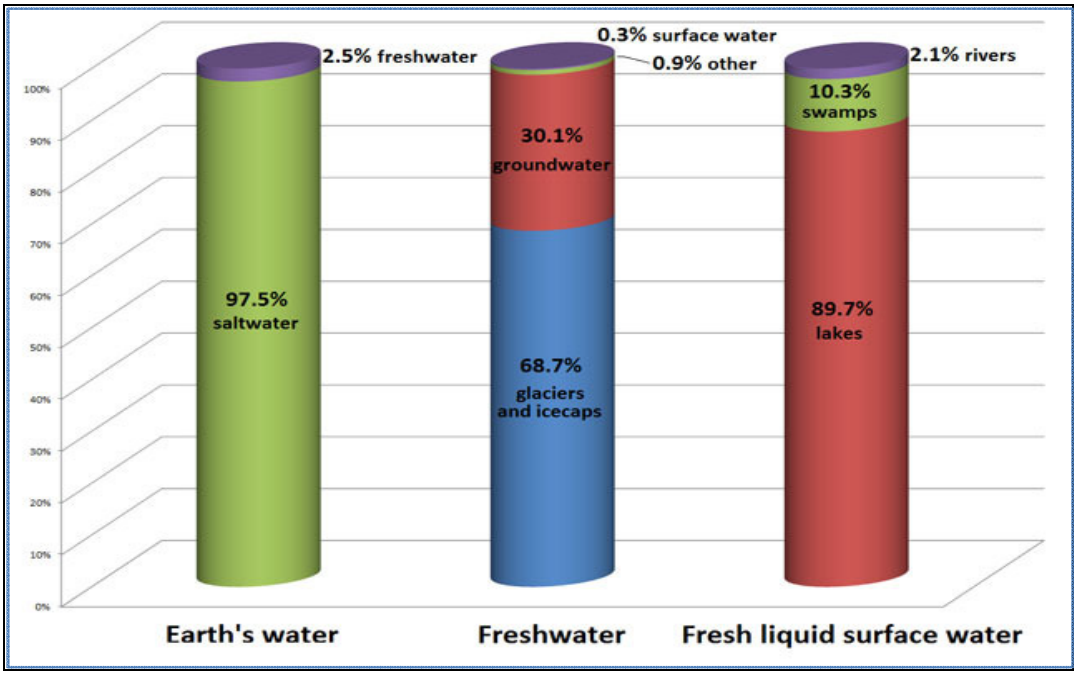
Water audits should be performed annually to help managers adjust priorities, monitor progress, define rehabilitation and replacement works, identify new areas of system losses, and establish new maintenance goals. Updating a water audit is usually cheaper than the original audit.

1.11. Global Scenario of Water

In all history, our planet contains 1,260 million of billions of cubic meter of water. In the graph 1.1 shows that water covers 71% of the Earth's surface. 96.5% of the Earth's water is found in oceans, 1.74% in glaciers and icecaps of Greenland and Antarctica, 1.7% in groundwater, around 0.01% in surface water bodies, and around 0.001% in the air as vapours, clouds, and precipitation.

Only 2.5% is freshwater, and 98.8% of that freshwater is inaccessible to humans, trapped into snow, ice, permafrost and deep groundwater. Less than 0.3% of all freshwater is in rivers, lakes, and an even smaller amount (0.003%) is contained within biological bodies and manufactured products.

Graph.1.1: Global Water Availability



Source:www.h2opune.com

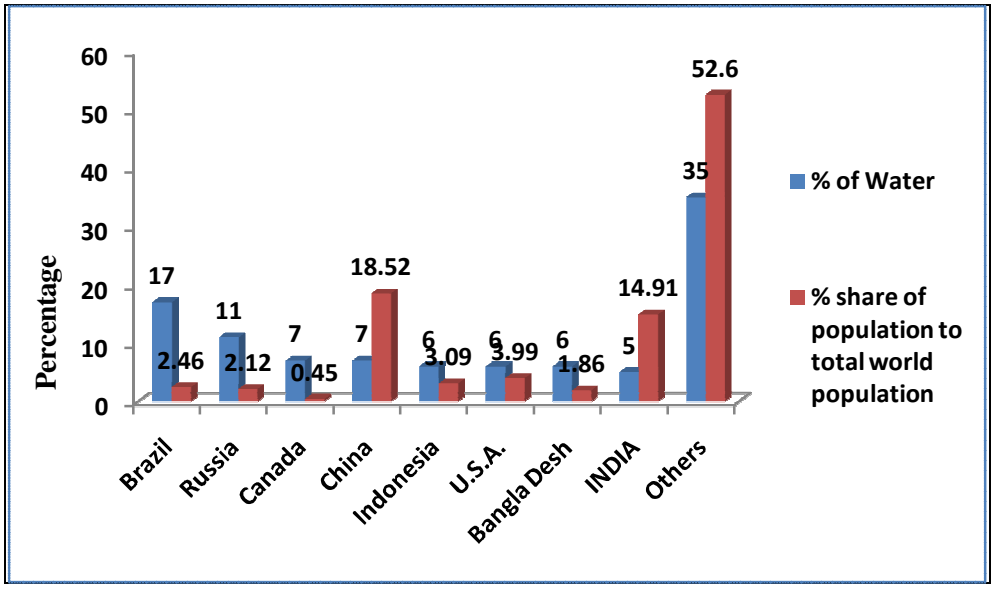
Fresh water that is continually renewed through the Global water cycle [8] is a finite natural resource in each country. The precipitation on the earth is also highly unevenly distributed as it is governed by natural factors that are favorable to some areas resulting in water surplus regions and unfavorable in other, causing water-deficit regions in the world. Following table illustrates the concept.

Table No. 1.1 Distribution of World's Water and Percentage Share of Population to total World's Population of few selected countries.

Sr.No	Country	% of Water	% share of population to total world population
1	Brazil	17	2.46
2	Russia	11	2.12
3	Canada	7	0.45
4	China	7	18.52
5	Indonesia	6	3.09
6	U.S.A.	6	3.99
7	Bangla Desh	6	1.86
8	**INDIA**	**5**	**14.91**
9	Others	35	52.6

(Source:- The Sakal Times News Paper on dated Saturday, 09-03-2013)

Graph 1.2. Distribution of World's Water and Percentage Share of Population to total World's Population of few selected countries.



From the above Graph, it is thus noted that India shares only 5 % of the total world's water and supports approximately 15 % of the total World's population. China & India and other countries together constitute 86 % of World's population but receive only 47 % of water, whereas 14 % of the world's population receives 53 % of water.

1.11.1 Global Demand for Water:

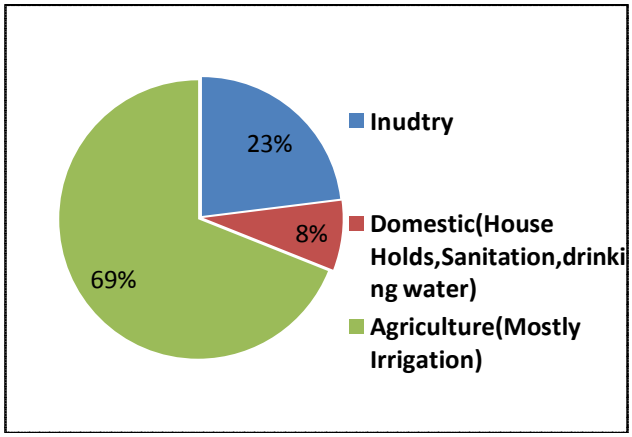
The global market for water is estimated at approximately $400 billion per year. The Global demand for water is expected to grow around 8-10%.

- The annual water volume used by industry is estimated to rise from 952 km3/year in 2009 to an estimated 1170km3/year in 2025. In 2025, the industrial component is expected to represent about 24% of total fresh water withdrawal.
- More than one billion people on the earth already lack access to fresh drinking water. If current trend persists, by 2025, the demand for fresh water is expected to rise to 56% more than the amount that is currently available.
- More people mean increased water use and less available on a per capita basis. In 1989, there was some 9000 cubic meters of fresh water per person available for human use. By 2000, those figures had dropped to 7800 cubic meters and are expected to plummet to 5,100 cubic meters per person by 2025, when global population is projected to reach 8 billion.

1.11.2. Global Uses of Water:

Agriculture (Mostly Irrigation) - 69%
Industry - 23%
Domestic use (household, drinking water, sanitation) - 8%

Graph.1.3: Global uses of water



(Source:www.unwater.org)

These global averages vary a great deal between regions.

1.12. Indian Scenario of Water

Water [16] is the most important renewable and finite natural resource, since it is required for agriculture, industry and domestic purposes. In India, there is a mismatch between the

endowment of natural resources and the population to be supported. While our country accounts for 2% of the world's geographical area and 4% of its fresh water, it has to support 17% of the world's population and 15% of its livestock. The status of fresh water availability in India is even more serious than the global figures indicate. The per capita availability of fresh water in the country, which was a healthy 5,177 cubic meters in 1951, has dropped to 1,869 in 2001. It is estimated to further decline to 1,341 by 2025 and 1,140 by 2050.The demand by 2050 is likely to reach the level of the full utilizable quantum. The following figure shows the water availability on the earth and in India.

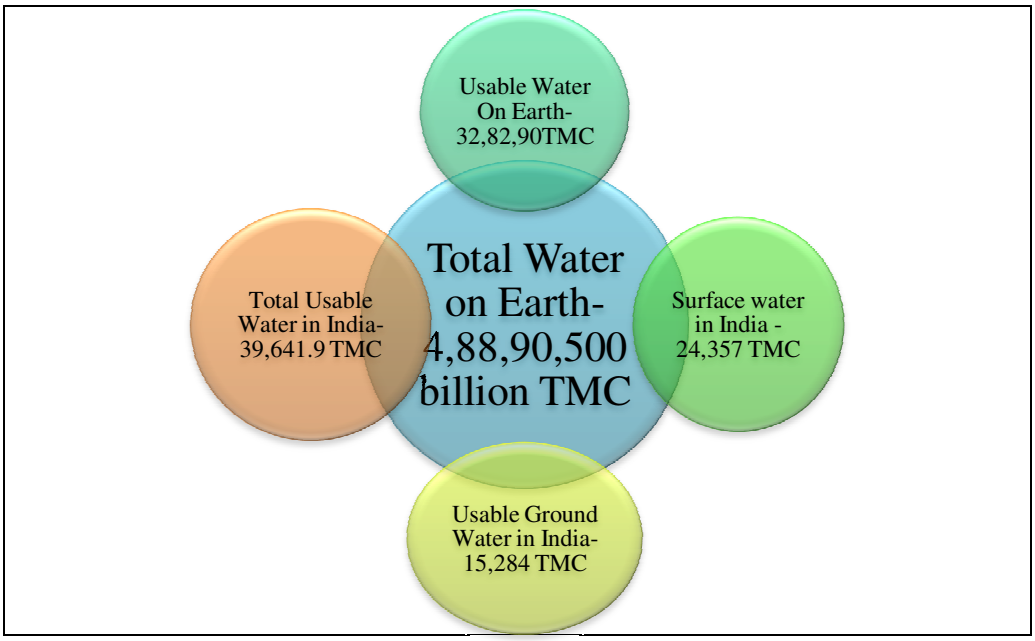


Fig.1.4 .Water Availability on Earth and in India

(Source:- The Sakal Times News Paper on dated Saturday, 09-03-2013)

The current population on the earth is around 7.7 billion. By 2030, it will be between 9-10 billion. Lakhs of underprivileged people across the globe get even less than 20 liters of water per day. Forty six percent population of the world does not get tap water. By the year 2025,180 corer people would live in water scarce regions. Every year world population increases by 8.3 corer. In the next 20 years, per head water availability will reduce by 30 percent.

1.12.1. Current Scenario of Water in Maharashtra:

Water availability and distribution of surface water in Maharashtra

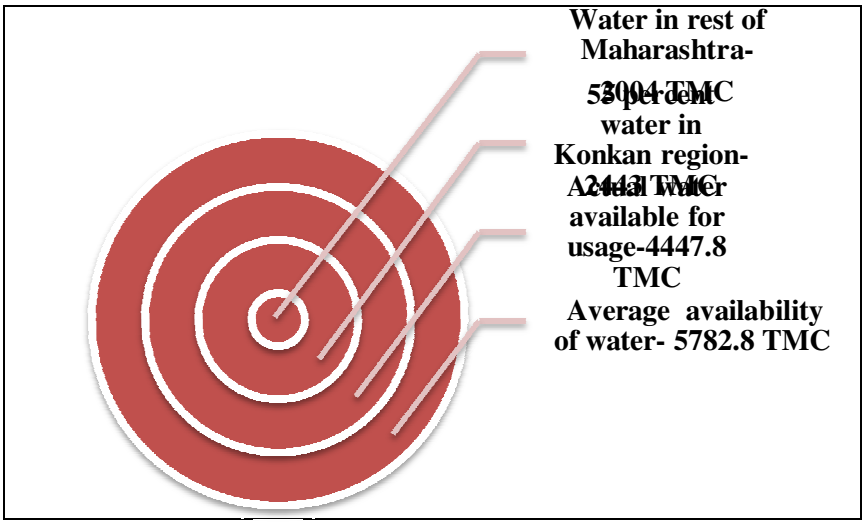


Fig. 1.5. Current Scenario of Surface Water in Maharashtra

(Source:- The Sakal Times News Paper on dated Saturday, 09-03-2013)

The above figure shows the current scenario of surface water in Maharashtra. It indicates that, Average water availability of water is 5782.8 TMC. Out of actual usage of water is 4447.8 TMC. Actual availability of surface water is 55 percent available in Kokan region and remaining 45 percent rest of Maharashtra.

- **Industrial Water Usages**

Due to urbanization and industrialization, water reserved for agriculture is being diverted towards industries and fulfilling the need of drinking water of cities. Water is also the raw material for industries involved in producing mineral water, packaged water, wine , pharmaceuticals etc. Hence, there is an increasing demand of water**.**

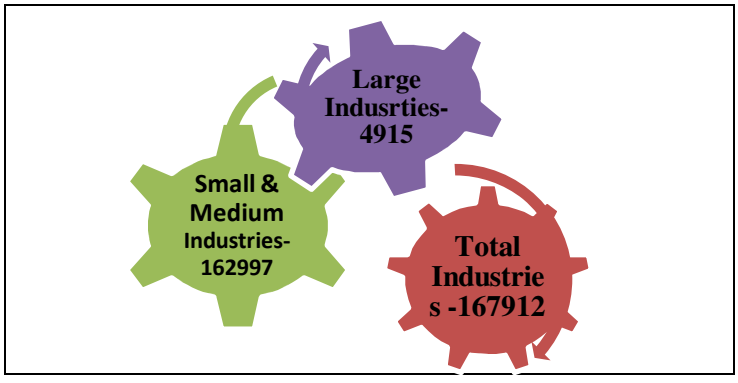


Fig: 1.6.Distribution of Industries in Maharashtra (Source:- The Sakal Times News Paper on dated Saturday, 09-03-2013)

Table No. 1.2.Distribution of Division wise number of industries under the MIDC

Division	No. of Industries
Mumbai & Konkan	11125
Pune	9272
Nashik	6135
Aurangabad	4577
Nagpur	2687
Amravati	1589
Total	**35385**

(Source:- The Sakal Times News Paper on dated Saturday, 09-03-2013)

Table No.1.3. Requirement of Water for Industries in Maharashtra

Requirement of Water for Industries	194 Cr Liter per day
Present use of Water	128.6 Cr Liters per day
The number of water schemes of MIDC	69
Dams of MIDC	5

(Source:- The Sakal Times News Paper on dated Saturday, 09-03-2013)

Table No. 1.4.Water Resources for Industrial use in Maharashtra

Irrigation Projects	65%
Projects owned by MIDC	34%
Other	1%

(Source:- The Sakal Times News Paper on dated Saturday, 09-03-2013)

- **Wells and Tube Wells in Maharashtra**

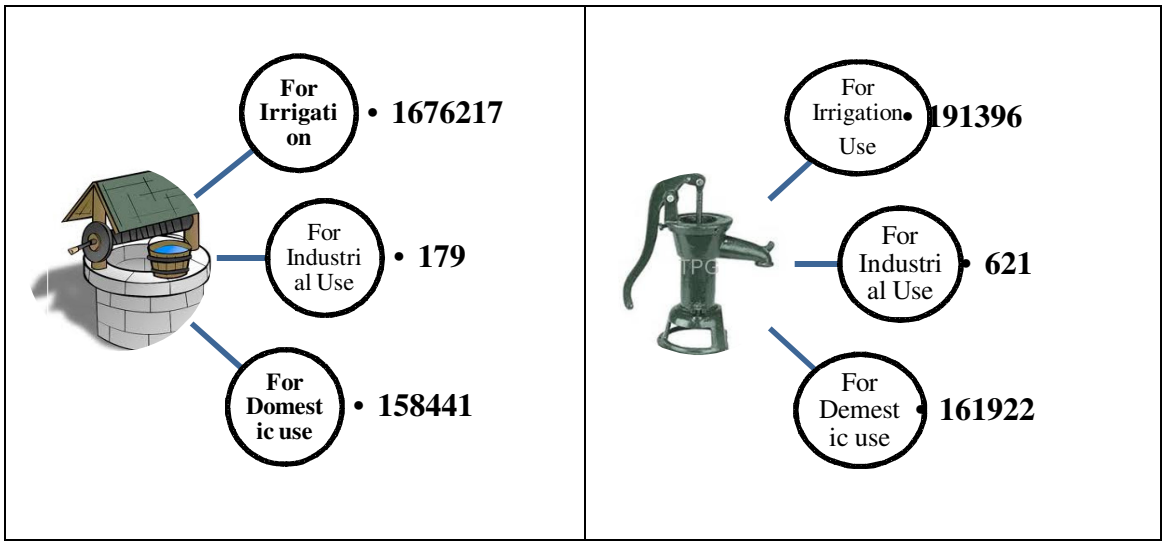


Fig.1.7. Statistics of Well and Tube well in Maharashtra

(Source:- The Sakal Times News Paper on dated Saturday, 09-03-2013)

Acute shortage of drinking water is probably the most important issue in India. Millions of villages in the country have become water-scarce or no-source villages. The National Water

Policy (NWP) gives highest priority to drinking water but despite more than five decades of planning, much lesser than the expected has been achieved. More than three-fourth of the rural population still does not have proper water supply systems. In the urban areas, quantities delivered are inadequate and the service is unreliable, mostly intermittent, resulting in wastage of water. Although, on an average, the country gets enough rainfall each year, it is unequally distributed. As a result, same region could be affected by drought in one year and by flood in another.

Continuous droughts affect many parts of the country due to both natural and man-made reasons. Natural reasons of droughts are wide variations in rainfall and inequitable distribution of perennial rivers in various parts of the country. Man-made reasons are improper water management like excessive groundwater extraction, inefficient use and wastage of water, absence of rainwater harvesting, etc. This has resulted in a sharp decline in the ground water table, which in turn, has increased salinity in coastal areas. On the other hand, several regions in the country remain flood affected every year and measures for flood plan zoning and disaster preparedness are inadequate.

Broadly, there are two kinds of uses of water- abstractive use and in-stream use. The former includes domestic, industrial and agricultural uses, while the latter refers to hydropower, fisheries, navigation, community bathing and washing and cattle bathing and watering. Ground water exploitation is divided into three categories. Category I consists of lesser than 65 per cent, category II lies between 65 to 85 per cent and category III consists of more than 85 per cent of exploitation of the annual utilizable groundwater resources. In respect of quantity, India has a precipitation of about 4000 km^3 but most of it is lost through evaporation, transpiration and surface flow and only 700 km^3 can be put to any beneficial use. Taking into consideration all inland resources (rivers, canals, reservoirs, tanks, lakes and ponds, derelict water and brackish water), Orissa has the largest area of water bodies followed by Andhra Pradesh. According to the Ministry of Water Resources (MoWR) in 2001-02, nearly 25 billion cubic meters (BCM) was used for domestic, 460 BCM for irrigation and 40 BCM for industry purposes, in the country. Inefficient use and misuse of water in all sectors are the major problems in the country.

1.12.2. Norms for Water Supply

Water is basic to survival and well-being and, therefore, adequate quantity of water of potable quality must be provided to all. Water needs may be broadly classified into domestic and non-domestic. Domestic needs include water for drinking, cooking, washing and cleaning (utensils, clothes, house) and for use in water closet. To this, other requirements such as watering plants/garden and washing personal vehicle etc. may be added. Non-domestic use of water would include industrial, commercial and institutional uses, and water used for public purposes such as fire fighting, street washing, and watering trees/public gardens etc.

- **CPHEEO Norms**

Norms for water supply suggested by the Central Public Health and Environmental Engineering Organization (CPHEEO) are given in Table No. 1.1. These norms are to be followed by Indian cities and towns while designing water supply schemes.

Table No.1.5 Norms of Water Supply Levels for Designing Schemes

Sr.No.	Classification of towns/cities	Recommended maximum water supply levels (lpcd)
1	Towns provided with piped water supply but without sewerage system	70
2	Cities provided with piped water supply where sewerage system is existing/contemplated	135
3	Metropolitan and Mega cities provided with piped water supply where sewerage system is existing/contemplated	150

Note: i) In urban areas, where water is provided through public stand posts, 40 lpcd should be considered.
Figures exclude "Unaccounted for Water (UFW)" which should be limited to 15%.
Figures include requirements of water for commercial, institutional and minor industries. However, for bulk supply such establishments should be assessed separately with proper justification.
(Source: Ministry of Urban Development, Central Public Health and Environmental Engineering)

- **Ninth Five Year Plan Norms**

The norms for water supply followed by the Eighth Five Year Plan which have also been maintained for the Ninth Five Year Plan are as follows:

- 125 lpcd for urban areas where piped water supply and underground sewerage systems are available.
- 70 lpcd for urban areas provided with piped water supply but without underground sewerage system.

- 40 lpcd for towns with spot-sources/stand posts. One source for 20 families within a maximum walking distance of 100 meters.

These norms are marginally lower than the norms suggested by CPHEEO

- **Per Capita Water Supply in India**

Drinking water standards have been formulated and updated time to time, as more and more knowledge about effect of various parameters in drinking water is acquired. Drinking water standards formulated by Bureau of Indian Standards (BIS) and also guidelines of Central Public Health and Environmental Engineering Organization (CPHEEO), as recommended by the World Health Organization (WHO) are given at **Annexure 1** and **Annexure 2** respectively.

Per Capita Water Supply per day is arrived normally including the following Components:

- Domestic needs such as drinking, cooking, bathing, washing, flushing of toilets, gardening and individual air cooling.
- Institutional needs.
- Public purposes such as street washing or street watering, flushing of sewers, watering of public parks.
- Minor industrial and commercial uses.
- Fire fighting.
- Requirements of live stock
- Minimum permissible Unaccounted for Water (UFW)

Water supply levels in liters per capita per day (lpcd) for domestic & non domestic purpose and Institutional needs, as recommended by CPHEEO for designing water treatment schemes are given at Table No.1.6. The water requirements for institutions should be provided in addition to the provisions indicated for domestic and non-domestic, where required, if they are of considerable magnitude and not covered in the provisions already made.

Table No.1.6: Per Capita Water Supply Levels for Design of Scheme

S.No.	Classification of Towns / Cities	LPCD
A.	**Domestic & Non- Domestic Needs**	
1.	Towns provided with piped water supply but without sewerage system	70
2.	Cities provided with piped water supply sewerage system is existing / contemplated	135
3.	Metropolitan and Mega cities provided with piped water supply where sewerage system is existing/contemplated	150

B.	**Institutional Needs**	
1.	Hospital (including laundry)	
	a) No. of beds exceeding 100	450 / bed
	b) No. of beds not exceeding 100	340 / bed
2.	Hotels	180 / bed
3.	Hostels	135
4.	Nurses home and medical quarters	135
5.	Boarding schools / colleges	135
6.	Restaurants	70 / seat
7.	Air ports and sea ports	70
8.	Junction Stations and intermediate stations or express stoppage (both railways and bus stations)	70
9.	Terminal stations	45
10.	Intermediate stations (excluding mail and express stop)	45
11.	Day schools / colleges	45
12.	Offices	45
13.	Factories(could be reduced to 30 where no bathrooms)	45
14.	Cinema, concert halls and theatre	15

(Source: Annexure-1)

One of the working groups of the National Commission for Integrated Water Resources Development Plan on the Perspective of Water Requirements also deliberated regarding the norms for urban and rural water supply. In their view, a variety of factors affect water use in rural and urban areas. These include population size of habitat, economic status, commercial and manufacturing activities. A host of other factors like climate, quality of life, technology, costs, conservation needs etc. also influence these requirements. Desirable and feasible norms can be established by reviewing past performance and modifying these on the basis of equity and sustainability. Since, fresh water resources are very unevenly distributed around the world; it is not surprising that the per capita water supply also varies widely ranging from 50 lpcd to 800 lpcd. Keeping in view the above factors, the Working Group of the National Commission for integrated Water Resources Development Plan, as a final goal, has suggested the norms for water supply as 135 lpcd for urban areas.

Consumption pattern /Per Capita Consumption (Liters per person per day):

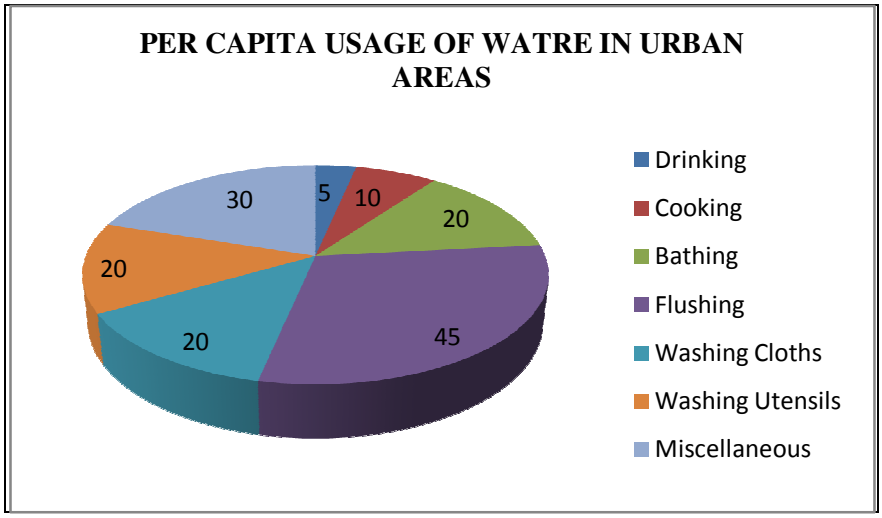
The following Table No.1.7.shows standard per capita water consumption/requirement

Table No.1.7: Standard Per capita water Consumption/requirement

Sr.No.	Activity	No. of Liters
1	Drinking	5
2	Cooking	10
3	Bathing	20
4	Flushing	45
5	Washing Cloths	20
6	Washing Utensils	20
7	Miscellaneous	30
Total		**150**

(Source:-Sakal Times News Paper, 9th March, 2013)

Graph. 1.4: Standard Per capita water consumption/requirement



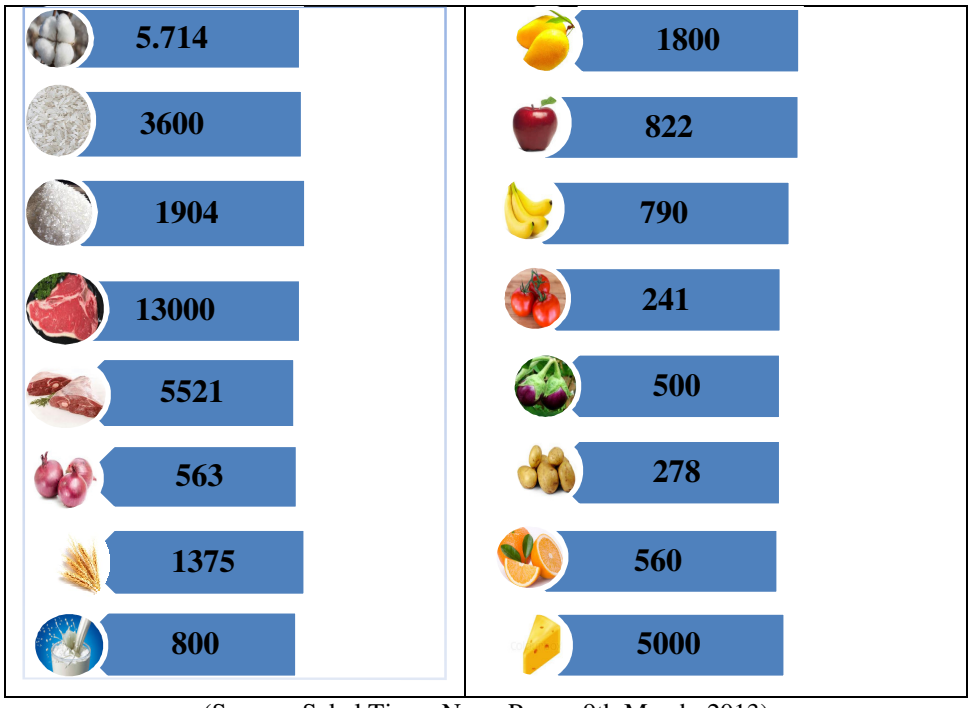
2. Virtual Water

The water used in the production of an eatable or product, directly or indirectly is known as Virtual Water.

Example:-To make a chapatti, we need wheat. The total water used for a chapatti includes, the water used for growing the wheat required or one chapatti, water used while making the chapatti and water required to make the fuel used to roast the chapatti.

Water needed to produce one kg to following products (Liters)-

Table No.1.8: Virtual Water for to produce one Kg to following products (In liters)



(Source:-Sakal Times News Paper, 9th March, 2013)

1.13. Water Crisis

1.13.1 A Global Scenario:

Water scarcity describes the relationship between demand for water and its availability. Water scarcity can be determined as both the availability of water and its consumption patterns. There are several factors that influence the availability and consumption of water. Hence, the definition for the availability and consumption is different in various regions. Because of these factors, water scarcity will vary widely from country to country and from region to region within a country. Therefore, it is little difficult to adopt a global figure to indicate water scarcity but simply we can say water availability of less than 1000 m^3/capita as a water scarcity.

Rapid population growth, combined with industrialization, urbanization, agricultural intensification and water-intensive lifestyles is resulting in a global water crisis. About 20 per cent of the population currently lacks access to safe drinking water, while 50 per cent lacks access to a safe sanitation system. Falling water tables are widespread and cause serious problems, both because they lead to water shortages and, in coastal areas, to salt intrusion. Both contamination of drinking water and heavy pollution of rivers, lakes and reservoirs are common problems throughout the world. The world supply of freshwater cannot be increased.

More and more people are becoming dependent on limited supplies of freshwater that are becoming more polluted. Water security, like food security, is becoming a major national and regional priority in many areas of the world.

1.13.2. Indian Scenario:

India [17] is facing a serious problem of natural resource scarcity, especially that of water in view of population growth and economic development. Water being a prime natural resource, a basic human need and a precious national asset, its use needs appropriate planning, development and management. The thirst of water for India's rapid development is growing day by day. In spite of adequate average rainfall in India, there is large area under the less water conditions/drought prone. There are lot of places, where the quality of groundwater is not good. Another issue lies in interstate distribution of rivers. Water supply of the 90% of India's territory is served by inter-state rivers. It has created growing number of conflicts across the states and to the whole country on water sharing issues. Some of the major reasons behind water scarcity are:

- Population growth and Food production (Agriculture).
- Increasing construction/ infrastructure development Activities.
- Massive urbanization and industrialization throughout the country.
- Climatic change and variability- Depleting of natural resources due to changing climate conditions (Deforestation etc.).
- Lack of implementation of effective water management systems.

❖ **Future Water EMI:-**

Due to water crises, in future everyone have to pay water EMI. With natural sources of water drying up in rural areas, tankers have to be deployed for water supply. Private companies are purchasing drinking water at an average rate of Rs.15 to 20 per liter. Tomorrow if the urban population has to buy drinking water:

- Daily per capita requirement: 150 liters
- A family of four would need:600 liters
- Monthly requirement of water:18,000 liters
- Total cost of this water:Rs.3,600/-

1.14. Pune Municipal Corporation

Pune has been known as Oxford [21] of the East & it is the second largest city of the state. It is situated on the banks of Mula and Mutha. These rivers originate along the eastern flank of Western ghats of Maharashtra. Pune is one of the historical cities of India with a glorious past, an innovative present and a promising future. Pune is among the greenest urban areas in the country. The Pune Municipal Corporation (PMC) administers the city. The Pune Municipal Corporation (PMC) was established on 15th February 1950.The PMC controls the whole administration of Pune. The executive power of the corporation is vested in the Municipal Commissioner, an IAS officer appointed by the Maharashtra state government. The corporation consists of directly elected corporators headed by a Mayor. The mayor has few executive powers. The city comes under the Haveli Taluka of Pune District, Maharashtra. The collectors are in charge of property records and revenue collection for the Central government. They also conduct national election in the city. Like other metropolises in India, the Pune Police is headed by a Police Commissioner, an IPS officer. The Pune Police is the law enforcing agency in the city and comes under the state Home Ministry. The Municipal Corporation of Pune, is established as a state government department with the objective of providing community services throughout the city. The Municipality serves a large urban population of 4.5 million people and aims at refining their programs with the growing demands of the occupants of the city. Pune Municipal Corporation since the day of its formation is committed to provide the best of civic amenities in the entire city and including this, the corporation has to serve a lot many tourists as well.

Pune is a highly developed city as it is a center for many industrial activities as well as top educational institutes and universities. It is also growing in terms of software and IT developments. The Pune Municipal Corporation provides numerous services broadly divided into obligatory and discretionary services. The obligatory service of the department includes construction of schools, health centers, ensuring sufficient water supply to all. Its discretionary services include maintaining public spaces like parks, museums and community halls. Besides this, it also works for the rehabilitation of slums and squatter areas. For administrative convenience, the Municipal Corporation of Pune city has been divided into four zones which include 14 Ward Offices (144 wards). Each ward office includes more than 9 sub wards. By the earnest endeavors of the corporation, the city is making new developments.

The following Table No. 1.9. Shows all details about Pune Municipal Corporation.

Table No.1.9: Details of Pune Municipal Corporation

Establishment of Pune Municipal Corporation	15th February 1950
Country	India
State	Maharashtra
District	Pune
Sub district	Haveli taluka
Population (2011) [10]	9,426,959 Million
Total Ward Offices	14
Total Wards	144
Website	http://www.punecorporation.org

(Source:PMC office)

1.15. Water supply in Pune city

In Pune city, drinking water supply system is very old and it exists since 1750. Pune city received first piped drinking water supply from Katraj via Amboli odha, Shaniwarwada. After this scheme of water supply, the Swargate water work came in existence in the year 1873. Such scheme is planned to treat raw water and supply to Pune city. Such water supply scheme is on Mutha right bank cannel and it is picked up at Swargate. Total water supply was inadequate for rising population. When Pune city reached at the status of Municipal Corporation in the year 1950, a project of 45mld was developed on the Mutha right bank cannel. Such scheme has provided water to the Pune city and Cantonment. Other than two major water supply schemes, Pune city gets drinking water from the Holkar water works.

Holkar was constructed in 1919 on Mula River. It supplies 22mld water to Pune city and Khadki Cantonment. Warje water work was constructed in 1999 which added 23mld drinking water. This scheme is built on the Khadakwasla dam. The capacity of Khadakwasla dam is 56 million cubic meters. The length and height of the dam is 1939 m and 3179 m respectively. It is named after the nearby village of Khadakwasla. This dam is one of the main sources of water for the city of Pune. Catchment of Khadakwasla near Sinhagad fort and surrounding area is being developed with the Forest Department wherein PMC is spending around Rs. 3 crores

for soil and water conservation. PMC has also initiated work on provision of security for the protection of Khadakwasla dam to reduce the contamination of water through public interference. Water Treatment Plant at Parvati consists of following unit processes.

1. Reception of the raw water
2. Pre chlorination
3. Flash mixing or coagulation
4. Flocculation
5. Clarification or Settling
6. Filtration
7. Disinfection
8. Clear water storage and Pumping from Master Balancing Tank

Wagholi water work was built on the Pavana dam in 2000. It added 23mld drinking water. Such scheme is planned to provide water to the villages on the boundary of Pune city. Due to the merger of the villages in the Pune municipal area, the villages are obliged to provide the drinking water. Total installed capacity of five water supply schemes in Pune Municipal Corporation is 793mld.

The Pune city uses the water of Mutha from the Khadakwasla reservoir. Dams at Panshet, Warasgaon and Temghar supplement the storage capacity of Khadakwasla. The Katraj and Pashan dams are not directly used for water supply by the PMC, but probably have a significant role in recharge of ground water which is used by thousands of citizens. All these dams are managed by the Irrigation Dept. PMC buys water from the Irrigation Dept, treats and supplies it to us. The forests in the Sahyadri help to trap rainwater during the monsoon. Thus, the city of Pune is dependent on the mountain range for its water. Water is supplied to different parts of the city through a network of pumping stations and pipelines. Since these water pumps run on electricity, the electricity bill is a large part of the cost of distributing water. Several large water storage tanks have been built in different parts of Pune. If impurities enter these tanks, thousands of people can fall ill. Citizens are expected to keep the area around these tanks clean. Sewage or impurities can also enter water pipes if they are broken. Illegal connections from the pipes or other damage can cause this. If one sees a leaking or broken water or sewage pipe, citizens are expected to immediately inform the PMC Water Dept or nearest ward office. There are 14 wards under PMC. All the complaints are managed by respective wards.

1.15.1. Access to Basic services

Most of the slum households [2] either have direct access to services or access them through community or common facilities. The figures indicated in 20 are based on a survey of 211 declared slums. They reveal that over 58 per cent of the households have individual water supply connections. The rest are dependent on public stand post (PSP) and the ratio per PSP is also reasonably good at 8.5 families per PSP.

The following Table No.1.10 shows the details about basic services accessed by Citizens

Table No. 1.10: Basic services accessed by Citizens

Water Supply	**Level of service**
Households with Individual water connections	49,352 households
Households using PSPs	34,892 households
Number of PSPs	1,377
Number of common taps	2,718
% Households with Individual House service connections	58%
Common tap to household ratio (including PSP)	8.50

(Source: Shelter Associate (based on survey of 211 slums))

1.15.2. Nature of environmental problems, their causes and impacts on the drinking water supply sector of Pune city.

Drinking water is a basic requirement for life and a determinant of standard of living. However, besides government efforts, supply and demand side factors of both surface and groundwater determine the level of drinking water available to people. The supply and demand factors increase with the natural and human factors like pollution. This limits drinking water supply provision and raises the delivery cost. Decline in groundwater table and availability of surface water, particularly in summer months, has put large number of people at risk for drinking water. Poor water quality problem has also been observed in more number of habitations. Inadequate resource management and institutional system seems to be the major causes for the present problems.

Rain Water Fall in Pune City:

The following Fig. 1.8 shows average rainfall in Pune city.

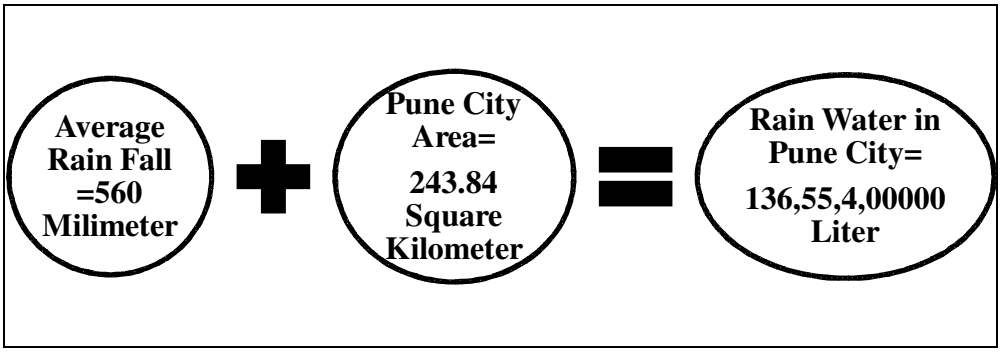


Fig.1.8. Statistics of Rain water in Pune city

(Source: Maharashtra Times, 21st March, 2013)

The study observes that activities like operation and maintenance of drinking water supply schemes, water quality monitoring, groundwater conservation and rainwater harvesting measures have to be implemented for better provision of drinking water supply.

Drinking water, in adequate quantity and safe quality, is a basic requirement for life and a determinant of standard of living. Poor or no access to safe water supply can result in many diseases including diarrhea, flourosis, cholera, hepatitis – A, trachoma, etc. These ailments potentially constrain human resource development and productivity, especially of the poor. The National Water Policy 2002 reflects the significance attached to drinking water by stating, "Adequate safe drinking water facilities should be provided to the entire population both in urban and rural areas. Irrigation and multipurpose projects should invariably include a drinking water component, wherever there is no alternative source of drinking water. Drinking water needs of human beings and animals should be the first charge on any available water." [11] Hence, significant efforts are being made by the central and state governments for increasing the coverage of households with adequate and safe drinking water supply, along with sanitation services, which coincide with the Millennium Development Goals.[19]

While governments attempt to provide adequate and safe drinking water to all households, supply and demand side factors determine the level of water availability. The supply side factors include sustainability of water sources (e.g., rainfall, surface flows, groundwater availability and recharge, surface run-off etc.), quality of available water, kinds of institutions and establishments, operation and maintenance of water supply schemes. Likewise, on the demand side, several factors such as population pressure, use and discharge of water by industries, inefficient land use, wastewater, fertilizer and pesticide flow into water bodies and soils, inappropriate water pricing mechanisms etc., are contributing to the problems of the

deterioration of water quality as well as depletion of the resource per second. Majority of these factors being environmental in nature are directly affected by an increasing pollution, degradation and depletion of resources such as water and land, limited water supply provision and rise in the delivery cost. To examine the nature of environmental problems, their causes and impacts on the drinking water supply sector of Pune city.

1.15.2.1. Environmental Pressures in Drinking Water Supply

In Pune city, maximum habitations depend upon groundwater and are facing major risks of depletion of the resource. The pressures exerted by supply and demand side factors on water resource have caused several environmental problems in drinking water supply, categorized as:

- Inadequate quantity of drinking water supply, a problem of scarcity and governance.
- Scarcity of drinking water in summer months, a problem of natural factors, seasonality, governance and management.
- Depletion of drinking water sources, a problem of resource management and
- Deteriorating quality of drinking water, a direct environmental problem.

1.15.2.2. Causes for Environmental Problems in Drinking Water Supply

Environmental problems in drinking water supply are caused by both supply and demand side factors. Two major supply factors are depletion and deterioration in water quantity and quality, which are aggravated by demand factors like over extraction and pollution as they are interdependent. This section examines some of the causes for environmental problems in drinking water supply sector in Pune.

Major environmental factors causing inadequate drinking water supply include non - availability of perennial water sources and high dependency on groundwater. It is important to note that like depletion of groundwater (a supply factor), over extraction (a demand factor) also contributes significantly to this depletion. The rapid and accelerated drawl of groundwater to meet competing demands from agriculture, industry and other sectors has led to decline in the groundwater table.

Another related cause for inadequate drinking water supply is reduction in availability of surface water, particularly during the summer season. Supply capacity of surface sources like rivers, lakes, reservoirs and tanks decrease owing to forest degradation, siltation, uncertainty and fluctuations in rainfall. The general neglect in conserving rainwater has resulted in waste

of rainfall by way of run-off and evaporation. Finally, human made factors like discharging untreated waste, sewage flow, etc., to water bodies also have caused depletion and deterioration of water resources.

Increasing demand and overexploitation are the other demand-based causal factors leading to inadequate drinking water availability. Groundwater extraction is growing rapidly as it is used for drinking, irrigation and industrial needs. The agriculture sector demand for groundwater has risen significantly.

All these factors reduce groundwater availability in aquifers, particularly during summer season, creating wide fluctuations in drinking water supply.

Leakages and unaccounted for water cause disparity in distribution reducing the actual quantity of drinking water supplied. In city areas, water loss through leakage is a major factor reducing the quantity, but precise information on the quantity of water lost in distribution network in the state is not available.[18] However, the enormity of the leakage problem can be visualized from the data on water leakage according to PMC engineers in Pune City, which is around 35 per cent of the flow. The leakage occurs mainly due to corroded pipes in distribution network, damages caused during road widening and repair works and also use of poor quality pipes in majority of household connections.

Deterioration in drinking water quality either at source or in the distribution system has been caused by factors such as natural, human made (or demand driven) and institutional (like lack of monitoring system). In addition, the common practice of using open places for defecation, washing clothes and animals, bathing around water bodies, also pollute water sources. Industrial effluents discharged to open place and water bodies is another major cause for decline in water quality.

1.15.2.3. Impacts of Environmental Problems in Drinking Water Supply

Environmental problems in drinking water supply impact significantly on health status and other resources like water and land. Consumption of inadequate water results in 'water washed diseases' like scabies, fungal infections, trachoma, etc. Inadequate water use further creates blocks in sewage flow, which could contaminate water sources. Irregular water supply causes pollution in distributional pipes due to rusting and back-syphonage of water because of low pressure and insufficient water flow. Apart from health effects, inadequate water supply increases hardship on women and children, compelling them to spend more time and energy in

collecting water. Impact of water loss in the distribution system would be severe on poor and people living in outlying.

1.15.3 Water Purification Plants

There are 10 Water treatment plants built by PMC at Parvati, Pune Cantonment (old and new) , Holkar Bridge(old & new), Warje (new and old), Wagholi,Chikhli and Wadgaon. Untreated water from the dam may contain dirt and germs. It is treated by PMC to make it safe for consumption and use. The treatment involves straining, alum addition (flocculation), settling, filtration and chlorination.

Water purification plant serves three basic functions as 1) To control the physical parameters of the water i.e. to raise the aesthetic value of water. If you take water in transparent glass, it should be so clear that at first sight you must wish to drink it. i.e. it should be crystal clear. 2) The second function is adjustment of the chemical parameters. PH is the most important chemical parameter which needs adjustment. 3) Third & most important function of any water purification plant is DISINFECTION. This is very important that water which is treated for drinking purpose must be disinfected. In all, we have seven water purification plants under maintained by PMC.

1.15.3.1 Parvati Water Purification Center

Parvati Water Purification is of the highest water purification capacity. It covers 80% population of Pune city. This plant is commissioned in two steps or stages. First stage was commissioned in the year 1969 (By Candifilters) & second was commissioned in year 1972(By Hindustan Cons. Compony). Both stages are functionally identical & the only difference is in their water purification capacity. The first stage has water purification capacity of 48 MGD i.e. 217.92 MLD. Second Stage has water purification capacity of 70 MGD i.e. 317.8 MLD. The total capacity of Parvati W.W. is 118 MGD i.e. 535.72 MLD. These plants run completely under gravity. It covers 60 % to 70% population of Pune city.

Source of water - Khadakvasla Dam is our direct source of raw water. Khadkvasla Dam in turn receives water from Panshet dam, Warasgaon Dam, or from Temghar Dam. So we may say that these three dams act as an indirect source of raw water.

1.15.4 Water Transmission and Distribution System

In Pune city, water supply operation is divided into seventeen zones. Each zone has its specified area and service. In some part of the city water is pumped and in some part, water is distributed through gravity. It is also dependent on the zonal reservoirs. Water is distributed through pipes which are of different diameters. The lowest diameter size of pipe is 80mm and highest diameter is 1600mm. Total length of the network of pipeline in the city is 647.18 km. Total length of the distribution of drinking water pipeline is 2474 km. It also includes the 24km transmission line. In Pune city, water supply pipeline is mainly located near the roads. Some roads have more than one pipe line. The reason is that it has been put at different time. Total length of road in Pune city is 1750km.

The following Table No. 1.11 shows all details about Water Supply& Distribution in Pune City.

Table No.1.11: Details of Water Supply & Distribution in Pune city

Pune Water Distribution area	2474 sq. km
Growth rate	2.77
Present Water Supply	1123 MLD
Present Water Demand	671MLD
Average supply hours	5 hours/day
Average rate of leakage	20 percent
Total number of Treatment plants	9

1.15.5. Water Treatment and Quality

In Pune city, quality of drinking water is regularly maintained as per IS 10500, 1991. The laboratory facilities at Parvati and Cantonment water works are well equipped with machinery. The physical, chemical and bacteriological tests of raw water as well as filtered water are carried out in the laboratory on regular basis. Daily, 90 samples are collected at different points. It includes overhead and service reservoirs, intermediate connections in distribution network. The major portion is collected from the consumer taps. Water tests are divided as physical, chemical, microbiological examination of water. In daily supply of raw water, there is

possibility of the presence of coli form and E coli organism. They may be more than 1800 per 100ml. After treatment of water, they are destroyed. In the month of August, turbidity in drinking water increases. The efficiency of Parvati water works for turbidity removal is approximately 67 per cent, which is of good quality.

There is possibility of water contamination through open drainage system. If there is any complaint of water contamination in Pune city, it is solved within 24 hours by engineers and staff.

1.15.6. Current Scenario of Water Supply, Consumption, Demands in Pune City

Table No. 1.12: Statistics of Water Supply and Consumption in Pune City

Status of Water Consumption	In terms of Quantity
Daily Water Supply	1123 MLD
Daily Per Capita Water Supply	194 Litres.
Daily Grey Water	744 MLD
Recycling of Grey Water	382 MLD
Without Recycling of Grey Water supply in river	362 MLD
Time required for recycling of Grey Water	2 yrs.

(Source: - The Time Of India News Paper on dated Thursday, 05-08-2010,Pg. No-2)

1.15.7. Water Demand in Pune City

Demand for water is growing in most cities in India, as every urban citizen requires almost double the amount of water than a rural citizen requires. Moreover, India is rapidly urbanizing. It is estimated that there are around 50,000 bore wells within Pune city. More than five lakh people are entirely dependent on ground water for their water needs. This grave imbalance in demand-supply explains the mushrooming of water supply business, which is very much conspicuous in the Pune city in the form of water tankers.

Potable water is used by household units for cooking, washing, bathing and drinking purposes. The schools, colleges, hospitals are also using the potable water for cleaning and toilet purposes. Commercial units and garages in the city are also using the drinking water for different purposes. The Pune Municipal Corporation has 590.81mld water demand. Such water

demand is higher in the metropolitan area because of population, commercial units, hotels, restaurants and institutions.

1.15.7.1. Water Demand and supply projection

In Pune Municipal Region, demand of drinking water is increasing fast. It is assumed that domestic, commercial units and institutions will increase in 48 zones of Pune Municipal Corporation, Khadaki and Pune Cantonment. The number of theaters, shops, hotels and restaurants will spread across the wards. They will also increase with increase in the population density. Workers working in various industrial units will also increase with increase in population. The required doctors, nurses and midwives will increase along with population and number of hospitals in the metropolitan region

The given table shows the current scenario of water supply, consumption and demands of Pune city. Table 1.13 shows current status of water consumption like daily water supply, grey water, recycling of water and required time period for recycling of Gray water. Table 1.12 shows the Statistics of Water Demand in Pune City. According to Government rules and regulation, 150 lit. water is required /person /day. But PMC demands 260 litre water per person/day.

Table No.1.13: Statistics of Water Demand in Pune City

Status of Water Demand	In terms of Quantity
11 TMC	25 Lacs Populations
14 TMC	35 Lacs Population
17 TMC	47.46 Lac Population
Demand of PMC to Irrigation Dept	260 Lit.-person/Day

(Source:- The Sakal News Paper-Today on dated Friday, 23-07-2010, Pg.No-3)

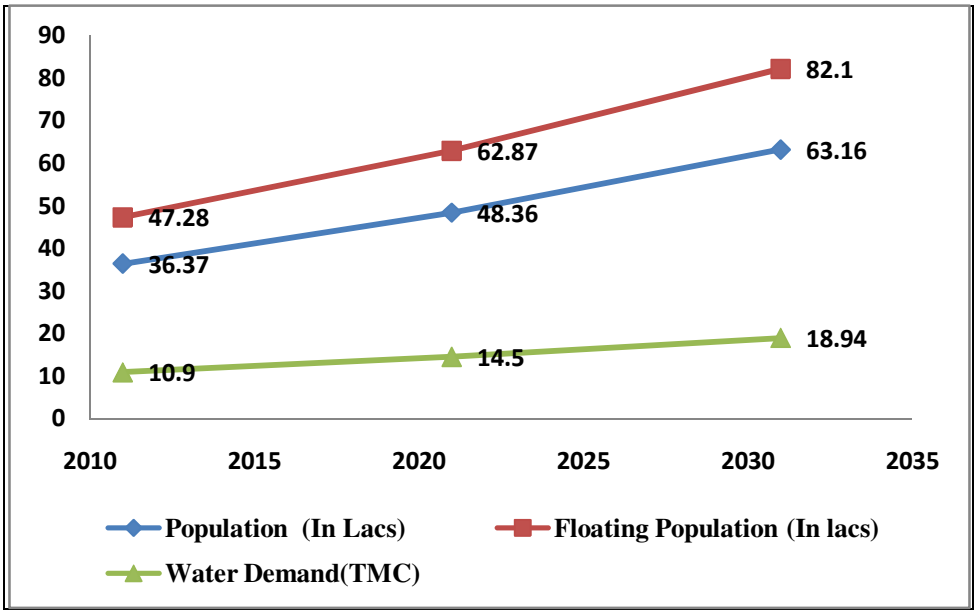
Table No.1.14: Yearly Water Demand as per Population in Pune City

Year	Population (In Lacs)	Floating Population (In Lacs)	Water Demand(TMC)
2011	36.37	47.28	10.90
2021	48.36	62.87	14.50
2031	63.16	82.10	18.94

(Source:- The Maharashtra Times News Paper on dated Thursday, 14-03-2013, Pg.No-2)

From the above Table No 1.14. shows forecasting of water demand as per population of Pune city in the coming years. It is shows that, water demand will increase 4 TMC every 10 years. But still water resources are as it is. There are no chances to develop new water resource for upcoming years but the only possibility is the increasing the capacity of recycling of gray water and implement rain water harvesting technology everywhere.

Graph 1.4. Yearly Water Demand as per Population in Pune City



- **Domestic Water Demand**

With increasing household income and increasing contributions from the service and industrial Sectors, the water demand in the domestic and industrial sectors could increase substantially. We assume that the average domestic water demand would increase from 85 liters per capita per day (lpcd) in 2000, to 135 and 170 lpcd by 2025 and 2050, respectively. The Business-as-Usual (BAU) scenario approach differs from the approach adopted by the National Commission of Integrated Water Resources Development (NCIWRD) commission. They assumed norms, where the rural domestic water demand in 2025 and 2050 are assessed at 70 and 150 lpcd, respectively, and the urban water demand at 200 and 220 lpcd, for 2025 and 2050 respectively. They also assumed 100 % coverage of domestic water supply. We estimate the livestock water demand to increase from 2.3 billion cubic meters (BCM) in 2000 to 2.8 and 3.2 BCM by 2025 and 2050, respectively.

- **Industrial Water Demand**

In a rapidly booming economy, we expect the contribution of the industrial sector to increase very much, and the industrial water demand to also increase accordingly. However, the dearth of information—the types of industries, their growth, water use and the extent of recycling is a constraint for future projections in the context of increasing economic growth. The NCIWRD commission, based on a small sample of industries and their water use, projected that industrial water demand would increase from 30 BCM in 2000, to about 101 and 151 BCM by 2025 and 2050, respectively.

However, an analysis using the global trends show that, with the present economic growth rates, the per capita industrial water demand could increase from 42 m^3/person in 2000, to about 66 and 102 m3/person by 2025 and 2050, respectively or the total industrial water demand to increase to 92 and 161 BCM by 2025 and 2050, respectively. The BAU scenario too assumes these growth rates.

- **Environmental Water Demand**

As a result of increasing economic activities, the quality and quantity of water in some rivers are at a threateningly low level. However, with increasing campaigns by NGOs and civil Societies, awareness of water-related environmental problems is increasing. As a result, the water demand for the environment could increase rapidly. At the least, we believe that a minimum flow requirement (MFR) provision will be established in most river basins.

1.15.8. Impact of Industrialization

The government of Maharashtra has promoted industrialization across Pune region [21]. Due to such policy, automobile, engineering, electronic, information technology and biotechnology industries have grown very fast. Such industries have created huge employment opportunities in the region. Therefore, immigration of indigent rural labour and qualified professionals from other states took place. Along with the production and manufacturing, the growth of services sector also concurred. The numbers of corporate offices, business processing units, call centers, banking and insurance services have grown significantly. The abandoned industrial sites are converted into residential locations in the region. Township planning and low cost affordable housing is developed for growing population.

All these factors resulted into increase in pressure on existing civic infrastructure. In the region, drinking water is not supplied on equitable basis and coverage is low. The reasons are

topography, faulty and old pipeline, inadequate distribution system, transmission and distribution losses of water etc. The storage capacity of drinking water is also low. It is also a common observation that underground water table is depleting due to uncontrolled extraction of water. The state of Maharashtra covers an area of 307,713 square km and supports a population of 82 million. Over half of this population is in rural area which faces problems related to water. Conventional sources like open well, bore well and piped water supplies have failed due to depleting water tables, poor water quality and high cost involved in operation and maintenance. Every year a great amount of water is being lost that falls on terraces, all of which finds its way to the storm water drains.

Major parts of India have been facing continuous failure of monsoon and consequent deficit of rainfall over the last few years. Also, due to ever increasing population of India, the use of ground water has increased drastically leading to constant depletion of ground water level causing the wells and tube- wells to dry up.

Nature replenishes the ground water resources annually through rainfall; by way of infiltration though soil layers. Due to urbanization, the soil surface exposed to natural recharge gets reduced. Therefore, natural recharge is diminishing, resulting in drying of wells. Ground water source has the benefit of availability where water is needed and during emergencies and scarcity period, the public at large or NGOs should take measure to improve the ground water recharge by rain water harvesting to maintain the reliable and sustainable ground water resource for supplementary domestic and industrial needs by ground water balance use.

References

[1] A Report by Wurbs Ralph A. Texas A&M University, Department of Civil Engineering Environmental, Ocean and Water Resources Division on "Computer Models For Water Resources Planning And Management" July 1994

[2] A Report on "City Development Plan -2010-11",Pune Municipal Corporation

[3] Blacksburg, "Overview and Introduction to. Geospatial Technologies" VA. July 24th – 30th, 2010. (http://gep.frec.vt.edu/VCCS/materials/PDFs/1.1-Clayton_Intro2GIS.pdf)

[4] Buckley David J. , " The GIS Primer- An Introduction to Geographical Information System" Corporate GIS Solutions Manager, Pacific Meridian Resources, Inc http://bgis.sanbi.org/gis-primer/page_06.htm

[5] Buckley David J., " The GIS Primer- An Introduction to Geographical Information System" Corporate GIS Solutions Manager, Pacific Meridian Resources, Inc.(http://bgis.sanbi.org/gis-primer/page_25.htm)

[6] Burrough P.A., 1986"Principles of GIS", Oxford, Clarendon Press

[7] Dewi Rogers and Alessandro Bettin on "Saving the World's Most Precious Resourc Sustainable Development – Education, Business and Management – Architecture and Building Construction – Agriculture and Food Security"(7/03/2012)

[8] Dr. (Mrs) Savitsmita Vilasrao Chawan Reade, Head of the Geography Dept on "Water resources of India", National Level Conference on Water Management Scenario 2025 Problems, Issues and Challenges(www.vpmthane.org/publication-wms)

[9] F. DE SMEDT, L. YONGBO and S. GEBERMESKEL , 2000, Hydrologic modeling on a catchment scale using GIS and remote sensed land use information, Department of Hydrology and Hydraulic Engineering, Free University Brussels, Belgium..16)

[10] Government of India & Central Water Commission Training Program on "Applications of GIS in Water Sector" dt.7-18 June,2010 organized by National Water Academy, Pune.

[11] Government of India (2002), The National Water Policy, Ministry of Water Resources, New Delhi.

[12] http://en.wikipedia.org/wiki/Geographic_information_system

[13] http://www.census2011.co.in

[14] http://www.informationsoftwaresystems.com/

[15] Rosenthal, W. D., R. Srinivasan, and J. G. Arnold. 1995. Alternative river management

using a linked GIS hydrology model. Transactions of the ASAE. 38(3): 783-790.

[16] Roy P.S. and Rao V.V. Indo-US Workshop on "Innovative E-technologies for Distance Education and Extension/Outreach for Efficient Water Management", March 5-9, 2007, ICRISAT, Patancheru/Hyderabad, Andhra Pradesh, India

[17] Shailesh 'Times of India ' dt July 19,2011

[18] SLB Report, PMC-2010-11

[19] United Nations Development Programme (UNDP) (2003), Human Development Report 2003: Millennium Development Goals - ACompact Among Nations to End Human Poverty, published by UNDP.

[20] Wilson J.P., Mitasova H., Wright D.J.," Applications of GIS in Water Resources" GIScience Publications, 23/03/2000.

[21] www.punecorporation.org

[22] www.virtualpune.com,www.punediary.com

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

An extensive literature review will be done on the concepts and theories related to Role of GIS in Water supply system. A review of research papers, articles is undertaken to take note of and acknowledge work that has been done in the field of Role of GIS in Water supply system. The Researcher has collected secondary data from reputed Journals and Magazines, Newspapers, articles, Internet websites and Archives. The Researcher has visited libraries in and around of Pune City, to collect secondary data.

The researcher has identified 45 research papers along with 10 articles published in renowned journals and news papers on various topics such as GIS based Decision support system in water supply dept., Water Problems solved by GIS .The review of available literature on each topic is taken into account in this chapter in following headings-

- **Role of GIS in Natural Resources**
- **Use of GIS in Water Resources**
- **Role of GIS in Water Distribution & Supply**
- **Articles on GIS based Decision Support System in Water resource management**
- **Water Conservations**
- **Public private partnership development in water utilities**
- **News Paper Articles on Water**
- **Observation of researcher and usefulness of review literature**

2.2. Role of GIS in Natural Resources

Toleti Rao B.V.M., Chaudary , B.S., et al have published their article on**" Integrate Ground Water Resources Mapping in Gurgaon District, (Haryana) India using Remote Sensing and GIS Techniques". [51]**

The study area was conducted in Gurgaon District, India and discusses the preparation of Integrated Ground Water Resource (IGWR) map indicating ground water prospects,

quality and depth and thus the authors prepared a map using satellite data, delineated the ground water potential zones, and produced an integrated ground water resource map. The authors describe the physiographic, drainage, geology, soil and extent of the area as factors for the mapping of the ground water resource in the area. They describe the ground water prospects, as well as the water quality in terms of area extent. The authors concluded by stating that the use of Remote Sensing and GIS technology is very useful for the preparation of ground water prospective areas mapping & management plan on a scientific basis and that the information generated on prospects, quality and depth in a single map will help the planners and decision makers for devising sound and feasible ground water development plans.

Martínez-Solano, F. Javier; Pérez-García, R. & Iglesias-Rey, P.L. have published article on **"Water Mains Creation Using GIS"** [29]

In the present paper, authors have suggested methodologies for planning, design and project new pipes in water network are presented. This method allows completing the whole problem of creating the new pipes since their conception. The problem of sizing the pipes has been sufficiently studied. However, most of the existing algorithms need a demand in the nodes of the network to perform the calculations. This paper tries to help in demand estimation from the land uses information stored in a Geographic Information System (GIS). Finally, the work is completed by a description of the data organization.

In this methodology, infrastructure and cartographic information in the GIS has been combined to drive an efficient pipe sizing when neither layout nor demands have been defined yet. In order to get these demands, a topology operation has to be made by the GIS. An overlay between the lands uses topology obtained from a development plan and the tessellation to divide the served area among all the nodes where the demands must be loaded has been made. This simple topology operation has driven to a demand that allows the pipe sizing in a traditional way. Finally, an overview of the whole process of the creation of a new pipe since its conception until it is a reality, including the project and construction stages of the process has been presented.

2.3. Use of GIS in Water Resources

Garaci Mike has published their article on **"Simplified GIS for Water Pipeline Management"** [15]

This paper discusses water pipeline operators have seen new inspection technologies and failure analysis techniques that enable them to determine the condition of their pipeline assets, the pipeline deterioration rate and probability of failure. Routine inspection and analysis of a pipeline system and related aboveground features creates the numerous datasets necessary to accurately and efficiently plan capital improvement projects to maintain the pipelines and associated assets in a sustainable manner. The quantity and diversity of this data can be a challenge to manage especially if one uses differing electronic file systems and standard paper files. Complexity increases further when engineers discover that the real-world conditions surrounding their pipelines have changed from that shown on their original as-built plans of construction.

By deciding upon a GIS-enabled database, pipeline engineers can work towards an intuitive and dynamic system that provides users with timely information and analysis tools. Using GIS technologies effectively for a water pipeline requires a detailed data structure to address the jointing aspects specific to water pipelines. The data model needs to track individual pipe segments, from bell to spigot, with inspection and integrity information. Enabling this database for view through common software packages such as Microsoft Word, delivers GIS technology with a high value data set that is very accurate at representing existing water pipeline infrastructure but without expensive licensing fees and long learning curves. Using case studies, the paper illustrates how GIS technologies can leverage off a well designed pipeline data model and pipeline operators can fully realize the advantages of maintaining their pipeline assets in a spatial database including 1) increased data availability; 2) identification of urgent repair needs; and 3) improved maintenance and capital planning.

Hussain Jama Ismail Bait-Ishaq , Philip Burden have published their article on **"GIS Implementation in the Ministry of Water Resources in Oman"** [19]

The importance of water as a source of life is indisputable. Water has become more important in this century due to the great technological advancements which have brought about comprehensive development in the various aspects of life. The Ministry of Water Resources (MWR) has implemented different kinds of information technology in order to assist in the effective management and monitoring of the Sultanate of Oman's water resources. One of the information technologies implemented in MWR is

Geographic Information System (GIS). To guide its implementation, an implementation plan has been written which sets out the resources and tasks required to realize the objectives of establishing an operational GIS for priority applications at 1:100,000 scale, and other scales, with Ministry wide access for an effective trained GIS user community.

This paper describes various experiences learned from Implementing GIS in the Ministry of Water Resources in Oman and the impact that had on helping MWR to better manage water resources in Oman. This will be presented by discussing the benefits of GIS within the MWR' the GIS implementation strategy in MWR, GIS applications identified within MWR and constraints in GIS implementation. The main objectives was to *establishing* and maintaining a computerized geographic information system (GIS) to assist in the effective assessment, planning and management of Oman's water resources. GIS implementation within MWR is seen as providing both tangible and intangible benefits, including:

- Increased productivity with more efficient map updating and the ability to compile and report information more rapidly.
- More up-to-date, accurate and reliable information resulting from standardization and integration of data used throughout the Ministry.
- Reduced duplication of effort as more readily accessible data will avoid duplication of data collection and analysis.
- All map data will be integrated into a single shared, distributed database.
- Improved coordination between departments and Ministries facilitating the storing of data and maps.
- New geo processing techniques will be available for problem solving.
- Better service to Government users will result from more efficient information processing.
- Higher quality products will be produced from more reliable, more accurate data in a more timely, efficient and cost effective manner.

After initial user surveys, several areas for GIS application were identified within MWR such as National Well Inventory Project (NWIP), Wadi Day qah - Dam Site Planning, Flood Risk Mapping Project. GIS has helped to bring to the attention of senior management the need for better control and management of the data the Ministry collects.

In spite of several GIS applications having been successfully developed, overall implementation of GIS within the Ministry has fallen behind schedule and needs to be further accelerated. There are several reasons for this, including:

- Being a service provider at the same time as trying to implement GIS. This has directly impacted upon and resulted in the slow capture / conversion of graphic data;
- Not spending enough time on producing quick GIS applications which could be useful to selected Ministry personnel, rather than giving a great deal of attention to the overall corporate GIS data issues.
- Spending too much time on training, and not enough on fast application development;
- The slow speed of addressing the corporate data issues raised by GIS in the early stages of its implementation.

GIS in MWR has been successful, for it has helped to make personnel, both within MWR, and external to the organization, more aware of the powerful tool GIS is in managing and querying an organization's spatial / attribute data.

I. MOURATIDIS, G. DIMOPOULOS, T. ASTARAS, S. SAVVIDIS have published article on **"Sustainable Water Resources Management Through The Use Of GIS Technologies"** [20]

Water is one of the most important renewable natural resources. By the term "exploitation of a region's water resources", we refer to the activities that aim in rational exploitation of these resources within the quantity limits of the annual fluctuation of water resources. The purpose of this study is the application of procedures for sustainable management and development of the water resources of the Gravesites basin, using Geographic Information Systems. The study reveals the capability of itself-reliance of the area of Gravesites basin in covering the total water needs and the new perspectives for sustainable development of the area with the exploitation of the surface waters of Gravesites River. It's also shown the important contribution of GIS technology with the creation of databases for the continuous monitoring of the various parameters with their changes and the convenience for direct drawing of thematic maps. The evaluation of quality parameters of drinking water brings to light useful results and recommendations in order to assist and improve current water

quality monitoring and protective actions.

Methodology for Water resources through GIS-

Firstly, it conducted the collection and study of related bibliography, papers, essays, legislation and data concerning the study area (maps, demographic, hydrologic, climatic, drills, water quality analysis, water consumption). Then followed the field research so as to measure and record the analysis, water consumption). Then followed the field research so as to measure and record the next step which includes the examination of the demographic data, morphological relief and drainage network, the estimation of the rainfall – altitude relation and of hydrological balance equation, the examination of geological and hydro geological data, the hydraulic parameters of the aquifer, the determination of the daily and annual consumption of water, the determination of water chemical characteristics, the comparative examination between the today's and the future's balance of water supply and water needs, the level of exploitation of surface and underground water and the of the rational exploitation plan of the water resources which contributes to sustainable growth of the area. Databases and thematic maps were created using GIS ARC/INFO and AUTOCAD programmes, while MS EXCEL programme was used for tables and diagrams and HYDROPOINT programme for water chemical analyses data process.

The present study concerns the application of procedures for sustainable management and of the water resources of the rural drainage basin of Grevenitis River, using Geographic Information Systems (GIS) technology.

1) It reveals the potentiality of the area of hydrologic basin of Grevenitis River, to be self-reliant. As far as the water resources are concerned. As a result, it can cover the area's total water needs. So far the area covers its needs for water by the use of the water resources located outside the study area.

2) It also emphasizes the contribution of GIS in rational management procedure of an area. Water resources, along with the utilization of the geomorphologic, hydrologic, hydrogeological data, the development of data bases for the constant supervision, the direct plotting of various parameters and their fluctuations and the possibility to use and exploit these data at any time in order to create easily new thematic maps.

Zorkeflee Abu Hasan , Nuramidah Hamidon , Norazazi Zakaria , Aminuddin Ab. Ghani and Leow Cheng Siang have published their article on**"INCOPERATING GIS IN WATER RESOURCES MODELLING: Application of SWAT 2005 Model in Sungai Kurau, Perak and CCHE2D Model in Tasik Harapan USM, Penang"** [58]

GIS is gaining its popularity with the water and environmental related applications. Many mathematical models have incorporated or integrate the GIS application to generate inputs and display output or as interface for the entire modelling processes. In this paper, researcher focuses on to demonstrate the use of ArcView as the interface for the mathematical modelling at the river basin level using Soil and Water Assessment Tools (SWAT) 2005 and as a tool to assist the data input for the two dimensional modelling using CCHE2D. The SWAT models with GIS interface were used to predict the impact of land management practices on water, sediment and agricultural chemical yields in Sungai Kurau basin in terms of water quality and water quantity. The GIS software was used to assist the modeller in finding the locations of areas having potential instability problem that might occur in Tasik Harapan. The results show that GIS is a versatile tool for water resources management, as interface for modelling at river basin level using Soil and Water Assessment Tools (SWAT 2005) and as a tool to assist the preparation of geometric input for the two-dimensional model CCHE2D to analyze the flow pattern in a lake.

SWAT is a watershed model developed to quantify the impact of land management practices in large watersheds .SWAT was developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields large watersheds with varying soils, land use, and management conditions over long periods of time. The model simulates eight major components: hydrology, weather, erosion and sediment transport, soil temperature, crop growth, nutrients, pesticides, and agricultural management. Sediment yield prediction is improved because runoff is a function of antecedent moisture condition as well as rainfall energy. This was the case study of utilizing GIS software and capabilities to assist hydrodynamic modelling for Tasik Harapan and Tasik Aman. The two-dimensional Mathematical model used for this case study is CCHE2D. The CCHE2D was developed by the Center for Computational Hydro science and Engineering at the University of Mississippi, USA. The CCHE2D

computation model was used to analyze the flow pattern inside the river reaches and also in the two lakes, and to design the optimum configuration of the river system.

Norsaliza Usali & Mohd Hasmadi Ismail have published their paper on **"Use of Remote Sensing and GIS in Monitoring Water Quality"** [52]

This paper however discusses the application of remote sensing and GIS specifically in monitoring water quality parameter such as suspended matter, phytoplankton, turbidity, and dissolved organic matter for Malaysia. In fact, the capability of this technology offers great tools of how the water quality monitoring and managing can be operationalised in this country. Potential application and management is identified in promoting concept of sustainable water resource management. In conclusion, remote sensing and GIS technologies coupled with computer modelling are useful tools in providing a solution for future water resources planning and management to government especially in formulating policy related to water quality. Ground water cannot be detected directly from the earth's surface, so remote sensing and GIS technique can provide information concerning its potential occurrence. The purpose of study was to predict the groundwater potential zone through the various thematic maps from remote sensing and GIS technique. Since the past few decades, the increasing anthropogenic activities specially in industrial area has effects on water bodies. This is the global issue which is happening throughout the world and Malaysia also faces these problems. Today, with the advancement of science and technology, the population, industries, agriculture activities, and urban development's have grown up along the corridor or riverbanks of Malaysia. The domestics' sewage, factories effluents, and agriculture waste can lead to the deterioration of river water quality. Because of that, the river water quality monitoring programme are needed in order to raise awareness of public by address the consequences of present and future threats of contamination to water resources. The characteristics of water can be categorized into three namely, physical, biological and chemical. These characteristics are used in water monitoring programme. The valuable data can be obtained to provide a basis comparison of state's stream at different seasons and different years. The monitoring and assessment may be useful for research and policy making purposes. In situ measurements and collection of water samples for subsequent laboratory analyses are currently used to evaluate water quality. These measurements are accurate for a point

in time and space but do not give either the spatial or temporal view of water quality in wide space. Thus, the technologies such as remote sensing and GIS are very useful as a tool in evaluating and monitoring water quality.

Overall, the purpose of the monitoring of water quality parameter in Malaysia using remote sensing technique are because of the limit of the field cost, to improve the information contents, to produce the digital map, and to monitoring the large scale monitoring of water quality that will offer the significance source of information. Water provides variety purpose such as a source of water supply for domestic and industrial use, irrigated agriculture, livestock and mining activities. However by the increasing industrial development and anthropogenic activities the quality of water has decreased dramatically. Therefore, the monitoring programs using remote sensing and GIS are needed to threats all contamination occurs and provides the effective action at all levels. The remote sensing and GIS techniques are the effectiveness, cheaper and valuable tools in monitoring water quality parameter in coastal level and fresh water bodies (lakes, river, ground water, and reservoir) compared to in situ where measurement is restricted to selected sampling points.

Durmus Cesur have published article on **"GIS as an information technology framework for water modelling"** [13]

In this paper author has discusses , the use of a Geographic Information System (GIS), as an integration framework for the water modelling systems, together with object-oriented data modelling and programming schemes is explained. Integration of the modelling systems on a GIS platform, through a surface-water-specific GIS data model, Arc Hydro, and interface data models as data repositories for common water features, hydrologic and hydraulic modelling elements, is presented with a case study. Arc Hydro served as an integration data model for the simulation models of concern. The simulation model integration on a GIS using Arc Hydro as a common integrator data model, and the interface data models, which are linked using object-oriented programming tools through geospatial information exchange points, are explained. The simulation models, data models and linkage tools are assembled together on a ModelBuilder interface. The methodology has been proven to be feasible through the implementation at a prototype scale. Arc Hydro and the interface

data models provided the data structures for the communication of GIS and the modelling systems. Time series and other attribute data transferred between a GIS and modelling systems at information exchange points using object-oriented linkage programme.

The interface data models facilitated two-way communication between models and GIS by providing mapping between data and parameters of the model, and its corresponding GIS representation. Through the use of these models in GIS, additional visualization and spatial analysis capabilities for the modelling data were achieved. These capabilities assisted in the evaluation of models and their parameters, quality control and quality checks. Additionally, the interface data models facilitated storage of the modelling time series data in a manner that will be compatible with the standard GIS-based time series storage scheme and associated tools. The interface data models also enabled the incorporation of modelling systems into the enterprise spatial database, information, decision support and knowledge management systems.

The interface data models can be further standardized and refined, the common model elements may be incorporated to the base model, further object-oriented features can be allocated in the data models and the linkage programmes, and GIS-compatible input and output formatting options for modelling systems could be developed to further streamline the integrated modelling process and to reduce the time due to expensive input and output operations between the GIS and the modelling systems. In the case study the integration data model was Arc Hydro, but this could as well be replaced with some other base data model, or even may be dropped as long as the relationships between modelling systems could be established through some mechanism such as cross-reference tables between modelling elements that are used for the information exchange.

GIS is mostly used in the integration for water management applications other than the floodplain mapping such as water quality, water supply and wastewater and water treatment.

Alaguraja Yuvaraj .D, P Sekar.M, Muthuveerran.P, Manivel .M have published article on **" Analysis of drinking water problem in Coimbatore City Corporation Tamil nadu, India using Remote Sensing and GIS tools**". [3]

In this paper, a researcher focuses on drinking water problems in Coimbatore city. Due to over population, increase in drinking water consumption was arisen. Relevant data was collected from relevant Government departments. The data was analyzed and the objective of the study was derived from the data analysis. The aim of the study is to find the characteristics of distribution of water supply in Coimbatore city, in order to identify positive and negative areas with respect to water supply and we may maintain the quality of the drinking water in order to live a hygienic life. In this paper, researcher does the survey about 300 citizens in and around Coimbatore city. Random sampling method has been adopted in the selection of samples people of different social status have been interviewed to get relevant information.

Researcher concluded that, there is an imbalance in Drinking water supply and demand and that is also perennial in nature and to create the awareness among the citizens regarding the water conservation. Coimbatore protected drinking water supply system has done the needful. The scholar would like to recommend that the various urban system of the Coimbatore City which comes closer to an efficient system, although there are yet some deficiencies

2.4. Role of GIS in Water Distribution and Supply

Shakoor, A., Shehzad, A., Asghar, M.N. have published article on, **"Application of Remote Sensing Techniques for Water Resources Planning and Management,"** [37]

This paper describes the importance and capabilities of modern techniques such as remote sensing (RS) and geographic information systems (GIS) as water resource management and conservation tool. RS/GIS analysis can show where water enters a system and how it leaves through evapotranspiration and runoff. Using this information, planners can identify areas where there is potential for development of new water resources; where water can be reallocated from one use or one basin to another; and identify potential areas of water scarcity before water shortages occur. The main

objective of this research is to calculate accurate crop water requirement by using RS/GIS in combination with hydraulic models. The results helped in devising guidelines, which in turn will help the policy makers to release the water supplies based on crop requirement only rather than supply based. Multi -temporal satellite images were used to identify various crops and cropping pattern in the area. This study was conducted for the Pehure High Level Canal (PHLC) and the Upper Swat Canal (USC) system in the North Western Frontier Province (NWFP) of Pakistan.

For water managers, sufficient spatial and temporal information is necessary. Conventional techniques are not sufficient to provide all such information on a large scale. Modern technologies such as remote sensing and GIS have proven its worth to provide timely and reliable information about various phenomena of the earth. Water is a global problem and vital to manage especially for developing countries like Pakistan. This research provides a tool for water resource planning and management at distributaries level.

For better water resources management, the accurate relationship between water demand and water supply must be realized and established. Accurate crop identification is important to know about actual demand of water in the area. This study has revealed that remote sensing information along with sufficient amount of ground truth data can be useful in identification of various crops with reasonably high accuracy. Therefore, accurate cropped area can be calculated from remote sensing image. Comparison of water supply with water demand showed that there is extra water during rabi season, which can be saved and used to increase irrigated areas and enhance crop productivity in the area. Water managers can adopt the methodology developed in this research as a tool for water planning and management. More detailed planning at field level can be made if advanced remote sensing models like Surface Energy Balance Algorithm for Land (SEBAL) are used. Also accurate areas can be calculated by using spectral mixture analysis techniques, which can provide estimates of crop fraction within pixel. In addition to all this, modern irrigation practices and resource conservation technologies will be helpful for improving water use efficiency and overall conservation of water resources.

Xiao-Li Cao; Chao-Yuan Jiang; Si-Yuan Gan; have published article on, **"Leakage monitoring and locating method of water supply pipe network."** [56]

In this article, the author has discussed about GIS based system to easily locate leakages in water supply dept. To solve the monitoring and locating problems of the underground booster and leakage of the supply water network, a remote leakage monitoring and locating system based on GSM/GPRS is designed. The parameters of water supply pipe network, i.e., flow, flow velocity, flow direction and pressure are collected by monitor terminal. The data transmission is realized by GSM/GPRS network and the status of tap water pipe network is monitored by the GIS based Web software. Based on the feature of the underground booster and leakage of the water pipe, negative P wave and flow detecting methods is used based on the pattern recognition. Practice shows the system can detect leakage of the water pipe timely and found the leakage location accurately. At present, it has been used in practical tap water pipe network with excellent results, and it is valuable for generalization and application.

Bo Yan1, Xiaorong SU 2, Yiyun Chen1 have published article on **"Data Management of Urban Water Supply Network Based on GIS,"** [7]

This paper probes into all aspects in the data management of the urban water supply network, such as the basic data collection, the structure framework of basic geographic information bank, the process to construct GIS basic information bank of water supply network, data conversion and entry into banks, data vectorization and entry into banks, data refreshment and maintenance, and so on., then the system database is designed. Experience in Yiyang indicates that the development of the water supply network system in this. The author has adopted SuperMap of Beijing SuperMap GIS Technologies, Inc. as GIS platform software. Different from other GIS products, all spatial and non-spatial information is stored in the database for SuperMap, and can be called by SDX, a spatial database search engine. Dataset is the basic unit of spatial data, and one dataset for one map sheet in general. Each record in the dataset indicates a certain spatial element, which can include non- spatial information either or not. How to adopt advanced GIS technology to raise utilization ratio of water resource and management level of urban water supply enterprises is brought forward. For supply water enterprises to utilize the existing water resource in time, rationally and effectively, for accelerating the urban construction and economy development, it had general practical significance. Test run of YiYang water supply network system indicates that the development has achieved

scheduled target and established a solid basis for subsequent development and further research.

Zhao-Shun WANG and Zu-Kuan WEI * Qian y in have published article on "**The design of water supply network based on GIS"** [57]

Water supply pipeline network is a system which has a large of spatial attribute data. In order to improve the management and work efficiency, reducing the workload of workers, the best way is to design a water supply network based on GIS, the system based on Arc GIS platform, using Client-Server and Browser-Server model to form a new composite model to set up the system. This paper introduces every function and the key technology of this system in detail, such as seamless integration of GIS of water supply pipeline network and hydraulic model which based on building pipeline network concise model dynamic and use the hydraulic calculation function to guarantee the authenticity of hydraulic model, hydraulic model which can help to simulate the whole system and analyze the condition of pipeline network, the model of pipe blowout statistical can help operator to know the condition of every segment of water pipe in the system and forecast the events of pipe blowout, and according to the requirements of system, the fast locating algorithm was modified to reduce the time of searching objects. All these important technologies can strengthen the security, improve the speed of locating objects and help operator to analyze the pipeline condition. The system was tested in the laboratory environment and ran successfully, because it accords with the requirements of water supply network. The system was composed of nine function models, including manage pipeline network function, analyze pipeline network function, manage user function, assistant design function, programme pipeline network function, manage map layers function, system tools function, maintain data function and Web serving function.

With the rapidly developing city construction of our country, the standardization, science and modern construction of city water supply network are more important and urgent, managing water supply network by using the technology of GIS, is an effective way to manage pipeline network standardization, science and modern construction. The system has been completed preliminarily, and it has actualized all user requirements run in laboratory environment during the testing, especially that there are several key characteristics in this water supply network GIS, such as friendly systemic interface, use

easily for operator, it can accord with the managing requirements of water supply corporation. Using the system will have great efficacy to programming, command, query information, fast maintaining, fast and accurate locating, assigning operator in optimization in water supply of city.

Bahadur Rakesh, Pickus Jonathan, Amstutz David and William Samuels have published their article on "**A GIS-based Water Distribution Model for Salt Lake City". [3]**

In this article, author have been suggested, EPANET model and Arcview to assist emergency managers in assessing the risks to public water supplies. The integrated system is called PipelineNet. This system calculates, locates, and maps the population at risk from the introduction of contaminants to the public water supply. The EPANET toolkit allowed Arcview to utilize the EPANET engine to route a contaminant through the system under extended period simulation. The results of the simulation are viewed within Arcview along with additional coverage representing population and infrastructure. This model was tested using the Salt Lake City database composed of approximately 31,000 links and 52 pressure zones. The author summarized the paper by stating that the information from the research can also be the PipelineNet simulates the flow and concentration of biological or chemical contaminants in a city or municipality's water distribution system. The integrated model is a powerful tool for routine planning and emergency response. It gives emergency managers real time information for estimating the risks to public water supplies and population at risk. The PipelineNet can calculate, locate, and map the population at risk from the introduction of contaminants to the public water supply.

Labadie John W. ,Margaret T. Herzog have published article on **"Optimal Design of Water Distribution Networks with GIS" [24]**

To assist water engineers to utilize an advanced water distribution system optimizer, a user-friendly interface, database support, and mapping utilities have been integrated into ArcView 3.1 GIS using AVENUE and the Dialogue Designer extension. This decision support system (DSS) is developed into an ArcView extension called WADSOP - Water Distribution System Optimizer. WADSOP optimizes pipe sizing and layout, as well as pump station sizing and layout, to improve cost-effectiveness and reliability over most

existing water distribution models based on less effective pipe simulation algorithms. GIS provides functions for development and preparation of accurate spatial information for input into the network design optimization model, which includes network layout, connectivity, pipe characteristics and cost, pressure gradients, demand patterns, cost analysis, network routing and allocation, and effective colour graphic display of results. Municipal water distribution systems represent a major portion of the investment in urban infrastructure and a critical component of public works. The goal is to design water distribution systems to deliver potable water over spatially extensive areas in required quantities and under satisfactory pressures.

The goals of WADSOP are to:

- combine GIS with pipe network design and analysis models
- encourage greater use of optimization models by design engineers

Provide a flexible tool for engineers for:

– analyzing existing networks
– optimal design of new water distribution networks
– expansion of existing systems.

The WADSOP application was developed exclusively in ArcView GIS (3.1) as an extension using AVENUE programming and ArcView project customization capabilities. All dialogues were developed using the Dialogue Designer extension to ensure that the application could be used on any platform. The CAD Reader extension was used to permit CAD drawing input, mapping, and conversion, and the Spatial Analyst extension was used for digital elevation model input and usage. One of the most useful extensions incorporated was the Network Analyst for routing new pipes and rerouting old ones, allocating water supply to demand zones, and for developing pressure zones. It concluded that, improve interface to allow more input options such as determining node elevations from contours. Complete network allocation module to assign supply or pressure zones. Allow more flexibility in input parameters to the optimization model. Include a simulation model for comparison to optimization and for expanded functionality.

Tian Yu et al have published article on "**Construction of Water Supply Pipe Network Based on GIS and EPANET Model in Fangcun District of Guangzhou"** [43]

In this article, the author has suggested GIS based EPANET model for water supply pipe network. With extensive use of GIS technology in the field of water resources management and river basin.

Water environment simulation has unique advantage management and expression of data accurately, integration of data operation and spatial analysis, becoming important basis for urban infrastructure planning. Based on the powerful pre-treatment system of GIS software platform, information of pipelines and ancillary facilities are edited, searched and statistical analysis in the paper, and second development is done based on ArcEngine of GIS technology, coupled with EPANET pipe network model, water supply pipe network model in Fangcun of Guangzhou is developed based on GIS technology. Preparation for model, basic information is as follows-

- Collection of pipe information - The basic information in the GIS map of water supply networks includes pipe length, pipe diameter and roughness coefficient of pipe.
- Water consumption data and water supply data-The water consumption data keeps the monthly record of 130,000 consumers in Fangcun district from January 2009 to May 2010. After statistic analysis of the data, 87 big consumers are chosen. The water consumption of the big consumers adds up to a proportion of 52% of the total water consumption. The water supply data comes from SCADA (Supervisory Control and Data Acquisition) monitoring nodes.
- Node elevation extraction based on ArcGIS 9.3

The calculation result of water supply network model in Fangcun district of Guangzhou shows that errors of pressure and flow measurement are all less than 6%, indicates that the result of model is applicable in the region. Coupled GIS software and EPANET model do hydraulic calculation of water supply pipe network, improves calculation efficiency and accuracy, and provides preconditions to research on monitoring warning of water quality. Through the establishment of hydraulic model of water supply network can

give evaluation of recently running status of pipe network, and through analysis calculation of pipe network to approve the layout rationality of water plants.

Chen Yuli et al have published article on" **Application Analysis on the Information Management System for Water Supply Network in Guangzhou"** [11]

In this paper, the author has discussed information management system for water supply network in Guangzhou. This paper, based on data research, introduces the general situation of the system, analyzes the present situation in the application process, explains the existing problems in details and proposes improvement programmes preliminarily, providing a basis for the improvement of the information management system for water supply network in Guangzhou. With the enlargement of water supply network scale and the complication of network topology structure, the related network management becomes more and more complicated. In that case, the traditional manual modes and measures of management cannot meet the requirement of safe water utilization and high quality service proposed by water enterprises. In order to improve the management level of water enterprises, it is imperative to establish a set of information management system for water supply network.

The information management system for water supply network in Guangzhou is a system that consisted of computer software and hardware. Based on Geographic Information System (GIS), combined with Supervisory Control And Data Acquisition (SCADA) system, the information of pipelines and facilities are acquainted, storied, managed, analyzed, inquired, outputted, updated in the form of digital, using geophysical techniques, the mapping technology, computer technology, GIS technology, database technology and communication technology. This system is consisted of GIS and SCADA system. ArcGIS 9.2 of Environmental System Research Institute (ESRI) is chosen as geographic information system platform and Oracle10GR2 is adopted as its database. The system structure is separated into three different cooperatively levels by the presentation logic, business logic and backend database. The function of presentation logic is the input and output of information and the business logic is for handling affairs while the backend database is for lasting preservation of the data in the business logic.

Tabesh M. , Asadiyani Yekta A. H. and R. Burrows, have published their article on " **An Integrated Model to Evaluate Losses in Water Distribution Systems**" [40]

To evaluate non-revenue water (NRW) and losses in water distribution networks, a methodology is developed by applying "annual water balance" and "minimum night flow" analyses. In this approach, the main NRW components such as leakage from reported and un-reported bursts and background leakage, with real or estimated data, enabling assessment of indices of leakage performance are evaluated. Also, a novel procedure is introduced in this paper that can determine the nodal and pipe leakage by using a hydraulic simulation model. Recognizing the pressure dependency of leakage, the total consumption is divided into two parts, one pressure dependent and the other independent of local pressure and the hydraulic behaviour of the network is analyzed. A computer code is developed to evaluate all components of water losses based on the proposed methodology. For better representation of the results and management of the system, the outputs are exported to a GIS model. Using the capabilities of this GIS model, the network map and attribute data are linked and factors affecting network leakage are identified. In addition, the effects of pressure reduction are investigated. The model is illustrated by a real case study. The results show that the suggested model has overcome the shortcomings of the existing methodologies by accounting for the leakage and other NRW components in water distribution networks more realistically.

C. Jun a et al have published their article on **"An Integrated Model to Evaluate Losses in Water Distribution Systems"** [9]

The water mains burst in Seoul, Korea and it is one of the most frequently raised water management problems and the major reason can be found in the inefficiency in design and management of the network. The study developed a prototype system that allows the user to evaluate the level of deterioration and to design alternative water mains for simulation. The study suggests an evaluation scheme that models mains failure based on different variables such as pipe age, diameter, ground elevation, and pipe materials. Also, the user can interact with the system to create virtual pipelines that link the user-provided origin and destination points considering the efficiency in regional supply, distance, road network and construction cost. The shortest path algorithm called Dijkstra's algorithm was used for the pipeline simulation. The data was constructed using the GIS based on

the residential blocks which are defined by supply region, water demand and street network. The system was applied to a test region in Seoul, Korea.

The study suggests a framework to develop a GIS-based management system to monitor superannuated pipes and design alternative network. The analysis of old pipes was done based on the distribution block units. A shortest path algorithm called Dijkstra's algorithm was used for the pipeline simulation. The data was constructed using the GIS based on the residential blocks which are defined by supply region, water demand and street network. The system was applied to a test region in Seoul, Korea.

The main objective of the study is to support such decision making, develop a prototype system that can help in two areas; firstly, block designing and pipe monitoring and second, optimal path simulation between major reservoirs. The system is expected to help in following aspects such as block-designing, the pipe management module, alternative pipe routes can be created by simple user operations on the screen showing existing reservoirs and pipe network.

Suchith Anand , Dr K. Vairavamoorthy have published article on "**GIS in Design and Asset Management of Intermittent Water Distribution Systems". [39]**

In this article, the author has been highlighted role GIS in Design & Asset management for water distribution system.GIS can be used as an effective tool to help the engineers in the design and asset management of intermittent water distribution systems. The broad areas where GIS can be applied are –

Data Collection: Conventionally data on Networks was collected and stored in paper format. With the advent of newer technologies like GPS and digital cameras, data collection can be made faster and accurate and also better GIS integration of data. In areas where this digital data is not available paper plans can be scanned and used instead. For newly developed areas, where no data is available, aerial photographs or satellite images can be used. It is also possible to use a combination of raster and vector data.

Data Storage: Data on network components can be stored in GIS for spatial querrying. The main data that will be stored will be pipe and node locations and characteristics, reservoir details, valve details and depending on level of sophistication even include types and details of consumer locations. This data can be collected and inputted by field staff in spreadsheets and later imported into a GIS. Pipe data is held in the system in a

node and line type format. Data can be input in several ways, either directly onto to the screen, from a digitizer, or from previously captured data that can be read into the database as long as it has a record of its grid co-ordinates and connectivity.
Data Mapping: Generating the mapping of distribution system for various criteria using GIS makes everyday querying based on specific criteria quick, easy and understandable for engineers. Fundamentally, the model presents information, as on a map. There is a great deal of flexibility in the way that data can be used. Background maps in a variety of formats can be supported.

The GIS contains a standard database structure to hold all the data that is regularly used for distribution systems, but the system is not limited to just this data. Any data set can be viewed provided that the information is given either a grid reference or a cross-reference to an item (node or line).

Analysis: Statistical analysis, data interpolation and spatial statistics to be carried out with the GIS. Due to the voluminous amount of data that has to be stored in case of any distribution network, the various analysis tools in any standard GIS not only help in Spatial analysis but also in statistical analysis of data sets.
Visualization: Multimedia data like photographs, videos and 3D panchromatic imagery to be stored for corresponding data sets to enhance real-life scenarios. This enables site condition assessments for immediate actions. Also the visualizations tools in GIS can be used to find patterns and relationships in the huge amounts of data collected like pressure and flow recordings

GIS in Demand Modelling and Design: GIS to be used to model hydraulic conditions in spatial terms and how it can be used to help in design of systems. Performance information is so important to network design and in planning. A dynamic, hydraulic, water-distribution model helps to understand the effect of different demands on the network, and allows the right design decisions to be made to allow for future increases in demand.

Pickard Brian D. and Levine Audrey D have published their article on "**Development of a GIS Based Infrastructure Replacement Prioritization System: A Case Study"** **[30]**

Infrastructure Management Systems (IMS) have been developed to assist utilities and decision-makers in determining how to allocate resources for infrastructure. This project utilizes the Tampa Water Department (TWD) as a case study to develop a tool for prioritizing infrastructure replacement. TWD is responsible for managing over 2,240 miles of pipeline. Building booms in the 1920s and 1950s have inadvertently resulted in a significant need to replace or rehabilitate pipelines due to the aging of the overall water supply infrastructure. To address this problem, TWD is taking the first steps in applying IMS to transmission and distribution pipelines. Currently, approximately 500 miles of water mains have been slated for replacement or rehabilitation. The TWD has a GIS that has been used to map and integrate information on main breaks, service line breaks and customer complaints. Information on fire hydrant spacing and line flushing dates are also integrated into the GIS. Following development of the GIS based infrastructure replacement prioritization system, approximately 3,000 pipe segments were identified and querries were performed to help develop cost to benefit analyses.

The GIS was also used to develop indicators of the overall infrastructure condition. From this analysis, it was possible to develop an approach to categorize projects and identify the resources needed to address high priority problems associated with undersized mains, unlined cast iron mains, asbestos cement mains, and hydraulic looping projects. This study has demonstrated the ability to prioritize long-term and short-term infrastructure projects using a GIS platform in conjunction with databases and spreadsheets.

This project successfully consolidates master plan programmes, main break reports, service main break reports, customer complaint logs, flushing reports, fire hydrant spacing criteria and estimated water age into a single database eliminating analysis difficulties due to inconsistent data formats. Once a consolidated database is obtained, benefit to cost ratios for 2,886 planned projects are successfully calculated based on GIS analysis. Analyzing the top 10 percent of planned capital projects allows the water utility to appropriately allocate available funding between master plan programmes. This project successfully implemented following things such as master plan programmes are successfully converted into an electronic format appropriate for GIS analysis. Databases containing listed infrastructure condition indicators are consolidated into a common format suitable for GIS analysis.

A prioritization matrix developed by Tampa Water Department policy makers is developed. Benefit to cost ratios for 2,886 planned capital projects are included as part of this project.

Ingeduld, Zdenek Svitak, Pradhan Ajay, Tarai Ash has published article on "**Modelling Intermittent Water Supply Systems with Epanet" [22]**

Modelling rural networks and intermittent water supply systems is a challenging task because these systems are not fully pressurized pipeline networks but networks with very low pressures, with restricted water supply hours per day, and with thousands of ferrule points and roof tank connections. The alternate emptying and refilling of water pipelines makes it problematic to apply standard EPANET based hydraulic models because of low pressures and pipes without water. EPANET source code was adjusted to allow for modelling pressure dependent demands, for dealing with low pressure and dry pipe situations. A configurable tool was developed for incorporating roof tanks into the water supply analysis and for better formulation and schematization of the system hydraulics. Two case studies, water distribution model of Shillong in India and detailed water distribution model of Dhaka in Bangladesh are used to illustrate the practical use of this approach. The experience from using and adjusting the EPANET engine for the modelling of intermittent water supply systems is discussed in this paper. The presented solution for modelling intermittent water supply system is based on EPANET toolkit for hydraulic modelling. The solution is robust, simple, and it proved to be useful and practical for the modelling as it is illustrated on the hydraulic models of Shillong in India and Dhaka in Bangladesh. The algorithm is implemented to DHI's water distribution software packages MIKE NET and MIKE URBAN.

Tao Song, Kyehyun Kim have published article on "**A Study of Developing GIS-Based Water Quality Management System of Rural Area " [42]**

Water is one of the most important natural resources. The wise and sustainable uses of water, especially paying much attention on the water quality, are very essential. Nowadays, the rapid increase of population and industrial activities has been the major source of pollutants carried off through sewers and drains. This study mainly concentrated on developing a GIS based system which can provide estimation of the amount of pollutants and effective decision making for mitigating water pollution. Major

work tasks can be divided into threefold. Firstly, a pollutant database was generated for the study area including different types of digital layers and the Unit Load Coefficients were used to calculate water pollutants. Three types of water pollutants were calculated such as generated, discharged, and flowed. Secondly, one water quality model QUAL2E was adopted to simulate the water quality status for the study area such as Hongseong Gun and Yesan Gun of Chungchongnam Do in South Korea. The QUAL2E model was used to forecast water pollution for rivers and streams. Finally, one GIS-based management system was developed to integrate pollutant DB, water quality model, and GUI for decision making process. The results showed that the developed system could facilitate estimation and prediction of water pollution based on GIS. Furthermore, GIS can provide easier process for decision making to decrease water pollution by investigating numerous scenarios of the study area.

In this research, a study of developing GIS-based water quality management system was implemented to try to manage and analyze the water quality information of one study site, and to support decision-makings for local governments. Totally, three steps, including water pollutants calculation, water quality modelling, and system development, were carried out. This developed system has the abilities to integrate various water resources and water quality related information, calculate and analyze the water pollutants, and predict the water quality status and trends. Therefore, the system is potential to help local governments make decisions and plans on water quality improvements such as decreasing water pollutants and properly redistributing sources.

Breiling Meinhard has published article on **"The Use of Geographic Information Systems (GIS) in local Planning and Possible Contributions to Integrated Water Management in Sweden"** [8]

In this paper, the author has focused on the planning problem of integrated water management with the application of the supportive tool GIS (Geographic Information Systems). It is structured in three different sections, a theory of GIS utilization, a particular contextual embedding of local water management in Sweden and examples of local projects to support integrated water management and how these projects should be used in a municipal GIS.

Water management is a highly interrelated procedure covering different spatial scales and various fields of expertise. However, different institutions usually reduce the meaning of water management to their individual requirements, and develop the subject isolated from each other. To reintegrate different approaches to water management is today a general aim in Sweden, but integrated water management is easier to define in theory than to carry out in practice.

Communication during the local planning process has to bring together three different main groups; specialists, generalists and the public. First, specialists present their view of the affected landscape according to natural properties and social interests, second, planners or mediators combine the available information to conceivable scenarios, and third, the public concerned by the intended project should evaluate possible planning alternatives. GIS is supposed to be a suitable device to ease communication between all involved groups. Integrated water management means covering the whole water cycle in a global, regional and local dimension. It combines information originating from different sources.GIS is a presentation, a co-ordination and a public participation tool. GIS can combine information of different fields but to use it for local planning, interpretation and simplification are needed. It can increase communication by reducing complex information to a few and practical categories. Sector interests and conflicts become obvious and manageable. GIS technologies can be used to motivate.

Many planning processes take place simultaneously over different geographic scales. The role of the participants in several ongoing planning processes may be different in each one. Being a specialist, coordinator or concerned public may change according to the topic and scale of the planning problem. Awareness of which role the participants are playing will contribute a lot to the efficiency of GIS. It should not be only a technical playground but primarily should help to solve problems. Considerations of local GIS use should start first with a large scale approach, and then an approach to smaller scales is recommended. The smaller the scale of the planning task, the more problematic is the use of a large scale GIS. The “Local Agenda 21 Plan“ of the Swedish municipalities is a major challenge to achieve more integrated water management and the application of an adapted GIS may be have interest.

Leigh Eric and Dr. Guy Fipps have published article on **"Use of Geographical Information Systems (GIS) In Defining Municipal Water Supply Networks"** [25]

Geographical Information Systems (GIS) have been helping the Irrigation District Team (IDEA) of the Irrigation Technology Center to provide services and assistance to the agricultural communities and irrigation districts in the Lower Rio Grande Valley of Texas. This paper is mainly focused on to identify the extent of the municipal water supply networks (MSN) defined as those portions of the water distribution networks and control structures of irrigation districts that transport raw water to municipal treatment plants. This study was a time and labor intensive process and involved frequent visits to the irrigation districts for the collection and review of field data and analysis. This paper presents the procedures and methods used to produce the first initial estimates of the MSN. The study was done in the following steps:

- Identification and verification of the districts with municipal water deliveries;
- Production of review maps for each of the 14 districts;
- Initial meeting with irrigation districts to: review maps, identify on the maps the locations of municipal takeout points and downstream control structures, and collect available data on sizes, dimensions and capacities of MSN components;
- With the help of district staff, conduct field reconnaissance and measurements as needed.
- Mapping and computing the surface areas of reservoirs using aerial photographs and GIS mapping tools.
- To determine the lengths of MSN components from GIS-based maps.
- To process data, completing analysis, and production of tables and maps for districts to review.
- Meetings with district personnel to review data and analysis.
- Follow-up field measurements and other efforts as needed to develop complete data sets and analysis.
- To finalize MSN estimates under normal operational conditions, including:
  Static volume, evaporation and seepage losses;
- Feasibility assessment of analyzing MSN requirements assuming no agricultural water deliveries; and

- Formation of recommendations for further analysis.

Abdollah Ardeshir et al **have** published article on **"Leakage Management for Water Distribution System in GIS Environment"** [2]

Leakage control is one of the most important issues in water networks. This paper presents leakage management and how to organize and analyze a water distribution system for leakage purposes. Also, various aspects of management of water supply networks are depicted in order to provide integrated hydraulic model in (Geographical Information System) GIS. These consist of determination of required data structures and, how to supply and reintegrate the information in GIS. The specification and applicability of the hydraulic model, in GIS for leakage management in urban water system, is studied with practical project in Saveh city of Iran. These are accomplished using Arcview as GIS base and EPANET software for hydraulic modelling and link between the above programs is DC water extension. Based on the analyses carried out and using the relationship between hydraulic and physical characteristics of distribution system, leakage indices have been calculated. The results can provide valuable management guidelines to identify leakage location in the system. Also, a flowchart of data management and analyzing hydraulic systems in GIS environment has been obtained that can be useful in any other process of such analysis.

Ifatimehin, O.O. and Musa, S.D have published article on"**The Prospects of Sustainable Management Of Domestic Water Supply And Sanitation In Kogi State."** **[21]**

The ultimate goal of any credible and legitimate government is to ensure sustained improvement in the provision of basic water utility and its effectiveness in the efficient delivery of this service to the citizenry. This research aims at achieving the objectives such as to examine the status of water supply and sanitation in Anyigba, to ascertain the prospects for the development of an effective water supply and sanitation infrastructure, to suggest how best to manage and sustain an efficient service delivery that will be affordable by all.

The importance and implication of efficient delivery of portable water and its management, and also access to hygienic sanitation facilities are of utmost importance to every human sector. Field survey and the review of technical and research literatures

were done to generate the data and information used for the study. Simple statistics were used in its analyses and GIS techniques for spatial analysis. It was observed that about 35% of the sampled population has access to clean but untreated water from the boreholes only and 32.9% to untreated polluted water from the stream and lake while 67.1% access the borehole water in different measures. 8.6% access their water through pipe network and the total sanitation coverage is 8.6%. The entire population at the risk of water and food borne diseases. It is quite evident that the available source of portable water in Anyigba is inadequate and needs to be improved upon. This improvement is required also in the area of sanitation, which is presently very poor. The measures suggested in the study, for the improvement of the quality of water supply in Anyigba, are increase in the number of boreholes, pipe-networking of the boreholes and sanitation facilities; community involvement in water and sanitation projects among others will not only alleviate the problems of water supply in the area but will also ensure that the energy formerly expended in searching and carrying water is better utilized for more productive work .

Guizuo Wang,Liliang Ren,Tianfang Fang,Jinping Zhang have published article on **"The Study and Application of GIS-based distributed Hydrological Model"** [16]

Based on the multi-angled underlying surface information provided and generated by GIS, the authors took into account topology, vegetation and soil's effects in the developmental process of runoff and built a spatial distributed model of basin water storage capacity. On the base of these studies, IHMS-VSWSC (Integrated Hydrological Modelling System Based on Various Spatial Water Storage Capacity) was explored and developed to simulate basin rainfall runoff process, which simulated hydrologic processes including canopy interception, snow melt, evapotranspiration, runoff production and flow concentration. This model was applied and verified in the hydrologic simulation of Laoha River Dianzi basin, China. An average NASH-Sutcliffe coefficient of 0.807 was achieved and it indicated that this hydrologic model was a good one, as well as the spatial distributed model of water storage capacity the authors built could describe relative spatial distribution of water storage capacity in cold and arid area.

In this paper, the authors built a conceptual distributed hydrologic model based on the spatial distributed model of water storage capacity (IHMS-VSWSC) which applied

saturation excess runoff mechanism to describe the soil water change of grid vegetation root system layer. This way avoided the direct description of complicated soil water movement process, and the structure of this model was simple as well as could be applied with multiple source data. The description of the spatial distributed model of water storage capacity towards the spatial distribution of basin water storage capacity was verified, and the method of build distributed basin hydrologic model based on the spatial distributed model of water storage capacity was feasible.

Bartolin Hugo J., Fernando Martinez have published article on **"Modelling and Calibration of Water Distribution Systems. A NewGIS Approach"** [6]

GIS is becoming an essential tool for utility companies, especially water companies, which have found an excellent way to manage and assess their assets. This paper presents an ArcView® GIS extension called GISRed, which is a customized application oriented to the task of water network modelling. GISRed is capable of simulating, analyzing and retrieving the actual network status under certain conditions using an integration of the widely used EPANET engine. In addition to this, a new functionality has been developed to allow the final user to calibrate the network model by means of a genetic algorithm module which works seamlessly along with the extension.

Hydraulic simulation models are becoming of common use among planners, water utility personnel, consultants and many others involved in analysis, design, operation or maintenance of water distribution systems.. The integration of GIS and hydraulic modelling software, offers many additional capabilities of analysis and data management. For this reason, it is not unusual to see built-in applications that lump together GIS and hydraulic simulation/optimization software to obtain a valuable tool in terms of modelling and decision-support. The benefits of the integration are quite evident. The modeler can save a lot of time in constructing a network model making use of all the potential that the GIS offers when it comes to data management, manipulation and analysis. This paper presents an extension to ArcView that basically integrates hydraulic modelling tools, hydraulic simulation software and a hydraulic calibration module.

The capabilities of a GIS can be extended beyond that of maintaining utility records into the area of planning and managing. It is becoming more and more popular to use computer models to simulate the reality before taking any decision.

The use of ArcView GIS along with the additional functionality given by a customized extension oriented to water distribution network modelling, may suppose a major advance in terms of analysis, assessment and maintenance of the main assets of a water company. The integration of a hydraulic simulator within a GIS, offers a series of advantages for the water engineer, not only in terms of evaluation of the system performance, but also at other levels, such as, planning, design, management and decision-making issues.

Kui Chang, Jinliang Gao, Yixing Yuan, Wenyan Wu have published article on **"Establishment of the Scheduling Training System of Water Distribution Network Using Virtual Reality" [23]**

A water distribution network model which was based on virtual reality was constructed and the state of- art was simulated in a 3D scene. It works with a clear sense. The water network engineering database was built firstly in this paper to keep the precision of the 3D model.

All kinds of data for water distribution network could be shown in the VR based simulation of the water distribution network directly. The system overcomes the limitation of the traditional GIS system, and the simulation is exact and believable.

An urban water supply network is buried under the ground. The topology is complex, and it is not visible. There are thousands of nodes and pipes in the water network. The design and operation control is very difficult. The administrators must be trained strictly in order to worth their salt. Urban water network topology linkage is expressed by the way of floor plans and the profiles in traditional geographic information system. The results are abstract and difficult to understand. Virtual reality employs detailed computer graphics to create quasi-real 3D objects that respond to user interactions. Three essential characteristics of a VR system are: (1) response to human interaction, (2) real time 3D graphics and (3) immersion. The first two characteristics are self-explanatory. Virtual reality is defined as the use of various computer graphic systems in combination with various display and interface devices to provide the effect of immersion in an interactive 3D computer generated environment in which the 3D objects have spatial presence. In this paper, a novel methodology of virtual design and operation control and training of complex water network using virtual reality was proposed.

The Virtual Reality Theory has been applied in the field of water network simulation. Users could be trained in the system, and had the water network hydraulic and water quality information in a visual way. Virtual reality based simulation of urban water supply network system will have important significance for water supply network management, as well as of digital urban construction to make the large number of data in the water supply network visualization, to achieve the virtual design for water supply network, to provide a platform for the urban water supply networks security control, to play a guiding role on the new and old water source switching. Reality based simulation of urban water supply network system achieve the dynamic simulation of long distance transport of water. Virtual reality based simulation of urban water supply network system can be made as virtual training.

Lin Ji-Hao has published article on **"Scenario Simulation of Water Supply Network "** [27]

This paper studied the flow of water in the pipelines of the Taipei city before and after earthquakes using GIS and computer simulation. Then, the analysis results were displayed using the Google Earth system for visualization. The result will help users examining the conditions of the water supply network for disaster preparedness and mitigation.

This study combines Google Earth with EPANET to analyze the water supply systems in Beitou District and Shilin District, and then shows the analyzed result on the Google Earth. With such visual displays, users can quickly and clearly understand flow and pressure head information of pipeline in the water supply systems. This preliminary stage of study results can already help users to understand the information of water supply in actual geography from the visual displays. The author has recommended future scope as; this study will apply more rigorous analysis method with seismic damage ratio and Monte Carlo simulation to simulate the situation of major earthquakes. In addition, the study will also analyze the distribution of the location of broken pipes in the water supply systems in order to assess the operational conditions of the water supply systems after large earthquakes.

Howard, J., K. Larson1, D. White, and E. Wentz have published article on **"The Use of GIS as a Decision-Support Tool by Water Managers in Phoenix, Arizona"** **[18]**

Water managers in the Phoenix metropolitan area must cope with uncertainty on a continuous basis. The levels of uncertainty in terms of data, climatic variability, global climate change, political context, and social environment are distinctively complex for water resource managers in water providing organizations. Knowing how water managers address uncertainty is important in understanding how large-scale uncertainties with water supply are addressed at the institutional level. Water managers need access to the right tools to help them assess conditions and data where the picture of reality may be obscured by inaccurate or incomplete data. GIS is a tool that can be directed toward that end. In order for GIS to be used effectively in that regard, it is important to understand how it is currently used by water managers. This research is guided by three questions. First, how do water managers address uncertainty in decision-making? Second, how is GIS used by water managers in decision-making? Third, how do water managers deal with uncertainty in their use of GIS? This poster will present the preliminary findings of the analysis of 12 interviews conducted with Phoenix-area water managers in 2005. The goal of this research is to understand how water managers cope with uncertainty in their line of business, how GIS is used within water management organizations, and finally to understand how GIS is used by water managers, particularly with respect to how they use GIS to address uncertainty. Water managers address uncertainty using a variety of tools and techniques, most prominently visualization tools and techniques and scenario analysis. Within water management organizations, GIS is used by water managers as a decision-making tool and analytical tool more than as a strictly map-production or data maintenance tool, although mapping is still a key role for GIS within these organizations. Less straightforward is the use by water managers of GIS as a tool for addressing uncertainty. The initial results from this research would tend to indicate that this particular use of GIS is not widely adopted by water managers.

Werner de Schaetzen and Paul F. Boulos have published their article on "**Optimal Water Distribution System Management Using ESRI MapObjects Technology**" **[55]**

GIS can greatly assist in various modelling applications through the development of automated tools for constructing and maintaining reliable hydraulic network models of water distribution systems. This paper presents a comprehensive GIS-based decision support system, called H_2OMAP Utility Suite, for use in the effective planning and management of water distribution systems. Built with Esri MapObjects technology, the resulting software will effortlessly read GIS data, extract necessary modelling information, and automatically construct, skeletonize, load, calibrate, secure and optimize a representative network model. It also makes it easy to run and simulate various modelling conditions, identify optimal monitoring stations, locate system deficiencies, and determine the most cost-effective improvements for optimum performance. The optimization model uses an efficient variation of the genetic algorithm for solving network model calibration, field sampling design, pump scheduling, and network design and rehabilitation problems in an optimal fashion. This paper presents a new perspective to water distribution planning and management. It is a unique network analysis platform that addresses the requirements of the modelling engineer while providing the functionality of a GIS for consistent facility asset management. The graphical interface is developed using Esri's MapObjects geospatial technology and provides an informative structured framework for database management and complete network model construction, analysis, and result presentation. The role of a GIS in the analysis of a distribution system is to provide up-to-date and accurate data to be used in the engineering analysis. The software makes it easy for any utility to work seamlessly across platforms and to manage water systems in a single environment.

Shandas Vivek et al have published article on **"A GIS based Water Demand Analysis for Municipal Application" [38]**

In this paper, the author has proposed a methodology that utilizes a Geographic Information System (GIS) and empirical data for analyzing spatial water consumption patterns with the objective of prioritizing water conservation areas within the City of Seattle, Washington (USA). While the proposed method is applicable to one city, namely, Seattle, we foresee application to any city that has the appropriate data. The raw data is publicly available, provided by the City of Seattle and the National Oceanic and Atmospheric Administration (NOAA). In this paper, the author has developed a spatially

explicit methodology for assessing the potential application of rainwater catchments in the city of Seattle. The methodology aims to address the question, which parcels within the city have the highest overall potential for water conservation using rainwater capture systems. It is important to emphasize that this study does not examine the role of price or householder's characteristics on water demand; rather it examines water use patterns at a specific time in priority areas of the city. The intention of this paper is to develop a GIS based methodology upon which householder characteristics can later be incorporated. Moreover, this study is the first piece of the rainwater catchment assessment, namely, the identification of households within specified areas with highest potential for water conservation. There are three parts to this paper. The first section describes the study area, data and methods; second, we use statistics and the GIS to evaluate results; and last, we provide recommendations for refining this analysis so that water managers can apply this methodology at the city scale.

Water demand indicates both current and/or expected water consumption in any given area over a specific time period. Due to varying requirements and spatially explicit characteristics of individual users, water demand must be determined separately for individual user groups. Multiple uses of water can be differentiated according to the demand for potable water, industrial/commercial processes, as well as irrigation. The advantage of using a GIS for this analysis is that it helps with the initial identification of the parcels, visual cross checking with statistical data, and provides a platform for presenting the analysis to city officials for review.

Henriette Tamasauskas*, L.C. Larsen, O. Mark have published article on **"Using Gis In Water Supply And Sewer Modelling And Management"** [17]

Geographical Information Systems (GIS) are becoming the universal backbone in most information systems managing data for water and wastewater systems. Using GIS is a great aid in graphically presenting geo-referenced information and providing the necessary tools to accurately locating needed information and linking water supply and sewer modelling systems using the spatial position as the main indexing mechanism. This ability to work with vast amounts of spatial data in a visual and easy to understand way means that otherwise slow and cumbersome processes such as building hydraulic models of water or sewer network systems can become much more efficient. This presentation will

describe examples of how GIS can be a good partner for hydraulic modelling and integrating with asset management systems to form an efficient work bench for building, maintaining, and graphically presenting accurate water supply and sewer models. DHI's modelling tool MIKE URBAN combines DHI's 20 years of innovation in urban water distribution and collection system modelling with ESRI's ArcGIS technology, thus providing a complete urban water modelling environment based on GIS. Management and display of spatial data hence takes place in a GIS environment, allowing MIKE URBAN to utilize GIS features for building, maintaining and graphically presenting accurate water supply and sewer models.

Tabesh M., M. R. Delava,A. Delkhah have published article on **"Use of geospatial information system based tool for renovation and rehabilitation of water distribution systems"** [41]

In this study, a methodology is presented to manage the rehabilitation and replacement of water distribution network using hydraulic and geospatial information systems models. A preprocessor subroutine is developed to link geospatial information systems and hydraulic software. Hydraulic parameters together with the attribute data of pipes are used to determine the required renovation schemes based on several criteria. The proposed indices consist of pipe breaks and leakage analyses, hydraulic and quality performance and mechanical reliability of the network. A novel approach is also introduced to calculate leakage values throughout the network. Results of a real case study by the developed model introduced replacement of 4 km 40 mm galvanized pipes instead of 11 km 100 mm asbestos-cement pipes from conventional method. It is observed that the suggested geographic information system based model produces more realistic results with less cost for renovation schemes in comparison with conventional method which just consider number of bursts as a key criterion.

In this study, an integrated model was built which links the GIS and hydraulic simulation software. Then a robust and appropriate methodology for renovation and performance improvement of water distribution network was presented. This method consists of several parts such as calculating the number of breaks, break rates and burst analysis based on pipe diameter, length and leakage values. Using the performance indicators developed for hydraulic and quality parameters (pressure, velocity and residual

chlorine), the performance of each node, pipe and entire network are evaluated and represented on the network map directly. Thus, the best scenario for rehabilitation and replacement of water network can be identified. The model calculates the cost of any operational decision. Results of the real case study showed that applying simple index of number of breaks is not a good criterion for pipe renovation scheme because the developed model introduced 4 km 40 mm GA pipes instead of 11 km 100 mm AC pipes from conventional method which leads to save huge amount of money. The model suggests the required pipes to be replaced to improve the hydraulic and quality performance of the network, because it is able to calculate and use the updated hydraulic and quality values from the simulation model.

Madhavan K.D. has published article on **"Mapping & Maintenance of Water Distribution System and Sewer Collection System Network using Remote Sensing and GIS"** [28]

The main aim of this project is to address the need for equitable Water distribution and sewerage collection system. The specific objectives of the project component assigned to Chennai city are -1) To map the existing water distribution system 2)To map the existing sewer collection system 3)To develop a model for Water and Sewer network system 4)To analyse the sewer network system. This paper mainly discussed about the creation of data model for water / waste water and its utilities up to the extent of construction of data model, data management, data base system and data linking.

The step-by-step approach followed for the study is as follows

- Collection of field data on the existing water supply distribution system, sewer system, elevation by various survey methods & survey equipments such as Ground Penetration Radar (GPR), Electronic Pipe Locator (EPL) etc.
- Preparation of various thematic layers viz. Road Networks, Rivers, Railway line, Buildings, Building groups etc., Maps are prepared from existing vector based NRSA map (1:2000scale)
- Development of network layers via, Road network, Water Distribution Network, Sewer network, and preparation of input data for the data models by incorporating field attribute data

- Generation of data model from GIS.
- Data model Management by using GIS Network Analysis and development of a user-friendly tool for data Management.

The Maintenance & implementation of data modelling of urban design for Chennai pilot study using GIS has been successfully conducted.

- The data is well created such that upgrading is easier.
- User can quickly identify features by simple querying.
- Utilities created with database can be used for Tax Collection, Billing, and other related purpose.
- If a fault takes place in the network and if the concerned engineer knows the place of fault a he can obtain all the information about the network by querying GIS and can rectify the problem at the earliest.
- Using a GIS you can enter new data or modify existing data. This example shows a GIS interface that allows easy editing of geographic data and the display of related documents.

This product provides GIS users with an interface tool for network analysis for water flow. Key concepts in any network-modelling interface include minimizing data redundancy and simplifying the model/management process.

Abaje I.B.,O.F. Ati, and S. Ishaya have published paper on **"Nature of Potable Water Supply and Demanding Jema'a Local Government Area of Kaduna State, Nigeria"** **[1]**

Water is a natural resource of fundamental importance. Without water, life as it exists on our planet, impossible. This research work examines the nature of potable water supply and demand in Jema'a Local Government Area of Kaduna State. A total of 220 questionnaires were administered to households in five wards within the study area, although only 200 of these questionnaires were used for the purpose of analysis. Out of the 44 questionnaires administered to households in each of the five wards, 40 each were analyzed because not all were completely returned or answered. The analysis was based on descriptive statistics and presentation. The total water demand in the area is obtained by finding the product of population figure of the study area and the average daily per capita water consumption. The role of water in modern society

such as the urban centers of Nigeria cannot be over-emphasized. People depend on its good quality-and quantity-for drinking, recreation, and use in industry and for growing crops. This research work has highlighted the nature of potable water supply and demand in Jema'a Local Government Area of Kaduna State. Despite the considerable attention paid to water supply in the study area over the years, inadequate water supply remains one of the major problems.

Findings revealed that most of the people that have pipe-borne water in their houses are not satisfied with the water supply; and whenever the water is pumped, it does not last more than 2 hours in a day. As a result, the use of alternative sources of water is indispensable. These have not been accompanied by an increase in water supply, and hence water scarcities are critical especially in the months of February-April. As a result of that, the uses of alternative sources of water are indispensable. Result further revealed that an individual needs an average quantity of 37.45 liters of water per day. The low service level of water accounts for prevalence of water-borne diseases which could get to epidemic scale if not attended to promptly.

Prof.Vidya S.Gavekar have published article on "**Enhancement of Water Supply System through GIS"** [31]

This paper describes a project to integrate EPANET and Arcview to assist emergency managers in assessing public water supplies. The integrated system is called PipelineNet. This system calculates, locates, and maps the population at risk from the introduction of contaminants to the public water supply. The EPANET toolkit allowed Arcview to utilize the EPANET engine to route a contaminant through the system under extended period simulation. The new system would improve the efficiency and accuracy of the data retrieval, mapping and analysis. This paper is an extensive overview of the recent applications of **G**eographic **I**nformation **S**ystems (**GIS**) in the water resources engineering

GIS has a wide range of use. Water Supply can use GIS in conjunction with the source water Assessments to help protect the various water supply system. A GIS provides a powerful analytical tool that can be used to create and link spatial and descriptive data for problem solving, spatial modelling, and to present the results in tables or maps. Furthermore, it can also be used for management and to test consequences of

development. The PipelineNet simulates the flow and concentration of biological or chemical contaminants in a city or municipality's water distribution system. The integrated model is a powerful tool for routine planning and emergency response. It gives emergency managers real time information for estimating the risks to public water supplies and population at risk. The PipelineNet can calculate, locate, and map the population at risk from the introduction of contaminants to the public water supply.

2.5.Articles on GIS based decision Support system in Water resource management

LIAO Xiao-yu has published their article on**,"A GIS-based Decision Support System for Water Resources Management of Song-Liao River Basin"** [26]
In this article, the author has been suggested, the study area is Song-Liao River Basin have been an important factor which influences economy development of Northeast of China. The measure solving these problems is integrated management of surface and groundwater resources and optimal management policy (OMP). In this study a GIS-based support-decision system was designed to assist water resources professionals in making economical and efficient decision. This paper describes a framework and a methodology for the design, development, and implementation of a GIS-based decision support system for water resources management. The DSS is based on five components: Geographical Information System (GIS), a database subsystem, mathematical models, a knowledge base and a graphical user interface. GIS perform data acquisition, management and visualization. The DSS makes use of mathematical methods in order to help seek OMP of the water resource system. The author has suggested two main modules.
The first one is stochastic simulation and forecasting of hydrologic inputs. The second one is simulation and optimization of the hydro system, which allows the detailed study of the hydro system under alternative management policies implementing the parameterization–simulation–optimization methodology. By the end of the DSS development, all components of the DSS will be able to use the GIS as a user interface, entering data and representing simulation results with a geographical dimension. The whole system has been developed under the software development environment Delphi, also using Oracle for the relational database system, ArcInfo and ArcView for the GIS. This DSS fulfils the need

for a tool that allows water resources managers to explore their water resources and support the new master plan of the hydrosystem management.

Vairavamoorthy K. et al have published their article on **"IRA-WDS: A GIS-based risk analysis tool for water distribution systems"** [54]

In this article, the author has mentioned development of a new software tool IRA-WDS. This GIS-based software predicts the risks associated with contaminated water entering water distribution systems from surrounding polluted water bodies such as sewers, drains and ditches. Intermittent water distribution systems are common in developing countries and these systems are prone to contamination when empty. During the non-supply hours, contaminants from pollution sources such as sewers, open drains and surface water bodies enter into the water distribution pipes through leaks and cracks. Currently, there are no tools available to help engineers identify the risks associated with contaminant intrusion into intermittent water distribution systems. Hence, it is anticipated that IRA-WDS will find wide application in developing countries.

This paper summarizes the details of the mathematical models that form the basis of IRA-WDS. It also describes the software architecture, the main modules, and the integration with GIS using a tight coupling approach. A powerful GUI has been developed that enables data for the models to be retrieved from the spatial databases and the outputs to be converted into tables and thematic maps. This is achieved seamlessly through DLL calling functions within the GIS. This paper demonstrates the application of the software to a real case study in India. The outputs from IRA-WDS are risk maps showing the risk of contaminant interruption into various parts of the water distribution system. The outputs also give an understanding of the main factors that contribute to the risk.

Vairavamoorthy K., Jimin Yan a, Galgale Harshal M., Gorantiwara Sunil D. have published their article on "**A GIS based spatial decision support system for modelling Contaminant intrusion into water distribution systems"** [53]

The paper presents a GIS based spatial decision support system for modelling contaminant intrusion into water distribution system. Three models have been developed to simulate the process and risk of contamination. A seepage model predicts the contaminant zone of pollution sources and the change of concentration during migration through soil. A pipe condition assessment model ranks the condition of water pipe in

terms of the potential of contaminant ingress. An ingress model combines the geometry algorithm with contaminant zone to obtain the potential pollution areas of water distribution pipe. The three models were integrated with ArcView GIS for supporting decision making for risk mitigation. Zone VIII of water supply system in Guntur, India was selected for the case study. The contaminant ingress potential and potential pollution area of water pipes were displayed as thematic maps in GIS. The areas resulting in high risk were identified from the GIS maps. The availability of resources for maintenance activities is limited in developing countries. Thus, GIS based spatial decision support system helps to achieve maximum risk reduction.

The objectives of the study were to develop a spatial decision support system (SDSS) for contaminant intrusion into water distribution system. The developed SDSS was applied to a real world water supply system to obtain risk areas of contamination. The developed SDSS package provides useful tools for water utilities to manage their water distribution asset.

The ingress model predicts the areas of contamination which will assist engineers to choose the point for water quality monitoring. The risk obtained from coupling the above two outputs enables engineers to priorities locations in water distribution system for risk mitigation. It is anticipated that the developed SDSS for risk management of contaminant intrusion into water distribution system will find ultimate application in water utilities, especially in developing countries where intermittent water supply are norm.

E.MANOLI.G. et al have published article on **"Water Demand And Supply Analysis Using a Spatial Decision Support System"** [14]

A prototype Spatial Decision Support System for the evaluation of water demand and supply management schemes is presented. The water basin is topologically mapped to a network of spatial objects representing the physical entities and their connections. Several GIS functions, which include data input/update, network derivation from the basin map and network building/modification are incorporated. The tool integrates suitable models for demand site requirements calculation and water allocation. Alternative scenarios can be constructed, trends and interactions of the complex water system can be analyzed, strategies to solve water allocation conflicts can be evaluated and necessary infrastructure interventions can be planned in advance in order to meet water needs. The tool is

demonstrated through a case study, involving the current situation and future policies for a typical Greek island.

A prototype spatial decision support system for the evaluation of water demand and supply management schemes has been outlined. The system integrates a spatial database of the study area and its infrastructure, tools to for network editing and specifying assumptions that affect demand, supply and hydrology, model to perform demand analysis and water allocation and components to manage and present the information. The tool was tested for a characteristic case study that demonstrated its effectiveness in analyzing and supporting decision making.

Rao N. H., Brownee Sheena M. and Sharma P. B. have published article on **"GIS Based Decision Support System for Real time water demand estimation in canal irrigation systems"** [32]

This study presents a scheme for the development of a Geographic Information Systems (GIS)-based decision support system (DSS) for real time water demand estimation in distributaries. The DSS dynamically links a field irrigation demand prediction model for the area irrigated by a distributary with a GIS of the canal network. The system allows interactive selection of distributaries and on-line real time estimation of water demands in each distributary over the entire network. For real time estimates, the model is used with current season information on weather, weather forecasts and distributary level information on crops and soils. Since the distributary is the unit of operation, the DSS integrates well with the actual process of decision-making by the operators of canal irrigation systems in India. The development of the overall scheme and procedures is illustrated with data from a case study area in India.

This study develops a scheme for providing a GIS-based tool for irrigation system managers to assist them in making such estimates. It is shown that the features of GIS for storing, manipulating and analyzing spatial data related to soil, crop and weather can be used to (i) provide an effective information system for the project area that is interactive and representative of the hierarchy of irrigation system operation, and (ii) obtain real time, systematic and quick estimates of irrigation demands in the distributaries taking-off from different canals/branch canals. The study developed a GIS-based decision support system for water demand estimation in canal irrigation systems.

The Patna canal network of the Some Irrigation Project in India was used as a case study. The main problem faced by water managers is estimating demand at the head of the distributaries of the canal network in advance for each irrigation cycle. This is mainly because of spatial variations in weather and rice crop transplanting dates. It was shown that real time water demands for any distributary can be estimated by linking dynamically the GIS of the canal system with a soil water balance model and current sea-son data of weather, weather forecasts, and crop and soil conditions. The system managers can obtain the required information by simply selecting the distributaries in the GIS. The DSS also allows quick estimation of the variations in irrigation requirement in different distributaries that form the canal network and comparisons with the available channel capacities and actual supplies. Though the various procedures have been developed for the case study area selected, they are sufficiently general to be adapted to other canal irrigation networks.

Asadi S. S., Vuppala Padmaja and Reddy M. Anji have published article on **"Remote Sensing and GIS Techniques for Evaluation of Groundwater Quality in Municipal Corporation of Hyderabad (Zone-V), India"** [4]

The present study monitors the ground water quality, relates it to the land use / land cover and maps such quality using Remote sensing and GIS techniques for a part of Hyderabad metropolis. Groundwater quality in Hyderabad has special significance and needs great attention of all concerned since it is the major alternate source of domestic, industrial and drinking water supply .Thematic maps for the study are prepared by visual interpretation of SOI top sheets and linearly enhanced fused data of IRS-ID PAN and LIS S-III imagery on 1:50,000 scale using AutoCAD and ARC/INFO software. Physico-chemical analysis data of the groundwater samples collected at predetermined locations forms the attribute database for the study, based on which, spatial distribution maps of major water quality parameters are prepared using curve fitting method in Arc View GIS software. Water Quality Index (WQI) was then calculated to find the suitability of water for drinking purpose. The overall view of the water quality index of the present study area revealed that most of the study area with > 50 standard rating of water quality index exhibited poor, very poor and unfit water quality except in places like Banjara Hills, Erragadda and Tolichowki.

GIS can be a powerful tool for developing solutions for water resources problems for assessing water quality, determining water availability, preventing flooding, understanding the natural environment, and managing water resources on a local or regional scale. The analysis of the results drawn at various stages of the work revealed that integration of Remote Sensing and GIS are effective tools for the preparation of various digital thematic layers and maps showing spatial distribution of various water quality parameters. Overlaying spatial distribution water quality maps on Satellite imagery is a very authenticate concept to identify the water quality problems and to correlate them with the land use to interpret the reasons for deterioration of environmental quality.

Monitoring of pollution patterns and its trends with respect to urbanization is an important task for achieving sustainable management of groundwater. An integrated remote sensing and GIS study proves to be an essential tool to evaluate and quantify the impacts of land use land cover on ground water quality.

S. Mohan and K. Danimon, India K. Vairavamoorthy have published article on **"Development of GIS based contamination risk assessment in water distribution systems"** [34]

In this article, the authors have to develop a GIS based contamination Risk assessment procedure in water distribution systems. Water distribution network analysis model EPA NET 2. 0 was integrated with Arc GIS 8. 3 for the water quality analysis retrieving data from the GIS database. Water supply system of Zone V I of Guntur, India was selected for the case study. The main objective of the study reported here is to develop an integrated model by combining water supply network analysis model (EPANET 2.0) and ArcGIS Desktop 8.3 (GIS package) to meet the following tasks as-

- To determine the locations prone to contamination and the propagation of contaminant in a water supply network.
- To apply the integrated model to a real world water supply system, and
- To evolve strategies for management of water supply, and mapping of risk areas using GIS.

The methodology used in the study reported here consists of three phases. The first phase involves integration of the pipe network analysis model with GIS. The network analysis

model is used to simulate the propagation of contaminant through the network in order to identify the affected sections of the network at any point in time. The integrated model is then applied to water supply network of zone VIII in Guntur city and this constitutes the second phase. In the third phase, a suitable decision support system has been developed for the risk assessment in the water distribution network.

The results of water quality simulation were displayed in the GIS interface and the areas affected were mapped with the spatial analyst tool of GIS. Data on number of household connections and standpipes affected by a particular event of contamination was also retrieved from the GIS database. The events resulting in high risk were identified from the GIS maps. Thus GIS based risk assessment proves to be an efficient decision support system. It provides an easy way of deciding upon the activities that need to be undertaken immediately, especially in situations of limited resource availability. This information helps in the decision making process of prioritizing the maintenance activities particularly, in case of limited fund availability.

2.6. Water Conservations

D.Hardwick and, G. Maree have published article on **"You are here": Marking the progress of GIS in river conservation planning."** [12]

Water Conservation planning in South Africa has traditionally focused on terrestrial ecosystems and planning for aquatic biodiversity. This shift has required that new data and methods be developed to model biodiversity pattern and process for freshwater ecosystems and translate them into a GIS-compatible format.

A GIS is used at every stage of the conservation planning process. A careful balance needs to be maintained between the stakeholders who provide data and expert knowledge and the GIS operator who creates and communicates information. As the stakeholders determine the accuracy and applicability of the final product, it is important to build and maintain networks between multi-disciplinary groups and keep the technical aspects of GIS as simple and transparent as possible.

In this article, the authors have suggested examining how GIS has been used to develop data layers from field collections and expert knowledge and provide management options to decision makers. Lessons learnt from the conservation planning process show

the importance of GIS as a tool for creating and communicating information and building networks between stakeholder groups.

Satti Sudheer R. et al have published article on **"A GIS-based model to estimate the regionally distributed drought water demand "** [35]

In this research paper, the researcher was mainly focused on A GIS-based Water Resources and Agricultural Permitting and Planning System (GWRAPPS) was developed by integrating the Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) crop water model, a Geographic Information System (GIS) and a database management system within an ArcGIS framework.

GWRAPPS facilitates the quantification of irrigation water for regional planning and farm scale permitting purposes under statistically average to drought conditions using spatially distributed soils, land-use, and long-term daily climate data. In addition, the system provides regional estimates of daily water withdrawals that are necessary for input into conjunctive surface/ groundwater models.

This paper presents two Florida case studies that demonstrate GWRAPPS' ability to characterize irrigation needs based on spatially heterogeneous soil and climate data in contrast to a spatially lumped model. GWRAPPS provides a consistent tool for water use planning and permitting by extending the AFSIRS model from a farm-scale model to a regional-scale irrigation requirements simulation model. The integrated GIS system facilitates effective usage of spatial distributed data to estimate farm and regional scale irrigation requirements. GWRAPPS provides water demand maps that facilitate the study of regional irrigation requirements using farm level inputs. The author has suggested simple users-friendly interface provides easy access to the components of the system by maintaining the complex data and control transfer operations in the background.

The present research demonstrates that the integrated system was capable of providing critical information to planners and farmers about different crop's plant–soil–water relationship under a range of drought conditions.

Reddy Anji has published article on **"Impact Assessment of Water Conservation Measures: A GIS Approach"** [33]

In this article, the author has carried out a pilot study on the evaluation of impacts of Neeru-Meeru (WATER AND YOU) programme, the most popular development programme of the Government of Andhra Pradesh. This study was based on scientific parameter; NDVI and land use/land cover change detections etc. A scientific methodology was developed to monitor, assess and evaluate the Neeru-Meeru programme.

This study finds conclusions as cursory examination of the land use/land cover maps depicted an increase in the areas under agricultural land, forestland and water bodies to the tune of 69.59 sq. km during post launching of Neeru-Meeru. This comparative study revealed that the soil and water conservation practices being in practice/adopted are yielding fruitful results besides other development factors.

The considerable decrease in areas of waste/degraded land conveys that the structural measures taken up have increased the soil moisture status and paved the way for rising chlorophyll status. The positive rise in the vegetative index for all the land use/land cover categories and the absence of the index values for waste/degraded class corroborates with the observations. The scientific approach through the methodology developed in this pilot study can be adopted for the overall evaluation of watershed activities elsewhere.

Saxena Praveen R. , N.S.R. Prasad have published article on "**Integrated Land & Water Resources Conservation and Management –Development Plan Using Remote Sensing & GIS of Chevella Sub-Watershed, R.R. District, Andhra Pradesh, India** [36]

In this paper, the author was described the primary objective of the study was the soil and water conservation through multi-thematic information derived from remote sensing data for optimal management of soil and water resources for drought proofing on long-term basis. This study was to suggest an action plan for the sustainable development of the area using GIS and Remote Sensing techniques. The study area Chevella located at a distance of about 42 km from Hyderabad city covers an area of about 5000 ha, is one of the drought prone areas in the Rangareddy district of Andhra Pradesh. Groundwater was the main source for irrigation and for drinking purpose.

Arc Hydrology model of ArcGIS 9.0 version has been used to propose various soil moisture conservation and water harvesting structures. Six check dams, two percolation tanks were suggested at different locations across streams and farm ponds, in the agricultural lands for the development of ground water. Similarly, some alternate land use practices like horticulture, silvipature, nurseries have been suggested for the optimum utilization of land & water resources. The author has suggested the water harvesting should be given importance to avoid the wastage of rainwater from the watershed. This was also increase the groundwater recharge besides providing supplementary irrigation during Rabi season. Farmers should be encouraged with regard to making of farm ponds and soil conservation measures.

Water conservation in India, Pune Submitted by **"Water Conservation Advisory Council",** December 2008.

This study mainly focused on water conservation in Pune, India Submitted by Water Conservation Advisory Council, December 2008. In this study, researcher found that 98 percent of respondents believe water conservation was important. Water conservation as an issue has almost universal support among. Only 28 percent of definitely knows the natural source for their drinking water. Nearly half (48 percent) of the respondents believe there will probably not be enough water or that India Pune will experience a considerable shortage of water within the next 25 years. More than half of the respondents (54 percent) do not believe that state government is doing enough about water conservation. Thirty-one percent believe it is doing enough and 15 percent aren't sure. Seventy-one percent believe statewide funding should be used to implement water conservation strategies. Nine out of 10 respondents indicate they presently conserve water, and 72 percent believe they could do more. Eighty-seven percent feel it would be beneficial to residents to increase their awareness of water conservation through a campaign similar to "Don't Mess with India Pune."

Review of Case study on water conservation

Case Study on "Excellence in Water Management 2008 "(Confederation of Indian Industry) by, Kirloskar Brothers Limited, Kirloskarvadi Plant [10]

Water is Life, We give life to water. Mission of Kirloskar Brothers Limited shall be known globally as a reliable, innovative and cost effective solution provider in hydraulic

machines & systems and in water business. Vision is Kirloskar Brothers Limited shall be amongst the first five pump companies in the world by the year 2015 and become the preferred choice of customers as well as employees and values are -

- Developing and working with mutual trust.
- Building and nurturing teamwork.
- Assessing and enhancing employee satisfaction level.
- Giving the best to customer and giving value for the money.
- Enhancing relation with stakeholders.
- Maintaining fairness in dealing with customers and suppliers.

In their organization, they make Water Consumption Distribution for various purposes like Process -65%, Drinking/domestic-9%, Colony resident-13% and Gardening-13%.This project is certified by ISO 9001:2000, ISO 14001:2004. For Awareness of Water Saving, they conduct daily sun rise meetings, colony meetings as well as give contract training to employees how to conserve water. For water saving, they implement Monitoring & Reporting Processes like daily reading of incoming water meter, Daily reading of water consumption for Factory, daily reading of water consumption for colony and monthly reading of process water. For this project, they use various water conservation faucets.

They also use various faucets for the conservation of water like Close Loop Hydro Testing-savings 6 lacks liters/month, Use of percolated rain water for Process-4 lacks liter/year, Use of A.C. condensed water-save 10,000 liters/year and Replacement of water cooled compressor by air cooled-save 18 lacks liters/year.

Table No. 2.1: Faucets used for water conservation

Sr.No.	Name of Faucets	Quantity/Area
1	Sensors for Hand Wash & Urinals	200 numbers
2	Drip for Garden	800 Sq. Meter
3	Sprinklers for Lawn	27000 Sq. Meter
4	Push type tap	200 numbers
5	Float Valves for old Overhead tank	225 numbers

(Source: http://www.pfisterfaucets.com/design_center/conservation.aspx)

During 2007-2008 , they waste zero water discharge. They plant more than 3000 trees. In year 2008-2009, they implement 100% rain water harvesting, replacement of old pipeline by new APVC piping, adoption of close loop tanks for pump testing, cooling tower for Cupola wet scrubber water and separate piping for factory gardening & toilet flushing.

2.7. Public private partnership development in water utilities

Agreement between government and the private sector regarding the provision of public services or infrastructure. The social priorities with the managerial skills of the private sector, relieving government from the burden of large capital expenditure, and transferring the risk to the private sector. The public assets are transferred to the private sector as privatization, so the Government decided to work together with the private sector to provide services.

Public-Private Partnership (**PPP**) describes a government service or private business venture which is funded and operated through a partnership of government and one or more private sector companies. These schemes are sometimes referred to as PPP or P3.Thus PPP refers to a long-term contractual partnership between the public and private sector agencies, specifically targeted towards financing, designing, implementing and operating infrastructure facilities and Services in the State. These PPPs aim to achieve the twin objectives of high growth and equity on a sustainable basis.

Need For Public-Private Partnerships

In a competitive global environment, governments around the world are focusing on new ways to finance projects, build infrastructure and deliver services. Public-Private Partnerships (PPP's or P3's) are becoming a common tool to bring together the strengths of both sectors. In addition to maximizing efficiencies and innovations of private enterprise, PPPs can provide needed capital to finance government programs and projects, thereby freeing public funds for core economic and social programs.

Table No.2.2.List of Projects under taken PPP Perspectives [59]

Project:	Implementing Continuous Water Supply in Malkapur Town
Implementing Agency:	Maharashtra Jeevan Pradhikaran and Malkapur Nagar Panchayat
Impact:	

Parameter	Pre Project	Post Project
Continuity of water supply	2-3 hours every second day	Pressurized continuous water supply full day
Coverage	Partial	Complete
System losses	40% unaccounted water	12 % unaccounted water
Manpower	Large number of valve operators	Valve operation became redundant and workers were redeployed for other municipal services.
Recovery of cost	60%	80%
Use of technology for	Limited use	AMR, etc., were deployed for improving efficiencies
Project:	From Intermittent to continuous water supply in Amravati City	
Implementing Agency:	Maharashtra Jeevan Pradhikaran and Amravati	
Impact:	• The initiative has resulted in 24X7 water supply in two pilot zones, Sai Nagar and Arjun Nagar of Amravati. • The initiative has resulted in significant reduction in NRW. The NRW has reduced from 51% to 33% in Arjun Nagar and from 37% to 25% in Sai Nagar. • Water consumption has also reduced from 1.98 MLD to 1.48 MLD in Arjun Nagar and 1.81 MLD to 1.61 MLD in Sai Nagar. • Six PSPs were removed from Arjun Nagar and around 60 slum households were given individual connections. • The initiative has resulted in increased coverage and access, quality, reduction in water borne diseases and reduced customer grievances. • The initiative was implemented completely by utilizing in-house expertise. This has resulted in cost effectiveness. • The initiative has successfully demonstrated the role of GIS and hydraulic modeling and also highlighted the significance of 'whole to part' approach. • Water supply pressure has improved considerably to reach	

	up to the second floor. As a result the customers need not use electricity for pumping water to their overhead tanks. • There is also no need to store water and waste the same by throwing it away. • The initiative has resulted in increased consumer satisfaction. • The initiative has resulted in increased cost recovery. • It is also reported that the incidence of water borne diseases has come
Project:	Sustainable Water Supply Operations through 100% Metering and Billing, Online Payment Collection and Supply Management of Water Districts through SCADA
Implementing Agency:	Pimpari Chinchwad Municipal corporation
Impact:	• Equitable distribution of water manifested in reduced complaints over time. • Metering is more or less complete and has started paying dividends. For e.g.,in Nisarg Darshan Society with 68 flats on a flat rate basis, the annual bill was • Rs. 14,000, but after metering and bills being delivered on a volumetric basis, the society paid Rs.1,12,677 which is a substantial increase in revenues. • Preparation of road map for introduction of 24X7 water supply in the city. • Effective grievance management system with escalation facility, web based tracking and communication of complaint redressal through SMS or other means. • Streamlined billing and collection procedures in place and introduction of online payment system. • Increased frequency of billing and collection - from annual to bi-annual – PCMC proposes to further reduce the billing cycle to quarterly and later monthly. • Introduction of penalty system resulted in effective water management and greater compliance of billing and collection time lines. Rebates and incentives in water tariff contributed to water conservation (through RWH). • Rebates and incentives to the poor resulting in

	compliance to metering in poor localities.
Project:	Water Audit through Ultrasonic Bulk Flow Meter
Implementing Agency:	Bangalore Water Supply and sewage board
Impact:	After implementation of the project, areas with high volume of water supply were identified those are, BTM layout, JP Nagar, Kumaraswamy layout, Banashankari. After detailed analysis of data, water supply is now controlled and diverted to the eastern part of the city which has always been a water scarce area. Similarly the North–Eastern part of the city identified as a low supply area is now supplied with an additional quantity of water.
Project:	Leakage Mapping and Its Positive Impact
Implementing Agency:	Surat Muncipal Corporation
Impact:	• Developing a record and history of all leakage points. • Developing maps and computerizing the same for all leakage points. • Addressing the leakages on permanent and sustainable basis. • Redressing customers complaints related to leakages and contamination as per the citizen charter leading to better citizen satisfaction. • Creating a sustainable O&M system in the long run. • Reduction in non-revenue water. • Enhanced water quality. • The initiative is being implemented at a low cost.
Project:	Implementation of un-interrupted water supply and reduction of UFW in Nagpur
Implementing Agency:	Nagpur Municipal Corporation
Impact:	• Removal all 130 PSPs. • Provision of residential water connections to all 5,200 houses. • Collection of water bills from all consumers. • Establishment of water bill collection counters as part of the Customer Care Center. • Willingness to pay water bills regularly - about 68% recovery of demand so far against 20% earlier. • Avoidance of water wastage and saving of water (no

	study on the extent of water saved). • Happy and satisfied slum communities with water facility at their doorstep. • High water pressure enables water to reach up to the second floor of buildings. • Improvement in living standard with water at the door step.
Project:	Reduction in Non Revenue Water – Kundapura
Implementing Agency:	City Manager's Association, Karnataka and Town Municipal Corporation,Kundapura
Impact:	There is a remarkable improvement in the water supply in Kundapura town. There is no drinking water scarcity during the summer and treated water is supplied for a minimum of six hours. As the number of public stand posts has decreased, there is a reduction in the percentage of non-revenue water. Use of high-density polyethylene (HDPE) distribution lines has led to fewer leakage problems being registered. The percentage of non-revenue water has reduced significantly as leakage in the distribution network has been contained. Metering has also led to better demand management.

2.8.Review on News Paper Articles-Water Problems stated by Citizens

"No water cuts this summer to cost Rs 1200cr" [50]

In this article, Mr.Mahesh Zagade, Commissioner, PMC has stated, what important water supply projects are in the pipeline this year. PMC is spending Rs 90 crore to install boosters to double the water carrying capacity of the water supply pipe which supplies water from Khadakwasla dam to Parvati pumping station. The pipe currently supplies 650 MLD water per day, this would shoot up to 1150 MLD post installation. A water supply line from Parvati pumping station to Cantonment would be laid from these funds. The Pune Municipal Corporation (PMC) may have to spend anywhere between Rs 500 to Rs 1,200 crore, to relay and revamp the Peshwa-British era water distribution network in the city which would cater to the city's needs for the next 25 years, said top PMC officials. Zagade said that the maps of the water distribution pipes in the city have gone

missing. This means that the consultant would have to do an extensive job of digging up many streets in the city to check where the pipes are, in order for the maps to be made again. Only after this can they work out a solution for the city.

The consultant would give PMC a workable model to ensure smooth water supply to the city for the next 25 years. The PMC's current water network was designed to cater to a population of 10 to 12 lakh people. The city's population is estimated to shoot upto 60-65 lakh by 2027.

"Water of excess supply, dry taps and plugging the leaks" [47]

In this article, Mr.Jadhav has discussed excess of water. According to Mr.Mahesh Zagade, Pune's population being 35 lakh and 135-150 liter water per head per day consumption which put the total water consumption at about 7.8 TMC. We get 14 TMC water when our need is about 7.8 TMC. We must find answers to what happens to the remaining water. The Environment Status Report of 2008-09 has said the city lacked an efficient water supply system because of negligence. The old water supply lines are rusted and require repairs. The PMC lacks a system to control water supply. Faulty meters and absence of water supply data make it difficult to calculate water usage, the estimated population of the city is 35 lakh and the daily water supply to the city is 1,005 MLD. The total wastage is 20 per cent, of which 12 per cent is because of the distribution system and 8 per cent is wasted during treatment. About 20 MLD water is supplied daily to Urali Devachi, the fire brigade gets 6 MLD water while 2 MLD water is given to tankers. Tenders floated require reputed consultants in the urban water sector with experience in leak detection, water audit, analysis of hydraulic defects in water supply, rehabilitation of water distribution to comply with leak prevention/correction of all hydraulic defects to ensure equitable distribution, flow measurement of all commercial properties, suggesting way forward for all other properties.

"Water crisis in Pune "[48]

In this article, Sahil Nagpal has discussed water crisis in Pune City. Water crisis looms large over Pune, as delayed arrival of monsoon has lead to the drying up of water in Khadakwasla dam, lone source of water to the city. According to the Pune Municipal Corporation (PMC) authorities, only 2.23 per cent of water is now available in the dam. They have been forced to slash the water supply to Pune by 20 per cent and look for

alternate sources. The officials are hopeful that they will be able to tide over the situation by July 20 when monsoon is expected to hit the city. However, delay in rains could mean a serious water crisis. Only 62 TMC or 2.23 per cent of water is left in the dam. Slashing the water supply by 20 per cent and another 30 per cent, we will be able to supply water till July 20 or July 21. Pune will not face any water crisis. There will be lot of problems if the monsoon does not arrive till July 20, said Avinash Surve, Superintendent Engineer, Pune Irrigation Circle.

Even though there are dams in the vicinity, it is not possible to lay a pipeline. The experts are of the view that authorities should seriously think about constructing lakes to conserve water in the city.

"Water reform plan goes for a toss" [49]

Pune Municipal Corporation's (PMC) plan to rationalize the water supply system has gone for a toss with the civic standing committee rejecting the municipal commissioner's proposal to appoint a consultant to prepare a comprehensive overall plan for the city's water supply. The standing committee of the PMC on Tuesday rejected the municipal commissioner's proposal and asked him to rework the plan to tap the possibility for a Build Operate and Transfer (BOT) project plan. According to standing committee chairman Mr. Avinash Shinde, the municipal commissioner had placed a proposal before the standing committee. Only Tata consultants had submitted a proposal and had sought fees of Rs 37 corer for the same. All party members decided that the proposal should be returned to the municipal commissioner and asked him to rework on the same. The civic administration's proposal to appoint a consultant for the 24x7 water supply plan has been mired in controversy after civic groups and some political leaders from various parties objected to the tender process. The Environment Status Report (ESR) for 2009-10 states that the city's yearly requirement of water is 14 TMC. The irrigation department has earmarked 11 TMC for Pune, but it appears that 14 TMC of water has been lifted from the reservoirs of the four dams which provide water to the city. According to the ESR of 2008-09 had highlighted negligence towards ensuring an efficient water supply system for the city. The old water supply lines are rusted and require repairs. The PMC lacks a system to control water supply. The city has faulty meters and absence of water supply data makes it difficult to calculate water usage. The ESR also categorically mentioned

that the PMC has no maps of the old water pipeline network, and this makes it difficult to carry out repair works.

"PMC proposes metered water supply" [44]

Pune municipal commissioner Mahesh Zagade has tabled a proposal to introduce metered water supply system for household consumers (domestic supply). Based on the condition that the cost of service and its recovery should also be equal under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM), the Union government has set the 24-hour water supply norm and also installing meters for all consumers in Pune. The civic administration has repeatedly attempted to introduce the metered water billing system to calculate water tax, but the PMC general body had scrapped it for domestic users from April 1, 2000 and had instead been billing users on a system based on the Annual Rate able Value (ARV) of their property. In his fresh proposal before the standing committee, the municipal commissioner has said that the water meters should be made compulsory as per the JNNURM reforms.

The proposal states that 150 liters of water will be provided per head and a five-member family will be considered as a unit. If a family uses 150 liters water per head (750 liters in total), no extra charges will be imposed and the existing water rates will be charged. Rs 33 will be charged for every additional 1,000 liters. Proposal adds that modified water meters will be used for the purpose and consumers will have to pay for the meter in five installments while paying property tax. The city has for long been facing the problem of unequal distribution of water, with core areas receiving more water than the fringe areas. Experts in water management have reiterated the need for metered water system in Pune, which according to them, will help equitable distribution of water and ensure that people pay for the actual amount of water they utilize.

"Water dept projects Pune's needs at 15 TMC" [46]

The civic water supply department has projected a requirement of 15 thousand million cubic feet (TMC) as the yearly quota of water for the city. The water supply department mentions 15 TMC for the year 2010-11. According to Mr. Zagade, calculations are based on the city's population being 35 lakh and 135-150 liters water per head per day consumption, puts the total water consumption at about 7.8 TMC. Also, despite the

present sanctioned quota of 11.5 TMC, the city used 12.64 TMC water in 2007-08 and 14.01 TMC in 2008-09.

The PMC has no system of measuring the quantity of water it receives from the state irrigation department; this means that the city's water supply system is based on approximate calculations with no exact figure of the water supply available. The civic body's projection comes on the backdrop of the irrigation department asking the PMC to manage with its yearly quota of 11.5 TMC (thousand million cubic meters) water. One cubic meter is equal to 1,000 liters. Insufficient rainfall in the catchment areas in the mid-monsoon period for the last two years has woken up civic officials to the possibility of a water crisis. The Maharashtra Krishna Valley Development Corporation will provide 11.5 TMC water to Pune city every year. The irrigation department has made it clear that it cannot afford to give more water to Pune city as the farmers have already been complaining about excessive use by city residents. The PMC has to manage within the given quota (11.5 TMC) and make a time table so that water could be reserved till August 30. Now, with the PMC projecting a requirement of 15 TMC the civic administration and the irrigation department are at loggerheads.

"Village to adopt Jal Biradari model of water conservation" [45]

In this article, Jal Biradari is an organization floated by Rajendra Singh that works re-establishing community rights over water management. This organization is focusing on water conservation, forest-soil management and promotion of water conservation. This was firstly introduced in 2001 at Jaipur, the organization has undertaken construction of traditional dams in Rajasthan called Johad, and later the work of the organization has spread across the country in various states. So this organization has adopted Velu village for implementing Jal Biradari model of water conservation. They form Velu welfare Council which is pilot project of Jal Biradari model. They focus on cleaning and maintenance of water resources, constructing check-dams and improving water table of the village.

So it will result into sufficient water availability in all seasons and allow farmers to take a variety of crops stated by Rajendra Singh. Jal Biradari will also undertake water-literacy campaigns among villagers. It will enable villagers to know about water resources, their catchments area, rainfall and groundwater table which will help formulate policy for the

village in the future. Apart from it, Jal Biradari will also insist on villagers taking decisions with the consent of the women in the village. The organization will undertake mapping of the village, its resources, streams and catchments area with the help of the villagers. Sunil Joshi, convener of Jal Biradari for Maharashtra, said that, "The Maharashtra wing of Jal Biradari was trying hard to launch its operations in the state, but we were waiting for the farmers' response. Everything will be documented by the Jal Biradari for our future projects in the state." Finally, Velu villagers are ready to implement Jal Biradar Model of Water Conservation. The villagers will provide necessary information about water resources, small streams and their catchments area which is required for the initial planning.

"Water warriors of Maharashtra" [60]

With the state reeling under a severe drought, water conservation was the topic of discussion at the third edition of the two-day, Sakal Agrowon-Sarpanch Mahaparishad which started in Kolhapur on Sunday. Sakal Times met with eight, hard-working sarpanches (village heads) who have contributed significantly to water conservation efforts. Reading their stories, we must each work hard on rainwater harvesting, water recycling and other methods to conserve water in Pune city. The initiative by Agrowon is for the progressive Sarpanches of Maharashtra. It is to help them establish an effective role of Gram Panchayat in agriculture and allied businesses through innovation and entrepreneurship. The invitees are all educated, experimental and below 45 years of age from all the districts of Maharashtra.

2.8 Summary and conclusions of observation made by researcher based on exploring literature review.

From these articles and research papers studies, the researcher is benefitted. GIS is worldwide high-tech field of disciplines and technology system has been penetrated into all walks of life, and the resulting establishment of the various professional GIS software to solve the problem is not sufficiently strong professional, especially the high-level application model small. A large, complex pipe network to achieve safe, reliable, economical operation is not easy. From the long-term objective point of view, based on reliable and accurate information on the pipe network, the establishment of Mathematical

model of pipe network, and accordingly on the pipe network operating conditions for dynamic simulation, is to achieve optimal operation of pipe network to pass.

GIS, with its unique advantages, will serve as the implementation of the information on the pipe network simulation of an irreplaceable tool. In the GIS support, the pipe network integration of structural parameters and status parameters, we can use GIS digital elevation model to simulate the distribution pipe network water pressure status, and two-dimensional or three-dimensional graphic visual display. A computerized geographic information system (GIS) to assist in the effective assessment, planning and management of water resources. The GIS Section has been divided into two units, the CAD and GIS unit.CAD Unit: The CAD Unit is primarily concerned with the capturing of thematic map data for various Ministry reports and publications. It also provides digital graphic map data to the GIS Unit.

GIS Unit: The GIS Unit collects, stores, integrates geographically related (both graphic and textual) information. It also provides results of various requested analysis and thematic map products for inclusion in reports and publications.

The researcher has identified the tangible and intangible benefits of GIS implementation within water resources. They are-

- Management of data of water pipes and network devices- To increase productivity with more efficient map updating and the ability to compile and report information more rapidly.
- Planning of maintenance operation, maintenance logistics.
- Analysis of non-revenue water.
- Analysis of consumption information.
- Export of data for network modelling.
- Helping to analyze investment needs.
- Visualization of network data using attributes of the features
- Documentation of maintenance history-Up-to-date, accurate and reliable information resulting from standardization and integration of data.
- Reduced duplication of effort as more readily accessible data will avoid duplication of data collection and analysis.
- All map data will be integrated into a single shared, distributed database.

- To improve coordination between departments and storing of data and maps.
- Better use for decision making.
- Better service to Government users will result from more efficient information processing.
- Higher quality products will be produced from more reliable, more accurate data in a more timely, efficient and cost effective manner.
- Better use of Government resources by reducing duplication of effort in manpower and computing resources.

  For this study, the researcher has taken views of citizens, PMC employees from water Distribution Department of Pune City.

References

[1] Abaje I.B.,O.F. Ati, and S. Ishaya ,"Nature of Potable Water Supply and Demandin Jema'a Local Government Area of Kaduna State, Nigeria" ,Research Journal of Environmental and Earth Sciences 1(1): 16-21, 2009 ISSN: 2041-0492

[2] Abdollah Ardeshir, Mehdi Saraye, Farhad Sabour, and Kourosh Behzadian "Leakage Management for Water Distribution System in GIS Environment" ASCE Conf. Proc. doi:http://dx.doi.org/10.1061/40856(200)27

[3] Alaguraja Yuvaraj .D, P Sekar.M, Muthuveerran.P, Manivel .M " Analysis of drinking water problem in Coimbatore City Corporation Tamil nadu, India using Remote Sensing and GIS tools". International Journal Of Environmental Sciences Volume 1, No1,2010 ISSN 0976 – 440 2

[4] Asadi S. S., Vuppala Padmaja and Reddy M. Anji, "Remote Sensing and GIS Techniques for Evaluation of Groundwater Quality in Municipal Corporation of Hyderabad (Zone-V), India" International Journal of Environmental Research and Public Health 2007, 4(1) ISSN 1661-7827

[5] Bahadur Rakesh, Pickus Jonathan, Amstutz David and William Samuels "A GIS-based Water Distribution Model for Salt Lake City, UT"21st Annual Esri International User Conference, July9-13,2001,PaperNo-173 (http://www.proceedings.esri.com/library/useconf/proc01/professional/papers/pap173/p173.htm)

[6] Bartolin Hugo J., Martinez Fernando have published article on "Modelling and Calibration of Water Distribution Systems. A NewGIS Approach" 21st Annual Esri International User Conference, July 9-13, 2001 ,Paper No-126

[7] Bo Yan; Xiaorong Su; Yiyun Chen; , "Data Management of Urban Water Supply Network Based on GIS," Computing, Communication, Control, and Management, 2008. CCCM '08. ISECS International Colloquium on , vol.3, no., pp.353-357, 3-4 Aug. 2008 doi: 10.1109/CCCM.2008.370URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4609856&isnumber=4609776

[8] Breiling Meinhard ,"The Use of Geographic Information Systems (GIS) in Local Planning and Possible Contributions to Integrated Water Management in Sweden" Paper to

Conference “Water Savings Strategies in Urban Renewals“February 1 to 3, 1996, Schloß Wilhelminenberg, ViennaEuropean Academy of the Urban Environment, Berlin Interdisciplinary Institute of Environmental Economics and Management, Vienna

[9] C. Jun a, *, J. Koo b and J. Koh c , M. Tabesh, A. H. Asadiyani Yekta and R. Burrows “ An Integrated Model to Evaluate Losses in Water Distribution Systems” (Journal-water resourcemanagement,ISSN-0920-4741,VOL-23FEB-2009,477-492 (http://www.springerlink.com/content/w38x3680276r3111/

[10] Case Study on “Excellence in Water Management 2008 “(Confederation of Indian Industry) by, Kirloskar Brothers Limited, Kirloskarvadi Plant

[11] Chen Yuli; Wang Zhihong; Tu Yu; Wang Shen; Sun Wen; , "Application analysis on the information management system for water supply network in Guangzhou," Electric Technology and Civil Engineering (ICETCE), 2011 International Conference on , vol., no., pp.5758-5763, 22-24 April 2011doi: 10.1109/ICETCE.2011.5774622 URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5774622&isnumber=5774181S

[12] D.Hardwick and, G. Maree “You are here”: Marking the progress of GIS in river conservation planning”, Conference & Proceeding,26 November,2006, Map Africa 2006

[13] Durmus Cesur ,“GIS as an information technology framework for water modelling”, Journal of Hydroinformatics | 09.2 | 2007 Q IWA Publishing 2007 (http://www.iwaponline.com/jh/009/0123/0090123.pdf)

[14] E.Manoli,G. Arampatzis,E. Pissias,D. Xen Os, And D. Assimacopoulos “Water Demand And Supply Analysis Using A Spatial Decision Support System” Global Nest, the International Journal Vol 3, No 3, pp 199-209, 2001

[15] Garaci Mike “Simplified GIS for Water Pipeline Management” Journal of Water Resources Planning and Management, Vol. 119, No. 2, March/April 1993, pp. 412-419) http://cedb.asce.org/cgi/WWWdisplay.cgi?80147

[16] Guizuo,Liliang Ren,Tianfang Fang,Jinping Zhang “The Study and Application of GIS-based distributed Hydrological Model” 2008 International Workshop on Education Technology and Training & 2008 International Workshop on Geoscience Issue Date: 21-22 Dec. 2008 ,Volume: 2 ,On page(s): 223 - 227 ,ISBN: 978-0-7695-3563-0

[17] Henriette Tamasauskas*, L.C. Larsen, O. Mark, “Using GIS In Water Supply And Sewer

Modelling And Management"DHI Water and Environment report http://www.cjk3d.net/DHIPaper/urban/15.pdf

[18] Howard, J, K. Larson, D. White, and E. Wentz ,"The Use of GIS as a Decision-Support Tool by Water Managers in Phoenix, Arizona"

[19] Hussain Jama Ismail Bait-Ishaq , Philip Burden ,"GIS Implementation in the Ministry of Water Resources in Oman" User Conference 2003, http://www.gisqatar.org.qa/conf97/links/e2.html (3 of 8)8/20/2003 3:27:39 AM

[20] I. Mouratidis, G. Dimopoulos, T. Astaras, S. Savvidis ,"Sustainable Water Resources Management Through The Use Of GIS Technologies" Global Nest Journal, Vol 12, No 2, Pp 140-151, 2010

[21] Ifatimehin, O.O. and Musa, S.D,"The Prospects Of Sustainable Management Of Domestic Water Supply And Sanitation In Kogi State.".Geo-Studies forum: An International Journal of Environmental and policy issues volume 4:1812.2008

[22] Ingeduld, Zdenek Svitak, Pradhan Ajay, Tarai Ashok "Modelling Intermittent Water Supply Systems with Epanet", 4th Asia Pasific DHI Software Conference,2008

[23] Kui Chang, Jinliang Gao, Yixing Yuan, Wenyan Wu ,"Establishment of the Scheduling Training System of Water Distribution Network Using Virtual Reality" *Information Science and Engineering, International Symposium on*, vol. 2, pp. 625-628, International Symposium on Information Science and Engineering, 2008.

[24] Labadie John W. ,Margaret T. Herzog ,"Optimal Design of Water Distribution Networks with GIS" Journal of Water Resour. Plann. Manage. 122, 301 (1996); doi:10.1061/(ASCE)0733-9496(1996)122:4(301) (11 pages)

[25] Leigh Eric and Dr. Guy Fipps ,"Use Of Geographical Information Systems (Gis) In Defining Municipal Water Supply Networks" Third International Conference on Irrigation and Drainage, Water District Management and Governance, U.S. Committee on Irrigation and Drainage, San Diego, March 2005

[26] LIAO Xiao-yu,"A GIS-based Decision Support System for Water Resources Management of Song-LiaoRiverBasin"College of Urban and Environmental Science China http://www.gisdevelopment.net/application/nrm/water/overview/ma04042abs.htm

[27] Lin Ji-Hao has published article on "Scenario Simulation of Water Supply Network "Asian Conference on Remote Sensing (ACRS) proceedings,2007

[28] Madhavan K.D. ,"Mapping & Maintenance of Water Distribution System and Sewer Collection System Network using Remote Sensing and GIS" 8th Annual International Conference on Map India 2005 Geomatics 2005 at New Delhi.

[29] Martínez-Solano, F. Javier; Pérez-García, R. & Iglesias-Rey, P.L. "Water Mains Creation Using GIS", 5th AGILE Conference on Geographical Information Science, Palma (Balearic Islands, Spain) April 25th- 27th ,2002

[30] Pickard Brian D. and Levine Audrey D. "Development of a GIS Based Infrastructure Replacement Prioritization System: A Case Study" Water Distribution Systems Analysis Symposium 2006 Proceedings of the 8th Annual Water Distribution Systems Analysis Symposium, held in Omaha, Nebraska, May 22-25, 2006

[31] Prof. Gavekar Vidya S.,"Enhancement of water supply system through GIS", CIIT,International Journal of Artificial Intelligent Systems and Machine Learning, July 2009

[32] Rao N. H., Brownee Sheena M. and Sharma P. B. ,"GIS Based Decision Support System for Real time water demand estimation in canal irrigation systems" Current Science Journal, Vol. 87, No. 5, 10 Pg.629-637

[33] Reddy Anji," Impact Assessment of Water Conservation Measures: A GIS Approach" Environment Science & Technologies Centre for Environment, Jawaharlal Nehru Technological University, Hyderabad, AP, India.

[34] S. Mohan and K. Danimon, India K. Vairavamoorthy , UK ,"Development of GIS based contamination risk assessment in water distribution systems" 30th WEDC International Conference, Vientiane, Lao PDR, 2004

[35] Satti Sudheer R., Jacobs Jennifer M. "A GIS-based model to estimate the regionally distributed drought water demand", Dept. of Civil & Coastal Engg., University of Florida, Gainesville, USA ,Journal of Agricultural Water Management DOI:10.1016/j.agwat.2003.10.003

[36] Saxena Praveen Raj , Prasad N.S.R., "Integrated Land & Water Resources Conservation and Management –Development Plan Using Remote Sensing & GIS of Chevella Sub-Watershed ", Professor, Dept. of Applied Geochemistry, Osmania University, Hyderabad , India.(http://www.isprs.org/proceedings/XXXVII/congress/8_pdf/7_WG-VIII-7/01.pdf)

[37] Shakoor, A.; Shehzad, A.; Asghar, M.N.; , "Application of Remote Sensing Techniques for

Water Resources Planning and Management," Advances in Space Technologies, 2006 International Conference on , vol., no., pp.142-146, 2-3 Sept. 2006 doi: 10.1109/ICAST.2006.313815URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4106426&isnumber=4106396

[38] Shandas Vivek, Alberti Marina, Gibson John ,Steve Moddemeye, Jacqueline Meijer-Irons' "A GIS based Water Demand Analysis for Municipal Application" 6th Annual International conference MAP INDIA 2003, Seminar on Muncipal GIS

[39] Suchith Anand , Dr K. Vairavamoorthy ,"GIS in Design and Asset Management of Intermittent Water Distribution Systems"(Map Asia, 2002) (8th annual WD symposium EPA Cincinnati, August 27-30, 2006)

[40] Tabesh M. , Asadiyani Yekta A. H. and R. Burrows, " An Integrated Model to Evaluate Losses in Water Distribution Systems" (Journal-water resource management,ISSN-0920-4741,VOL-23FEB-2009,477-492 (http://www.springerlink.com/content/w38x3680276r3111/)WaterResources Management Volume 23, Number 3, 477-492,)

[41] Tabesh M., M. R. Delava,A. Delkhah "Use of geospatial information system based tool for renovation and rehabilitation of water distribution systems" Int. J. Environ. Sci. Tech., 7 (1), 47-5 8, Winter 2010,ISSN: 1735-1472

[42] Tao Song, Kyehyun Kim ,"A Study Of Developing Gis-Based Water Quality Management System Of Rural Area " Asian Conference on Remote Sensing (ACRS) proceedings,2006

[43] Tian Yu; Ma Liya; Lei Xiaohui; Jiang Yunzhong; , "Construction of water supply pipe network based on GIS and EPANET model in Fangcun District of Guangzhou," Geoscience and Remote Sensing (IITA-GRS), 2010 Second IITA International Conference on , vol.2, no., pp.268-271, 28-31 Aug. 2010 doi: 10.1109/IITA-GRS.2010.5604123 URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5604123&isnumber=5601975

[44] Times News Network 02/10/2010

[45] Times of India, 4th Aug 2009

[46] Times of India, Dec 21, 2010

[47] Times of India, Jul 22, 2010, 02.14am IST

[48] Times of India, Wed, 07/01/2009 - 06:59.

[49] Times of India,8th September 2010

[50] Times of India,Thursday, April 15, 2010 at 01:04:05 AM

[51] Toleti Rao B.V.M., Chaudary , B.S. “Integrated Ground Water Resources Mapping in Gurgaon District, (Haryana) India using Remote Sensing and GIS Techniques” , Asian Conference on Remote Sensing, MAP INDIA 2000. http://www.gisdevelopment.net/aars/acrs/2000/ts2/water0002.shtml

[52] Usali Norsaliza & Mohd Hasmadi Ismail “ Use of Remote Sensing and GIS in Monitoring Water Quality” (www.ccsenet.oo rg/jsd Journal of Sustainable Development Vol. 3, No. 3; September 2010)

[53] Vairavamoorthy K., J.M. Yan, H. Galgale UK, S.Mohan, India and S.D. Gorantiwar, UK ,“A GIS based spatial decision support system for modelling Contaminant intrusion into water distribution systems”30th WEDC International Conference, Vientiane, Lao PDR, 2004 People-Centered Approaches To Water And Environmental Sanitation

[54] Vairavamoorthy K., Jimin Yan a, Galgale Harshal M., Gorantiwara Sunil D., “IRA-WDS: A GIS-based risk analysis tool for water distribution systems”, International Journal of Environmental & Science Technology, Vol. 22, No. 7. (2007), 951-965.

[55] Werner de Schaetzen and Paul F. Boulos, “Optimal Water Distribution System Management Using ESRI MapObjects Technology” 22nd Annual Esri International User Conference, July 8–12, 2002.

[56] Xiao-Li Cao; Chao-Yuan Jiang; Si-Yuan Gan;, "Leakage monitoring and locating method of water supply pipe network," Machine Learning and Cybernetics, 2008 International Conference on , vol.6, no., pp.3549-3551, 12-15 July 2008doi:10.1109/ICMLC.2008.4621019 URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4621019&isnumber=4620933

[57] Zhao-Shun Wang; Zu-Kuan Wei; Qian Yin; , "The design of water supply network based on GIS," Cybernetics and Intelligent Systems, 2008 IEEE Conference on , vol., no., pp.209-213, 21-24 Sept. 2008doi: 10.1109/ICCIS.2008.4670974 URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4670974&isnumber=4670

728

[58] Zorkeflee Abu Hasan , Nuramidah Hamidon , Norazazi Zakaria , Aminuddin Ab. Ghani and Leow Cheng Siang, "INCOPERATING GIS IN WATER RESOURCES MODELLING: Application of SWAT 2005 Model in Sungai Kurau, Perak and CCHE2D Model in Tasik Harapan USM, Penang "http://www.infogigi.com/redac.eng.usm.my.html

[59] www.waterawards.in

[60] www.salkaltimes.com(24/03/2013)

CHAPTER 3
GEOGRAPHICAL INFORMATION SYSTEM FOR EFFECTIVE WATER MANAGEMENT

3.1. Introduction

The delivery of fresh water to millions of people is increasingly under threat, so smart water management will be a key policy for the 21st century. Economic growth, climatic conditions and rising population are all affecting the availability of water resources. The situation is being worsened by some effects of climate change, such as lengthy droughts and extreme weather events.

One of the major challenges for sustainable development faced by both developed and developing countries is to ensure that all people have reliable access to water supply and sanitation services. This means that water resources have to be managed carefully. The availability of information about conditions in a particular situation on a timely basis is crucial for decision-making in water resources management.

Technologies such as satellite remote sensing in combination with semantic sensor web and geographical information systems (GIS) can be used innovatively by water authorities to obtain information in real time about water use, to track and forecast the level of rivers and to identify new sources of fresh water.

Water management is the efficient and effective use of the water resource available by minimizing wastage, promoting recycling, and increasing water quality alongside sustainable economic development. Water management is a crucial issue to the survival of humans and all living things in the present era as it is a resource, which is getting scarcer. The amount of water we need and the availability is unbalanced. With proper water management, we could minimize the effect of drought and thus famine being faced by developing countries.

In order to manage water better, it is crucial to have an inventory of the water available, how it is being managed, the drainage area, the demand and supply of water. GIS has been very beneficial in mapping and data analysis, and thus greatly aiding in the understanding and decision making in water resource management. GIS is a powerful

tool for developing solutions for water resources such as assessing water quality and managing water resources.

Water is a fundamental resource[1] and its management is a challenge mankind is facing. Only an integrated approach has the potential of dealing correctly with the problems in caring water resources: integrated water management with a sustainable approach must then be promoted. Aiming at that, a fundamental component is the proper treatment of data in the different steps of the water-cycle, for efficient archiving, correct management and finally for the support for the decisions to be taken.

The objective is to establish a link in the two domains of Water Resources and GIS and to promote a scientific and technological interdisciplinary service.

The initiative is application-oriented and devoted to serve Nation with two scientific and technical domains to be jointly activated in general the services to demonstrate the catalyst role of GIS as integration tools for Water treatment & Environment, to assess how geographical knowledge can be transferred to potential water management users, to implement the proposed approach in the design of sustainable regional development. A geographic information system (GIS) is a powerful configuration of computer hardware and software used for compiling, storing, managing, manipulating, analyzing, and mapping (displaying) spatially-referenced information. It integrates database operations such as data storage, query, and statistical analysis with visual and geographic analysis functions enabled by spatial data. A GIS can serve as an integral part of any project that requires management of large volumes of digital data and the application of special analytical tools.

GIS is becoming an increasingly valuable tool for the water distribution model both as a source for modelling data and as a decision-support tool. Anderson, Lowry, Thomte [2] reported that although approximately 15 percent of water utilities currently use GIS in their modelling, almost 80 percent plan to use GIS in the future. In the past, most models were developed with a batch-run philosophy in which a text file (or card deck) containing the model data was required to drive the model.

3.2 Integration of GIS Model

Shamsi [6] describes the Integration of GIS Model in a three-step process:

- **Interchange:** Data is exchanged through an intermediary file, which may be an ASCII text file or a spreadsheet. Data is written to this intermediary file, where it is reformatted for the model, if necessary, and then read into the model. The model and GIS are run independently.
- **Interface:** Links are built between the model and GIS. These links are used to synchronize the model and GIS. The data is duplicated on each side of the link. Integrating GIS and Hydraulic Modelling and the model and GIS are run independently. One common approach is the use of shape files, which can pass data between the model and GIS and optionally update either based on data contained in the other.
- **Integration:** A single repository for the data is used. The model can be run from the GIS and vice versa. This integration of the hydraulic model and the GIS leads to the following benefits:
- Time-savings in constructing models.
- Ability to integrate different land use, demographic, and monitoring data using GIS analysis tools to more accurately predict future system demands.
- Visual, map-based quality control of model inputs.
- Map-based display and analysis of model outputs in combination with other GIS layers.
- The most powerful feature of a GIS, from a planner's perspective, is probably the ability of the GIS to integrate, through their spatial relationships, databases that would be difficult or impossible to integrate outside of a GIS environment.

3.3. Planning of Water Resources

Any organization requires perspective water resources plan put in position so as:

- To effectively plan, harness, develop and manage the water resources of the city.
- To ensure that requirements of all the users are met in an efficient and environmentally sustainable manner.

Objectives for Planning of water resources

Water being the common resource utilized by citizens, it is imperative that some common objectives must be adhered to for upkeep and management of this precious resource. Some of these objectives include:

- Create awareness for water conservation among citizens.
- Update the skills of the employees with respect to planning, design, and management of the projects under their jurisdiction.
- Enhance involvement of the end-users in management of water resources
- Ensure optimal utilization of surface and ground water at project level
- Undertake research and pilot development in domain areas for conservation of water resources.
- Work out cost implication for sustainable management of projects.
- Create GIS-based water resources information system with updating functionality for water distribution department.
- Create a GIS-based integrated framework for collation of water resources related information across the departments.
- Optimally allocate water among various sectors as per the policy and maintain the information on utilization using IT (Information Technology).

3.4. Use of Information Technology in Water Management

Information Technology (IT)[1] has been recognized as one of the basic technology for improving efficiency of operations in any organization. It is also a very good integrator of information. These two qualities make the IT a good candidate for implementation in departments connected with water resources. IT can be very effectively used for creation and implementation of an information base required for the integrated planning and management of water resources.

Some of the major activities related to water resources where IT can make appreciable improvement include:

- Water resource is a common resource shared by a large number of users through various line departments in a city. Invariably, all these users act on this common resource independently. It is pertinent for better planning and management that there is a common information base on such precious resource.
- There have been attempts of computerization of activities in some of the line departments but with no or little facility for sharing such information across the line departments and in many cases even within the same department. Facilities for

sharing information across locations as well as across line departments are essential to improve ingredients for better planning and decision making.

- There is a large amount of data related to water resources that is being currently maintained in hard copy format by most of the line departments. Many of these elements are common to many departments and thus result is duplication of effort and resources. Availability of common information base shall help in achieving all the benefits of a database such as integrity, security, efficiency of retrieval etc.
- Availability of such information base shall also facilitate use of various models for planning and decision making in water resources at the city level.
- There is a requirement that every city has to provide the 'Environmental Status of the city' report every year. A true status report is not possible without having a realistic interface with all the constituent departments. IT based information system is required to provide the environmental status of the city.

3.5 Benefits of Implementing Information Technology in water management

The main benefit of implementing the Information Technology shall result from the availability of reliable and accurate information on water resources entities. There would be many associated benefits that shall accrue because of such implementation. Some of these benefits are:

- Effective monitoring of project progress from the various offices through the information system.
- More time available for analysis since data collection and compilation would be done through the information system.
- Effective performance appraisal through the information system.
- Minimizing duplication of work involved in maintaining / generating similar information at various offices. Since the offices would be networked, information generated at one location could be accessed at other places.
- Facilitating information exchange with external entities through appropriate protocols.
- Activities such as design of water resources structures could be done through

technical applications. These could be stored in databases for easy retrieval in future.

- Collection of data in electronic format would facilitate applications of various models for improving quality of decisions.
- Better information dissemination to stakeholders at various levels through use of Intranet/ internet.
- Availability of such information base shall also facilitate use of various models for planning and decision making in water resources at the city level.
- There is a requirement that every city has to provide the 'Environmental Status of the city' report every year. A true status report is not possible without having a realistic interface with all the constituent departments. And IT based information system can provide the environmental status of the state at any particular instance once implemented effectively.

The above action taken collectively will have a positive impact on the overall objective of efficient water resource management.

3.6. Role of GIS in Design and Asset Management

An important component of a water supply system is the distribution network[7] (pipes, nodes, pumps, valves and storage tanks). A water distribution network design involves optimal design of network components and all the raw data needed for analysis and design has spatial component and hence the need for GIS integration. Any water distribution system design involves the analysis of network data in the form of pipe parameters (length, diameter, roughness, Coefficients etc). This task is voluminous and takes up huge resources in terms of skilled man hours in trying to build up a framework. Also, for optimal network design parameters of the network components are varied and recompilation carried out. This is a huge task in itself and by the use of GIS helps the design engineers in not only speeding up the process but also devising better techniques for doing this. Basically there are two types of design.

First case is to design for an entirely new system and second one is to augment an existing system. In both cases data on network components is of great importance. Proper techniques for Asset Management are a huge problem faced by engineers in developing countries and GIS holds the key in helping them do this. Also, by the use of web based maps of the network, the engineers in the different field offices can by cost-effective

means be able to access network information. Once all the network information is stored in a GIS, it makes the use of querrying possible with ease and helps the planners in better understanding of the system and is able to act in a effective manner to any contingencies that may arise. Use of GIS data though Web based interfaces offers staff in a distributed environment manages the assets in a cost-effective manner.

A water distribution network design involves optimal design of network components and all the raw data needed for analysis and design has a spatial component and hence the need for GIS integration. GIS finds its role in the Analysis, Policy, and Design and Implementation phases of Intermittent Water

GIS can be used as an integrated tool in processing of spatial data for the overall design and asset management of intermittent water distribution systems.

3.6.1. Functions of GIS in Design and Asset management System

GIS can be used as an effective tool to help the engineers in the design and asset management of intermittent water distribution systems. The main factors that are responsible for this situation are resource constraints and very little research concentrating on this aspect. The objective is to highlight the key application areas and highlight how through the use of GIS it will help for in both design and asset management.Fig.3.1 shows functions of GIS in Design and asset management

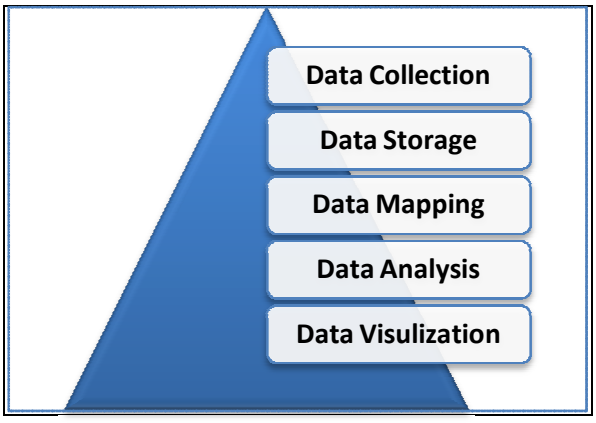


Fig.3.1.Functions of GIS in Design and asset management

A. **Data Collection**: Conventionally, data on networks were collected and stored in paper format. This is not only labour intensive and error prone but less effective. With the advent of newer technologies like GPS and digital cameras, data collection can be made faster and accurate and also better GIS integration of data.

In areas where this digital data is not available paper plans can be scanned and used instead. For newly developed areas where no data is available aerial photographs or satellite images can be used. It is also possible to use a combination of raster and vector data.

B. **Data Storage**: Data on network components can be stored in GIS for spatial querrying. The main data that will be stored will be pipe and node locations and characteristics, reservoir details, valve details and depending on level of sophistication even include types and details of consumer locations. This data can be collected and inputted by field staff in spreadsheets (e.g. MS Excel) and later imported into a GIS. This helps bring down costs as technicians with minimum GIS skills can do bulk of the data handling operations. Pipe data is held in the system in a node and line type format. This is ideally suited to the pipeline type layout with nodes and connecting pipe-work. Data can be input in several ways, either directly onto the screen, from a digitizer, or from previously captured data that can be read into the database as long as it has a record of its grid co-ordinates and connectivity. The GIS includes an import facility for standard GIS to enable interoperability.

C. **Data Mapping**: Generating the mapping of distribution system for various criteria using GIS makes everyday querrying based on specific criteria quick, easy and understandable for engineers. Fundamentally, the model presents information, as on a map. But it is an intelligent map in that each item that you can see is supported and described by other data that the user can access by a simple click on the mouse button. There is a great deal of flexibility in the way that data can be used. Background maps in a variety of formats can be supported. The GIS contains a standard database structure to hold all the data that is regularly used for distribution systems, but the system is not limited to just this data. Any data set can be viewed provided that the information is given either a grid reference or a cross-reference to an item (node or line). With maps and data in the system it is easy to view and interrogate. Information can be viewed selectively, for example with different layers switched on and off as need may be or data can be filtered: only pipes of greater than 100mm diameter can be displayed, or even those

greater than 400mm diameter viewed in blue, and those greater than 200mm diameter in red. The graphical output can be shown in GIS and other relevant features can also be shown relative, to for example pressure variation. The model output can be overlaid on an aerial photograph of the city and also the location of consumers potentially affected shown. If the population theme is turned on, the select feature can select an area of interest highlighting the population at risk. Searches can be made on various criteria. Areas for a search can be defined by boundaries such as municipality or zonal area, or an area defined on screen by drawing a line with the mouse. Reporting is also easy. Plots can be produced to replicate what is on the screen. Text reporting uses the GIS functionality to select data requested by the user, but outputs in a spreadsheet format suitable for exporting to a package such as Excel.

D. **Data Analysis**: Statistical analysis, data interpolation and spatial statistics to be carried out with the GIS. Due to the voluminous amount of data that has to be stored in case of any distribution network, the various analysis tools in any standard GIS not only help in Spatial analysis but also in statistical analysis of data sets.

E. **Data Visualization:** Multimedia data like photographs, videos and 3D panchromatic imagery to be stored for corresponding data sets to enhance real-life scenarios. This enables site condition assessments for immediate actions. Also, the visualizations tools in GIS can be used to find patterns and relationships in the huge amounts of data collected like pressure and flow recordings. Also, the functions in GIS to plot graphs for the data help the engineers in finding anomalies in the huge data sets that is otherwise impossible to detect. Besides, what-if ' scenarios can be generated and effects studied which helps in better and informed decision making.

3.6.2. GIS in Demand Modelling and Design

GIS to be used to model hydraulic conditions in spatial terms and how it can be used to help in design of systems. Performance information is important to network design and in planning. A dynamic, hydraulic, water-distribution model helps to understand the effect of different demands on the network, and allows the right design decisions to be made to

allow for future increases in demand. The performance of the network can be tested under extreme conditions. A model helps in the assessment of which parts of the network will be prone to low pressure conditions. A model gives an estimate of pressures throughout the network, during the supply interval, while maintaining an adequate pressure.

3.6.3. Role of GIS in Asset Management

Asset Management is the systematic process of maintaining, upgrading and operating physical assets. In the case of water distribution systems, physical assets include the network components such as pipelines, storage reservoirs, pumps, valves etc. The key advantage of Asset management is that it enhances the knowledge of the engineers of the various assets and their details, helps in logical decision making process, it acts as a framework that provides a measure of the network performance and links it to both short term and long term planning thereby helping in optimal improvement of assets at least cost.

Proper record keeping of the network components is a big task and GIS offers the tools to successfully implement that engineers require information on various aspects of the network for administrational as well as maintenance needs. Also, updating of information is an integral part in the successful implementation of O&M tasks. This part is focused on creating user friendly interfaces including option of web based facility to enable the engineers at different offices to have access to basic network information using familiar internet tools. Web based map services enable accessible better service of data more efficiently. The users can select the data they want by criteria when they want it in a cost-effective manner.

3.6.4. Role of GIS in Disaster Management (Emergency management)

All phases of emergency management depend on data from a variety of sources. The appropriate data has to be gathered, organized, and displayed logically to determine the size and scope of emergency management programs. During an actual emergency it is critical to have the right data, at the right time, displayed logically, to respond and take appropriate action. Emergencies can impact all or a number of government departments. Emergency personnel often need detailed information concerning pipelines, building layout, electrical distribution, sewer systems, and so forth. By utilizing a GIS, all

departments can share information through databases on computer-generated maps in one location. Without this capability, emergency workers must gain access to a number of department managers, their unique maps, and their unique data. Most emergencies do not allow time to gather these resources. This result in emergency responders having to guess, estimate, or make decisions without adequate information.GIS provides a mechanism to centralize and visually display critical information during an emergency.

Emergency management programs are developed and implemented through the analysis of information. The majority of information is spatial and can be mapped. Once information is mapped and data is linked to the map, emergency management planning can begin. Once life, property, and environmental values are combined with hazards, emergency management personnel can begin to formulate mitigation, preparedness, response, and recovery program needs.

Historically, emergency management programs are planned, implemented, and modified based on volume of business or reaction to emergencies as they occur. GIS allows emergency management needs to be identified prior to an incident. Disaster events, such as wildfires, tsunami, floods, earthquakes, hurricanes, epidemics, chemical cloud dispersion, and oil spills, can be modeled and displayed in GIS. Emergency management personnel can use modeling for training, for actual tactical deployment during a disaster or to analyze the consequences of a possible disaster. The use of this technology takes emergency management planning information off the shelf for utilization by response personnel for real-world operations. In short, the thoughtful application of a GIS can take much of the panic and surprise out of emergencies.

3.7. GIS based Functional requirement for Water Supply Network

At enterprise-level GIS system needs to complete the data processing and should also include other related business and functional systems [4]. The water supply network based on GIS should have proper functions as follows:

- Unified management with information such as network information like pipelines, valves, etc. and others such as urban terrain, streets, residential areas, divisions, meters, etc; organically integration of the attribute database and graphics database of the network. The network data and attribute data need to be stored in standard GIS graphics format in order to exchange data among different GIS platforms.

- Capable of arbitrary browse, zoom, roam, conditions enquiries, regional information, statistics and analysis, capable of operations with layers like viewing any layer, turning on or off the display of a layer conveniently, functions of Eagle Eye and index chart.
- Supporting data entry in multiple forms and formats including AutoCAD, GPS and manual entry of data and supporting network detection, network data edit, alteration and maintenance, entry completed drawings, every operation must control the consistency of the network information and support summary reports of network status and alteration data, having an optimized system structure and perfect system of database to satisfy the needs of development in years and being easy to be upgraded and maintained.
- Providing relevant schemes of valve closure, the opening and optional ones in case of occurrence of explosion and leakage in water supply network; providing regional analysis of water failure.
- Providing hydraulic calculation analysis, calculating pressure, flux, velocity, direction and head loss, etc. of each pipeline segment node by utilizing certain mathematical model and telemetry data received from SCADA system and other auxiliary data.
- Enterprise and public oriented integrated information inquiries.
- Aided design.
- Online office, such as water applications, designs, project construction, online application, reception, examination and approval, result notification of network maintenance.

3.8. Architecture of Water Supply Network Based on GIS

Three-tier/N-tier architecture [6] is superior in capabilities like operating speed, security, portability, augments ability and meets the requirements and characteristics of water supply management information system; therefore, the application structure chooses three-tier/N-tier architecture. In the system, the GUI based desktop application mainly faces design department and engineering department in water supply network, while browser based web application mainly aims at the decision-making sector or other user's inquiries and searches. In desktop application, the GUI graphics forms are designed in

VB to achieve the interface tier and the browser page is designed in ASP.NET in the interface tier of web based application. Both communicate and exchange data through XML with business logic tier of server side. Business logic tier adopts web service programmed in VB and the reuse and maintainability of software are improved greatly because of the unified interface being adopted. Application of logic structure for water supply network based on GIS is shown in Figure 3.2.

Information integration tier : It is also the data tier which stores and manages all system information, including specifically enterprise resource databases, business information bank, production information bank, management database, SCADA database and geographic Information database, etc, which is data foundation of information service and application.

Logic application tier: It is core application system of business rules in enterprise applications all in which core business processing component, middleware to ensure system business processing ability and load balancing applications are and is the core service of the entire system software application.

Information service tier: It is the application entry of the entire information system. Both customers and internal staff can access the service provided by the system through unified information service entry.

The outer user can obtain service provided through customer service system of business hall or enterprise portal website and internal staff can also achieve business processing required by the system via various internal application systems through browser or desktop applications.

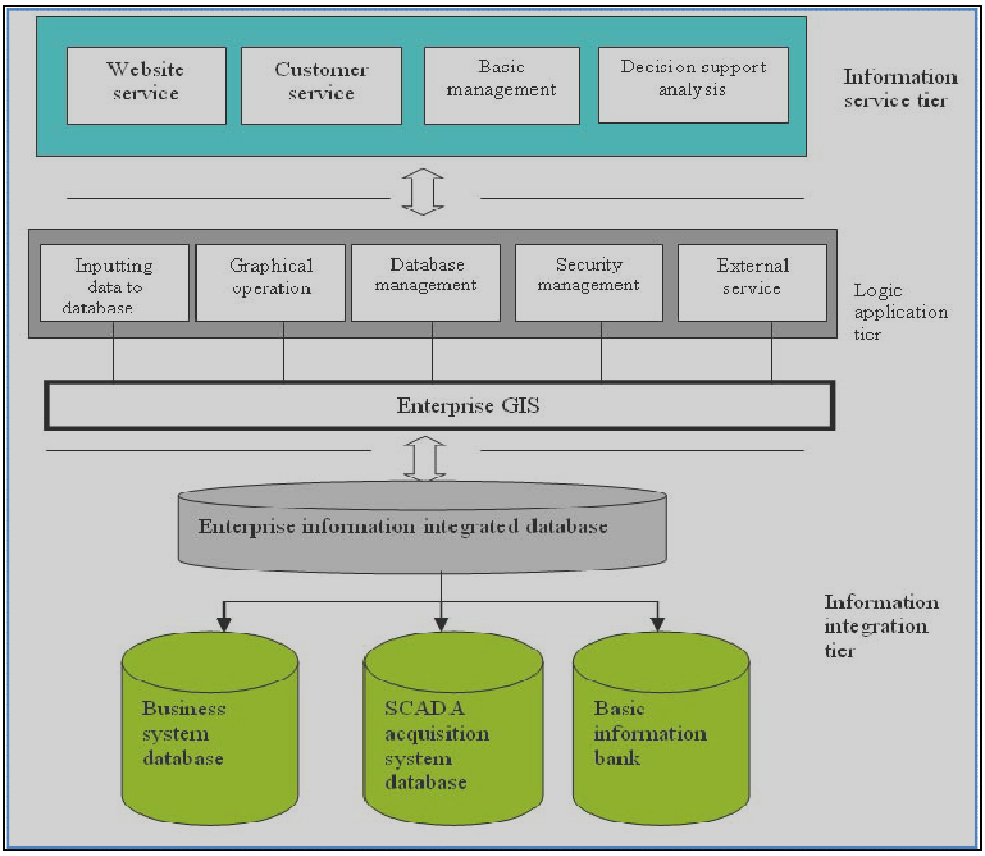


Fig.3.2: Architecture of Water Supply Network based on GIS

3.9. Design of System Function

3.9.1. Overall Design of System Function

According to requirements of the network system[6], the whole system can be divided into following six subsystems: system management subsystem, customer service subsystem, data management subsystem, installation and maintenance management subsystem, aided design subsystem, analysis subsystem. The system module figure 3.3. is shown below.

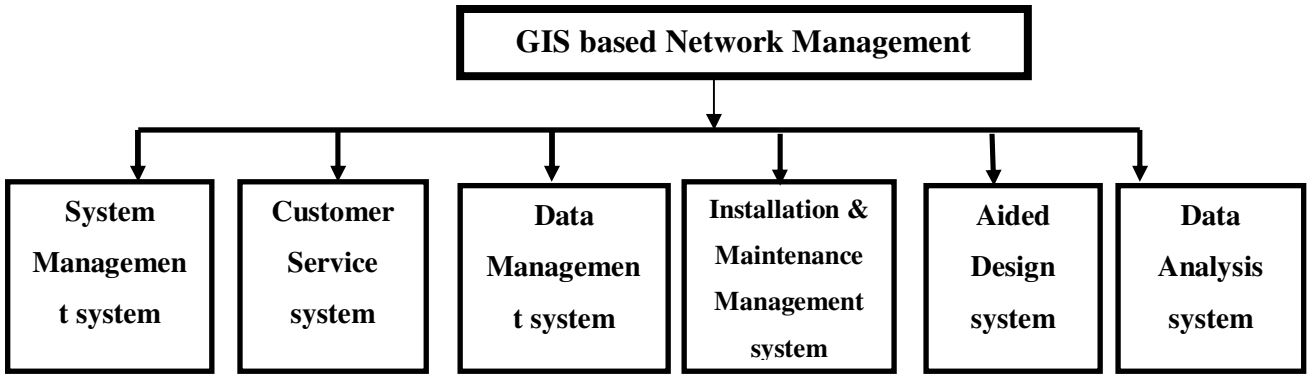


Fig.3.3: Functional module of the GIS based Network Management System

The relationship graph of the subsystems is shown in Figure 3.4, which illustrates the content of data exchange between the subsystems. Among them, analysis subsystem, aided design subsystem, installation and maintenance management subsystem and customer service subsystem serve data management subsystem. The system management subsystem is the control center of other subsystems.

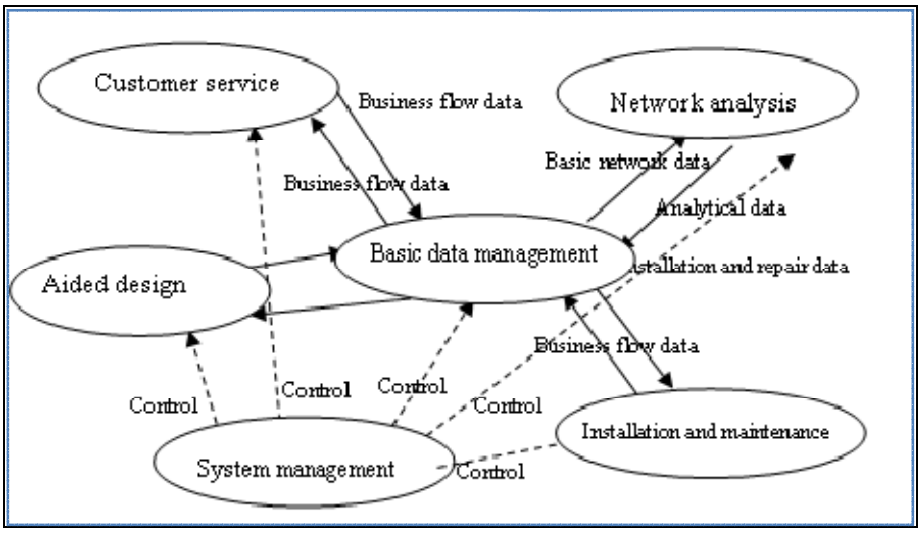


Fig.3.4: Relationship graph of the systems

3.9.2. System management system

The system management subsystem is the control center of the whole system which constructs the framework of the whole system, integrates all other subsystems and shoulders the task of system security management and maintenance. It specifically includes user login security, authority management, and common connection of data sources, called by other subsystems, data backup and recovery and network security log management. Its functional structure diagram is shown in Figure 3.5. All users login from the unified interface (Browser/GUI), obtain the access into the main interface of system functions after security certification (role and password). Users choose functional buttons in accordance with their purposes and tasks (the system will shield or turn on some functional buttons depending on different authorities), call other subsystems and share public components such as data source connection component at the same time, which makes the entire system a seamless organic whole.

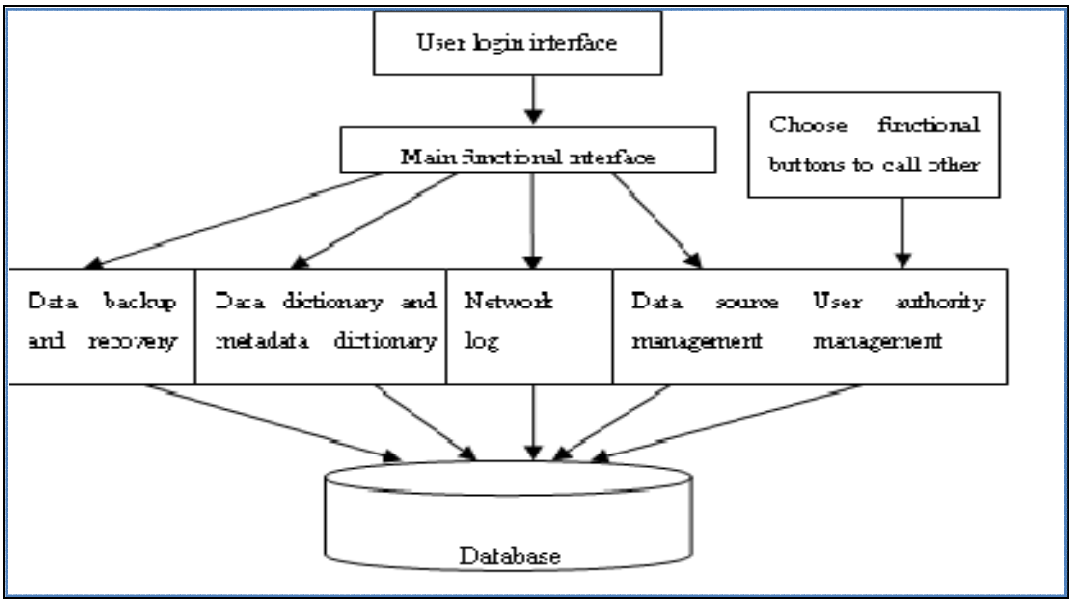


Fig.3.5: Functional structure diagram of system management

3.9.4. Customer Service System

Customer service subsystem provides business hall service module and online information service module. With customer service subsystem, customers can carry through operations such as installation, maintenance and breakdown report in business hall or via Internet. Relevant operation sectors in water enterprises can also inquiry information released by network GIS including pipeline segment information, node and appendage information and operating condition information of network, etc. via Internet.

3.9.4. Data Management System

Data management subsystem includes several functional modules such as network foundational data maintenance, query and statistics and interface data management. Figure 3.6 shows the functional modules of data management subsystem.

3.9.4.1. Network Foundational Data Maintenance

The main function is to convert various file information of network into GIS data, which include background data, network data management and attribute data management. Background data management import or export terrain data and convert data format; network data management is to manage the input, edit and deletion of the network data like file information, external detection information, pipeline, valve and fire hydrant information, for instance, it also verifies the rules of network data, error check and special topic check in order to eliminate obvious errors; attribute data management allows

the input of non-spatial operation attribute data either fast in batches or in single mode by clicking the map element needed.

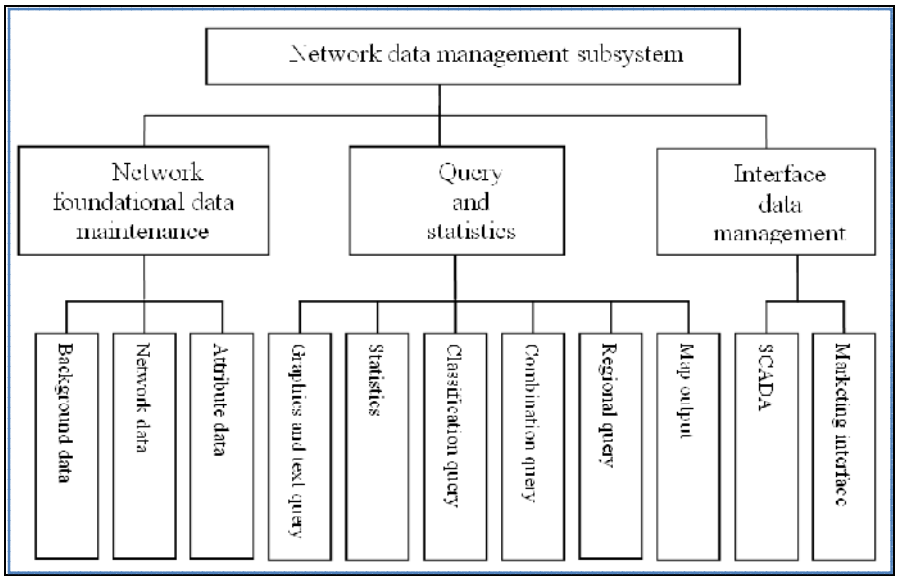


Fig. 3.6: Functional module diagram of data management subsystem

3.9.4.2. Query and Statistics

The result expression of the system is query and statistics. The comprehensive query, statistics and report forms occur in the function module, including two-way inquiries using graphics and attributes, classification query, self-defined combination query, regional query related to operation system and statistics report form output. Specific descriptions are as follows:

- **Graphic-attributes exchange query-**The main contents of query contain query of network and appendage information. The query can be divided into 3 types: 1) query graphics from graphics, find other relevant graphics information through some part of the map. The typical example is to search the small scale maps (known as detailed maps) on the large scale maps (known as sketches). The first step of the query is to establish a corresponding relationship between detailed maps and sketches.2) Query graphics from attributes. Refers to query based on attributes and display the graphics elements satisfying the conditions. There are two aspects in this application: one is to locate the graphics element by its attribute data. For example, when we need to find the valve with the condition of "valve No.= F0123", we actually need the display of the valve's location. The

other aspect is to locate its geographic position by the street.3) Query attributes from graphics, which is to display relevant attribute information by specifying some element.

- The query function allows graphic-attributes exchange query on information of water enterprises network and its appendage. The query content includes valve information query, fire hydrant information query, node information query, pressure-measuring point information query, flow measuring point information query and pipeline segment.
- **Network statistics-** Statistics of the total of the graphics elements, the summation, maximum, minimum average of the field or classification with the field of selected file attribute (or table) or classification number user appointed and scopes of each classification. The result can be presented in histogram or pie chart and may be finally saved or printed.
- **Classification query-** To carry out instant query varies from different classification and emphasis in different layers.
- **Combination query-** To carry out combination query based on customer attribute item on self-defined conditions.
- **Regional query-** Query relevant information in designated geographic region scope, such as statistics and details of the equipment distribution, water use information statistics.
- **Graphics and attribute output-** The output includes the map output, network spatial data and attribute data output in addition to table sheet output. The system can perform page editorial processing, typesetting, graphics grooming with various output data and output to all kinds of devices (various printers, mapping devices, CD burners, etc.). Query and statistics provide several convenient and shortcut operational functions aimed at motion and zoom of graphics, such as graphics zoom, graphics roaming, full extent of graphics, graphics refresh, layer control, proportional display, and Eagle Eye operation.

3.9.4.4. Interface Data Management

The interface with sectors and units within the enterprise function can put the share and utilization of information to full extent. Mainly interfaces with SCADA remote data

collection system and marketing management system. The interface with marketing system is to read the water meter information in marketing system, and relate it with the water meter thematic maps to meet the need from customer for query attributes from graphics; the interface with SCADA remote data collection system is to receive current state data of network sent by monitoring terminals at the network scene and display GIS map on the screen for the user in the a control room to seize the actual state of the network in real time.

3.9.5. Installation and Maintenance Management System

Installation and maintenance management subsystem consists of two function modules of installation management and maintenance management.

3.9.5.1. Network Installation Management Module

The module contains following functions:

- Institute capacity enlargement programme from installation plan information, line chart and capacity enlargement application.
- Payment management, which is the basis of network installation, manages the payment of capacity enlargement applications from users and includes payment input and payment query, and so on.
- Construction progress management that institutes installation plan based on network installation plan and capacity enlargement program, and output project status information and installation completion data.

3.9.5.2. Network Maintenance Management Module

The main task is to manage network maintenance information including equipment and facilities asset management, and equipment maintenance management. Equipment and facilities asset management is to manage the equipment, facilities asset of the network, perform statistics, query, classification and summary of equipment and facilities according to conditions. The results can be expressed in charts for analysis and statistics. Equipment maintenance management is to manage the information of equipment installation and it has following functions:

i) Task enrollment and dispatch management: the first one is for enrollment, input, edit and query of repair work, while the second one is for input, edit and query of staff dispatch work.

ii) Leak detection management: complete the plan-making, approval of detection, and enrollment-modification-query of results.

iii) Patrol road management: complete the plan-making, approval of patrol road work, and enrollment modification- query of results.

iv) Planned repair management: complete the plan-making, approval of repair work, and enrollment-modification query of results.

v) Repair results: record and manage information of different valves with workers sent and repair result of pipeline segment (Staff labour, materials, quality control, compensation and so on).

vi) Basic information input: input management of information of enterprises, staff and valves maintenance related to the repair.

3.9.6. Aided Design System

Network aided design subsystem accomplishes following functions:

- Data input- Permission bill of design, network geographic information, network technological standards and norms, capacity enlargement application and line chart, etc.
- Pipeline pavement-The system allows connections between each node and network appendage with different thickness for pipelines of different models and supports, real-time length calculation and display throughout the process for the design reference.
- Set nods and network appendage-The system provides with various graphic symbols in common use according to the characteristics of water industry such as valves, nodes, meters, etc. the selected symbol will be added to the corresponding position on the map with clicking the mouse.
- Additional attribute data- connecting the designed node with the attribute database.
- Optimizing design scheme and draft.
- Generation of construction design, generating and printing construction design.
- Budgetary estimate and budget management, programme comparison. The Budgetary estimate and budget list, which is a feedback to user, is generated automatically on the basis of appendage, pipeline length and material, price of

equipments and pipelines, construction man-hour, construction quantity of earth and stone, etc. The installation begins when the payment is made.

3.9.7. Data Analysis System

Analysis and decision, served with various acquisition and treatment of foundational data, is the core part of the system and the concrete expression of realization of "scientific management and rapid query analysis of information, support decision-making". The network analysis includes measurement and calculation of random distance or area, collision analysis; valves close analysis, analysis of the cutting off of water, hydraulic adjustment calculation.

- Measurement and calculation- Measure and calculate the distance of the appointed one or more lines and area of randomly-appointed region; measure and calculate pin length, angles, perimeter and area. Display graph scope of full map, a layer, or the window.
- Collision analysis- To ensure the shortest distance between two spatial objects of network.
- Hydraulic adjustment calculation- To establish a certain data model on the basis of network optimization and figure out flow pressure of nodes, etc, to provide water dispatch and network design with reliable basis.
- Pipeline explosion analysis and analysis of the cutting off of water. When a water leak occurs due to pipeline segment or node accident, output the best valve close project on the basis of network data through some strategy and fix on the water cutting off area project when the pipeline segment explodes

3.10. METHODOLOGY

3.10.1. Geographic Information System and Data Model

Geographical Information System (GIS) is an integrated system of computer hardware and software designed to manage, analyze, and display spatial data. It acts as an integration platform and offers the possibility of a consistent, interactive user environment. The advantage of GIS lies in its ability to relate disparate data sets through a common denominator, which is a spatial location. GIS also provides the tools for managing the modelling process, organizing model input parameters, analyzing the model results and displaying both model input and output as user-defined scale.

The step-by-step approach followed for the study is as follows:

- Collection of field data on the existing water supply distribution system, sewer system, elevation by various survey methods & survey equipments such as Ground Penetration Radar (GPR), Electronic Pipe Locator (EPL) etc.
- Preparation of various thematic layers viz. Road Networks, Rivers, Railway line, Buildings, Building groups etc., Maps are prepared from existing vector based NRSA map (1:2000scale).
- Development of network layers via, Road network, Water Distribution Network, Sewer network, and preparation of input data for the data models by incorporating field attribute data.
- Generation of data model from GIS.
- Data model Management by using GIS Network Analysis and development of a user-friendly tool for data Management.

3.10.2. Data Collection & Preparation

As a preliminary part of data collection [3], field visits were undertaken to the study area, and observations were made. The locations were chosen based on priority. Data were collected on characteristics of water supply distribution system & sewer system present in the study area. Data preparation part includes preparation of thematic layers viz., base map, etc, construction of network themes viz., pipe network, and sewer network. A GIS is a computer application programme that stores Spatial and Non-Spatial information in a digital form. Spatial information for an area is what is traditionally represented in maps which for a region, may broadly be classified as given in the following table. The corresponding source of such data for our country is also indicated.

Non-Spatial data, also called Attributes, refer to information like demographic distribution of a town or a village, width or identification tag of a road (like NH-4), daily discharge of a river at a particular place etc.

A GIS conveniently manages all variety of data of a given region in a single electronic file in a computer. This is helpful to any regional planner, including that of a Water Resources Project since all information is conveniently stored and accessed with the computer. Further, though the scales of various printed maps may be different, a GIS stores all of them in the same scale. Normally, different spatial features are stored in sub

files, called layers. Hence, one may use the GIS to open all the layers showing all thematic features. Else, one may display one or a few themes at a time by activating the respective layers. For example, the land-use layer may be displayed along with elevation Contours, the other layers being kept off.

Important features of GIS software include handling of spatial and attribute data, data input and editing, data analysis and output of data.

3.10.4. Structural framework for basic geographic data

The basic geographic data contains two types of graphic data respectively for city plane graph and water supply network elements. The graphic data of city plane graph is constructed according to the block and layer concept of SuperMap [5]. Horizontally, the city plane graph can be divided according to logical administrative area. Vertically, the city surveying and mapping information can be divided according to element factors, so that there will be a certain element factor for each layer, and be managed in a stratified manner. According to the characteristics of SuperMap spatial data organization, and combing with the graphic formula of the geographical map, the graphic data can be divided into eight layers: buildings, water system, traffic, boundary, control point, boundary address point, independent ground objects, public facilities and green area. The construction of water supply network elements graphic data mainly includes network characteristic points and pipelines. The network characteristic points can be divided into valve, air or pollution evacuation valve, fire hydrant, water tower, pumping station, knick or tapered point, water meter point, tee branch, and double tee, each of which has its own attribute expression.

3.10.4. Process to construct GIS basic data of water supply network

The Fig. 3.7 shows the process to construct network basic bank[7]. The basic information, administrative boundary information and standard framing information will be input into the bank as background geographical information; after topologic treatment and check on topological structure, network vector map will be input into the bank as final network data; the existing attribute data in the basic maps will be transferred into the data base with geographical data, while those attribute data that need to be added or modified can be input and modified manually after the input of network data.

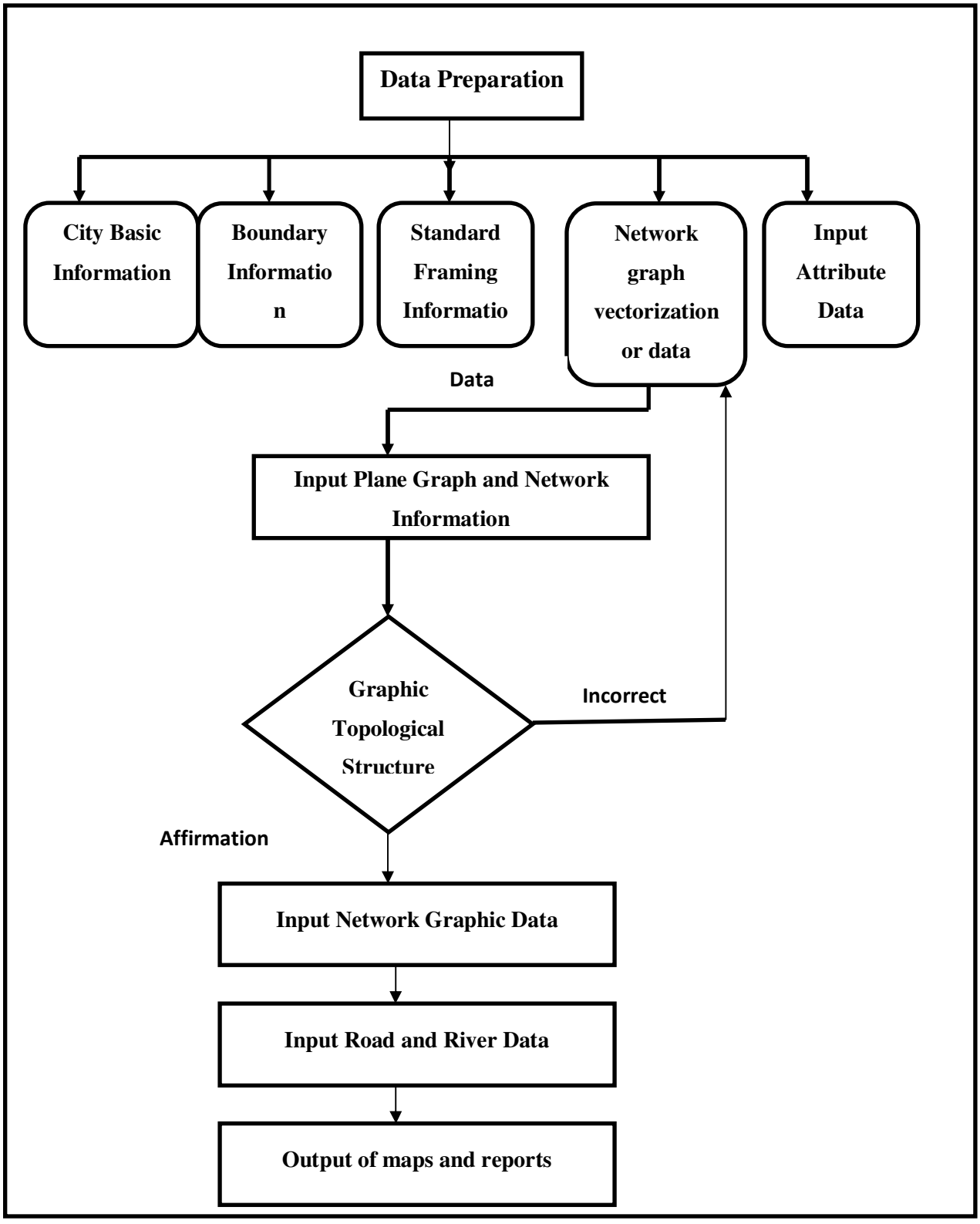


Fig.3.7. Construction Process of the basic Geographic Data

3.10.5. Data conversion and transfer into system

For the network system, there is always a problem for the existing systematic data to transfer into a new system. In the computer graphic management system of some water supply department, the graphic data is stored in DWG format of AutoCAD, and network attribute data is managed with Access database. With the development of the enterprise, it is an urgent need to transfer graphic data and attribute data to a unified relational database for centralized management.

The purpose of data conversion is to transfer data from Access database to spatial database in order to obtain more powerful functions. Data after conversion is unified with database layout requirements, and graphic data will be stored separately as point, line and poly. In the conversion process of attribute data related with space, ADO will be adopted as the data interface. ADO applications call on data in the database through OLEDB provider. When transferring attribute data related with spatial information, attribute relational empty tables, street tables, valve tables, water meter data tables, fire hydrant tables with the same structure as access will be established in the SQL server database, and then two links with connection objects: one to link with Access database, and another to link with SQL server. Therefore, when Access data is called on, data will be written into SQL server at the same time, that is, to write a field in another database when calling on a field until the Record set directing to empty.

3.10.6. Data Vectorization and transfer into system

The principle of scanning vectorization of network map. The Figure 3.8 is the flow chart of scanning vectorization. Paper map will be transferred into graphic files after scanned by the scanning instruments, and finally vector graphic data that can be processed by the GIS platform, after treatment by vector software and a series of operations like correction, joint and so on. Vector operations include vectorization of graphic content, addition on graphic attributes and sheet lettering. According to the requirements for GIS management, the graphic content can be divided into buildings, water system, traffic, boundary, control point, boundary address point, independent ground objects, public facilities, green area and so on. The general principle for vectorization operation is to keep the accuracy, precision and integrity of the original map, that is to select accurate codes for ground objects, to encode by superposition for multi-attribute lines, to capture

the point position exactly, and to apply those tools in software skillfully that can improve data precision.

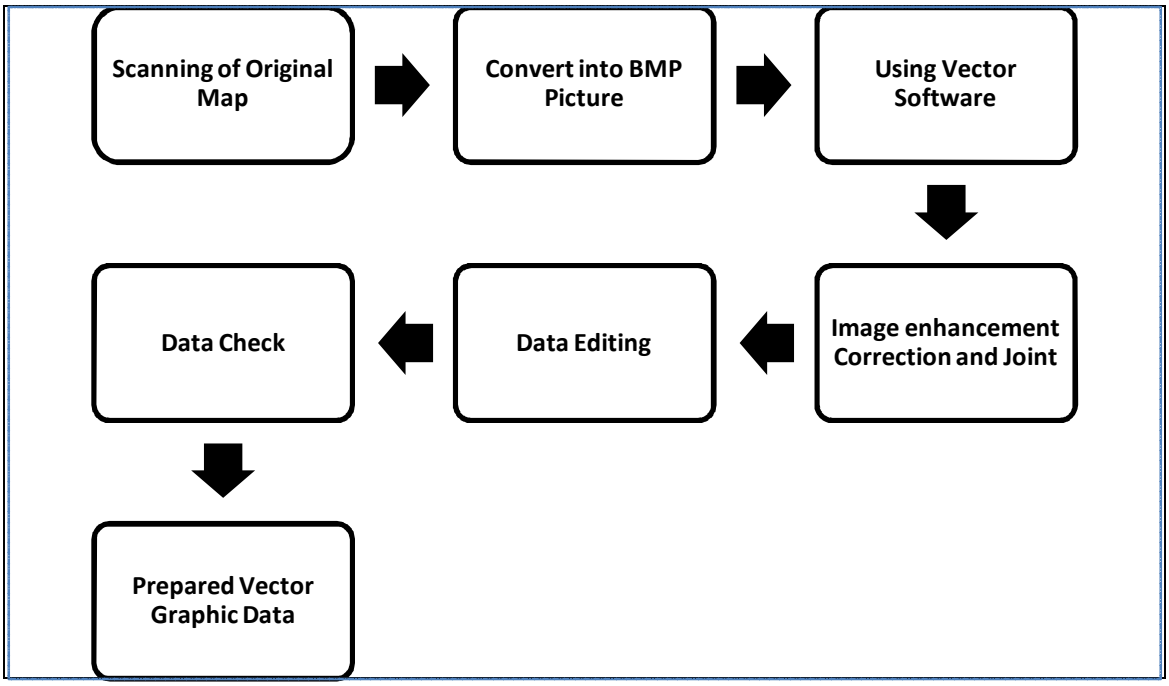


Fig. 3.8: Process of Scanning Vectorization

Vectorization content of network map-The vectorization content mainly includes vectorization of graphic content, addition of graphic attribute, and sheet lettering. Some key technology for quality control in network map vectorization In order to keep the integrity, precision and accuracy of vector graph of the network map, it is necessary to pay attention on the following technical problems such as rectangularity of buildings, treatment on suspension points, treatment on superfluous points and lines, closure of polygons, enclosing walls, benches and some other ground objects. The sign orientation after vectorization is relevant with the vectorization direction, and the sequence of points should be noticed in data collection.

3.10.7. Handling of spatial and attribute data in GIS

There are two types of data storage structures in a GIS-Raster and vector. According to the Raster system, the space is assumed to be divided into a grid of cells, with a certain value attached to each cell according to the data that is represented by a grid of cells, would be done by marking the corresponding cells black (and assigning the value of 1), with all other cells remaining vacant (that is, assigning the value of 0). In the vector system of data storage, the particular point would be stored by the coordinates of the

location. This was an example of a point feature. Other types of geographic features include line, area, network of lines and surface, which have been shown in the following Figure.

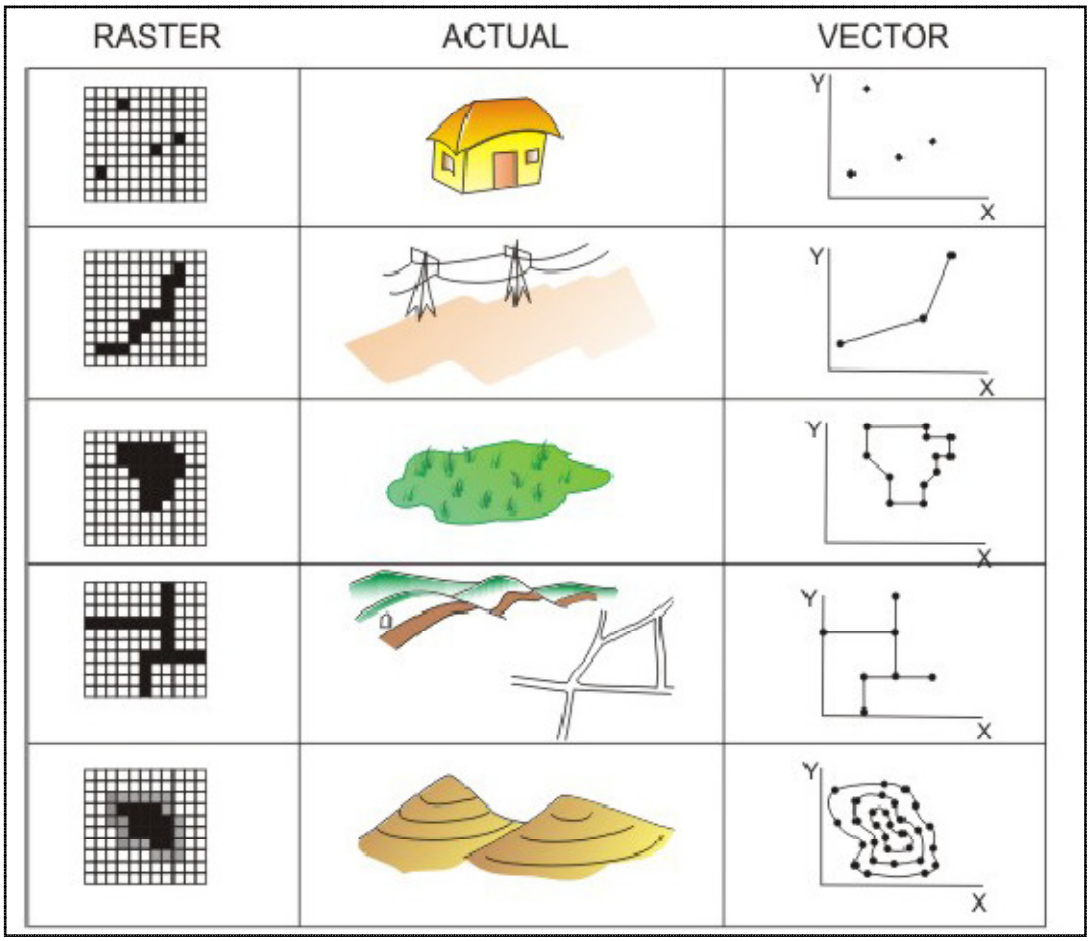


Fig.3.9: Geographic Features of Raster & Vector Data

In the raster grid representation of an area, the size of the grids is a choice of the person using the GIS. For example, in representing the spatial information of a town, a grid size of 10 to 25 m may be sufficient but for a state, 100 to 250 m would be enough. Adopting a finer grid size would, naturally, provide a better representation of data. But that would require a higher computer storage space, which therefore has to be judged optimally. For vector data representation, a better resolution of data may be achieved for line features by selecting more number of points closely. This applies also for representing the lines defining the boundary of an area. For surface representing more number of points

defining the elevation contours would result in a more precise definition of the region. Attribute data is non-spatial, that is, it is not something that varies continuously in space. This is actually the database that defines the spatial data. For example, the location of ground water wells is a spatial data, but the water level record or variation of water level with time is an attribute data of the particular well. Similarly, rivers may be represented as a network of lines, but the width and average depth at different points would be represented as attribute data.

3.10.8. Input and editing of data in GIS

The user of a GIS has to input data, whether Spatial (in Raster or Vector formats) or Non-Spatial (usually in the form of tables). Spatial data may be obtained from different sources and in different formats. They may be input into a GIS in a variety of methods, depending on the format in which they are being supplied. For example, maps would usually be supplied in printed sheets but the satellite image of an area or the land-use map derived from it would be in electronic, that is digital form. The latter may be directly transferred to a GIS but the former has to be Scanned and then Digitized.

Scanning means producing an electronic file of the image, which would usually be a raster representation of the map. This may be done with the help of scanners that are available from sizes of A4 (the smallest) to A0 (the largest). The scanned images are not of much use to a GIS since it does not differentiate between the different objects indicated in the image. For this, manual help is required in the form of Digitization, where by a person uses a mouse over the scanned image to physically point to the various features and store them in GIS format. In order to do this, the vectorization tools of the GIS software would be used. Tabular attribute data may be directly transferred to a GIS and attached to the corresponding spatial data with certain tools provided by the GIS software.

All the various data is stored in a GIS as layers, or themes. After data input, the uses might have to edit some of the data to remove duplicacy, redundancy, etc. of some of the vector data or to remove specks or ‘noise’ in raster data. The error in the vector data appears while undergoing the process of digitization and therefore, has to be corrected before an analysis with the data is made. For example, while digitizing the boundary of a reservoir from a map, the starting and ending points may not be located right over one

another. The GIS would not recognize the outline as a closed boundary, and the reservoir plan cannot be defined as an area. Hence, an editing has to be done to correct this deficiency. Errors in raster data appear due to a variety of reasons, one being the presence of aberration during data capture. Once spatial and attribute data have been enclosed and edited, it may be necessary to process the different data obtained through various sources in such a way, that all are geometrically compatible.

Some of the mathematical transformations used in this process are:

1. Translation and scaling
2. Creation
4. Rotation

3.10.9. Basic Data Preparation for GIS

The data preparation part includes the preparation of various data/layers required for the viz.

- Thematic layers
- Non spatial Database

Thematic Layers

The first step in data preparation is thematic layers preparation. The following thematic layers of study area were prepared by using the collected field data and Remote Sensing Data.

- Base Map
- Water distribution Map

Base Map

This map was prepared from National Remote Sensing Agency (NRSA) of scale 1:2000. The map was obtained from the organization. The entire area was divided into major classes viz, buildings, roads, rivers etc. ArcGIS tools were used for digitizing, editing and projecting the coordinates to projected coordinate system.

3.10.10. Design of System Database

The network system has many data sources and business data types, such as customer service data, dictionary data, geographical data, attribute data, business data and so on. The characteristics of data are also different, including both spatial data (vector, grid or image) on network geographical resources and non-spatial data (data statistics, data input,

and so on), so there must be some certain principles and unified standards for the scientific storage. Data is the blood of the information system, also the base for the run of system applications. The system database can be divided into system management database, customer service database, business database, spatial data dictionary database, spatial database and so on according to the sources, characteristics of data and business. The following Figure 3.10 Shows the general structure of the system database.

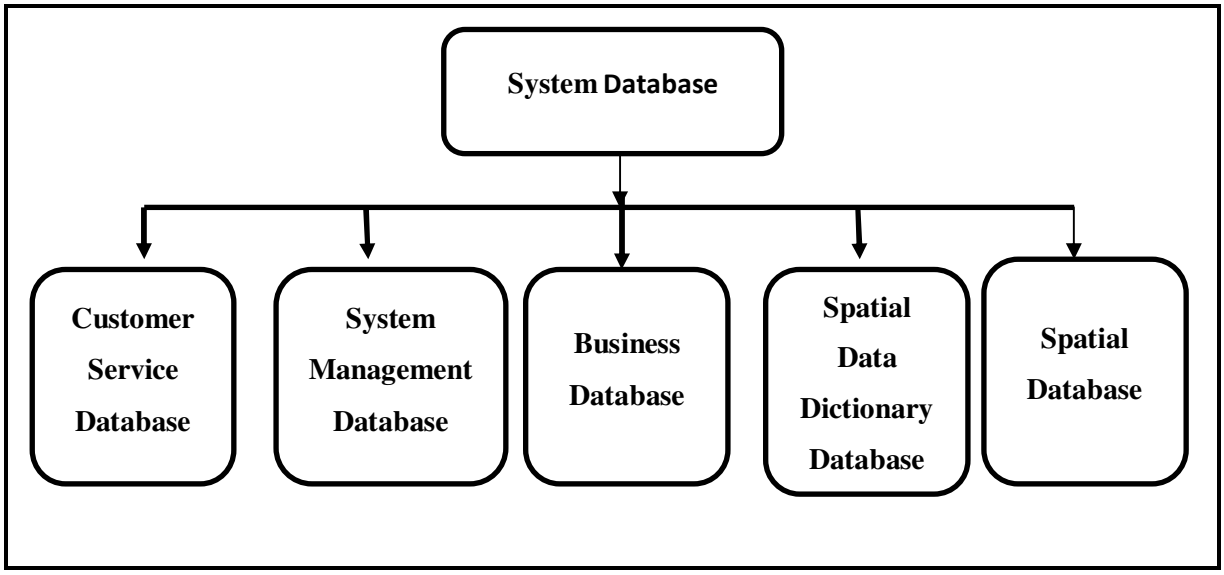


Fig.3.10: Structure of System Database

The system management database provides frame data for the service of the whole system. Staff data for the setting of the enterprise institutional system and staff, journal data for the record and assessment of the system usage status of users, authority data for users to operate all functional modules of the system under certain authority control, dictionary data for unification of codes for common fields in the system, and collocation data for management of the database link, interface and other individual operations.

The customer service database serves for the customer service subsystem, including customer data, business application data, business circulation data, notification and feedback data, complaint and suggestion data and other types of data. Each data category includes several data tables. For example, customer data includes customer basic data table, customer variation data table, and business circulation data includes business nodes data table, business circulation data table, and so on. Business database covers

installation, maintenance, and aided design data, runs in a flow manner, and includes business node data and real-time operation flow data with the core of business flow data. Spatial data dictionary database and spatial database are the core database of the network system: the latter is the real physical representation of space geography and attribute database, while the former is dictionary database to describe the relation of spatial physical databases, all of which are the basis for data management of the network system and network analysis.

3.11. Constraints identified for GIS Implementation in Water Management:

Any organization implementing a new and complex technology such as GIS will face difficulties. Key points any organization wishing to implement GIS in water Management should consider following requirement:

- **Adequate funding**

Always ensure that there is sufficient funding for implementing GIS within an organization. Funds are required for:

- the procurement and on-going maintenance of hardware and software,
- consultants to undertake GIS development activities where appropriate,
- purchase of digital data,
- short and long term training programmes, and

It should be recognized that the first years of GIS implementation are quite cost intensive. However, the pay back will be made in reducing the overall cost in the storage and access to information as compared with the continued use of conventional means. Also, more up-to-date, accurate and reliable information as a result of the use of automated up-dating procedures and the standardization of data used by Ministries will also see a return on investment for which it is hard to place a monetary value.

- **Availability of digital map data**

Without a complementary and efficient programme of digital map production and conversion, GIS will not operate. GIS conversion of all base map data, whilst other organizations are responsible for the conversion of their own data into a GIS format. The Nation's base data is still in the process of being converted into a GIS format.

Also, in order to take full advantage of GIS functionality, it is necessary to ensure that the positional accuracy of map features is adequate for the nature of the spatial analytical tasks being carried out.

- **Corporate attribute databases are well structured**

Within organization, there has been a rapid development of attribute databases created on standalone PC's. To take advantage of the networking technology that has been introduced into the organization, there is now a need to integrate these databases. For this reason, an organization wide database review of all its current digital and paper records has been undertaken. Successful corporate-wide GIS implementation in organization will be dependent upon the recommendations of this database review being undertaken. Without it, GIS data will not reflect changes made to the corporate databases as and when they occur. A well-structured corporate database will also eliminate duplication and erroneous data.

- **Adequate training**

For any organization, three types of GIS users are recognized;

- User who will use GIS through a Windows type interface and will not need to know GIS to use much of its functionality.
- Those who will use GIS through ARC/INFO directly either at the command line or through an interface.
- Those whose main application software may need to interface with the GIS.

In order to cater for these different levels of users, training has to be pitched at the correct level. Adopting a phased approach, staff of the GIS Section has first received comprehensive training, both in-house and via overseas tertiary studies. With this, complete, and as the GIS databases are being developed, training is now being given by GIS staff to the users of GIS data. Sufficient time should be allowed to enable training to be effective. If the time allowed for training is too short or is not pitched at the correct level to suit the user, adequate comprehension of this complex technology will not be attained.

Organizations need to carefully consider their existing databases, the language and standards used, and this will impact the transfer / utilization of database data to GIS applications.

- **Summary**

Any organization implementing a new and complex technology such as GIS requires sufficient funding. Funds are required for the procurement and on-going maintenance of hardware and software, consultants to undertake GIS development activities where appropriate, purchase of digital data, short and long term training programmes.

For efficient programme of digital map production and data conversion then, GIS will operate. Organization wide database review of all its current digital and paper records has been undertaken In order to cater for these different levels of users, training has to be pitched at the correct level. Adopting a phased approach, staffs of the GIS Section require comprehensive training, both in-house and via overseas tertiary studies. Sufficient time should be allowed to enable training to be effective.

References

[1] A Report on Water Resources Management for Himachal Pradesh for INRM consultants & Technology House Consortium ,New Delhi, Project Sponsored By Council for Science, Technology and Environment, Government of Himachal Pradesh, March 2006.

[2] Anderson, J. L., Lowry, M. V., and Thomte, J. C. (2001). "Hydraulic and Water Quality Modelling of Distribution Systems: What are the Trends in the US and Canada." AWWA Annual Conference, Washington,DC.

[3] Bo Yan; Xiaorong Su; Yiyun Chen; , "Data Management of Urban Water Supply Network Based on GIS," Computing, Communication, Control, and Management, 2008. CCCM '08. ISECS International Colloquium on , vol.3, no., pp.353-357, 3-4 Aug. 2008doi: 10.1109/CCCM.2008.370

[4] Bo Yan; Xiaorong Su; Yiyun Chen; , "Functional Structure of Urban Water Supply Network Based on GIS," Computing, Communication, Control, and Management, 2008. CCCM '08. ISECS International Colloquium on , vol.3, no., pp.348-352, 3-4 Aug.2008 doi:10.1109/CCCM.2008.369

[5] http://www.jiyainfotech.com/products.htm ,www.supermap.com

[6] Shamsi, U. M. (2001). "GIS and Modelling Integration." CE News, 13(6).

[7] Vairavamoorthy K., "Guidelines for design of Intermittent Water Distribution Systems", DFID, UK, Waterlines, Volume 21, Number 1, 1 July 2002 , pp. 19-21(3)

CHAPTER 4
RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

The study is related to the current scenario of water supply system and the water problems. It is based on Geographical Information System (GIS) model for water supply system in Pune city. The researcher has used survey and experiment based research methodology to carry out this research. In this research, purposive, quota and convenience sampling method has been used for the purpose of data collection at required strata. This is out of necessity because it was almost impossible to obtain a perfect random sample as per provisional reports of Census[8] India, population of Pune in 2011 is 3,115,431. For administrative purpose, Pune city is divided into 4 zones, which include 14 ward offices. It was not possible to identify the perfect sample population, due to the unavailability of complete and reliable data about water consumptions and problem such as Water shortage, Pipeline leakages, Low pressure, Water pollution, incontinent water timings, water scarcity etc. The method of selection of the sample is described in this chapter and after that the nature of primary data and secondary data is explained.

4.2 Problem Statement

Population of Pune city is increasing day by day due to industrialization and education. The water is required for cooking, washing, bathing and drinking etc. Demand of drinking water is continually increasing due to various factors. Urbanization is a major factor. Water supply distribution is unequal in the metropolitan region. The far flung and newly added areas are not covered under the water distribution system. In some wards, water supply pressure is very low. Unequal distribution of drinking water in terms of quality and quantity leads to water stress. The poor urban population often neglected for such demand is positive and significant.

Pune is a highly commercial city. The number of theaters, companies, schools & colleges has increased over the period of time. Water is mainly used for washing, cleaning, cooking etc. Therefore, the water demand has increased. The city may face future water shortages because

there is a finite supply of potable water and the population continues to increase. Therefore, in order to avert critical shortages that would adversely affect local and regional economies, and most certainly affect the quality of life for our citizens, it is imperative that cities establish, implement and succeed in their water conservation programme.

To study, the existing water supply system in Pune city and to identify various problems and gaps in existing system. To analyze the existing level of service and their management and try to fill the gaps by using different alternative solution and to evolve solutions for the present water supply problems in a Geographical Information System (GIS) framework and EPANET Water hydraulic Model. The researcher has selected the topic titled **"A Study of Geographical Information System (GIS) based computerized framework to enhance the water supply system in Pune city"**

Above problem is broken down into smaller components & objectives for each component it has been formulated.

4.3 Importance of the study

In recent year our population explosion has increased tremendously. The government in short of more infrastructural facilities to all the areas. In a broader sense, the study attempts to identify the problems of the present water supply system and then tries to establish alternative solution. The present available sources of water are not sufficient to cater to the needs of water demands of the city. Moreover, population explosion is putting tremendous pressure on water supply authorities. In this situation, the innovative solutions like wastewater recycling, rainwater harvesting, and Information Technology (IT) techniques like GIS are gaining importance.

For study purpose, Pune is selected because of its acute water supply problem. As per provisional reports of Census[8] India, population of Pune in 2001 is 2,538,473 and in 2011 is 3,115,431.Also, the recent advancements in the field of IT have boosted the growth of the city. Planning is thus needed to establish a strong management system, minimizing present problems and accommodating future demand. Pune is a fast developing city with a lot of real estate development all around and with this the increasing demand for water is obvious. When the demand is more than supply, the imbalance occurs and ultimately the end user suffers with water crisis.

In Pune, the demand for water is increasing day by day but the supply is not sufficient and here comes the water crisis problem, but have you ever thought how much water you need in a day and how much water you are using. Actually, if you analyze your daily water consumption, you will realize that you are actually wasting a lot of water. It has become a challenge today to meet the rising demand for water because of our negligence.

Pune City has relatively better water supply infrastructure. Water is processed at Parvati Water Treatment Plant, from where it flows to the rest of the city. Water is supplied to the entire city through Pumping, Gravity & Pumping & Gravity method. Water requirements reach at peak during certain times, generally in the morning. During this time, households draw the largest proportion of their daily requirements. But gravity-backed water flows are not adequate to serve the needs during this peak time. Consequently, many households do not receive water and need to obtain supplementary water supplies. This problem is not limited to peak hour scarcity.

Leaking pipes, water storage and the slow movement of water during transmission and distribution contribute to health problems, especially for those staying in slum areas. When water moves slowly, or is stored, this process accelerates. When pipes leak, impurities enter the water. Consequently, households are forced to filter and/or boil their water to make it fit for human consumption, a process that requires the use of electricity and cooking gas (or LPG). Households that are unable to do so have negative health consequences – in the form of water-borne diseases such as diarrhea, typhoid and many others.

Pune city[1] draws 1237 Million liter daily (MLD) water from various reservoirs. The Municipality claims to provide only 135 liter per person daily from Water Supply Department of the State Government who claim it to be 200 liters. The discrepancies continue since the pipe installation 2 years ago, due to technical snag. Besides, the canal also supplies 10% water, though it is feared to burst anytime, which may submerge its bank slums. About 20% water supply was cut recently due to inclusion of 23 villages from 238 sq. km recently, which was initially not planned for. Surrounding villages get only 40-litres/ person daily & the farmers agitate against the city overuse during summer. Conflicts occurred last summer when 10% water was diverted for drinking purpose to neighboring city hit by drought. Pune suburbs & fringe villages get inadequate piped supply & draw ground water from 107 wells/ bore-

wells, besides 350 tankers during summer. Quality is poor on outskirts & canal water turbidity rank is 10- equaling the safety level. Excess built up area has left no open areas for natural percolation, leading to floods each week during monsoon, causing traffic jam & reduced work hours, besides air pollution. So Rainwater Harvesting (RWH) is made compulsory for new buildings. Also, the recent advancements in the field of IT have boosted the growth of the city. Planning is thus needed to establish a strong management system, minimizing present problems and accommodating future demand. A computerized geographic information system (GIS) is to assist in the effective assessment, planning and management of water resources. It is also helpful for management of data of water pipes and network devices to increase productivity with more efficient map updating and the ability to compile and report information more rapidly, planning of maintenance operation, maintenance logistics, analysis of non-revenue water, analysis of consumption information, export of data for network modelling, visualization of network data using attributes of the features.

4.4 Scope of study

The researcher has restricted the investigation to

1. Pune Urban area-Citizens
2. PMC-Water distribution Employees

The researcher has considered the Pune[6] urban region for the study, since Pune is the second largest city in the western Indian state of Maharashtra. It is known for its educational facilities, having more than a hundred educational institutes and nine universities, as well as its growing industrial facilities. Pune is an administrative centre and now an important industrial hub with reference to IT.

4.4.1. Topography

Pune (180 31' N, 730 51' E) is a plateau city situated near the western margin of the Deccan plateau. It lays on the leeward side of the Sahyadri i.e. the Western Ghats and is hardly 50 km from the crest of the Ghat. It is 100 km east from the Konkan i.e. the west coast. It is almost 160 kms southeast of Mumbai, by road. It is situated at a height of 560m above the mean sea level, near the confluence of Mula and Mutha rivers. Two more rivers Pavana and Indrayani transverse the northwestern outskirts of the urban area. Mula-Mutha later empty into the Bhima river. In a sense, the city is located in the upper Bhima basin. The city is surrounded by

hills on the east and the south. The Sinhagad-Katraj-Dive ghat range is the southern boundary of the urban area. The highest point within the city is the Vetal hill (800 m) whereas the highest point of the urban area is the Sinhagad fort (1400 m).Refer Map 4.1.

The climate is typical monsoonal, with three distinct seasons- summer, rains and winter, as elsewhere in India. The height above sea level and the leeward location with reference to the Western Ghats have made the city climate moderate and salubrious. The mean daily maximum and the mean minimum temperature for the hottest month - May is 37°Celsius and 23° Celsius respectively. The evening sea breeze from west/northwest keeps the city summer nights at bearable levels.

The same for the coldest month of December as temperatures are 30° Celsius and 12° Celsius respectively. The relative humidity ranges from 36 percent in March to 81 percent in August. Three fourths of the annual rainfall of 70 cm occurs in just four months from June to September.

4.4.2. Geographic area and Governance

4.4.2.1. Geographic Area:

According to the Pune Zilla Census handbook of 1951, the total area under Pune Municipal Corporation jurisdiction in 1951 was 125 sq. km. with the population size of around 4,88,419 people. In 2001, the Pune Municipal Corporation covered a total area of 243.96 sq. km with a population size of 39.33 lakhs. The entire jurisdiction of PMC is divided in to 144 electoral wards.

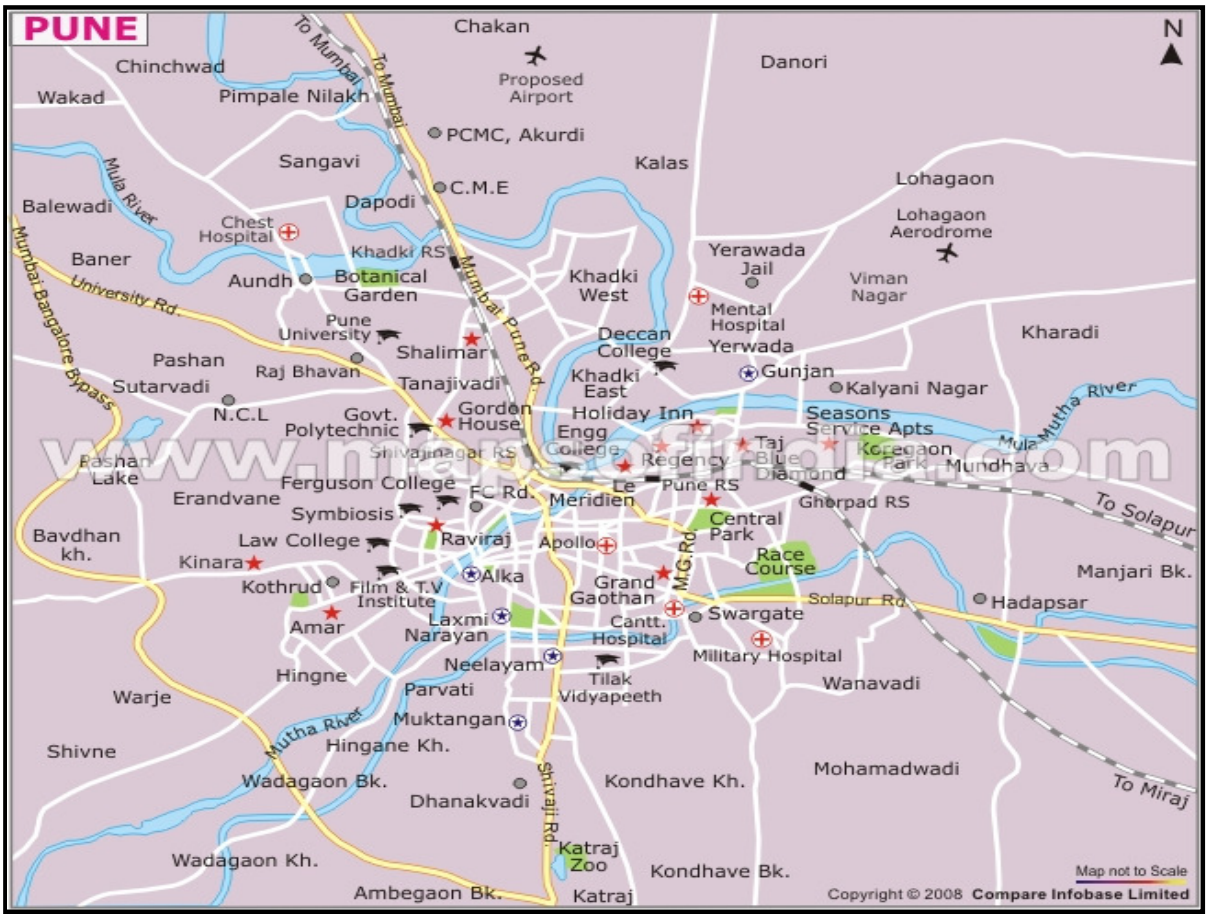
4.4.2.2. Governance:

Prior to 1950, the Pune City Municipality & Pune Sub Urban Municipality governed the city of Pune. Since the population of both these Municipalities reached a considerable number, the State Government constituted the Pune Municipal Corporation (PMC) on 15th February 1950. The Bombay Provincial Municipal Corporations Act, 1949, governs it. The Chief Executive of the PMC is the Municipal Commissioner. It consists of directly elected Corporators headed by the Mayor. The General Body of PMC is involved in policy making and its Standing Committee takes financial decisions. Refer Map No.4.1.

During the course of the present study, the researcher has focused on the citizen population data; infrastructure facility of water supply system data for Pune city is collected. Also, for

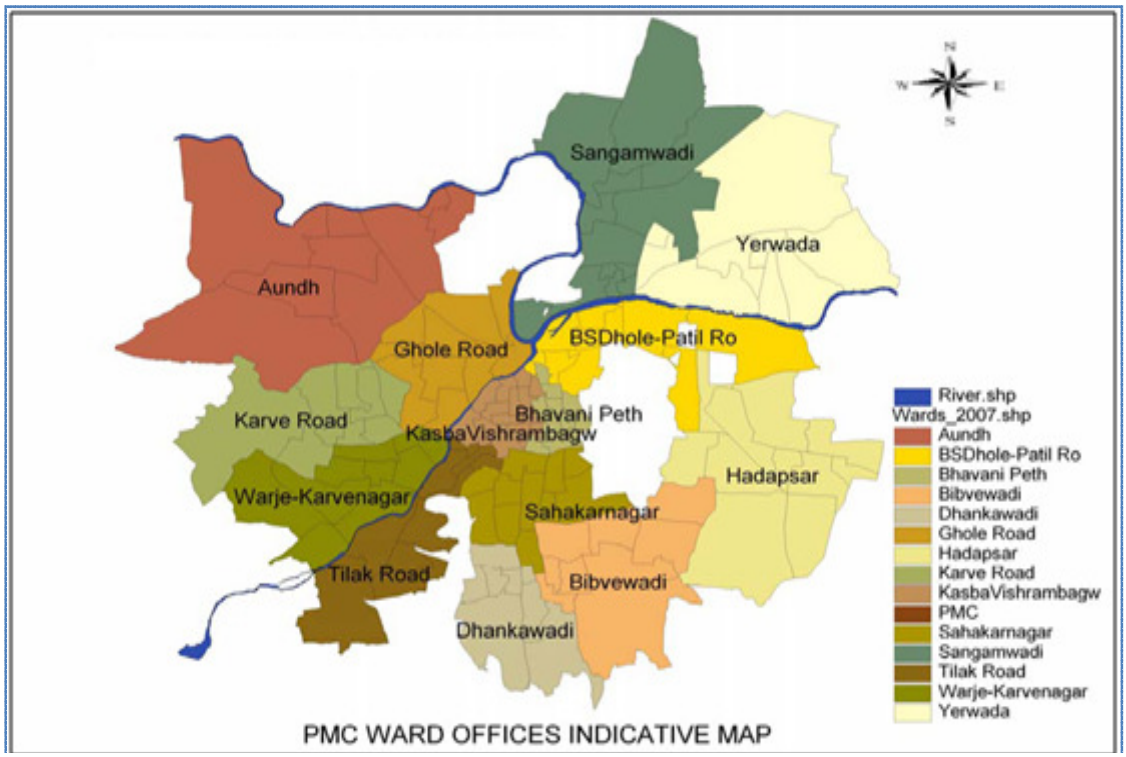
primary survey of citizens regarding water consumption, problems of water supply is being done for Pune city. Leak detection techniques, maintenance & operations data is collected. To study, GIS technology is being used in water supply department in various places in India. Finally, suggest GIS based computerized framework for water supply system in Pune city.

The geographical location[10] of the Pune city and ward offices are indicated by the map 4.1, 4.2 as follows



(Source: http://www.mapsofindia.com/maps/maharashtra/pune.htm(23/07/2008)

Map 4.1 Map of Pune city



Map 4.2 Map of 14 Ward Offices Location of Pune city

(Source:http://www.maharashtrafireservices.org/pdf/pune_mitigation_plan.pdf(23/09/2009)

4.5 Objectives of the study

1. To study the infrastructure facility of water supply system in Pune city.
2. To know the problems faced by citizens with respect to the water supply system.
3. To study the GIS technology being used in management of water supply department in India.
4. To suggest GIS based model to overcome existing problems of water supply department of Pune Municipal Corporation (PMC).
5. To increase the awareness among citizens of Pune & induce them to use water effectively, economically and conserve for future use.

4.6. Hypothesis of the study

4.6.1. Hypotheses

In consistency with the objectives, following hypotheses has formed by the researcher.

$H_{1:}$ "Inadequate Infrastructure facility in Water Supply department of Pune Municipal Corporation (PMC)".

$H_{2:}$ "There is a discrepancy in the water supply as far as water requirement is concerned"

H_3: "Different punishment & reward systems are used to enhance the water supply system effectively & economically".

4.6.2. Description of Hypotheses

H1: "Inadequate Infrastructure facility in Water Supply department of Pune Municipal Corporation (PMC)".

This hypothesis has been tested by using statistical tool, on-site observations and interviews were conducted with higher authorities of Water Supply Department of 25 employees in PMC. The interviews and observations focused on understanding various infrastructure facilities (parameters) such as information system, obstacles in water supply system, water loss accounting, minimization of water loss accounting etc. available in the department. All these parameters are based on the questionnaire of Employees (**Annexure 5,6,7**)

$H_{2:}$" There is a discrepancy in the water supply as far as water requirement is concerned"

This hypothesis has been tested by using calculation of additional requirement of water ward wise using percentages and chi-square test. For testing the hypothesis, various parameters were also considered like sufficient water quantity, additional water requirement etc. These parameters are based on the questionnaire of citizens (**Annexure 4 and question No. 10**)

H_3: "Different punishment & reward systems are used to enhance the water supply system effectively & economically "

This hypothesis has been tested by using the punishment and reward system will enhance water supply system by using percentage and 5 point Likert scale applied for the both systems. These parameters are based on the questionnaire of citizens (**Annexure 4 and Q.28**).

4.7 Research Methodology

This research study is related to the water distribution system in Pune city and suggests GIS based framework for that. It utilizes both primary and secondary data. The secondary data

utilizes already available information both published as well as unpublished. For primary data, however, such a facility is not available and it has to be collected by the survey method. The scope of research is limited. The survey is undertaken by obtaining a **purposive and quota** sample. The description of the research methodology required for the process of obtaining a sample as well as the nature and size of sample should be adequately explained. Purposive, quota and convenience sampling techniques[3][4] involve the selection of respondents based on the important characteristics under study such as where they live, position in society, specific knowledge related to the research problem etc.

4.7.1. Primary Data

Primary data is obtained through a survey. Such data is first hand and original in nature. Several methods are used for collecting primary data like telephone survey/e-mail survey, mail questionnaire, personal observation and interviews. Particularly in survey, the important ones are – observation, interview, questionnaire, schedules, telephone survey[3][4] etc. Each method has its advantages and disadvantages. The primary data collected by the researcher is explained in the following manner:-

A) Selection of the city

The researcher has used purposive sampling method to select the city for the purpose of the study. The researcher has selected Pune City as it is “The Oxford of the East" and also a center of IT activity. The researcher has also ascertained that there is scope for the water distribution system in Pune city and suggest model for Middle Level Reservoir (MLR) Zone of PMC.

B) Selection of the citizens from Ward Offices including Wards in Pune City

Pune city is divided into 4 zones and the administrative wing of the PMC is divided into 14 wards, each headed by a ward office. The researcher has used **purposive and quota sampling** for selection of wards from ward offices in Pune city. In order to study the implication of e-governance services, the researcher has located citizens from 14 ward offices **[2]** from Pune city as shown in Fig 4.1.

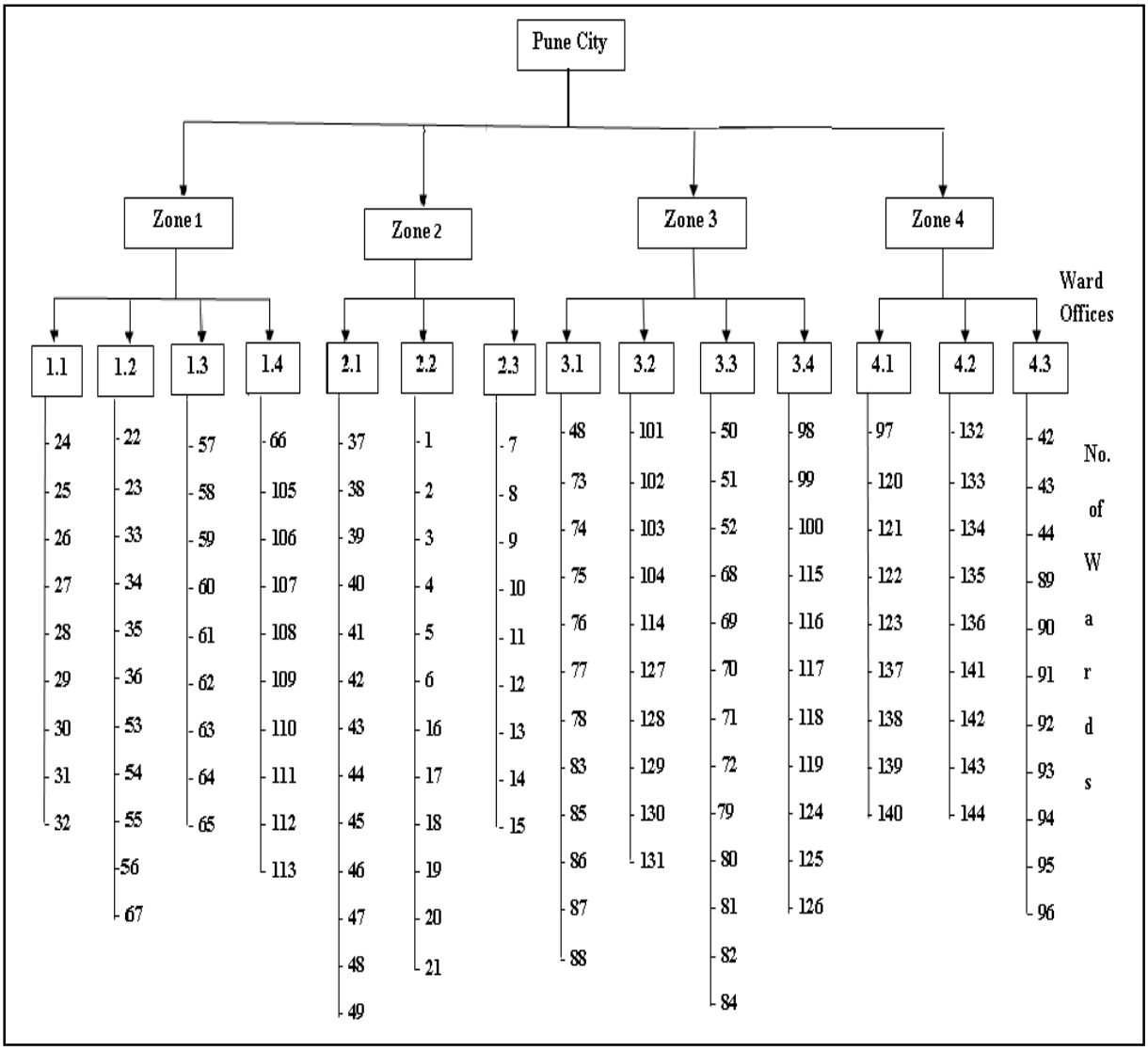


Fig 4.1 Ward coverage in the Four zones of Pune City (Source:PMC office)

The locations of these specific areas were ascertained for the collection of primary data. (For Ward office Name and Ward Name- Ref. Table No. 4.1)

B) Selection of the Ward Offices including Wards in Pune City –

Pune city is divided into 4 zones and the administrative wing of the PMC is divided into 14 wards, each headed by a ward office. In order to study the water consumption pattern, water

problems etc., the researcher has located citizens from 14 ward offices[7] from Pune city as shown in Table No.4.1.

Table No.4.1 Ward coverage in four zones of the city

Zone wise Breakup of Pune City		
Sr.No.	**Ward Office Name**	**Ward Office Address**
Zone 1		
1	Aundh	Indo BrehmanChowk, Aundh BodyGate, Pune-411007
2	Ghole Road	Near Pune Municipal Corporation Press,Ghole Road,Pune-41104
3	Kothrud	Karve Road,Near Railway Reservation center,Pune-411004
4	Warje Karve Road	Swpnashilp Commercial Building, Pune411038
Zone 2		
5	Dholepatil Road	Dhole Patil Market Building Pune-411001
6	Nagar Road (Yerawada)	Rashhing Office,Nagar road, Yerwada,Pune-411006
7	Sangamwadi	Rashhing Office,Nagar road, Yerwada,Pune-411006
Zone 3		
8	Bhavani Peth	General Arunkumar vaidya studium building, Bhavani Peth ,Pune-411042
9	Kasba-Vishrambaug	Pune Municipal Commercial Complex, Near ShaniPar,Pune-411030
10	Tilak Road	Shivajirao Dhere Udyog Bhavan, Tilak Road,Pune-411030
11	Sahakar Nagar	Utsav Building Corner,Near Market yard Corner,Pune-411037
Zone 4		
12	Hadapsar	Pandit Nehru Udyog Bhavan, Hadpsar Pune-411028

13	Dhankawdi	Near Old Katraj Naka, katraj,Pune-411046
14	Bibwewadi	Utsav Building Corner,Near Market yard Corner, Pune-411037

C) Selection of the Employees from PMC Water Distribution Department –

In order to study the water distribution system, the researcher has chosen employees from the PMC Water Distribution Department. The employee's population is selected based on the class and working pattern. It is to be found that 1139 total employees are working in the three different zones of water distribution department. In the present study, only Class I, Class II, Class III technical employees were considered**.** Following Table No.4.2 shows the detailed information about the employees working in the water distribution department.

Table No.4.2: Information about class of employees and their categories (Technical and Non-technical)

Sr.No.	Class of Employees	Technical	Non-Technical	Total
1	Class I	10	-	10
2	Class II	19	-	12
3	Class III	74	240	314
4	Class IV	-	796	796
Total		103	1036	1139

According to the Table No. 4.2, the total strength of officers and employees of Water Distribution Department is about 1139, out of which 10 belong to Class I category followed by 19 in Class II category, 314 in Class III category and remaining 796 belongs to Class IV category. All Water distribution data was collected from Class I & II category employees and very few employees from Class III category. Class IV category employers are non technical so that they are not considered for the present study. For the purpose of study, PMC water distribution employees were selected from the various Water distribution centers, Water treatment Plant, Water Metering Section etc. They are the ones who actually work on Water distribution and maintenance site.

D) Selection of Actual Sample

The study is concerned with the current scenario of water distribution system which includes the survey related to the citizens of Pune city with respect to citizen's problem, awareness of water conservation, opinion about reward and punishment system. It is concerned as well with the reviews on GIS based Water management system in India and suggests GIS based model for Water distribution system. The present research is a survey and experimental based study of GIS based Water supply system in Pune city. The researcher intends to collect information from PMC water distribution department employees and citizens. The purpose of the study is to find out the water consumption pattern and awareness levels of the citizens about water conservation and appliances. To know about water billing system and which system most in favor of citizens to know about reward and punishment system for water enhancement. To know the details regarding the GIS based Water utility in India and abroad, the researcher has visited many websites. In order to attain the above-mentioned objectives, it is necessary to collect both primary and secondary data for the research. The primary data has been collected from

Pune Citizens

PMC- Water Distribution Department Employees

i) Pune Citizens:

There were 144 sub wards in Pune city. For the survey among selected citizens, 144 sub wards from the Pune city were considered. For the present study, the samples were selected from respective 144 sub wards by using **purposive and quota sampling techniques**[3][4]. As the population of each ward was not known, the researcher has taken the data from respondents from each ward. Whichever number was higher was selected as a sample based on various parameters like water consumption, water sources, no. of hours water supply, additional requirement of water, billing system, awareness about water conservation, etc. from each ward of Pune city. The total sample size is one thousand fifteen (1015 citizens) on the basis of the purposive and quota sampling method. Researcher has taken the information from the respondents wherever they were available. The citizens from the 14 ward offices include mostly housewives, men's from the different wards of Pune city. The total number of samples selected from respective ward offices is shown in following Table No. 4.3.

Table No.4.3: Ward Wise Sample Distribution of Pune Citizens

Zone	Ward Office No. & Name	Ward		Ward Wise Respondents	Total
		No.	Name		
1	1.1 Aundh	24	Sanjay Gandhi Vasahat	9	74
		25	Bopodi	7	
		26	Pune University	8	
		27	Aundh	11	
		28	Baner Balewadi	10	
		29	Sutarwadi	10	
		30	Pashan	8	
		31	Aundh ITI	5	
		32	Rajbhavan	6	
	1.2 Ghole Road	22	Kamalnayan Bajaj Udyan	6	65
		23	Agreeculture college	5	
		33	Chaturshrungi Mandir	5	
		34	Model Colony	4	
		35	Modern College	6	
		36	PMC Building	6	
		53	Furgusan College	5	
		54	Dr.Homi Bhaba Hospital	5	
		55	Gokhalenagar	11	
		56	Law College	7	
		67	Deccan Gymkhana	5	
	1.3 Karve Road	57	Shankarrao More Vidyalay	6	86
		58	Rambaug Colony	11	

		59	Kishkindhanagar	7	
		60	Ramkrushna Parmahans	11	
		61	Vedbhavan	10	
		62	Mahatma Society Kothrud	12	
		63	Vanaz Company	7	
		64	Yashvantrao Chavan Natyagruh	13	
		65	Ideal Colony	9	
	1.4 Warje Karve Nagar	66	Dinanath Mangeshkar Hospital	7	75
		105	Major Tathawade udyan	8	
		106	Kotharud Gaon	8	
		107	Happy Colony	7	
		108	Dahanukar Colony	7	
		109	Warje Shuddhikaran Prakalpa	6	
		110	Popularnagar	6	
		111	Warje Malwadi	10	
		112	Maharshi Karvenagar	9	
		113	Hinge Womens Educational Institute	7	
2	2.1 Dhole Patil Road	37	Dr.Naidu Hospital	5	64
		38	Bandagarden	7	
		39	Wadia College	6	
		40	Koregaon Park	5	
		41	Mundhwa Gaon	9	
		45	Vikas nagar Ghorpadi	11	
		46	Dr.Babasaheb Ambedkar Udhyan	6	

		47	Sasun Hospital	7	
		49	Juna Bajar	8	
	2.2 Sangam Wadi	1	Dhanori	6	68
		2	Vidyanagar Lohagaon	4	
		3	Tingarenagar Pumping Station	6	
		4	Kalas Vishrantwadi	6	
		5	Nanasaheb Parulekar Vidyalay	7	
		6	Yerawada Prison Press	6	
		16	Phulenagar Yerawada	7	
		17	Netaji Subhashchandra Bose Vidyalay	4	
		18	Yerawada Gaon	7	
		19	Parnakuti	4	
		20	Yerawada Hotmix Plant	6	
		21	Deccan College	5	
	2.3 Yerwada	7	Lohagaon Airport	6	64
		8	Kharadi Gaon	4	
		9	Kharadi Infotek Park	6	
		10	Sunderbai Marathe Vidhyalay	6	
		11	Vadgaon Sheri	7	
		12	Ramwadi	6	
		13	Agakhan Palace	7	
		14	Don Bosco Highschool	4	
		15	Nagpur Chawl	7	
3	3.1 Bhavani Peth	48	Kamala Neharu Hospital	5	65
		73	Tilak Ayurved Mahavidyalay	4	

		74	Rajewadi	6	
		75	Harakanagar	8	
		76	Gen.Arunkumar Vaidya Stedium	5	
		77	Doke Talim	4	
		78	Swami Samarth Mandir Ganesh Peth	5	
		83	Ghorpade Udyan	7	
		85	Mahatma Phule Smarak	5	
		86	Lohianagar	5	
		87	Ekbote Colony	5	
		88	Gurunanaknagar	6	
	3.2 Tilak Road	101	Parvati Gaon	11	94
		102	Parvati Jalakendra	8	
		103	Dandekar Pool Dattawadi	11	
		104	P.L.Deshpande udyan	8	
		114	Janata Vasahat	6	
		127	Anandnagar Hingane Khurd	10	
		128	Vitthalwadi	9	
		129	Vadgaon Dhayari	11	
		130	Vadgaon Budruk	8	
		131	Manikbaug	12	
	3.3 Kasba Vishram Bag Wada	50	Kasaba Ganapati	4	66
		51	Shaniwarwada	4	
		52	New English School (Ramanbaug)	6	
		68	Rajendranagar	7	
		69	Vishrambaugwada	5	

		70	Mahatma Phule Mandai	4	
		71	City Post	4	
		72	Ganesh Peth Gurudwara	5	
		79	Dr.Kotnis Hospital	5	
		80	Renukaswarup Prashala	6	
		81	S.P.College	4	
		82	Subhashnagar	7	
		84	Panchahaud Mission	4	
	3.4 Sahakar Nagar	98	Salisbury Park	8	72
		99	Tilak Maharashtra Vidhyapeeth	6	
		100	Parvati Darshan	7	
		115	Shahu College	5	
		116	Parvati Industrial estate	7	
		117	Maharshinagar	8	
		118	Chhatrapati Shivaji Marketyard	7	
		119	D A D Colony	6	
		124	Shankar Maharaj Math	5	
		125	Padmavati Arenyeshwar	6	
		126	Taljai Mandir	7	
4	4.1 Bibwewadi	97	Mahadji Shinde Chatri	9	79
		120	Kondhva Khurd	10	
		121	NIBM	9	
		122	Mithanagar	8	
		123	Bibwewadi Gaon	12	
		137	Sukhsagarnagar	9	

		138	Vishwakarma Institute of Technology	8	
		139	Upper Indiranagar Bibvewadi	6	
		140	Kondhwa Budruk	8	
	4.2 Dhan kavadi	132	Chavan nagar	7	68
		133	Dhankawadi Ambegaon Pathar	9	
		134	Dhankawadi Gaon	8	
		135	Chaitanyanagar Dhankawadi	8	
		136	Balaji nagar	7	
		141	Katraj Gaon	7	
		142	Rajiv Gandhi Zoo Park	7	
		143	Bharati Vidhyapeeth	7	
		144	Agam mandir Katraj	8	
	4.3 Hadapsar	42	Magarpatta Hadapsar	16	85
		43	Hadapsar Audyogik Vasahat	7	
		44	Saint Petrik Town	10	
		89	Wanawadi Gaon	5	
		90	Ramtekadi	7	
		91	Hadapsar Gaon	4	
		92	Gliding Center	12	
		93	Sadhana Vidyalay	6	
		94	Satavwadi	5	
		95	Kaleboratenagar	12	
		96	Mahamadwadi	7	
Total					1015

ii) PMC Water Distribution Department Employees

For the present study, employees were selected from PMC who work in water distribution department by using purposive and connivance sampling techniques. Researcher has selected only those employees, who actually work on water distribution sites. In PMC, there are 1139 employees working in Water distribution department. Researcher has collected data from only Class I, Class II and few from Class III Category which includes all Heads of Water Purification Plant, Heads of Water distribution Centers, Exe. Engineers, Junior Engineers from Water distribution & supply dept. of PMC. The total employees are 74 who work in water distribution centers and hence for study purpose 25(34%) employees are selected.

All the selected employees were personally interviewed by the researcher. Maximum information is also collected by conducting group discussion with selected employees. During the field work, it was found that they don't have historical data about no of water connections and pipeline details. It was discovered that there is no record about illegal water connections, water loss details, and no water audit. Table No. 4.4. shows the information of total number of employees and sample selection from each category.

Table No. 4.4: Category Wise Sample Distribution of Employees

Sr.No.	Class of Employees	Technical	Non-Technical	Total	Sample Size
1	Class I	10	-	10	4
2	Class II	19	-	12	10
3	Class III	74	240	314	11
4	Class IV	-	796	796	-
Total		103	1036	1139	25

The following Figure.4.2 shows the Organizational chart of zone wise water distribution department of PMC.

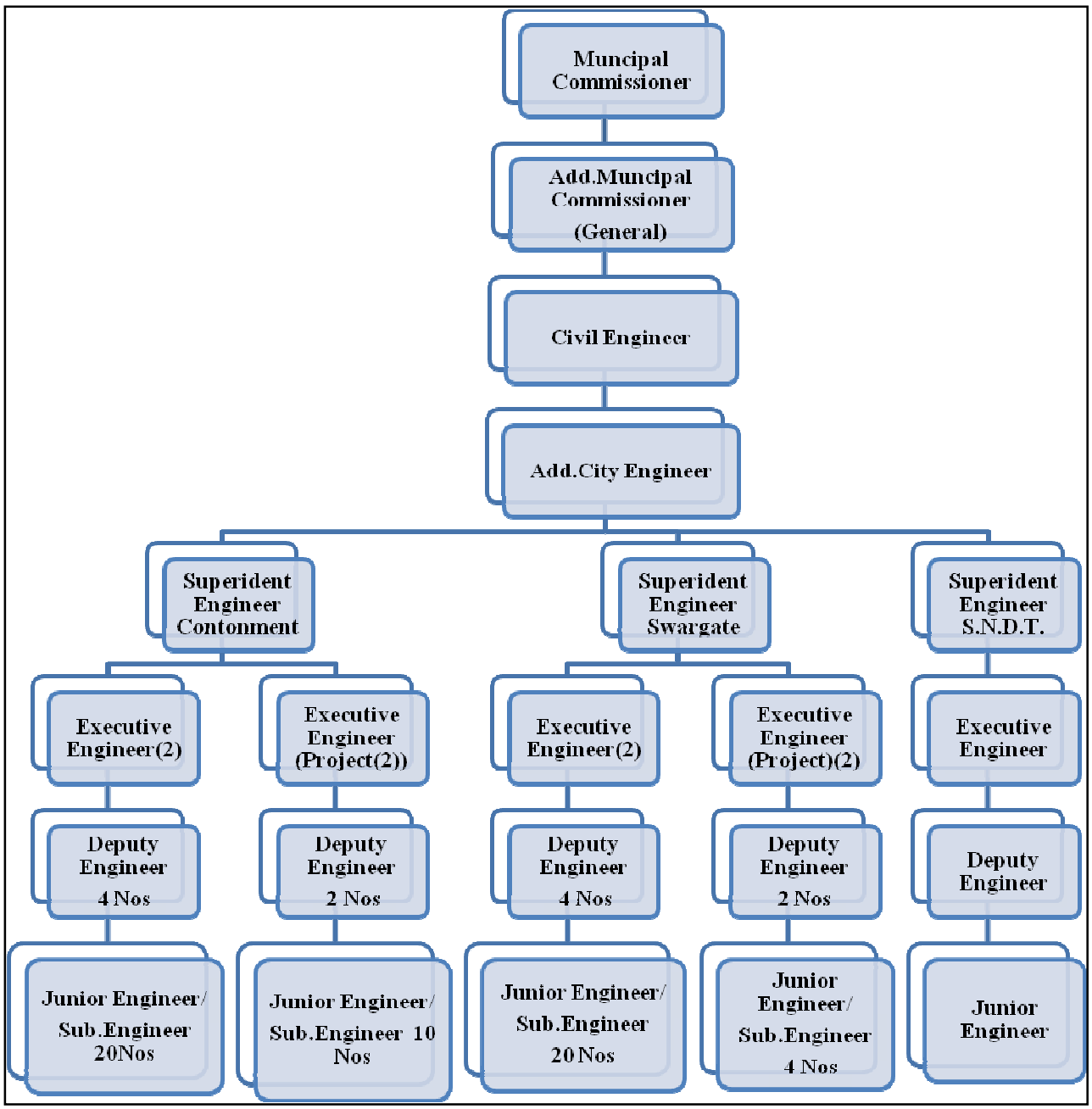


Fig. 4.2: Organizational Chart of Water distribution department of PMC

(Source: Water Distribution Department, PMC)

Following steps were used for collecting the primary data-

Distributing the questionnaire & getting it filled by the concerned respondents, for this purpose, online questionnaire as well as manual method was used for collecting data.

Personally visited to PMC office and 14 ward offices including Water Treatment Plant, Water Distribution Centers etc.

Telephonic and/or personal interview conducted with the higher authority of water distribution centre in PMC office.

Total number of samples and size of sample are given in Table No. 4.5

Table No.4.5 Sample Size

Sample No.	**Constituents**	**Number of sample point in the sample**
1.	Pune citizens	1015
2.	PMC Employees (Water Supply & Distribution Department)	25

The unavailability of purposive samples in the study will be obvious from what has been explained now and in earlier paragraph.

4.7.2. Secondary Data

The Secondary data is used to study theoretical background of Geographical Information System (GIS) with the help of earlier research study made by others. It is helpful to study the objectives and hypothesis framed for the present study.

The secondary data regarding citizen's population, infrastructure facility of water supply department (Pipeline, Pumping stations, Valves) has been collected from reliable sources. Also, secondary data regarding Natural resources, Water Purification Plant, water distribution network, Water connection, tankers, and reservoirs is also collected relevant to current water supply scenario.

- Citizen Population Data: It is collected from Pune Municipal Corporation office. Pune citizen's population data in year 2011.
- Natural Sources of Water Data: Natural sources of water data for Pune city is collected from Water distribution department of PMC office. Natural water sources are divided

into Rivers, Lakes, Dams, Ground Water. Further data related to number of rivers, number of lakes, number of dams, and number of dug well and bore well has been collected.

- Dam data: Dam storage capacity data & usable capacity data are collected from PMC, Water Supply & distribution Dept.
- Water Distribution Network : Water distribution network is divided into number of water distribution zones, total length of pipelines, number of water treatment plants, number of pumping stations, number of chlorinators, number of gravity storage reservoirs.
- Water Purification Plant: There are 9 water purification plants in Pune city. They are located at Parvati (Sinhgad Road), Holkar(old & new, Holkar Bridge),Vadgaon,Warje –old (Warje) ,Warje-new(Kakde City), Cantonment(Old & new , Contonment), Wagholi, New Holkar. All purified water data is collected from these plants.
- Water Connection Data: Water connection data is collected from Metering Section of PMC office. Water connections are divided into two groups as- Metered Connections & Unmetered Connections.
- Tanker Data: Tanker data is collected from Water distribution department of PMC office.
- Operation & Maintenance Data: This data is collected from Water distribution Centres. Also, daily water complaints & water redresses data is collected.

Secondary data regarding pumping stations, reservoirs, valves, maps of water distribution zone wise etc. is collected from Pune Muncipal Corporation, Water distribution department.

The secondary data was collected from Reputed Journals and Magazines, Newspapers, Articles, Internet Websites and Archives. To collect this data, the researcher has visited various Libraries. Few of these libraries are CWPRS (Centre Water of Power & Research Station) Library, Ground Water Survey & Agency (GSDA) Library ,library of Society For Promoting Participative Ecosystem Management, Pune, Jaykar Library (Pune University), British library, Sinhgad Institute of Management Library, Indsearch Library and ICFAI(Institute of Chartered Financial Analysts of India) library.

4.7.3. Questionnaires

One questionnaire[3][4] was prepared for Pune citizens. It contains information about daily water consumption. It also relates to daily water supply in no. of hours, problems of water supply system, awareness about water conservation, also to discuss with citizens who are getting water from public tap and find the reasons for not having PMC connections and GIS based water supply system, opinion about punishment and reward system. The researcher has selected citizens only from Pune city. The following framework is used in the questionnaire for the study and it lists the dimensions assessed for Water supply system.

- Usage of water at residential place
- Regarding water resources
- Water supply problem: Measured on a 5-point Likert scale factoring in the key attributes of a water supply by PMC.
- Awareness of Water Conservations –Motivations, Water saving Appliances Reward & Punishment system for reducing wastage of water.

Second set of structured interview is for employees of water distribution department of PMC. It focuses mainly on infrastructure facility of water supply system. The research has covered entire part of Pune city water distribution infrastructure facility. The research has collected data from Water distribution centers, PMC main water diction department, Water treatment Plant, Metering section, Ward offices etc. The researcher has applied the following measurement framework for identifying key areas of direct and indirect qualitative and quantative data of water supply system.

In this questionnaire, researcher has focused on following key areas-

a. Raw Water resources

b. Water Purification Plant

c. Water Distribution Centers

d. Water Connection details

e. Water Tanker details

f. Water Complaints details

g. Water maintenance details

Personal interviews were conducted & questionnaires were filled. The questionnaire and structured interviews are given in **Annexure 5, 6 and 7.**

4.7.4. Contact method:

The respondents have been contacted personally for getting the questionnaire filled up. This has ensured obtaining more accurate and relevant information from the respondents also many time personal talking was done to know the problems of citizens regarding water problem, views about water supply system & water conservation.

4.7.5. Informal Discussions & Unstructured Interviews

After the administration of questionnaire, it was necessary to have detailed investigation for certain issues which could not be adequately covered through the questionnaire. The questionnaire which has opened in nature or area in which a further investigation was required was taken up and information was elicited through informal discussions or through structured and unstructured interviews.

4.7.6. Observation:

During the visit, the researcher observed the infrastructure, layout and the activities carried out at water distribution centers, water treatment plant, and ward offices at Pune city. The researcher also observed the activities carried out at the PMC –Water distribution Offices.

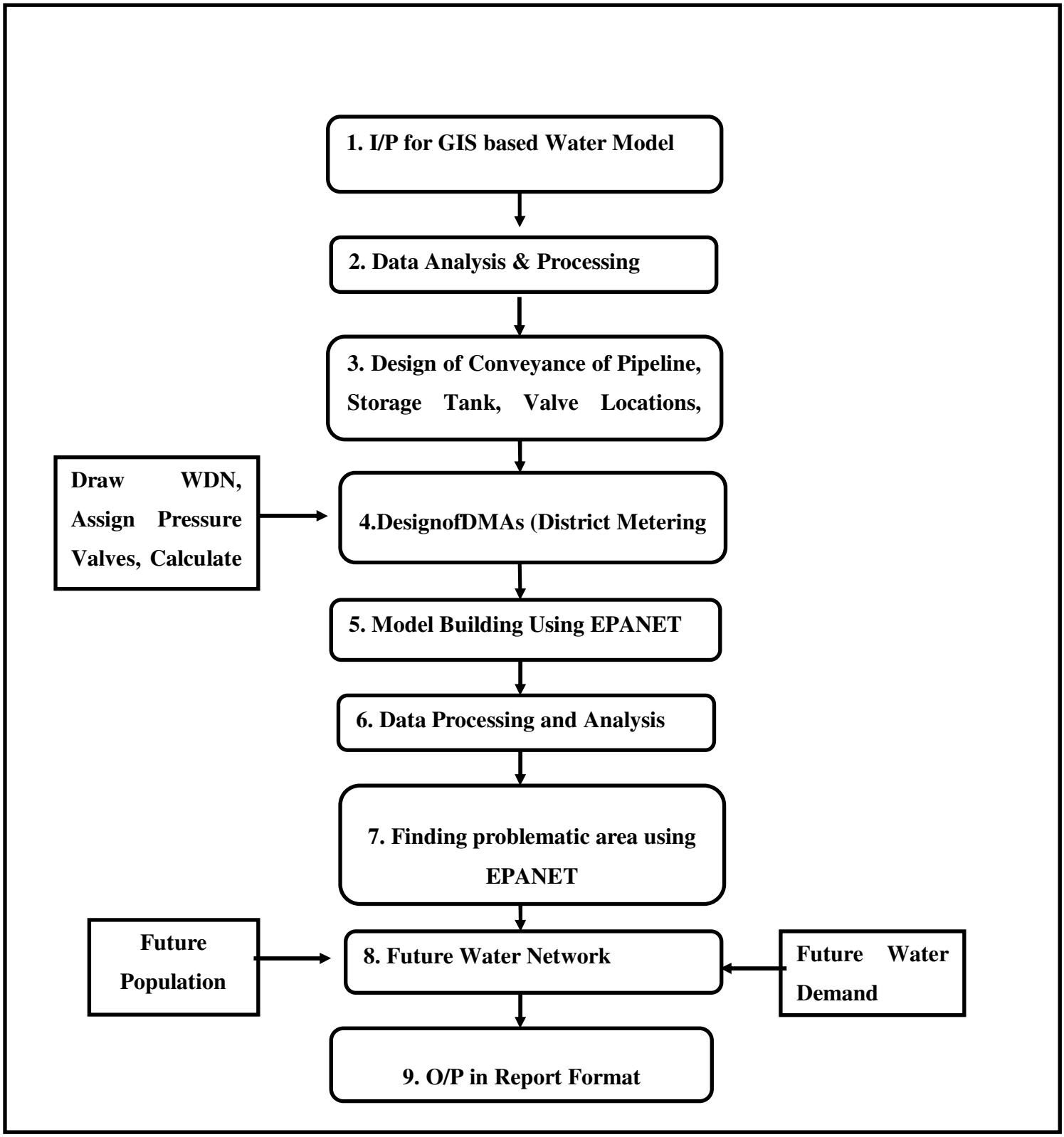


Fig. 4.3.GIS based Water Model –A Step

4.7.7.1. Steps for Designing GIS based Water Model

Step1. I/P for GIS based Water Model[2]

Input for GIS based Water Model is required following parameters-

- **Identification of the Problem:**

Pune city is growing very rapidly. The water is required for cooking, washing, bathing and drinking etc. Demand of drinking water is continually increasing due to various factors. Urbanization is a major factor. Water supply distribution is unequal in the metropolitan region. The far flung and newly added areas are not covered under the water distribution system. In some wards, water supply pressure is very low. Unequal distribution of drinking water in terms of quality and quantity leads to water stress. The poor urban population often neglected for such demand is positive and significant.

- **Study Objectives:**

To study, the existing water supply system in Pune city and to identify various problems and gaps in existing system. To analyze the existing level of service and management and try to fill the gaps by different alternative solution and to evolve solutions for the present water supply problems in a Geographical Information System based Water Model.

- **Study Area:**

The Parvati Middle Level Reservoir (MLR) zone consists new as well as old tanks with capacity of 6.48 ML (Million Liters) and 13.14 ML respectively situated at the Parvati paltue. The water supply in these tanks is done by four pumps from Parvati water plants.

- **Data Collection:**

Data has to be collected for MLR Zone of Pune City through Field Survey-

- Pune city Water Distribution Network-Auto CAD drawings
- Pune city Map- Google Images
- Pune city-Topography Data
- MLR zone details –Ward details, Population details, Water source details, Water Connection Details, Valve Details

Step2. Data Analysis & Processing:

Preparation of base map using existing data and geo-referenced map using ERDAS Imagine 9.1 and ArcView GIS Software.

Step 3. Design of Conveyance of Pipeline, Storage Tank, Valve Locations, Ward Boundary Layout:

With the help of ArcView GIS software design various GIS Layers or Create Shape files such as-

- MLR Boundary
- MLR Sub ward Boundary
- MLR Valve Location-Open, Closed
- MLR Water Design Network

Step 4. Design of DMAs for MLR Zone:

The District Metering Areas (DMA) design is an innovative methodology of water network management, based on the pressure patterns control and on the water flows monitoring, in order to reduce water losses and to optimize the water systems management. A District Meter Area is an area supplied from few water inputs, into which discharges can be easily measured to determine leaks. So, the DMA design represents an alternative to the traditional approach based on heavy looped distribution network.

Water District Metering (WDM) is one of the most efficient techniques for water loss detection and pressure management and consists in partitioning a water network into subsystems called District Metering Areas (DMA).Design DMAs for entire MLR zone area and calculate water loss by using DMAs.

Step 5. Model Building Using EPANET:

EPANET is computer software used for analyze the water distribution networks. It can be used for different types of application in the distribution system analysis such as a simple network design.

Step 6. Data Processing and Analysis:

Design new GIS based water Hydraulic Model for problematic areas. Firstly, as per population and developed areas calculate population density. By using density, calculate

water demand for each node. It requires the data such as, base water demand, elevation, diameter, junction data, reservoir data, node data etc. By using Hazen–Williams equation, remaining values are automatically calculated. (Refer Para. **5.23.1.7.)**

Step 7. Finding problematic area using EPANET:

By using EPANET, measure pressure for each node for each hour. Some of the areas having peak demand at peak time, at that time, pressure goes in negative. Some areas are having sufficient pressure.

Step 8. Future Water Network:

Any water distribution system must be designed to adequately satisfy the water requirements for combination of domestic, commercial and industrial purposes that are placed on it at all times during the design period. The population increases and the growth of the city during the last period have an effect on the existing network. The increasing water demand and the improvement in socio-economic conditions and standards of living have increased the need for more water supplies. Since a future distribution system is expected to provide effective service for many years. The future water demands should be based on estimated future requirements such as future population and future per capita water demand rate.

EPANET programme evaluates the network under the scenario obtain of future population increase.

Step 9. O/P in Report Format:

Prepared Water Distribution Network (WDN) Layout for recommendation to the Pune Municipal Corporation, for implementation of such type of methodology for better and efficient water management system. It will reduce 30 to 35 percent leakages. It will save around 20 per cent of the water. Prepared various table graphs such as Time series pattern for 24 hrs. Prepared graph which shows water demand pattern for each node in 24 hrs.

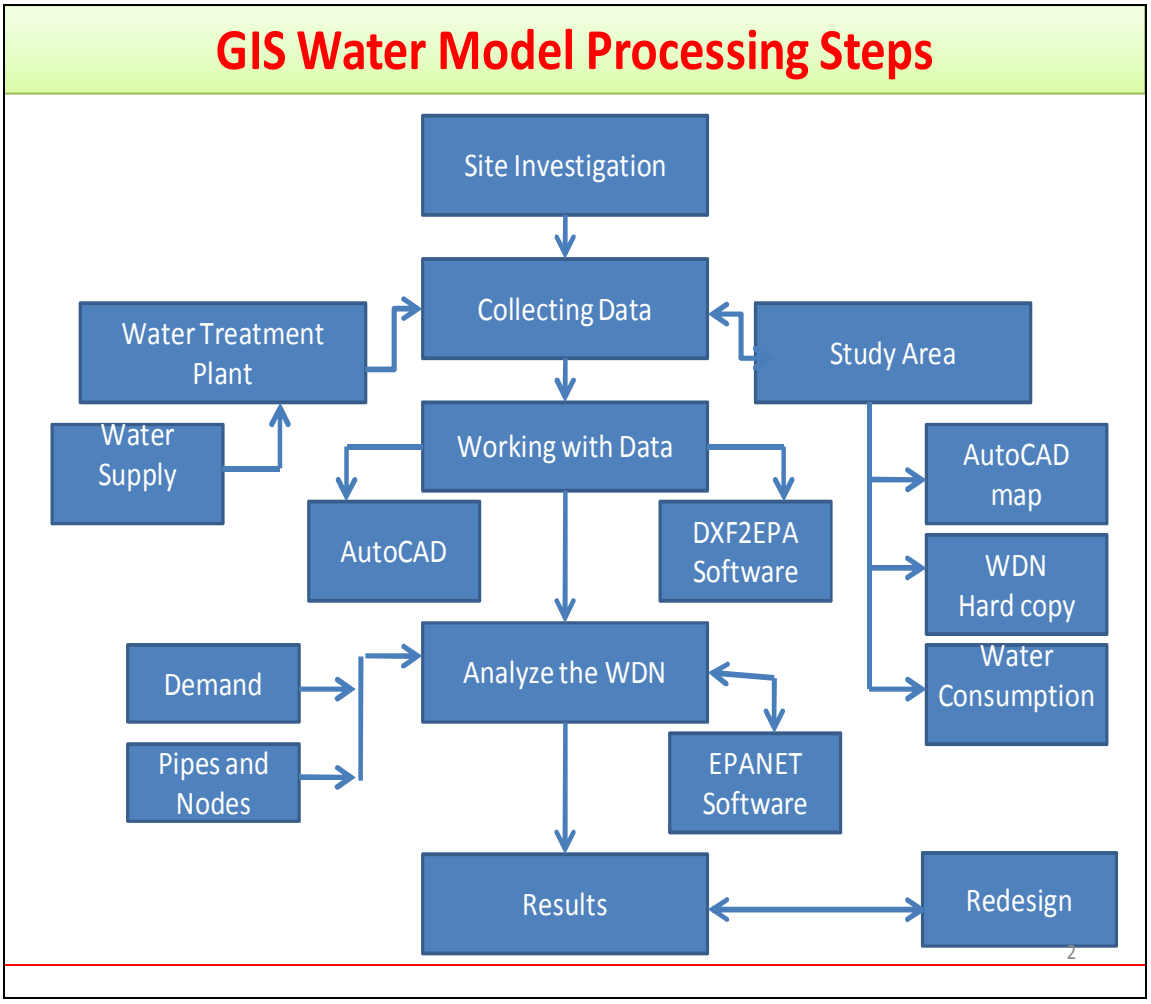


Fig.4.4.Geographical Information System Model Processing Step

4.7.8. Statistical tools used for Data Analysis

The researcher has analyzed secondary data and primary data with the help of software like Microsoft excel, SPSS[5] (Statistical Package for social science) with version 19.0. & curve expert software for fitting trends. The following statistical techniques such as Percentage, Average, Cross tabulation, the techniques of hypotheses testing are also used. Necessary graph and charts have also been prepared to support the analysis of the data wherever necessary.

4.8 Testing of Hypothesis

Testing of hypothesis guides the direction for the research study. It identifies facts that are relevant and those that are not. The hypothesis has been tested on the basis of different

statistical tools and criteria due to the nature of available data only the criteria norm majority has been used in testing hypothesis. For hypothesis No. 1, on site observations and interviews were conducted with higher authorities of Water Supply Department of employees of PMC. The interviews and questionnaires focused on understanding various infrastructure facilities available in the department. All the questions were analyzed. For hypothesis No.2, Chi-square test is applied with 13 degree of freedom at 5% level of significance. For hypothesis No. 3 statistical tools such as percentage and 5 point likert scale have been used. Other secondary and quantitative information has been used wherever possible to supplement this test.

4.9 Time Budgeting:

The researcher has concentrated on the duration from 2009 to 2012 to study water distribution details of PMC.

4.10 Limitations of the study

Even though all attempts are made by the researcher to make a comprehensive study of water supply system and suggest new frame for that, there are limitations observed by the researcher, which are as follows.

The scope of the project is limited to the data published and sources available from different water supply and distribution department of PMC. Scope of the project does not include the technical details of the system. The study is carried out based on the secondary data obtained.

While selecting secondary data for water treatment plant, water distribution, water connection, water tanker operation and maintenance, Dam data, Natural resources etc., the available data scattered in different organizations is used. The total number of population of properties and population in respect of each ward office cannot be exactly ascertained. However, the researcher has made an attempt to locate the maximum number of citizens in Pune city itself.

The study pertains to only Pune city.

4.11 Chapter Scheme:

Researcher has done the following chapter scheme based on study.

No.	Name
Chapter No.1	Introduction
Chapter No.2	Review of Literature
Chapter No.3	Geographical Information System for Effective Water Management
Chapter No.4	Research Design and Methodology
Chapter No.5	Data , Analysis & Interpretation
Chapter No.6	Design And Development Of Geographical Information System (GIS) Based Water Supply Model
Chapter No.7	Findings, Conclusion, Suggestions And Scope For Further Research
	Appendix
	Bibliography

The first chapter is of Introduction where the researcher has given brief background about the study. The second chapter deals with Review of Literature. It describes the review of the existing available literature on Use of GIS in Water Supply, Water Supply Problems, Water Conservations, and Role of GIS in Decision Support System for Water resources etc. The third chapter is Geographical Information System for Effective Water Management focuses on development of GIS in water Management and its Methods. The Fourth chapter, Research Design and Methodology has discussed the importance, scope, objectives and hypothesis of study. It also describes the research methodology and research design. The fifth chapter presents the analysis of the data in two parts, Part – I Pune Citizen, Part – II PMC Infrastructure of Water distribution and Supply department and Part-III deals with the testing of hypothesis. The sixth chapter presents GIS based Water Utility Management in India, design and develops GIS based Model for Water Supply system. The last and seventh chapter summarizes observations, conclusions, findings and suggestions of the present study. References have been given at the end of each chapter themselves and a selected bibliography is given at the end.

References

[1] Annual Report on Water Distribution system ,PMC, Pune

[2] Burrough P.A., 1986"Principles of GIS", Oxford, Clarendon Press GIS Science Publications, (Wilson J.P., Mitasova H., Wright D.J., 2000)

[3] C.R.Kothari, "Research Methodology Methods & Techniques", New age International Publication, New Delhi.

[4] Donald R. Cooper and Pamela S. Schindler,"Business Research Methods", Tata McGraw Hill , Delhi

[5] Dr. S. P. Gupta, "Statistical Methods", Sultanchand & sons Publication, New Delhi.

[6] http://en.wikipedia.org/wiki/Pune(11/7/2008)

[7] http://government.wikia.com/wiki/PMC_Electoral_Ward_Administration (20/6/2009)

[8] http://www.census2011.co.in(1/1/2012)

[9] http://www.maharashtrafireservices.org/pdf/pune_mitigation_plan.pdf (23/09/2009)

[10] http://www.mapsofindia.com/maps/maharashtra/pune.htm(23/07/2008)

CHAPTER 5
DATA ANALYSIS AND INTERPRETATION

5.1 Introduction

This research is to study of Geographical Information System (GIS) based frame work to enhance the water supply system in Pune city. The researcher has tested positively the hypotheses of this research study, with the help of primary and secondary data. The researcher has collected data from sample 1015 citizens of Pune city, from 14 ward offices (Includes 144 wards) and 25 PMC employees from Water distribution department officers, Engineers and workers of Pune Municipal Corporation of water supply and distribution department refer in (Para 4.7.1.C). The data has been collected through exhaustive questionnaire and it is presented in tabular and a graphical form and also appropriate statistical tool has been used to process the data. The interpretation has been written by using the statistical figure which helps to reveal the final conclusion. In order to fulfill the objectives of the study, the following tables have been used. The data analysis and interpretation is grouped in 3 parts as given below.

Part I: Citizens

In Part I, the primary data is collected by the researcher in respect to required 1015 sample form 14 ward offices of Pune city(Para 4.7.1 C). An analysis is carried out under two broad headings as follows.

1. About Water Consumption, problems faced by citizens with respect to water supply system and opinion about water billing system.
2. Awareness of Water conservation and appliances for future use and suggestions on various ways for conservation.

Part II: PMC-Water Supply Department (Employees)

In part II, the primary data collected by the researcher in respect to 25 Employees from Water supply and distribution department of PMC main office is presented(Para 4.7.1 C). From the collected data, analysis is carried out under nine broad headings which are:

1. Natural Sources of Water Supply
2. Situational analysis of Water Supply System
3. Water supply Service Delivery and Service Level Benchmark
4. Per capita supply of water

5. Extent of metering of water connections

6. Extent of Non Revenue Water (NRW)

7. Continuity of water supply

8. Quality of Water Supplied

9. Operation and Maintenance

Part III: Testing of Hypotheses

5.2. Pilot Survey

The researcher has conducted pilot survey randomly to test the questionnaire. To know the consistency of questionnaire to be administered for the research, the researcher has applied the Cronbach's Alpha reliability test. Initially, the questionnaire was circulated to 80 Pune citizens and reliability test was conducted.

The result of pilot survey about Pune citizens is given in following Table No. 5.1

Table No. 5.1: Reliability Statistics of pilot survey of Pune citizens

		No of Respondents	percent	Cronbach's Aplha	N of Items
Cases	Valid	80	100	0.783	32
	Excluded[a]	0	0		
	Total	80	100		

a. List wise deletion based on all variables in the procedure

It is observed that questionnaire is relevant and Cronbach's Alpha score is 0.783.It means 78 percent respondents understood the questionnaire. Thus the researcher concludes that this questionnaire can be administered for the future research. The sample of 1015 citizens was selected for the purpose of study.

Part I: Citizens

In Part I, the primary data collected by the researcher in respect to 1015citizens and analysis is carried out under two broad headings of Pune Citizens as follows.

1. About Water Consumption, problems faced by citizens with respect to water supply system and opinion about water billing system.

2. Awareness of Water conservation and appliances for future use and suggestions on various ways for conservation

5.3 Introduction

Water is the most important part of our lives. We can't even think of living without water for a day. In Pune city, drinking water supply system is very old and it exists since 1750.

Pune city received first piped drinking water supply from Katraj via Amboli Odha, Shaniwarwada. After this scheme of water supply, the Swargate water work came in existence in the year 1873. Such scheme was planned to treat raw water and supply to Pune city. Such water supply scheme is on Mutha right bank cannel and it is channelled up to Swargate.

In Pune, the demand for water is increasing day by day but the supply is insufficient and here comes the water crisis problem but have you ever thought about how much water you need in a day and how much water you are using. Actually, if you analyze your daily water consumption, you will realize that you are actually wasting a lot of water. It has become a challenge today to meet the rising demand for water because of our negligence.

Pune is a fast developing city with lots of real estate developments all around us and with this, the increasing demand for water is obvious. Now it becomes a highly commercial city of India. When the demand is more than supply, the imbalance occurs and ultimately the end user suffers with water crisis. The water is required for cooking, washing, bath and drinking etc. Demand of drinking water is continually increasing due to various factors. Urbanization is a major factor. Water supply distribution is unequal in the metropolitan region. The far flung and newly added areas are not covered under the water distribution system. In some wards, water supply pressure is very low. Unequal distribution of drinking water in terms of quality and quantity leads to water stress.

Pune city is likely to face future water shortages because there is a finite supply of potable water and the population is increasing continually. Therefore, in order to avert critical shortages that would adversely impact local and regional economies, and most likely impact the quality of life of our citizens, it is imperative that cities establish, implement and succeed in their water conservation programme.

5.4. About Water Consumption, problems faced by citizens with respect to water supply system and opinion about water billing system.

Problems of the citizens with respect to water supply are studied by checking the parameters as per capita water consumption, various water resources, and frequency of water supply, water pressure, and additional water requirement at different ward. First, water consumption per person is found out at different places. Also, for different uses how much is the consumption per person at different area is found out, to know disparity in the use of water requirement at ward level.

To study the above mentioned parameters, first water consumption per person is found out at different wards. Also, water consumption per person for different use at different wards is analyzed, further followed by analysis of water supply at different places. Additional requirement of water is studied thereafter. Also, disparity in the consumption of water at different wards is highlighted. Conclusively, the overall citizens' satisfaction is analyzed through the rated responses. Citizen has rated different problems and opinions about water billing systems which are studied in details through following tables.

5.4.1. Per capita Water Consumption at various wards

An attempt is made to measure the per capita water consumption through survey at household level. To find out the consumption, availability, access and methods adopted for conservation of water in households in Pune City, the samples are selected from domestic areas in each ward office of Pune city. This shows that per capita water supply in the city is less than the Service Level Benchmark (SLB) indications of 135 lpcd(liter per capita per day)

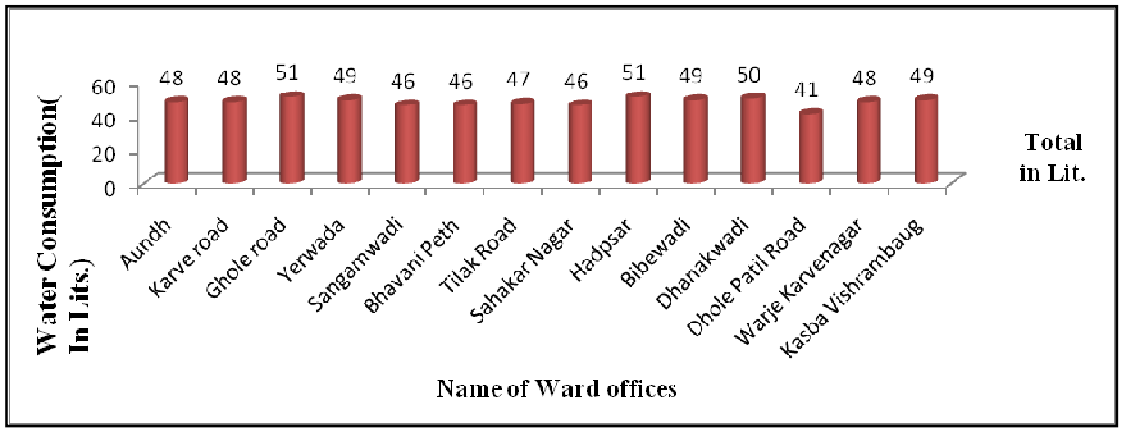
Table No. 5.2: Ward wise Per Capita Water Consumption

Ward Office	No of Respondents	Total Water Consumption in (Lit.)
Aundh	74	48(7.29)
Karve road	86	48(8.47)
Ghole road	65	51(6.40)
Yerwada	64	49(6.31)
Sangamwadi	68	46(6.70)
Bhavani Peth	65	46(6.40)
Tilak Road	94	47(9.26)
Sahakar Nagar	72	46(7.09)
Hadapsar	85	51(8.37)
Bibwewadi	69	49(6.80)
Dhanakwadi	68	50(6.70)
Dhole Patil Road	64	41(6.31)
Warje Karvenagar	75	48(7.39)
Kasba Vishrambaug	66	49(6.50)
Total	**1015**	**669(100)**

Table No. 5.2 shows per capita consumption of water in fourteen ward offices of Pune city. It is very obvious from the table that in all the ward offices, the water consumption (indication of availability of water per capita) is much lower than what is recommended by the Bureau of Indian Standard, IS:1722-1993, and the Tenth Five Year Plan.

It is revealed that, 9.6 percent water usage is from Tilak Road, whereas usage of water within the range of 6 to 8 percent is from other ward offices. It is to be concluded that the usage of water on an average from all ward office is same i.e. overall; consumption of water in all ward offices is more or less equal.

Graph 5.1. : Ward wise Per Capita Water Consumption



The above Graph 5.1 shows Ward-wise per capita (Per person) water consumption in Pune city. This graph shows the highest consumption of water at Ghole road and Hadapsar. It is followed by Dhanakwadi, Yerwada & Bibwewadi etc. and remaining wards having consumption more or less equal.

5.4.2. Activity-wise Consumption of Water

World Health Organization (WHO) [19] classifies the supply and access to water in four service categories. These categories are, (1) no access (water available below 5 lpcd), (2) basic access (average approximately 20 lpcd), (3) inter-mediate access (average approximately 50 lpcd), and (4) optimal access (average of 100-200 lpcd). Considering the fact that various agencies recommend different quantities of requirement of water for domestic use, we have taken 100 lpcd consumption (an indication of availability, as consumption is determined by the availability) of water as benchmark for finding out water deficient households.

The data is collected through a structured questionnaire and target respondents were mostly housewives. The volume of vessels (bucket) in which households used to store water was measured and the number of vessels of water used in different activities was

ascertained. Where running tap or piped water was used in some activities, the duration for which the tap remained open was arrived at and the quantity of water per minute coming out from the tap was measured. By multiplying the time with the quantity of water per minute, the amount of water used through running taps was arrived at. The amount of water used in toilet was assessed by volume of bucket used, and flush tank capacity. The assessment of quantity of water used in various activities was a difficult task, but all the efforts were put in to assure the accuracy of data. The Table No.5.3 shows activity-wise Distribution of Water Consumption in various ward level (Average consumption by per person/day).

Table No. 5.3 : Activity-wise Distribution of Water Consumption in various ward level (Average consumption by per person/ day)

Activity-wise Distribution of Water Consumption in various ward level (Average consumption by per person / day)							
Ward Office	**Usage of Water for Cooking & Drinking(Lit.)**	**Usage of Water for Cleaning (Lit.)**	**Usage of Water for Bathroom (Lit.)**	**Usage of Water for Toilet (Lit.)**	**Usage of Water for Gardening (Lit.)**	**Usage of Water for Miscellaneous (Lit.)**	**Total (Lit.)**
Aundh	24(8.36)	47(6.80)	49(7.64)	40(8.24)	7(5.78)	19(8.71)	186(7.61)
Karve road	17(5.92)	41(5.93)	43(6.70)	35(7.21)	8(6.61)	12(5.50)	156(6.38)
Ghole road	27(9.40)	58(8.39)	55(8.58)	43(8.86)	11(9.09)	16(7.33)	210(8.59)
Yerwada	25(8.71)	55(7.95)	46(7.17)	37(7.62)	6(4.95)	18(8.25)	187(7.65)
Sangamwadi	21(7.31)	44(6.36)	41(6.39)	28(5.77)	6(4.95)	14(6.42)	154(6.30)
Bhavani Peth	19(6.62)	51(7.38)	41(6.39)	32(6.59)	8(6.61)	13(5.96)	164(6.71)
Tilak Road	16(5.57)	47(6.80)	42(6.55)	36(7.42)	9(7.43)	13(5.96)	163(6.67)
Sahakar Nagar	20(6.96)	46(6.65)	39(6.08)	28(5.77)	9(7.43)	18(8.25)	160(6.54)
Hadapsar	27(9.40)	55(7.95)	55(8.58)	45(9.27)	16(13.23)	14(6.42)	212(8.67)
Bibwewadi	20(6.96)	54(7.81)	45(7.02)	33(6.80)	6(4.95)	16(7.33)	174(7.12)
Dhanakwadi	18(6.27)	48(6.94)	39(6.08)	33(6.80)	9(7.43)	16(7.33)	163(6.67)
Dhole Patil Road	18(6.27)	52(7.52)	48(7.48)	30(6.18)	4(3.30)	15(6.88)	167(6.83)
Warje Karvenagar	16(5.57)	44(6.36)	48(7.48)	33(6.80)	14(11.57)	19(8.71)	174(7.12)
Kasba Vishrambaug	19(6.62)	49(7.09)	50(7.80)	32(6.59)	8(6.61)	15(6.88)	173(7.08)
Total	**287**	**691**	**641**	**485**	**121**	**218**	**2443**
Mean	**20.5**	**49.35714**	**45.785714**	**34.642857**	**8.6428571**	**15.571429**	**174.5**
Variance	**546.25**	**321.2143**	**368.35714**	**345.21429**	**135.21429**	**67.428571**	**4361.5**
Standard Deviation	**23.37199179**	**17.92245**	**19.192633**	**18.579943**	**11.628168**	**8.2114902**	**66.0417**

Among the wards, households from Hadapsar and Ghole road consume maximum utilization of water is 9.40% and minimum usage of water from Tilak road & Warje Karvenagar is 5.57% per day for cooking and drinking purposes. Cleaning Utensils & clothes consume 8.39% water at household level in the Pune city, the highest being in Ghole road and the least in Karve Road is 5.93%. For bathroom, maximum utilization of water is 8.58% in Ghole road & Hadapsar and minimum utilization of water is 6.08% in Dhankawadi. Maximum utilization of water for Toilet is 9.27% in Hadapsar and minimum in Sahakarnagar and sangamwadi is 5.77%. For Gardening, maximum utilization of water is 13.23% in Hadapsar and minimum utilization of water is 3.30% from Dhole Patil Road. For miscellaneous purpose, maximum utilization of water is 8.71% from Aundh,WarjeKarvenagar and minimum utilization of water is 5.50% from karve road.

Maximum average utilization of water is 49.35 for Cleaning and minimum average utilization of water is 8.64 for gardening purpose. Maximum variance of water usage is 546.25 for cooking and drinking whereas minimum variance of water usage is 64.42 for Mislleneous.

5.4.3. Duration of Water Supply supplied by PMC

Cleanliness of municipal water in cities is not the only issue, the supply is also very irregular and for a very limited duration. As the supply is highly irregular and for a very limited duration, the households and housing societies store water in their tanks and drums. Table No.5.4 shows wardwise frequency of water supply in Pune city. Among the ward, maximum households 36.17 percent getting water supply for 24 hrs in Tilak Road ward and least households 11.11 percent in Sahakar Nagar. Water supply once in a day, maximum in Sahakarnagar ward is 75 percent and least 28.79 percent in Kasba Vishrambaug ward. For frequency of water supply more than once in a day is maximum in Sangamwadi ward which is 55.88 percent and least in Bibwewadi is 8.70percent. Frequency of water supply once in two days is in very few wards with least proportion.

Table No. 5.4: Ward wise Frequency of Water Supply in Pune City

Name of Ward office	Frequency of Water Supply					Total
	24 Hours supply	Once in a day	More than Once in a day	Once in two days	Once in three days	
Aundh	21 (28.38)	28 (37.84)	24 (32.43)	1 (1.35)	0 (0.00)	74
Karve road	24 (27.91)	30 (34.88)	32 (37.21)	0 (0.00)	0 (0.00)	86
Ghole road	13 (20.00)	21 (32.31)	28 (43.08)	3 (4.62)	0 (0.00)	65
Yerwada	9 (14.06)	26 (40.63)	24 (37.50)	5 (7.81)	0 (0.00)	64
Sangamwadi	8 (11.76)	22 (32.35)	38 (55.88)	0 (0.00)	0 (0.00)	68
Bhavani Peth	16 (24.62)	34 (52.31)	13 (20.00)	2 (3.08)	0 (0.00)	65
Tilak Road	34 (36.17)	36 (38.30)	23 (24.47)	1 (1.06)	0 (0.00)	94
Sahakar Nagar	8 (11.11)	54 (75.00)	10 (13.89)	0 (0.00)	0 (0.00)	72
Hadapsar	17 (20.00)	33 (38.42)	31 (36.47)	3 (3.53)	1 (1.18)	85
Bibwewadi	12 17.39)	47 (68.12)	6 (8.70)	2 (2.90)	2 (2.90)	69
Dhanakwadi	11 (16.18)	44 (64.71)	7 (10.29)	5 (7.35)	1 (1.47)	68
Dhole Patil Road	11 (17.19)	46 (71.88)	6 (9.38)	1 (1.56)	0 (0.00)	64
Warje Karvenagar	24 (32.00)	23 (30.67)	27 (36.00)	1 (1.33)	0 (0.00)	75
Kasba Vishrambaug	8 (12.12)	19 (28.79)	34 (51.52)	3 (4.55)	2 (3.03)	66
Total						1015 (100)

(Source: Survey Data)

Figures in bracket indicates percentage

Graph 5.2 Shows Ward-wise frequency water supply in Pune City by getting four categories as 24 Hrs. Water Supply, Once in a day, More than once in a day, Once in two days, once in three days. As per it, most of the wards are getting water once in a day as compared to other categories..

Graph 5.2: Ward wise Frequency of Water Supply in Pune City

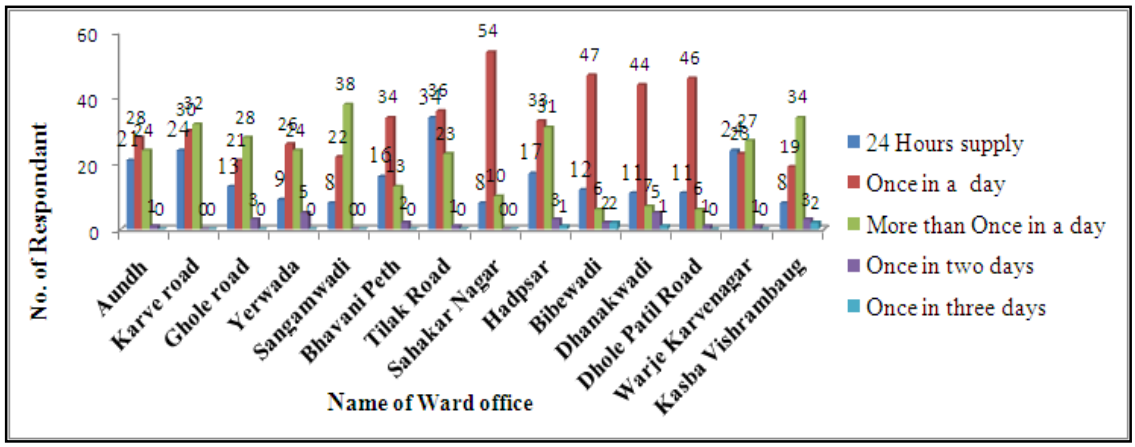


Table No.5.5 shows Overall Availability of Tap Water to Households (percent) in Pune city. In Pune city, about 21.3 percent of the households, are getting water supply through tap for 24 hours, while 45.6 percent have it for once in a day. Further 29.9 percent citizens say that water is available only for more than once in day and 3 percent citizens say water is available only once in two & three days respectively.

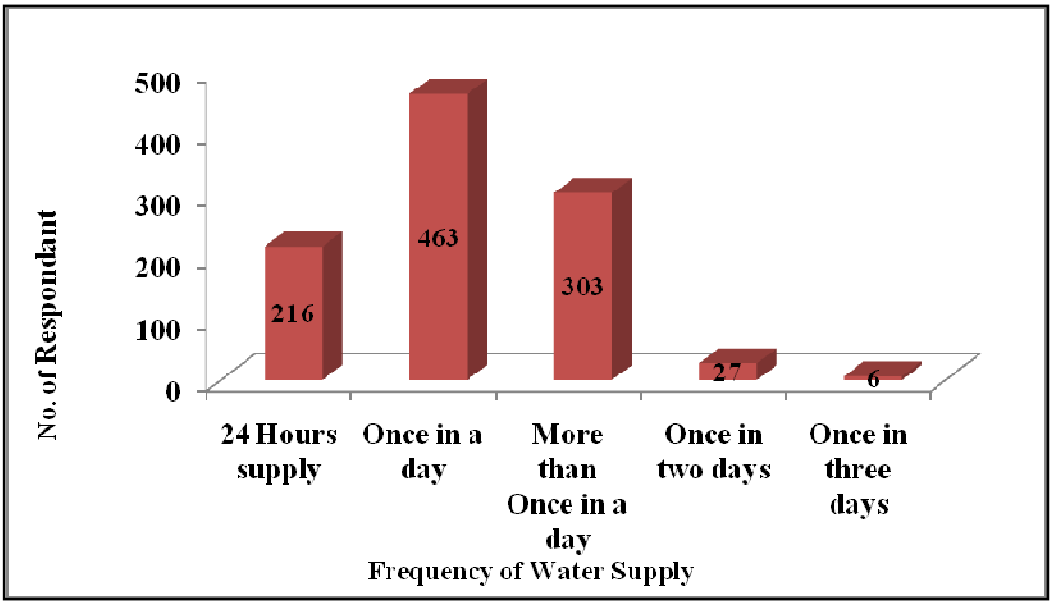
Table No. 5.5: Availability of Tap Water to Households (percent) in Pune City

Frequency of Water Supply	No. of Respondents
24 Hours supply	216 (21.3)
Once in a day	463 (45.6)
More than Once in a day	303 (29.9)
Once in two days	27 (2.7)
Once in three days	6 (0.6)
Total	1015 (100.0)

(Source: Survey Data)

Figures in bracket indicates percentage

Graph 5.3: Availability of Tap Water to Households (percent) in Pune City



Above Graph 5.3 shows Availability of Tap Water to Households (percent) in Pune city. This graph shows the distribution of respondents as per availability of water in Pune city. 45 percent citizens are getting water once in a day. It is followed by 29.9 percent for more than once a day. 21.3 percent citizens say that they get 24 hours water supply.

5.4.4. Continuity of water supply in Pune city

Water supply is intermittent. Generally, water is supplied twice a day. The duration varies from 3 to 6 hours, both in the morning and evening. Except for high level areas in the city and in fringe areas, pressures are reasonably high so that duration varies from area to area in Pune city. The following Table No.5.6 shows distribution of respondents as per water supply in number of hours. 50 percent citizens say that they get water 1-2 hours per day. 24.63 percent people are saying that, they are getting water 3-4 hrs per day. 12.51 percent people say that, they are getting water more than 4 hrs in a day. In few areas, it has been found that the water supply is 24 hrs a day. It means that topography of Pune city causes disparity in the water supply.

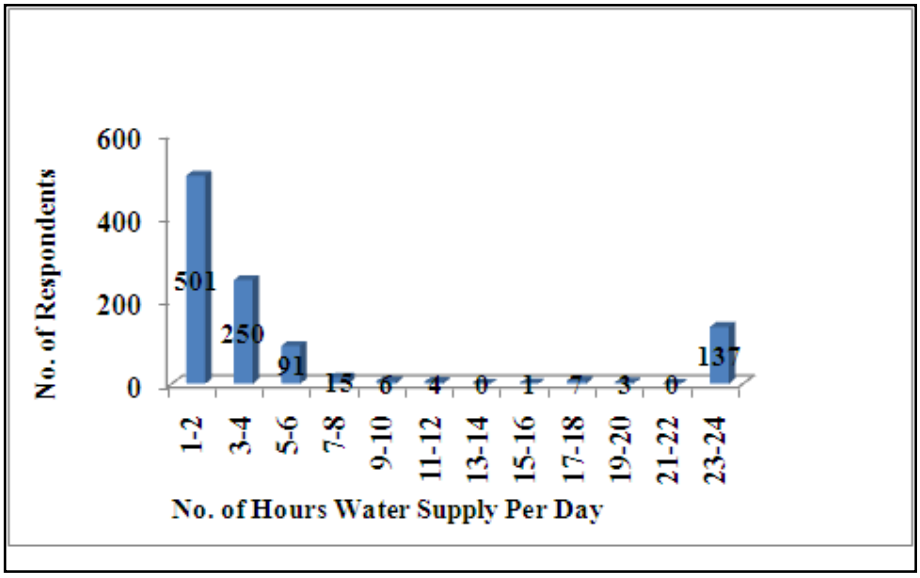
Table No. 5.6: Distribution of Respondents as per water supply in number of hours

No. of Respondents	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24	Total
No of Hours water Supply Per day	501 (49.36)	290 (24.63)	91 (8.97)	15 (1.48)	6 (0.99)	4 (0.39)	0 (0.00)	1 (0.10)	7 (0.68)	3 (0.30)	0 (0.00)	137 (13.50)	**1015 (100. 00)**

(Source: Survey Data)

Figures in bracket indicates percentage

Graph 5.4. : Distribution of Respondents as per water supply in number of hours



5.4.5. Sufficient quantity of water at household level

The average rate of water supply in the city appears satisfactory, but the distribution is not equitable. While some areas receive water supply round the clock, some areas hardly get water for an hour. Some high level areas do not get water through the pipe network and tankers need to be deployed in these areas. There is a wide disparity in the water supply rate and pressures. The inadequate service storage, small and leaking old pipes and unfavourable topography result in inequitable distribution. The following Table No.5.7 shows that 45 percent citizens are getting sufficient quantity of water at houses and 55 percent citizens are not getting sufficient quantity of water at houses. It is interesting to observe that though a majority of households consume water below the specified norms, they, by and large, show satisfaction with the available supply. This is mainly because they have delimited their aspiration and requirements of water in relation to available supply from the concerned municipalities or water authorities.

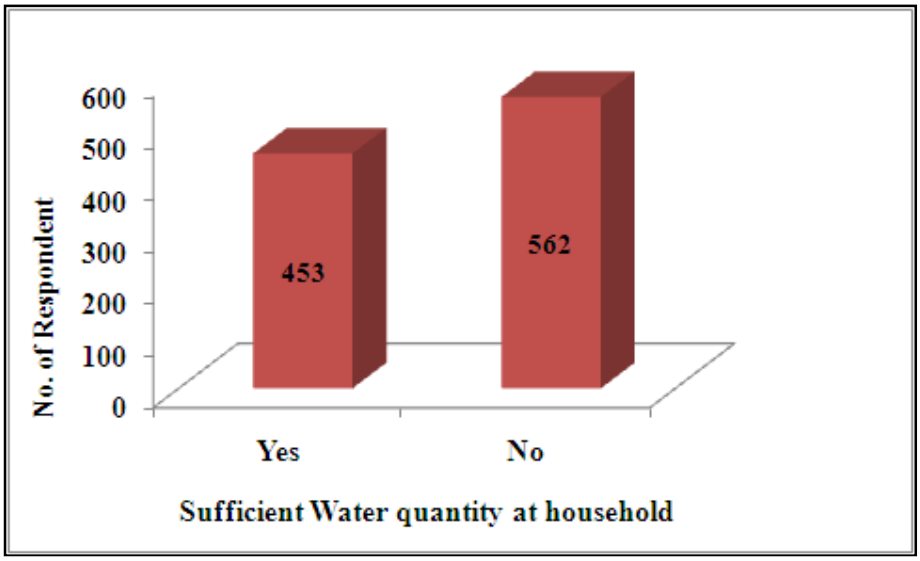
Table No. 5.7 : Distribution of Respondents as per sufficient quantity of water at household

Sufficient water quantity at household	No. of Respondents
Yes	453 (44.63)
No	562 (55.37)
Total	1015 (100.00)

(Source: Survey Data)

Figures in bracket indicates percentage

Graph 5.5: Distribution of Respondents as per sufficient quantity of water at household



5.4.6. Additional Requirement of water at various wards level

The distribution network in the old city is old. There are heavy leakages through the pipelines; faulty plumbing at households and uncontrolled public stand posts. A very substantial portion of water, supplied in the city, is lost due to leakage. And, therefore most wards are in need of additional requirement of water.

In Pune city, 14 wards are there. In every ward, discrepancy in water supply is observed. It can be seen that in the same ward, some people don't need additional requirement of water and

some people ask for it which shows evenly distribution of water is not happening within the ward also.

Table No. 5.8: Distribution of Respondents for additional requirement of water at ward Level

Additional Requirement of Water			Total
Name of Ward office	No. of Respondents		
	Yes	No	
Aundh	37(50.00)	37(50.00)	74
Karve road	42(48.84)	44(51.16)	86
Ghole road	43 (66.15)	22(33.85)	65
Yerwada	40(62.5)	24(37.5)	64
Sangamwadi	45(66.18)	23(33.82)	68
Bhavani Peth	40(61.54)	25(38.46)	65
Tilak Road	32(34.04)	62(65.96)	94
Sahakar Nagar	59(81.94)	13(18.06)	72
Hadapsar	29(32.94)	56(67.06)	85
Bibwewadi	50(72.46)	19(27.54)	69
Dhanakwadi	38(55.38)	30(44.12)	68
Dhole Patil Road	45(70.31)	19(29.69)	64
Warje Karvenagar	36(48)	39(52.00)	75
Kasba Vishrambaug	26(39.39)	40(60.61)	66
Total	562	453	1015

(Source: Survey Data)

From above Table No.5.8, it is clear that some wards like Shakarnagar, 81.94 percent people require additional water. It is followed by Bibwewadi as 72.46 percent people require additional water. Further, in Dhole Patil 70.31percent people have additional water and in Ghole Road & Sangamwadi 66.18 percent people have additional water, Yerwada & Bhavani Peth 62.50 percent & 61.54percent people have additional requirements and remaining wards have less percentage of additional water requirements. From above table, most affected wards are Sahakar Nagar, Bibwewadi, Dhole Patil Road etc. in Pune city. These wards require additional water compared to remaining wards. So these are most affected wards in Pune city. It shows discrepancy in water supply as well water requirements.

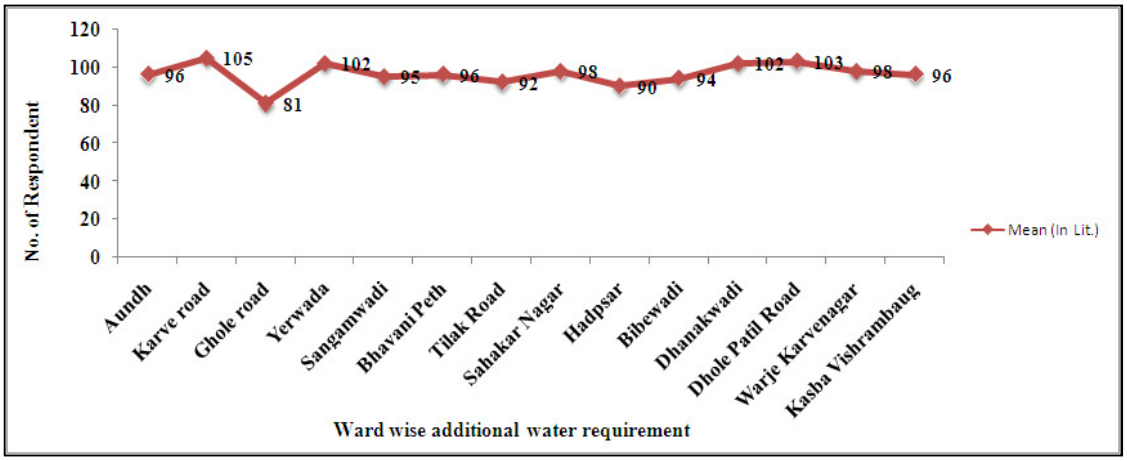
Table No.5.9 shows the additional requirement of water at all ward level. Maximum additional requirement of water at ward Karve road is 105 Lit. It is followed by Dhole Patil Ward which requires 103 Lit, Dhankwadi and Yerwada ward require 102 Lits. Additional requirement is minimum for Ghole road, Tilak Road, Hadapsar, Bibwewadi, Sangamwadi and it falls between 80-96Lits.Hence, it is seen that every ward requires additional water requirement for fulfilling daily needs.

Table No. 5.9: Distribution of Average additional requirement of water at various ward

Ward wise Additional requirement of Water	**Ward office**	Aundh	Karve road	Ghole road	Yerwada	Sangamwadi	Bhavani Peth	Tilak Road	Sahakar Nagar	Hadapsar	Bibwewadi	Dhanakwadi	Dhole Patil Road	Warje Karvenagar	Kasba Vishrambaug
	Mean (In Lit.)	96	105	81	102	95	96	92	98	90	94	102	103	98	96

(Source: Survey Data)

Graph 5.6: Distribution of additional requirement of water at various ward level



5.4.7. Sources of Water in Pune city

A majority of households in major cities in India depend on the municipal water supply for their daily needs. The 54th round National Sample Survey Organization[4] (NSSO) data reveals that 80percent of the households in urban India, across different segments, consider that they have sufficient water supply, and it shows that 70.1 percent of the households in urban India depend on tap water (municipal supply), 21.4 percent on tube wells, 6.7 percent on well/open wells, and the rest on other sources. However, the present study about 93.89 percent of the households in Pune city are using municipal water supply (tap

water). The Table No.5.10 also shows that some households are using water from multiple sources. It is noteworthy that, although, as mentioned above, about 93.89 percent of the households use municipal tap water supply,47.19 percent citizens depend upon bore well,9.46 percent citizens getting water through public tap,0.7 percent citizens get water from well and 3.45 percent citizens depend upon the tankers provided by municipal corporation.

Table No. 5.10: Distribution of Respondents uses various water resources

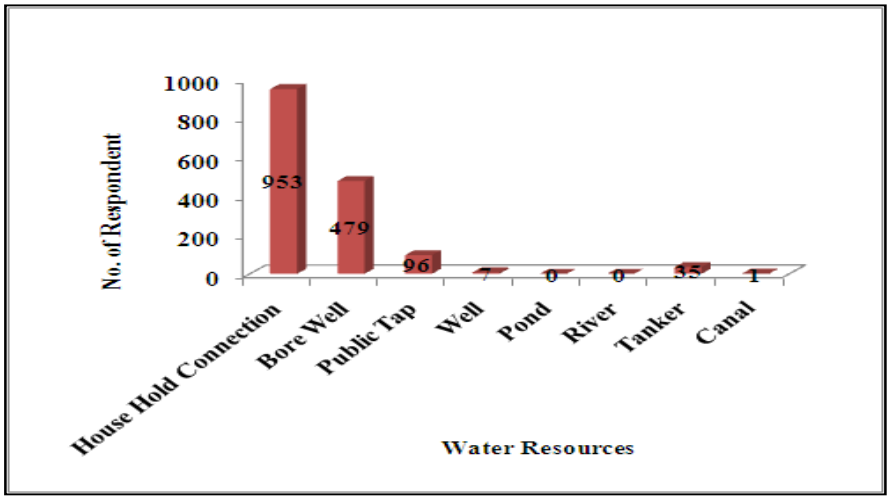
Water Resources	**No. of Respondents**
House Hold Connection	953(93.89)
Bore Well	479(47.19)
Public Tap	96(9.46)
Well	7(0.69)
Pond	0(0.00)
River	0(0.00)
Tanker	35(3.45)
Canal	1(0.1)

(Source:Survey Data)

Figures in bracket indicates percentage

Thus, the second largest source of water for a majority of citizens in Pune city is groundwater. The rapid increase in the population of these cities is making people more dependent on ground water and thereby causing depreciation in its level.

Graph 5.7 : Distribution of water resources usage by citizens



Households in these cities also face wide seasonal fluctuations in municipal tap water supply. More than 97.6 percent of the households in the city say that shortage in water supply becomes acute during summer. The seasonal variations in municipal tap water supply leads to use of ground water sources by households as it is seen as the easiest, fastest and to an extent durable solution to the water crisis. And, as mentioned above, this is resulting in groundwater reduction in and around the city. The overuse of groundwater resources has led to increase in arsenic concentration and fluoride concentration in many wards in Pune city.

Table No. 5.11: Distribution of Respondents uses alternative Water Resources (in absence of PMC Water Supply)

Water Resources	No. of Respondents
Bore Well	611 (61.72)
Well	70 (7.07)
Tanker	291 (29.39)
Dam	18 (1.82)
Total	990(100.00)

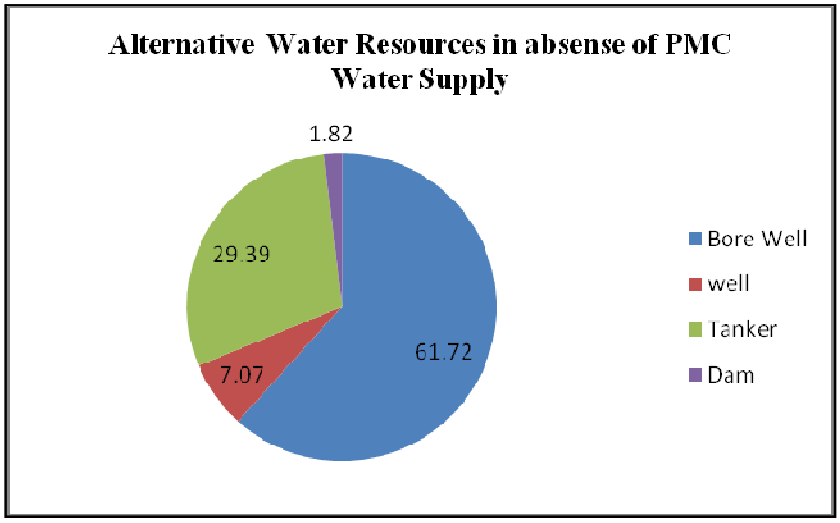
(Source:Survey Data)

*Total no. of Respondents who uses alternative Water Resources are 990

***NOTE:**Out of 1015 repondents, only 990 repondents are uses alternative Water Resources in absence of PMC Water Supply

The Table No. 5.11 shows the alternative water resources in the absence of municipal water supply.61.72 percent citizens depend upon bore well i.e. ground water resource,29.39 percent citizens depend upon tankers which are provided by PMC or private tanker, 7 percent depend upon well and further 2 percent depend upon dam.

Graph 5.8. : Distribution of Respondents uses alternative Water Resources (in absence of PMC Water Supply)



5.4.8. Water supply through Public Tap

With growing economic activities in Pune, the slum population has increased at a tremendous rate. This growth in population of slum is attributed to non-availability of housing stock at affordable costs which has led to the emergence of a large number of slums. The majority of slums are located on private lands. A glaring fact is that the total declared slum population of Pune occupies only four percent of the city's total area. Most of the slum households either have direct access to services or access them through community or common facilities. Majority slum domiciles are dependent on public stand post (PSP) and the ratio per PSP is also reasonably good about 8.5 percent families per PSP. It is observed that water from stand posts is being wasted in slums where they are fully covered in individual connections.

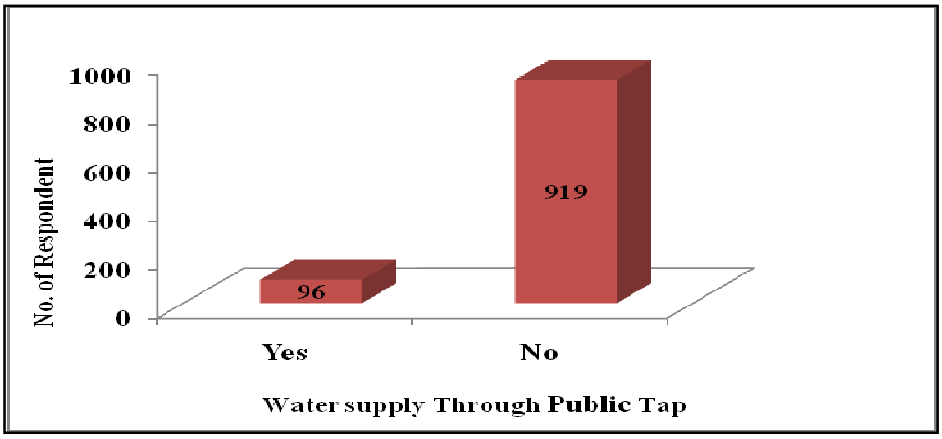
Table No. 5.12: Distribution of Respondents who are getting water through Public Tap

Water Supply through Public Tap	No. of Respondents
Yes	96 (9.46)
No	919 (90.54)
Total	1015 (100.00)

(Source:Survey Data) Figures in bracket indicates percentage

Table No. 5.12 shows distribution of respondents who are getting water through public tap.10 percent citizens are getting water through public tap or public stand post. Maximum 90 percent citizens are having own water connection. In slum areas[8], 58 percent people are having private connection and remaining depend on common tap or PSP.

Graph 5.9: Distribution of Respondents who are getting water through Public Tap



As it can be observed from Graph 5.9, very less citizens are getting water from public tap. Maximum citizens are having own water connections. It is seen that those citizens are staying in slum areas or chal and they are getting water through public tap or PSP.

5.4.8.1. Various Reasons for not having Water connections inside the house

The following Table No. 5.13 shows the various reasons for not having the water connection inside the house**.** It shows out of 96 respondents, 82.29 percent are staying in rented house such as Chal, slum areas etc. So they don't have individual water connection.

Table No. 5.13 : Various Reasons for not having Water connections inside the house

Reasons for not having Water connection	**Opinion of number of Respondents**	
	Agree	**Disagree**
Rented house	79(82.29)	17(17.71)
Connection fee is too high	41(42.70)	55(57.29)
Connection facility is not available	40(41.66)	56(58.33)
Monthly/Yearly charges are too high	10(10.41)	86(89.58)
Present arrangement is satisfactory	5(5.20)	91(94.79)
Waiting list	0(0.00)	96(100.00)
*Total no. of respondents who getting water through public tap is 96		

(Source:Survey Data) Figures in bracket indicates percentage

*__NOTE__:Out of 1015 repondents, only 96 repondents are getting water through public tap and 919 were getting water through household connection.

It is followed by 42.70 percent citizens who are saying water connection fee is too high. It is not affordable from economical point of view. Further 41.66 percent citizens are saying water connection facilities are not available in the area.10.41 percent citizens feel monthly/yearly charges are too high and not affordable.5.20 percent citizens believe present arrangement is satisfactory.

5.4.9. Measurement of Water Pressure at Households level

An attempt is made to examine the water pressure at household level, for which citizen's opinion is collected on a 1 To 5 point Likert scale. 1 and 2 being lowest while 4 and 5 suggest High agreement about water pressure at household level. And, point 3 represents neutrality between the two extremes and it has recorded Very Low response. Table No. 5.14 shows opinion about the water pressure at household level.

To meet the objective, questions were designed using 5 point scale where in the problems faced by citizens regarding water supply system were defined. It is observed that 4.10 percent citizens are getting a Very Low water pressure due to topographical disparity of Pune city. It's followed by, 43.40 percent citizens who also get water at Low pressure level. It is seen that 36.1 percent citizens had neutral responses i.e Neither Low Nor High. Whereas only 15.00 percent citizens get water supply with a High pressure level and the remaining 1.4 percent get supply at very High water pressure.

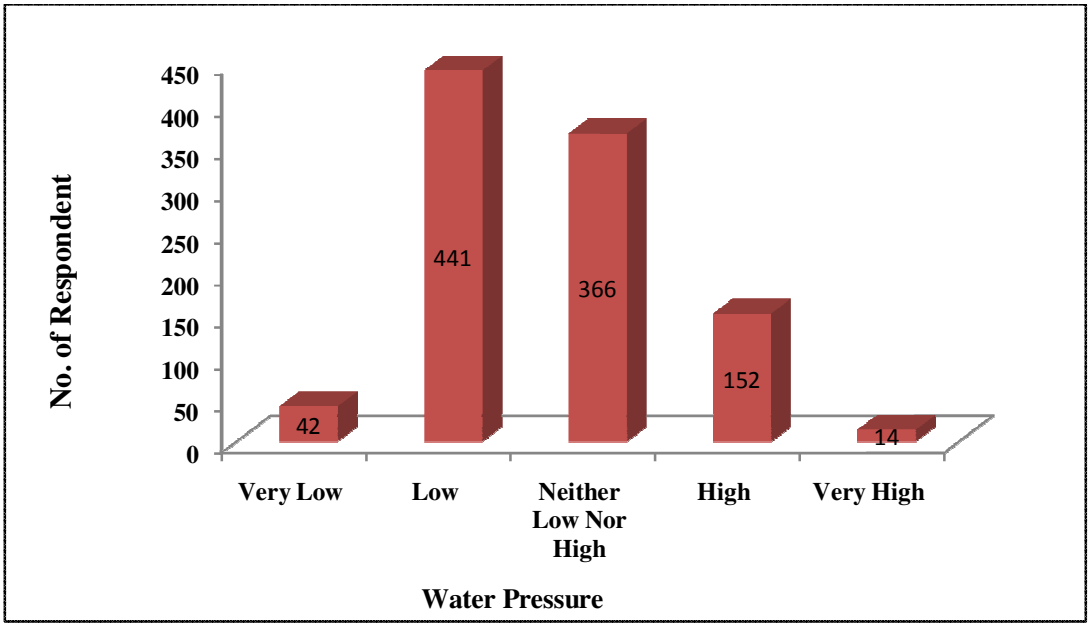
Table No. 5.14: Measurement of water pressure at house hold level

Water Pressure	**No. of Respondents**
Very Low	42 (4.1)
Low	441 (43.4)
Neither Low Nor High	366 (36.1)
High	152 (15.0)
Very High	14 (1.4)
Total	1015 (100)

(Source:Survey Data)

Figures in bracket indicates percentage

Graph 5.10 : Measurement of water pressure at house hold level



5.4.10. The Water Problem Criteria-Citizen Evaluation

In an attempt made to measure the problems faced by the citizens regarding water supply system, some observations have been laid down to be ranked on a 1 To 5 point Likert scale where, being 1 and 2 lowest responses while 4 and 5 represents highest. Point 3 represents moderation between the two extremes. From the responses, average value is calculated with regard to each observation. These observations are then ranked on the basis of average value. Here, the average value indicates that rank of water problem faced by citizens.

In a 5-point Likert Scale, having categories like Very High, High, Moderate, Low, Very Low are clubbed into three categories. Hence, this five category scale has been collapsed into three categories one like favourable, neutral and unfavourable perception. The reason for having mixture of favourable, neutral and unfavourable statements in a Likert scale is the responses by the respondents should not become monotonous while answering the questions. Hence, researcher has also applied 5-point Likert Scale and calculates weighted average value. There is very less difference between the comparative value of rank order average value and 5-point Likert scale value.

To meet the objective, questions were designed using various parameters which defined the level of water problem. It was observed that for each parameter average scale is calculated between 3 to 5 i.e. from moderate to very high. In fact, all the averages are above 4.0 which mean that all parameters account for concern.

It is seen that highest scale is for pipeline & valve leakages in various wards (4.48).And, then it is followed by low pressure (4.43), illegal water connection in various wards (4.41), misuse of water (4.38), insufficient water quantity (4.25) and costly (in terms of water connection & water consumption charges) (4.22).

All this indicates that the citizens are facing a varying degree of problem. Pune city has very old pipeline system so majority of problems are related to pipeline & valve leakages. Due to topographical disparity of Pune city, citizens are facing inequitable water pressure problem. Lots of unauthorized water connections in various wards are causing insufficient in water supply quantity. Most of the citizens are indulged in wastage of water in copious quantities for miscellaneous purposes such as washing vehicles, house cleaning, gardening etc. Apart from these problems, it is observed that inconvenient water supply timings(3.93),water contamination(3.62),insufficient water connection in concerning areas(3.57), impurity of water(3.22), electricity problem(2.42) are additional areas for concern..

Table No. 5.15 : Distribution of Respondents for Various Water Problems

Water Problems	Very Low	Low	Moderate	High	Very high	Total	Wt.Avg.	Wt.Avg (Likert Scale)	Rank Order
Leakages	20 (3.56)	32 (5.69)	85 (15.12)	163 (29)	305 (54.27)	562	4.48	4.73	1
Low Pressure	11 (1.96)	20 (3.56)	70 (12.46)	78 (13.88)	383 (68.15)	562	4.43	4.58	2
Illegal water Connection	29 (5.16)	23 (4.09)	42 (7.47)	64 (11.39)	404 (71.89)	562	4.41	4.7	3
Misuse of Water	22 (3.91)	39 (6.94)	37 (6.58)	72 (12.81)	392 (69.75)	562	4.38	4.67	4
Insufficient Water Quantity	26 (4.63)	56 (9.96)	43 (7.65)	64 (11.39)	373 (66.37)	562	4.25	4.63	5
Costly	14 (2.49)	41 (7.3)	69 (12.28)	121 (21.53)	317 (56.41)	562	4.22	4.47	6
Inconvenient Water Timings	24 (4.27)	34 (6.05)	111 (19.75)	183 (32.56)	210 (37.37)	562	3.93	4.22	7

Water Contamination	43 (7.65)	83 (14.77)	111 (19.75)	135 (24.02)	190 (33.81)	562	3.62	4.22	8
Insufficient connection in your area	35 (6.23)	75 (13.35)	122 (21.71)	196 (34.88)	134 (23.84)	562	3.57	4.08	9
Impurity of Water	50 (8.9)	105 (18.68)	170 (30.25)	145 (25.8)	92 (16.37)	562	3.22	3.95	10
Electricity Problem	146 (25.98)	182 (32.38)	113 (20.11)	93 (16.55)	28 (4.98)	562	2.42	4	11

Figures in bracket indicates percentage

(Note: Average scale on 1 to 5 (where Very Low =1; Low =2; Moderate=3; High =4; Very High= 5))

Table No. 5.15 shows the rank of each parameter representing water problems in water supply systems. According to the above table, citizens believe that they are getting enough quantity of water but they still are facing 'leakage' problem as they have ranked it **First,** followed by 'Low Pressure' at **Second** rank due to topographical disparity in Pune City. There are lots of unauthorized connections in every ward so people are facing problems of low pressure & insufficiency of water supply and they give **Third** rank to "Illegal water Connection". Many citizens involve in wastage of water for miscellaneous purposes, so **Fourth** rank has been given for "Misuse of water", followed by "Insufficient Water Quantity" at **Fifth** rank. Many citizens find water connection charges & water bill cost ineffective so they have ranked "Costly" **Sixth**. In Pune city, water supply to every ward is done at different timings, so citizens have given **Seventh** rank to "Inconvenient water timings". Some areas in Pune city get contaminated water so they have ranked at **Eighth**. In Pune city, some areas have large density population and less number of water connections. So it is ranked **Ninth**. The **Tenth** rank goes to "Impurity of water" and **Eleventh** rank to "Electricity Problem". As per the responses, it is clear that water supply system is working satisfactory but it needs focus on the problems highlighted above, so that wastage can be reduced, and then everyone will get sufficient quantity of water, which in turn will reduce stress for Pune Municipal Corporation.

It can be inferred that there are a lot of pitfalls in water supply system.

5.4.11.Citizens Satisfaction over Current Water Supply System

Table No. 5.16 shows the citizens' satisfaction analyses of current water supply system. 44.60 percent citizens are satisfied with water supply system provided by PMC, whereas remaining 55.40 percent citizens are dissatisfied. Ratio of dissatisfaction is high among citizens. According to these ratios, the need for rehabilitation of water supply system is necessary, so that the citizens get sufficient quantity of water.

As per Table No.5.16, 55.40 percent citizens are not satisfied with current water supply system given by PMC. PMC has huge storage capacity for water. Most of the problems pertain to pipeline leakages, wastage of water and misuse of water, and therefore citizens are facing problems. There is a lot of water loss in Pune city due to old pipeline; as a result citizens are not getting enough water. Reasons are many, but difference in the percent ratio less between satisfaction and dissatisfaction amongst citizens. It necessitates improvisation in water supply system. Also, metering system must be made compulsory in order to provide equitable water supply and pressure water for future.

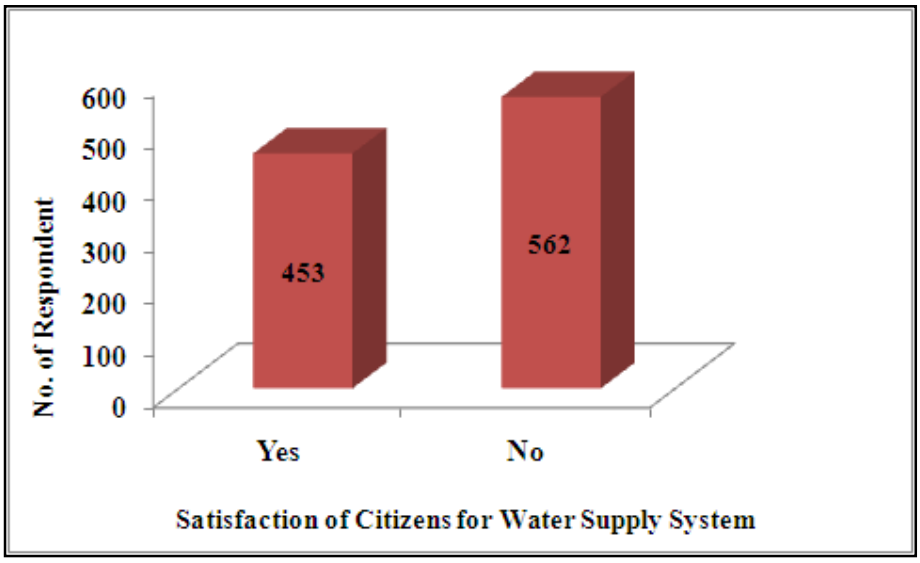
Table No. 5.16 : Satisfaction of Citizens for Current Water Supply System

Satisfaction of Current Water Supply	No. of Respondents
Yes	453 (44.6)
No	562 (55.4)
Total	1015 (100)

(Source:Survey Data)

Figures in bracket indicates percentage

Graph 5.11 : Satisfaction of Citizens for Current Water Supply System



Graph 5.11 shows the current water supply systems satisfaction level among the citizens. 55.40 percent citizens are dissatisfied with current water supply system. In comparison, the satisfaction level of citizens is 44.60 percent, difference is not much but rehabilitation of water supply system is required. It can be concluded that the water supply service is satisfactory.

5.4.12. Citizens Opinion about Water billing system

In Pune city, 97 percent citizens are paying water charges annually and very few 4 percent citizens are paying water charges on meter based (Monthly).It is seen that water metering system is not implemented 100 percent in Pune city.

Following Table No.5.17 shows distribution of respondents for preferred water billing system. In Pune city, 36.85 percent citizens preferred Meter basis water billing system and 63.17 percent citizens preferred annual basis water billing system. Ratio is high for annual basis because citizens are paying water charges once in a year or annual basis. If metering system is made compulsory, everyone has to pay water charges on mater basis i.e monthly and they have to pay more as compare to annual basis. So maximum citizens preferred annual water billing system which is included in property tax.

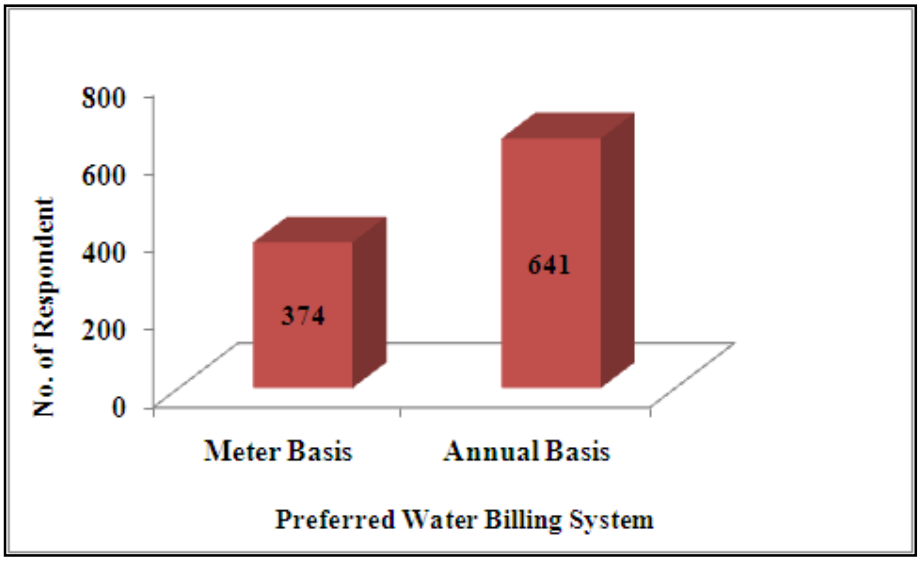
Table No. 5.17. : Distribution of Respondents for preferred Water billing system

Preferred Water Billing System	No. of Respondents
Meter Basis	374 (36.85)
Annual Basis	641 (63.15)
Total	1015 (100.00)

(Source:Survey Data)

Figures in bracket indicates percentage

Graph 5.12. : Distribution of Respondents for preferred Water billing system



From Graph 5.12, it is observed that, maximum citizens preferred Annual water billing system and very less citizens preferred meter basis. They think meter basis sysetm is an expensive system as compared to annual basis and they have to pay water charges monthly.So citizens are not ready to prefer metering system.

5.4.12.1. Opinion of citizens about preferring meter basis water billing system

As per Table No. 5.17, In Pune city, 36.85 percent citizens preferred meter basis water billing system. This ratio is low as compared to annual basis.Various reasons are identified for preferring meter basis water billing system such as, optimal use of water, water loss reduction and conserve the water for future.The Table No. 5.18 shows citizens' preferences for meter

basis water billing system.86.9 percent citizens preferred meter basis for optimal use of water, followed by 84.76 percent citizens preferred for water losss redcution and 69.79 percent citizens preferred conserve water for future use.

Table No. 5.18 :Various reason for preferring Meter basis water billing system

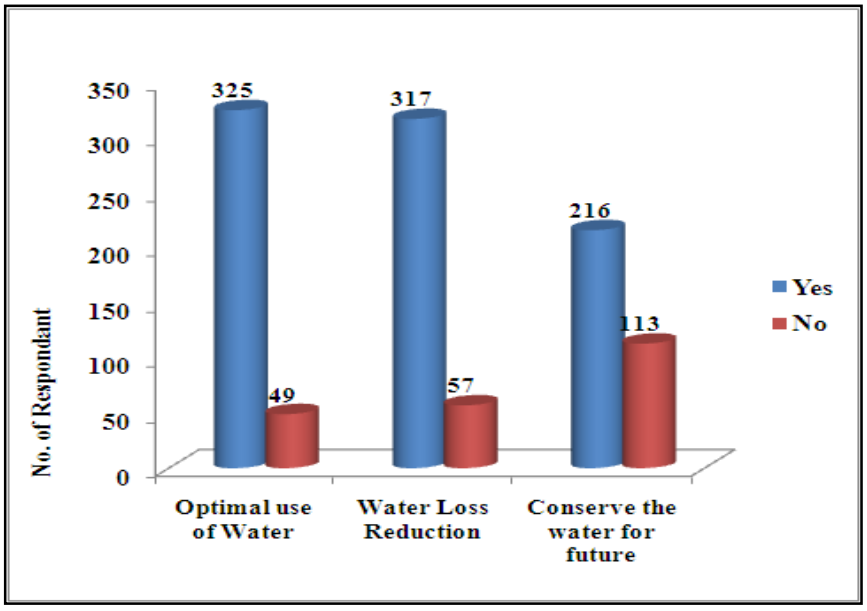
Various reason for preferring Meter basis Water billing System	Yes	No
Optimal use of Water	325 (86.9)	49 (13.1)
Water Loss Reduction	317 (84.76)	57 (15.24)
Conserve the water for future	261 (69.79)	113 (30.21)

(Source:Survey Data)

Figures in bracket indicates percentage

Graph 5.13 shows various reasons preferred by citizens for meter basis water billing system**.** According to citizens' preference, by metering system everyone can do optimal use of water and save water for nation. It is followed by next preferences for water loss reduction and conserves the water for future.

Graph 5.13: Various reasons for preferring Meter basis water billing system



5.4.12.2. Opinion of citizens about preferring Annual basis water billing system

As per Table No. 5.17, in Pune city 63.15 percent citizens preferred annual water billing system. This ratio is high as compared to meter basis.Various reasons are identified for preferring annual basis water billing system such as, economically feasible, faulty meter,unlimited use of water,irregualrity in meter checking.

Table No. 5.19 : Various reasons for preferring Annual basis water billing system

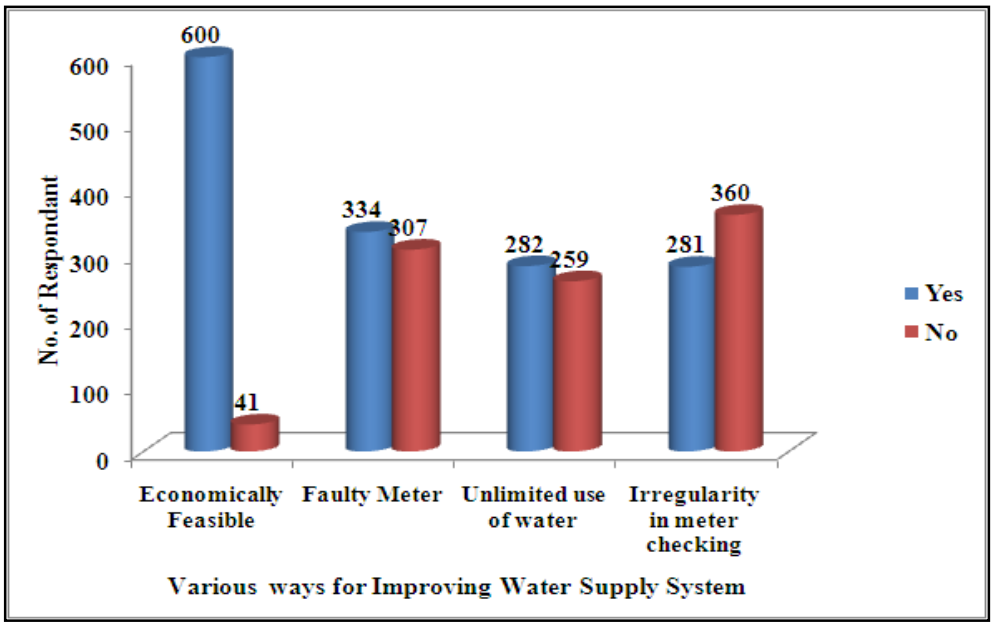
Various reasons for preferring Annual basis Water billing System	Yes	No
Economically Feasible	600 (93.6)	41 (6.4)
Faulty Meter	334 (52.11)	307 (47.89)
Unlimited use of water	282 (43.99)	359 (56.01)
Irregularity in meter checking	281 (43.84)	360 (56.16)

(Source:Survey Data)

Figures in bracket indicates percentage

Table No. 5.19 shows citizens' preferences for annual water billing system.93.6 percent citizens preferred annual water billing system because of economically feasible. In Pune city, citizens are paying water tax included in property tax either once in a year or twice in a year and it is economically feasible.It is followed by 52.11 percent citizens because of faulty meters. In Pune city, there are very few places where metering system is applied.In these places meters are not working properly, due to this reason citizens preferred annual basis.Further,43.99 percent citizens are preferred because of unlimited use of water.If metering system is made compulsory, everyone has to pay the water charges monthly and on meter basis.So the water charges will increase as compared to annual basis and there is automatically restriction on usage of water. Lastly, 43.84 percent citizens preferred it annually because of irregularity in meter checking. PMC employees are not checking meters regularly and maximum citizens feel if PMC will apply metering system, corruption will occur.So maximum citizens preferred annual water billing system.

Graph 5.14. : Various reasons for preferring Annual basis water billing system



5.4.13. Opinion about Reward & Punishment System will help in Reducing Wastage of Water

In an attempt made to measure the citizens' opinion about Reward and punishment system will help in reducing wastage of water, some observations have been laid down. Observations have been made into two parts such as, for reward system and another is for punishment System.

5.4.13.1. Reward System

Following Table No.5.20 shows distribution of respondents for opinion about Reward System. According to citizens' opinion, 82 percent feel reward system will help in reducing wastage of water and 18 percent citizens don't.

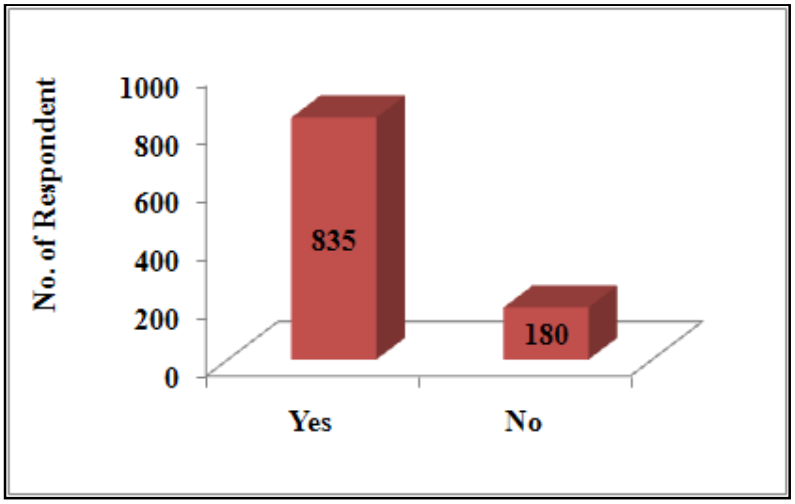
Table No. 5.20 : Opinion about Reward System

Reward System helps in reduce wastage of water	No. of Respondents
Yes	835 (82.27)
No	180 (17.73)
Total	1015 (100)

(Source:Survey Data)

Figures in bracket indicates percentage

Graph 5.15. : Opinion about Reward system



Above Graph 5.15 shows maximum citizens 82 percent have agreed that, reward system will help in reducing wastage of water. So it will help for conservation of water for future. Further 18 percent citizens are not feeling reward system will help in reducing wastage of water.

5.4.13.1.1. Various Ways for Reward System

Table No. 5.21 shows the distribution of the respondents according to their responses for various ways for Reward System for reducing wastage of water and optimal usage of water.83.95 percent respondents agree with discount on water bill. It is seen that most of the respondents agree for giving discount on water bill and it is economically feasible. It is followed by 34.43 percent respondents agreeing with Recognition in newspaper and web site, further 25.27 percent respondents agreeing with Supply extra water in dry or summer season and lastly, 16.41 percent respondents agreeing with supply extra water for agriculture purpose.

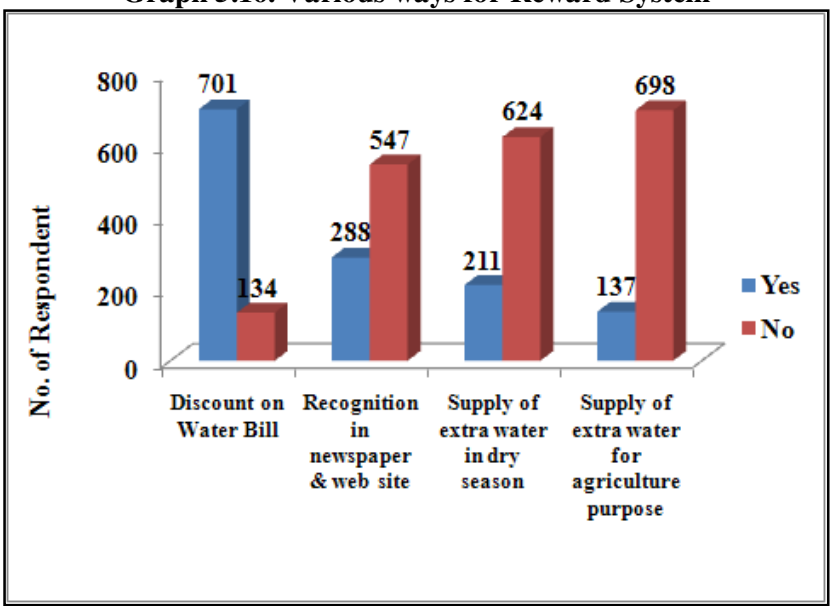
Table No. 5.21. : Various ways for Reward System

Various Ways for Reward System	Yes	No
Discount on Water Bill	701(83.95)	134(16.05)
Recognition in Newspaper & web site	288(34.49)	547(65.51)
Supply of extra water in dry season	211(25.27)	624(74.73)
Supply of extra water for agriculture purpose	137(16.41)	698(83.59)

(Source:Survey Data)

Figures in bracket indicates percentage

Graph 5.16. Various ways for Reward System



5.4.13.2. Punishment System

Following Table No.5.22 shows distribution of respondents for opinion about Punishment System. According to citizens' opinion, 82 percent citizens feel punishment system will help in reducing wastage of water and 18 percent citizens are not feeling.

Table No. 5.22: Opinion about Punishment System

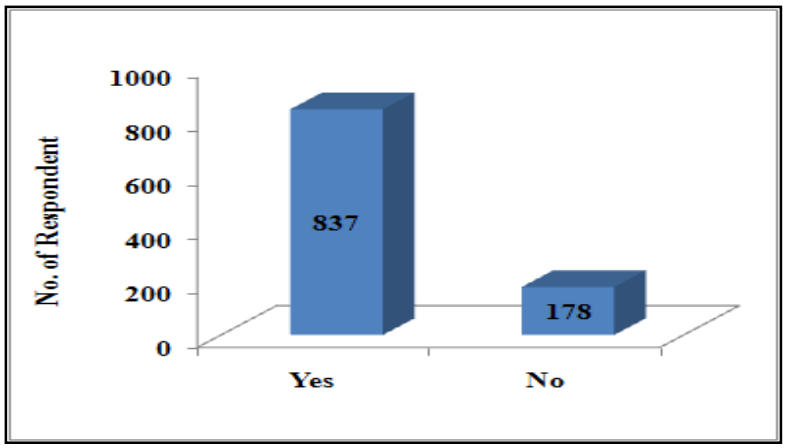
Punishment System helps in reduce wastage of water	No. of Respondents
Yes	837 (82.46)
No	178 (17.53)
Total	1015 (100)

(Source:Survey Data)

Figures in bracket indicates percentage

Graph 5.17 shows maximum citizens 82 percent think Punishment system will help in reducing wastage of water. So it will help in conservation of water for future. Further 18 percent citizens are not feeling Punishment system will help in reduce wastage of water.

Graph 5.17. : Opinion about Punishment system



5.12.13.2.1. Various Ways for Punishment system

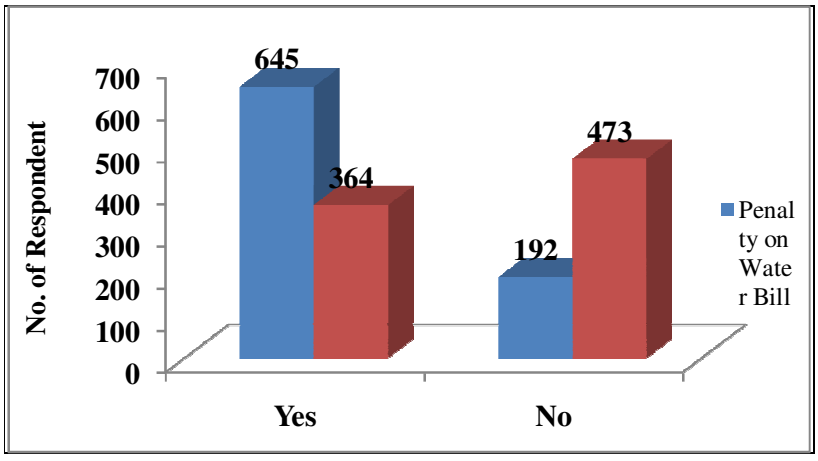
Table No. 5.23 shows the distribution of the respondents for various ways for Punishment System for reducing wastage of water and optimal usage of water. 77.06 percent respondents agree with Penalty on Water bill. It is followed by 43.50 percent respondents agreeing with close water connection. It is seen that most of the respondents agree for giving penalty on water bill so it will reduce wastage of water.

Table No. 5.23 : Various ways for Punishment System

Various Ways for Punishment System	Yes	No
Penalty on Water Bill	645 (77.06)	192 (22.94)
Close Water Connection	364 (43.50)	473 (56.50)

(Source:Survey Data)Figures in bracket indicates percentage

Graph 5.18. : Various ways for Punishment System



From above Graph 5.18, it is seen that 77.06 percent respondents agree for Penalty on water bill.So it will help in reducing wastage of water. And 43.50 percent respondents agree for close water connection punishment system.

5.4.13.2. Citizens' opinion about Reward & Punishment System will help in Enhancing Water Supply System

An attempt has been made to examine some opinions about whether reward and punishment system will enhance water supply system or not. For that, citizens' opinion is considered on a (Likert Scale) 1 To 5 point scale. Table No.5.24 shows opinion about Reward & Punishment System will help in Enhancing efficiency of water supply system. It is observed that the majority of the citizens (54.68 percent) agree that if both systems apply, citizens' will reduce wastage of water and conserve water for future. It is followed by (27.49 percent) citizens who are Highly agreeing that punishment and reward system will enhance water supply system. Hence, most citizens (82.17 percent) are in favour of the both system whereas the rest is negligible (17.84 percent). When comparing this ratio, we find that most citizens are in favour of punishment and reward system will enhance water supply system effectively and definitely they will use optimal use of water and reduce wastage of water.

Table No. 5.24: Different punishment & reward system will enhance water supply system

Different punishment & reward system will enhance water supply system	No. of Respondents	Avg. Scale
Highly Agree	279 (27.49)	4
Agree	555(54.68)	
Neutral	96(9.46)	
Disagree	75(7.39)	
Highly Disagree	10(0.99)	
Total	1015(100.00)	

(Source:Survey Data) Figures in bracket indicates Percentages

(Note: Average scale on 1 to 5 (where Highly Disagree (SD) =1; Disagree (D) =2; Neutral (N) =3; Agree (A) =4; Highly Agree (SA) = 5))

Hence 82.17 percent citizens' have agreed that if both systems apply everyone will use water optimally and it will reduce wastage of water and conserve it for future.

5.5. Awareness of Water conservation and appliances for future use and suggestions on various ways for conservation.

An attempt to meet objective of the study "To find out the ways & means to increase the awareness among citizens of Pune & guide them to use water effectively & economically, and conserve it for future use", the primary data is collected from the respondents to find out their opinion regarding water conservation. A series of questions were asked to know the views of citizens towards importance of water conservation, awareness regarding water saving appliances, various ways of water conservation, what motivates them to conserve water. Also, we found out the percentage of citizens who are willing to contribute in fund raising for water conservation. Such analysis helps to find out the different ways to increase awareness among citizen of Pune to use water effectively & economically, and conserve it for future.

To find out the awareness in citizens about water conservation, the parameters used were importance of water conservation, motivations, various ways for water conservation, water saving appliances, ways for improving water conservation & water supply system. If citizens are aware about water saving appliances, they can easily save water in gallons or liters.

5.5.1. Importance of Water Conservation

Water conservation is the most effective and eco-friendly method to fight global warming. Water conservation is one that can reduce the scarcity of water. It aims to improve the efficiency of use of water, and reduce losses and wastage. Water conservation is to reduce the misuse of water and recycling of waste water for different purposes like cleaning, manufacturing, agriculture etc. Water conservation is important for both water suppliers and water users. It necessitates a step towards water is conservation to secure the future. Table No. 5.25 shows importance of water conservation among the citizen of Pune. As per the responses of citizens' it is found highly important to conserve water as 84.83 percent. It is followed by 8.67 percent citizens feel importance of water conservation. Only 2 to 3 percent stated, it is not that important or less important.

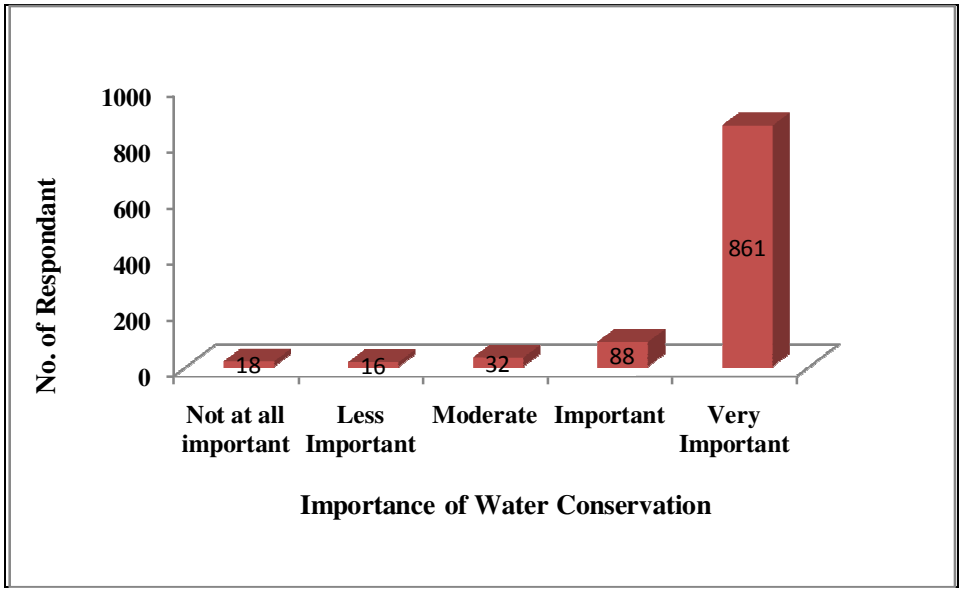
Table No. 5.25: Views of citizens towards Importance of water Conservation

Importance of water Conservation	No. of Respondents
Not at all important	18 (1.77)
Less Important	16 (1.58)
Moderate	32 (3.15)
Important	88 (8.67)
Very Important	861 (84.83)
Total	1015 (100)

(Source: Survey Data)

Figures in brackets indicates percentages

Graph 5.19: Views of citizens towards Importance of water Conservation



5.5.2. Awareness about water saving appliances

An attempt is to observe the awareness regarding the water saving appliance .Various water saving appliances are Low flow shower head, Spray Taps, Kitchen Faucet Aerator, Toilet Water Diverter, Dual Flush Toilet, Rain Water Tank, Grey Water Use etc. A low flow shower head is water saving shower head. It saves water up to 2.5 gallons per minute (gpm) or less. A kitchen faucet is reducing 2 gallons water per minute. Toilet water diverter saves half gallon water per flush. Dual Flush Toilet is saves 50 percent water per flush.

Table No.5.26 shows the distribution of the respondents according to their awareness of water saving appliances among the citizens' view. It shows out of 1015 respondents, 79.70 percent

citizens know rain water tank (rain water harvesting) for water saving appliances. It is observed that amongst different water saving appliances, the most known appliances are Rainwater tank. But citizens know the rain water tank but very few percent of citizens are implementing.

Rain water tank is followed by Grey water use. Out of 1015 respondents, 55.96 percent citizens are aware about water saving method. Almost 47.88 percent respondents were aware about low flow shower head appliance. This appliance saves water up to 2.5 gallon per minute. 31.63 percent respondents were aware about spray taps. Awareness of Dual Flush toilet is 28.37 percent. Only 17.93 percent were aware about toilet water diverter. It saves 50 percent water per flush. 13 percent respondents were aware about kitchen faucet Aerator. Kitchen faucet Aerator saves up to 2.0 gallon water per minute. Theses appliances are very important and therefore, they should be aware about their benefits. Hence, creating awareness about it is very essential.

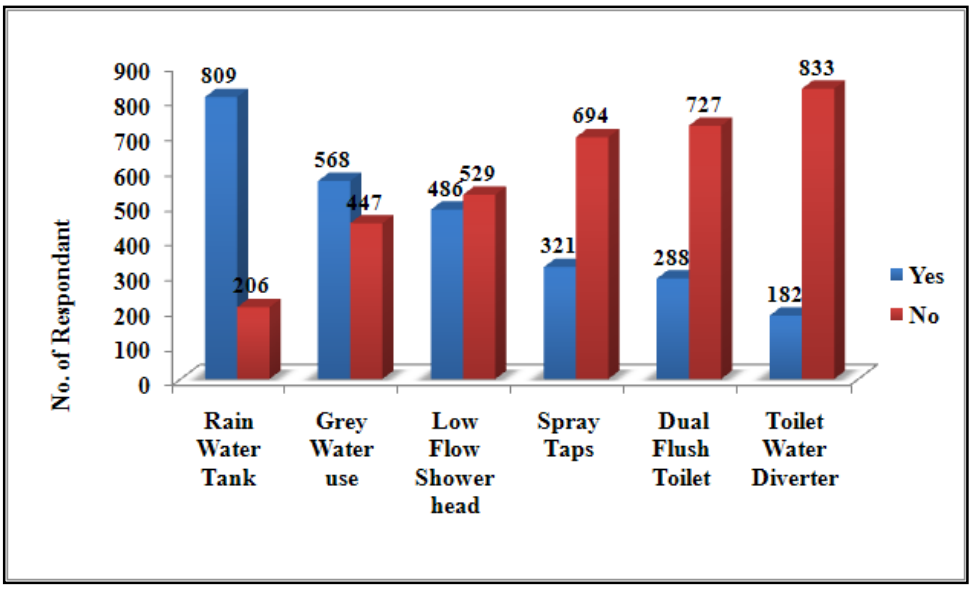
Table No. 5.26: Awareness of Water Saving Appliances

Water Saving Appliances	Aware	Not Aware
Rain Water Tank	809 (79.7)	206 (20.3)
Grey Water use	568 (55.96)	447 (44.04)
Low Flow Shower head	486 (47.88)	529 (52.12)
Spray Taps	321 (31.63)	694 (68.37)
Dual Flush Toilet	288 (28.37)	727 (71.63)
Toilet Water Diverter	182 (17.93)	833 (82.07)
Kitchen Faucet Aerator	132 (13)	883 (87)

(Source: Survey Data)

Figures in brackets indicates percentages

Graph 5.20 : Awareness of Water Saving appliances



From Graph 5.20 it is observed that citizens from Pune city are most aware of rain water tank (79.7 percent) followed by gray water usage (55.69percent).It indicates that in citizens' opinions, storage of water through rain water tank is the easiest way for water conservation in Pune city around 744 million lit. (9.5 TMC) drainage water is produced per day, out of which 497 million lit. (6.4 TMC) water is recycled and remaining 247 million lit. (33percent) drainage water is drained into river, without recycling. Further 47.88 percent citizens are aware about low flow shower head and remaining appliances are not much aware among the citizens.

5.5.3. Ways for Water Conservation

It is important to conserve water in your own home, it is important to help our towns and cities save water by teaching others to use water wisely. In agricultural areas, water may be saved by using more effective irrigation methods. In industrial areas, manufacturers can save water by reusing it and by treating industrial wastes. Cities and towns can save water by eliminating leaks and installing meters. Wastewater can be treated and reused. As we conserve water at home and in our community, it will help ensure that the water available now continues to meet the growing water needs and that of future. Table No. 5.27 shows to various ways for water conservation. It is observed that 80.2 percent citizens agree to rainwater harvesting method. Nowadays, while sanctioning building plans, PMC makes it compulsory for every builder do the rainwater harvesting in each & every plan, but very few builders are implementing such type of facility. It is followed by 67.19 percent respondents who agree with control on

leakages of taps. In Pune city, water pipelines are very old, so there are lots of leakages in pipeline and PSP. If we have control on it, it will save thousands of liter water per day. 56.55 percent respondents agree with control on illegal water connections. For that, ward to ward illegal connection is too identified and cancelled. So everyone will get sufficient quantity of water. 51.92 percent respondents believe in recycling of waste water and this water can be used for miscellaneous purpose such as gardening, washing car etc. and 51.72 percent respondents agree with tree plantation. Further 37.54 percent respondents agree with optimal use of water in summer can also contribute to conservation of water for future. Lastly, 32.41 percent respondents agree with GIS and ratio is very less. If we implement Geographical Information System, it will easily identify leakages of pipelines and control on water loss.

So it is observed that according to citizens' Rainwater harvesting is the most suitable method for water conservation. **It is interred that rainwater harvesting is the most popular way for water conservation.**

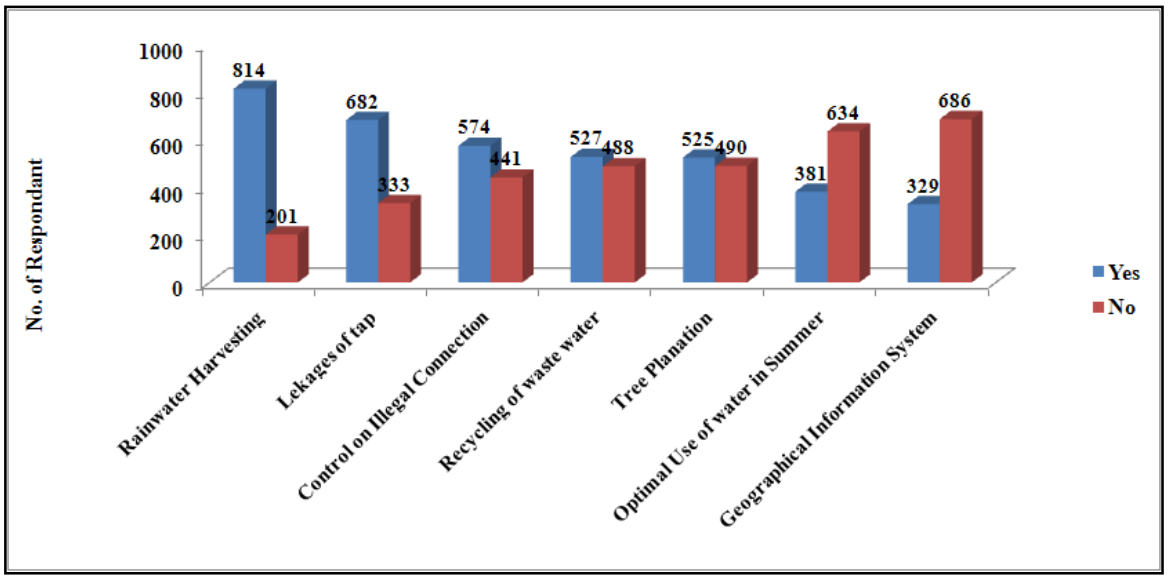
Table No. 5.27 : Various Ways for Water Conservation

Various Ways for Water Conservation	Agree	Disagree
Rainwater Harvesting	814 (80.2)	201 (19.8)
Leakages of tap	682 (67.19)	333 (32.81)
Control on Illegal Connection	574 (56.55)	441 (43.45)
Recycling of waste water	527 (51.92)	488 (48.08)
Tree Plantation	525 (51.72)	490 (48.28)
Optimal Use of water in Summer	381 (37.54)	634 (62.46)
Geographical Information System	329 (32.41)	686 (67.59)

(Source: Survey Data)

Figures in brackets indicates percentages

Graph 5.21 : Various Ways for Water Conservation



5.5.4. To instigate water Conservation

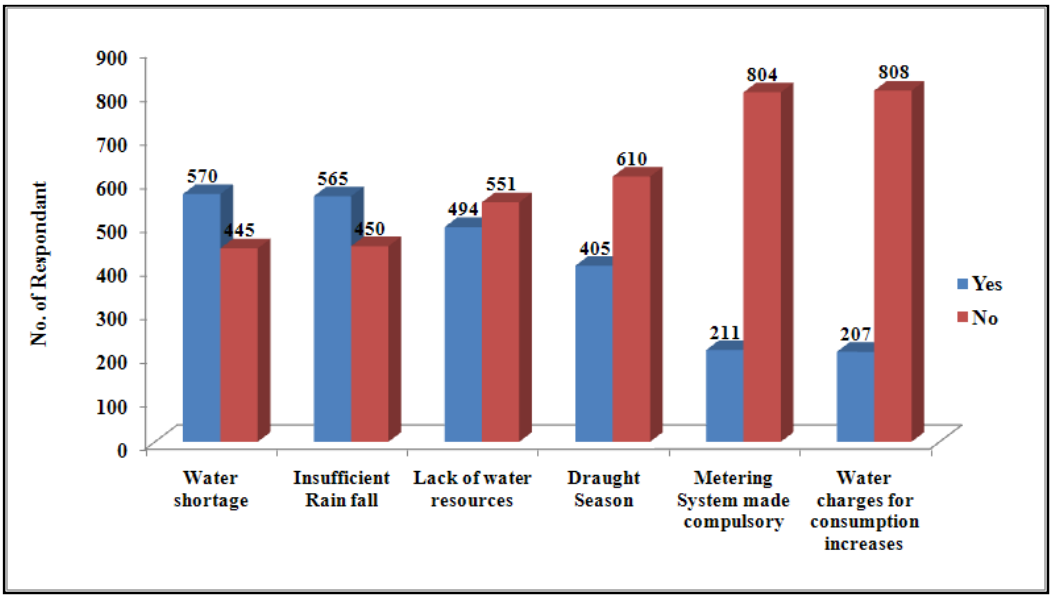
In order to understand the citizens' views for what motivates citizens for water conservation, the parameters used were metering system made compulsory, increase the water consumption charges, water shortage, draught season, insufficient rain fall, lack of water resources etc. The Table No. 5.28 shows the frequency distribution of motivation behind water conservation through various ways. It is observed from the table, 56.16 percent citizens believe due to water shortage, citizens will motivate for water conservation. 55.67 percent respondents agree with that, insufficient rain fall motivates for water conservation.Global warming has emerged as one of the most important environmental issues ever to confront humanity. This concern arises from the fact that our everyday activities may be leading to changes in the earth's atmosphere. This affects environment so it would get insufficient rain fall 48.7 percent citizens get motivated for water conservation due to lack of water resources,40 percent citizens get motivated for water conservation in order to survive draught season, 21 percent citizens feel that compulsory metering system as well as water charges on consumption will motivate people for water conservation i.e. 20 percent citizens feel that optimized charges can help them conserve water and remaining feel that it is the social responsibility of every person.

Table No. 5.28 : Motivation for Water Conservation

Motivation for Water Conservation	Yes	No
Water shortage	570 (56.16)	445 (43.84)
Insufficient Rain fall	565 (55.67)	450 (44.33)
Lack of water resources	494 (48.7)	551 (51.3)
Draught Season	405 (39.90)	610 (60.10)
Metering System made compulsory	211 (20.79)	804 (79.21)
Water charges for consumption increases	207 (20.39)	808 (79.61)

(Source: Survey Data) **Figures in brackets indicates percentages**

Graph 5.22 : Motivation for Water Conservation



From Graph 5.22, it is observed that 56.16 percent citizens get motivated for water shortages followed by 55.67 percent citizens get motivated for insufficient rain fall. Further, 48.7 percent feel due to lack of water resource, citizens get motivated for water conservation and very less citizens get motivated for Metering system made compulsory and increase water consumption charges.

5.5.5. Opinions about fund-raising for Water conservation

Citizens' willingness towards fund raising for water conservation is analyzed here. It is observed from Table No. 5.29 that maximum citizens 641(63.15percent) are not willing to additionally pay to community towards water conservation, followed by 374(36.85percent) that are ready to pay additionally to community. It indicates that citizens are not ready to pay additionally for water conservation. Because they feel that it is the duty of Pune Municipal Corporation & they are also not confident about any positive change after contribution. But, if they agree, PMC can suggest various ways for water conservation at society level.

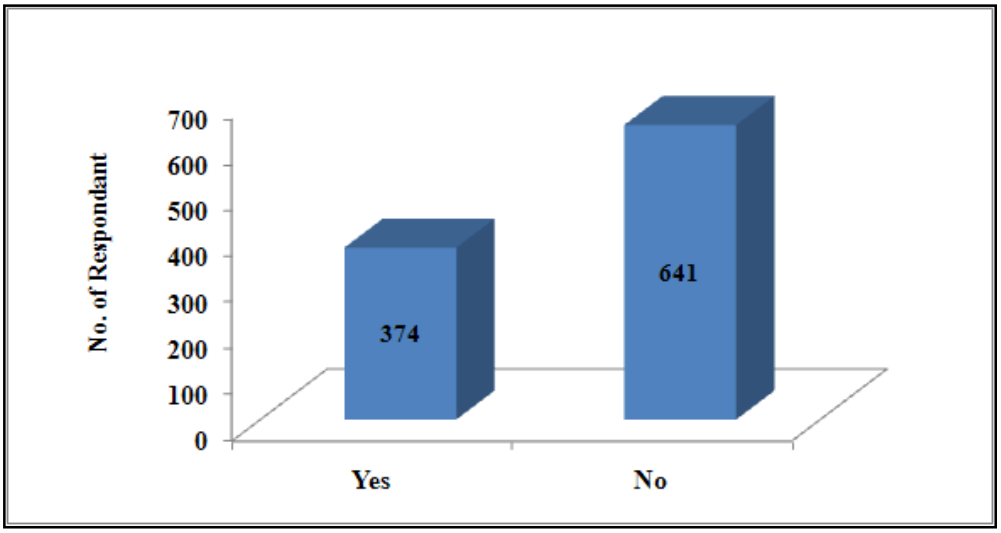
Table No. 5.29: Willing to pay for Water Conservation

Willing to pay for Water Conservation	No. of Respondents
Yes	374 (36.85)
No	641 (63.15)
Total	1015 (100)

(Source: Survey Data)

Figures in brackets indicates percentages

Graph 5.23 : Willing to pay for Water Conservation



As can be observed from Graph 5.23, most of the respondents i.e. 63.15 percent are not ready to contribute money for water conservation to community (PMC).Further 36.85 percent are ready to contribute the money to community for development of water conservation. It is

observed that one of the reasons is after contribution; there is no guarantee for positive change in society.

5.5.6. Various ways for improving Water Supply System

Along with water conservation, it is also essential to improve water supply system as supply is uneven; hence citizens' views were taken, so as to know what are the ways for improving water supply system in their opinion**.**

There are various ways for improving the water supply system as development & utilization of new resources, implementation of water loss reduction programme, regular checking of pipe & valve leakages, implementation of water metering system to optimize water utilization reducing wastage of water etc. and use water saving appliances.

Table No. 5.30 : Various Ways for Improving Water Supply System

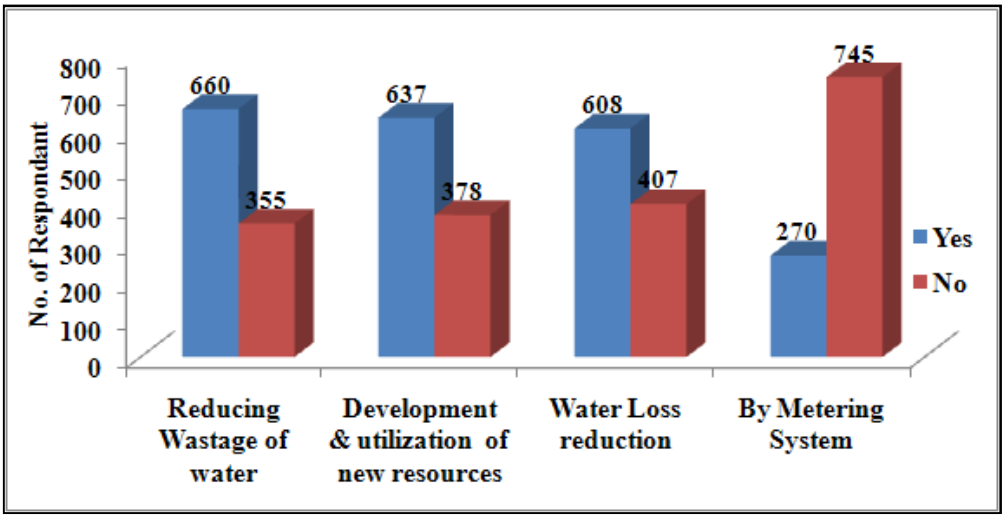
Ways for Improving Water Supply System	**Yes**	**No**
Reducing Wastage of water	660 (65.02)	355 (34.98)
Development & utilization of new resources	637 (62.76)	378 (37.24)
Water Loss reduction	608 (59.9)	407 (40.1)
By Metering System	270 (26.6)	745 (73.4)

(Source: Survey Data)

Figures in brackets indicates percentages

Table No.5.30 represents distribution of respondents as per their suggestion about ways for improving water supply system. It is seen that majority citizens i.e. 65.02 percent want to implement the idea of reduction in wastage of water. They are followed by 62.76 percent citizens who want to implement development & utilization of new resources. Further 59.9 percent citizens want to implement Water loss reduction programme and very few citizens 26.6 percent want to implement metering system. They feel that optimized cost of commodity can conserve water & all other feel that it is a social responsibility of every person.

Graph 5.24: Ways for Improving Water Supply Systemv



As can be seen, in Graph No 5.24 indicates that most of the respondents i.e. 65.02 percent feel reducing wastage of water will improve water supply system which is followed by 6.76 percent who feel that the development & utilization of new resources will improve water supply system. Further 59.9 percent respondents feel that water loss reduction programme will improve water supply system. Remaining 26 percent respondents feel metering system will improve water supply system. It indicates that for improving water supply system, reducing wastage of water supply new development technologies & water loss reduction programme will help and is suggested.

Summary:

It is observed that water consumption in Pune city is far lower than the norms laid down by Bureau of Indian Standards. It has also been found that in the Pune city, a majority of the households perceive the above activities as most water wasting activities. The study reveals that only about 21% of the total households in these cities get 24 hours municipal water supply. It is observe that majority Citizens are getting a Very Low water pressure due to topographical disparity of Pune city. All this indicates that the citizens are facing a very degree of problem. Pune city has very old pipeline system so majority of problems are related to pipeline & valve leakages. Due to topographical disparity of Pune city, citizens are facing inequitable water pressure problem.

It necessitates improvisation in water supply system. Also, metering system must be made compulsory in order to provide equitable water supply and pressure water for future. The most of the citizens were agree that if punishment and reward system apply then citizens will reduce wastage of water and conserve water for future. Amongst different water saving appliances,

the most know appliance is Rain water Tank. As per citizen's point of view, rainwater harvesting method is most popular method for water conservations. Citizens will motivate for water conservation due to water shortage. Pune citizens were not willing to additionally pay to community towards water conservation.

Part II: PMC-Water Supply Department

In part II, the primary data is collected by the researcher in respect of 25 employees from Water supply and Distribution department of PMC main office. The total strength of officers and employees of water supply and distribution department at PMC is about 1139.The distribution of Officers and Employees of water distribution department is as in the Table No.4.2 (Refer Para 4.7.C)

The data has been collected from PMC employees of water distribution from Class I, Class II and some employees of Class III category through questionnaires and interviews are further compiled into following tables.

The PMC Water Supply Infrastructure & Maintenance, the analysis is carried out under nine broad headings which are:

1. Natural Sources of Water Supply
2. Situational analysis of Water Supply System
3. Water supply Service Delivery and Service Level Benchmark
4. Per capita supply of water
5. Extent of metering of water connections
6. Extent of Non Revenue Water (NRW)
7. Continuity of water supply
8. Quality of Water Supplied
9. Operation and Maintenance

In this section, the researcher has analyzed the primary data collected from 25 employees of Pune Municipal Corporation of Water supply & distribution department.

First objective of the study is to explore about the infrastructure facility of water supply system in Pune City. To check this objective, the researcher has collected data from 25 employees of Water supply & distribution department of PMC.

In this objective, reviews on the existing situation and issues pertaining to all core municipal services provided by PMC such as water supply & sewerage(in terms of their current level of service and coverage). In Pune city, development, maintenance and operations of water supply system is undertaken by PMC. This section briefs about current water supply schemes in Pune city, in terms of their sources, treatment capacities & distribution network etc. Level of services and key issues with regard to water supply operations are also discussed.

5.6. Natural Sources of Water Supply

Water Supply is an obligatory responsibility of the municipal corporation according to the Bombay Provincial Municipal Corporation (BPMC) Act 1949, section 63.Pune City receives water supply from the following natural sources.

Table No. 5.31: Sources of Water Supply in the Pune City

Natural Sources	Details
Rivers	Mula,Mutha & Pawana
Lakes	Pashan ,Katraj
Dams	Khadakwasla,Panshet,Warsagaon & Temghar
Ground Water	Ground water has emerged as an important source to meet the water requirements of various sectors. There are around 399 dug wells & 4820 bore wells

Table No. 5.32: Existing water Storage Capacity of dams in Pune City

Name of Dam	Storage Capacity (in terms of TMC)	Usable Capacity (in terms of TMC)
Khadakwasla Dam	3.03	1.96
Panshet	10.97	10.65
Varasgaon	13.25	12.82
Temghar	3.76	3.71
Total Capacity	**31.01**	**29.14**

Source: PMC office

From the above Table Nos. 5.31 & 5.32, the two main resources of raw water are Dam & Canal. The consumers are divided in two groups namely Domestic & Non-Domestic. The annual water consumption is estimated at 15 TMC approximately. The domestic group consumes approximately 97.22 percent, whereas non-domestic group consumers approximately 2.78 percent of water received from Dam (70 percent) & Canal(30 percent).

The Charges for Raw water per group are as below-

1. For Domestic group consumers water from Dam is charged Rs.1.70 for 10 KL (Kilolitre) and Canal is charged Rs.6.60 for 10KL.

2. For Non-Domestic group consumers water from Dam is charged Rs.38 for 10 KL (Kilolitre) and Canal is charged Rs.95 for 10KL.

Projected Rate for upcoming year is as follows-

Consumers	Dam	Canal
Domestic	Rs.2.10	Rs.4.20 for 10 KL
Non-Domestic	Rs. 32	Rs.64 for 10 KL

5.7. Situational analysis of Water Supply System

Purified water supply to Pune city is in existence since year 1750. The first scheme was based on the Katraj tank of Ambil Odha. The Swargate Water Works came into existence in the year 1873. Water from Mutha Right Bank Canal was channeled to Swargate, treated and supplied to the city. After Pune gained the status of Municipal Corporation in year 1950, a project of 45 MLD was developed on the Mutha Right Bank Canal, for supply to the city and the cantonment. Another scheme, with 110 MLD capacity in the year 1975, was constructed at Parvati in the year 1968. It was augmented to 270 MLD capacities and further expanded to its present capacity of 470 MLD in two more stages in 1980 and 1990. The capacity of the Pune cantonment water works, which was earlier governed by Maharashtra Jeevan Pradhikaran(MJP), was later handed over to PMC, and augmented from 173 MLD to 273 MLD.

The service levels with regard to water supply are fairly good in Pune with a gross supply of over 260 lpcd and a net supply of 182 lpcd (accounts for 30 per cent distribution loss); this is well above the desired norm. In most cities, the supply level is in the range of 100-140 lpcd. Road length covered by the distribution network is 68percent, which implies almost 100 percent coverage of the developed areas including slums. The newly added areas are currently being catered to by tankers. The elevated storage capacity is 22 percent, which is lower than the desired norm; hence the reservoirs have to be filled more than three times a day.

5.7.1. Clear Water Transmission

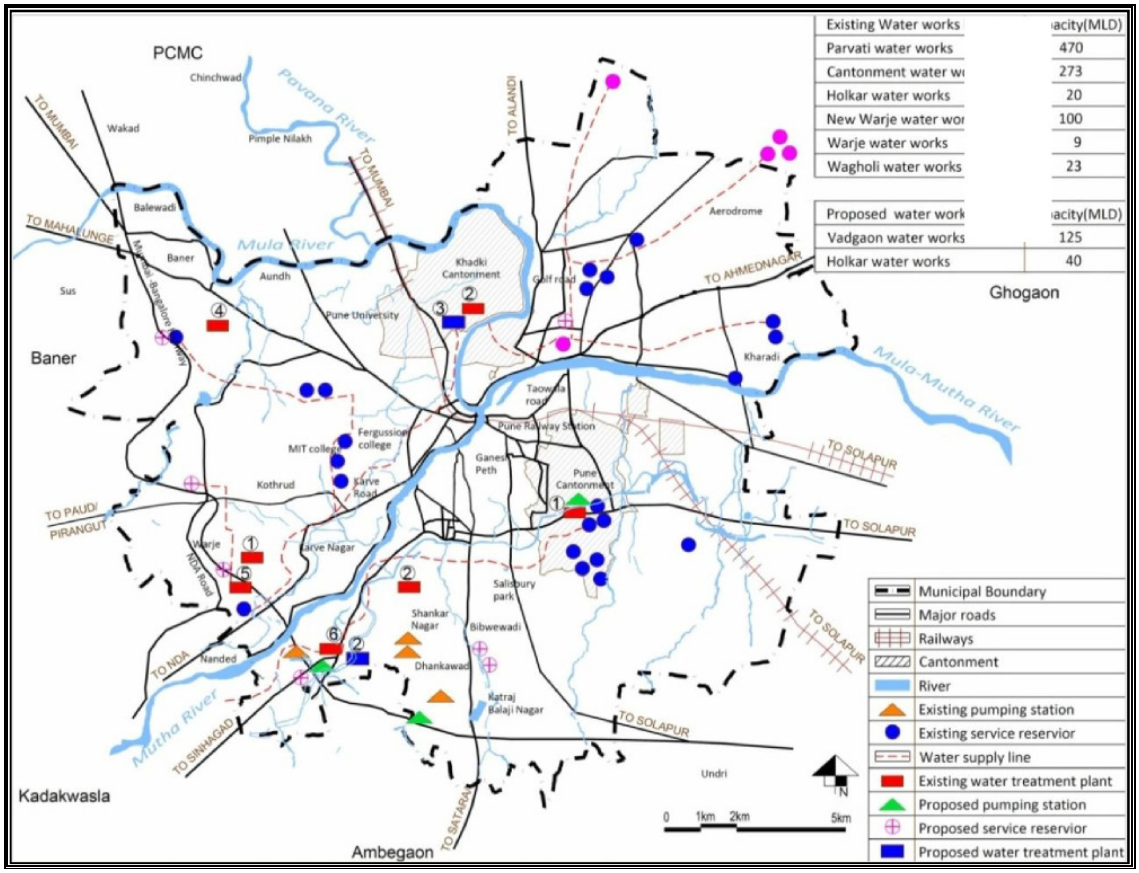
The entire water supply operation of PMC is divided into 48 zones; each zone has a specified area of service. The conveyance of water from the two principal water works is done by both pumping and gravity, depending upon available levels at the zonal reservoirs.

- **Distribution**

There are 39 reservoirs in the Pune city, fed by two principal water supply sources of these, 11 reservoirs (sumps) with a storage capacity of 42.96 ML, function as balancing storages. The remaining 28 reservoirs, with a storage capacity of 177.96 ML, act as service reservoirs.

- **Water Distribution Network**

The distribution network consists of pipelines, sizes varying from the smallest diameter of 80 mm to the largest diameter of 1600 mm. Total length of the network is 647.18 km. This apparently does not include all the tertiary pipelines. The total length of distribution is indicated to be about 2474 km including 24 km of transmission lines. The total length of the roads in the Pune city is 1750 km. This implies that some roads may have more than one pipeline, laid at different points of time to meet the demand.



Map No.5.1.Existing and Proposed Water Supply Distribution System - PMC

(Source: PMC office)

Table No. 5.33: Water Supply network in the Pune City

Description	Quantity
No. of Distribution Zones	48
Total Length of pipelines	2474Km
No. of Water Treatment Plants	10
No. of Pumping Stations	20
No.of Chlorinators	24
No. of (Gravity Storage reservoir) GSR & (Elevated Service Reservoir)ESR	47

5.8. Water supply Service Delivery and Service Level Benchmark

The population of Pune City is about 39.33 lakh which is supplied with 1123MLD of water on daily basis the details of which are as follows-

Table No. 5.34: Water Distribution Facts

Description	Quantity
Total Water Supplied	1123MLD
Total water supplied to (city +villages+PCB+KCB)	786MLD
Bulk water to Gram panchayat + Ammunition Factory	24MLD
Water Supply to city +PCB+KCB	762MLD
Water Supply to PCB+KCB	30MLD
Net Water Supply to City	732MLD

Table No. 5.35: Coverage of Water Supply Connections

Description	Number	percentage
Households served through water connections	937938	94.19
Total Household without connections	57793	5.81
Commercial Water connections	14000	
• Households served through tanker	6900	0.69

• Households in undeclared slums without water connections	24153	2.43
• Households to declared slums without water connections	26740	2.68

The present coverage of water supply connections in the city is 94.105 percent (as against 100 percent) as per Service Level Benchmark standards. This indicates that 5.81 percent of total household in the Pune city does not have access to water supply connections

- **Per capita supply of water**

The per capita water supply in the Pune city is 194lpcd.This shows that per capita water supply in the Pune city is more than the SLB indicators of 135lpcd.

5.9. Extent of metering of water connections

The Table No.5.36. reflects that the extent of water metering is very low (29.71percent) as compared to the Service Level Benchmark (SLB) indicator of 100percent.This indicates the need to improvise the water metering in the Pune city.

Table No. 5.36: Extent of metering of water connections

Description	Number of Connections	percentage
Total number of direct service connections (Unmetered Connections)	122643	70.29
Total number of metered connections	37000	29.71
a. Total number of functional metered connections	36564	
b. Number of metered public stand posts	436	

(Source: PMC office)

5.10. Extent of Non Revenue Water (NRW)

The population of Pune city is 39.33lakh which is supplied with 1123MLD of water on a daily basis. Considering a 25 percent distribution loss, 5 percent purification process, the quantity of water available for total population is 786MLD including villages & Cantonment.

5.11. Water Charges

Water charges for Domestic use were introduced from April, 2000. These user charges were linked with the Property and according to the property type water tax was collected. Previously, due to faulty metering there were problems like non-working of meter and preparation of faulty bills, thereby, water charges were collected on the basis of some fixed rate, based on quota system of property, without considering the property type and actual number of users in that particular property. Presently, the water charges are more dependent on the property, thus, based on the property type the usage of the water vary, hence, the water charges are linked with the Property tax, this reform has raised the collection efficiency of PMC for water charges to 90.93 percent making it more than the service level bench mark of 90 percent. Details of water charges in PMC are tabulated below:

Table 5.37: Water Charges in PMC

Domestic Property Taxable Amount (Rs)	Water Charges (Rs)
1-1000	900
1001-3000	1000
3001-5000	1100
5001 onward	25 percent or 2500 whichever is minimum

(Source: http://www.indiaurbanportal.in/bestpractices/bestpractices42/bestpractices420.pdf)

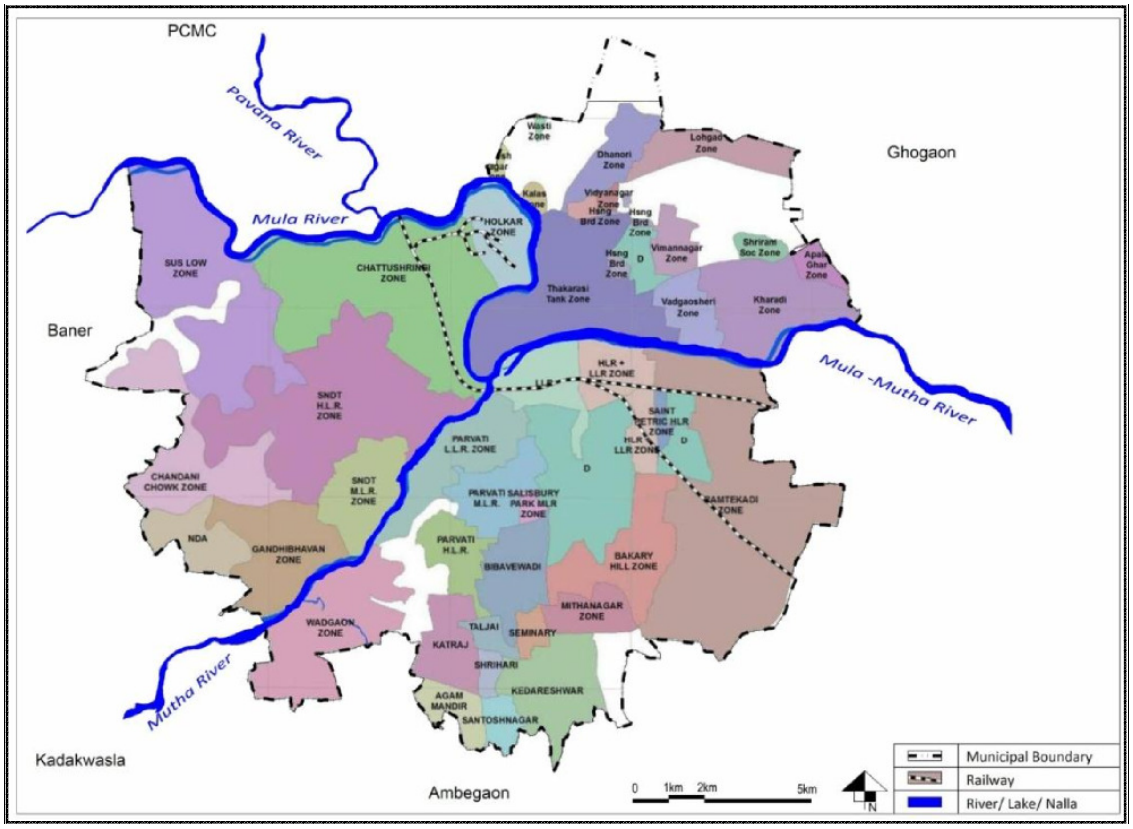
5.12. Continuity of water supply

On an average, Pune city receives water for about 4-5 hours a day. But there are many areas in the Pune city which receive 24 hours of water supply. Also, the average rate of water supply at the consumer end is 194 lpcd.

5.13. Quality of Water Supplied in Pune city

The water extracted from the surface and subsurface sources like intake wells, infiltration wells and bore wells is treated in the Water Treatment Plants (WTPs). At treatment plant, the raw water is made potable up to the standards of safe drinking water by pre chlorination,

primary treatment and filtration. Quality control is assured through laboratory testing at the WTPs.



Map.No.5.2:WaterSupplyDistributionZones

(Source: Water Supply Sewerage Department Pune)

Presently, there are 9 Water Treatment Plants under Pune Municipal Corporation (PMC). Table below shows the status of water treatment plants, areas and population served by treatment plants, method of treatment and their current installed treatment capacity. The current treatment capacity available in PMC is 1,318 MLD and water purified in these plants is 1,123 MLD.

Table No.5.38 Water Treatment Plants in Pune City

Name of Water Treatment Plant (WTP)	Installed Capacity (MLD)	Areas Served	Population	Treatment Method	Current Treatment (MLD)	Quantity required MLD (@210 lpcd)
Parvati	537	Old town,Satara road, SahakarNagar,Swargate, Taljai,Indiranagar,SNDT ,Chatushringi	1234000	Conventional	460	259.14
Cantonment All	380	Cantt., Solapur road, Kondhva, Kharadi, Thackercy hill,Wa nowri	882000	Conventional	380	185.22
Vadgaon	125	Vadgaon, Katraj, Balajinagar,Kedareshwar , Aagam Mandir	405000	Conventional	84	85.05
Warje Warje Augmentation	100 86	Warje, Kothrud, Gandhibhavan, Chandni chowk, Sus, Pashan, Baner, Balewadi	404000	Conventional	94 75	84.84
Holkar Old	20	Vidyanagar,Tingrenagar, Vimannagar,Dhanori, Kalas,Maske vasti, Lohgaon	190000	Conventional	14	39.9
Holkar New	20				14	
New Holkar Completion	20			Non - Conventional (tube Shelter)	19	0
wagholi	30		13Villages Scheme		23	
	1318				**1,123**	**654**

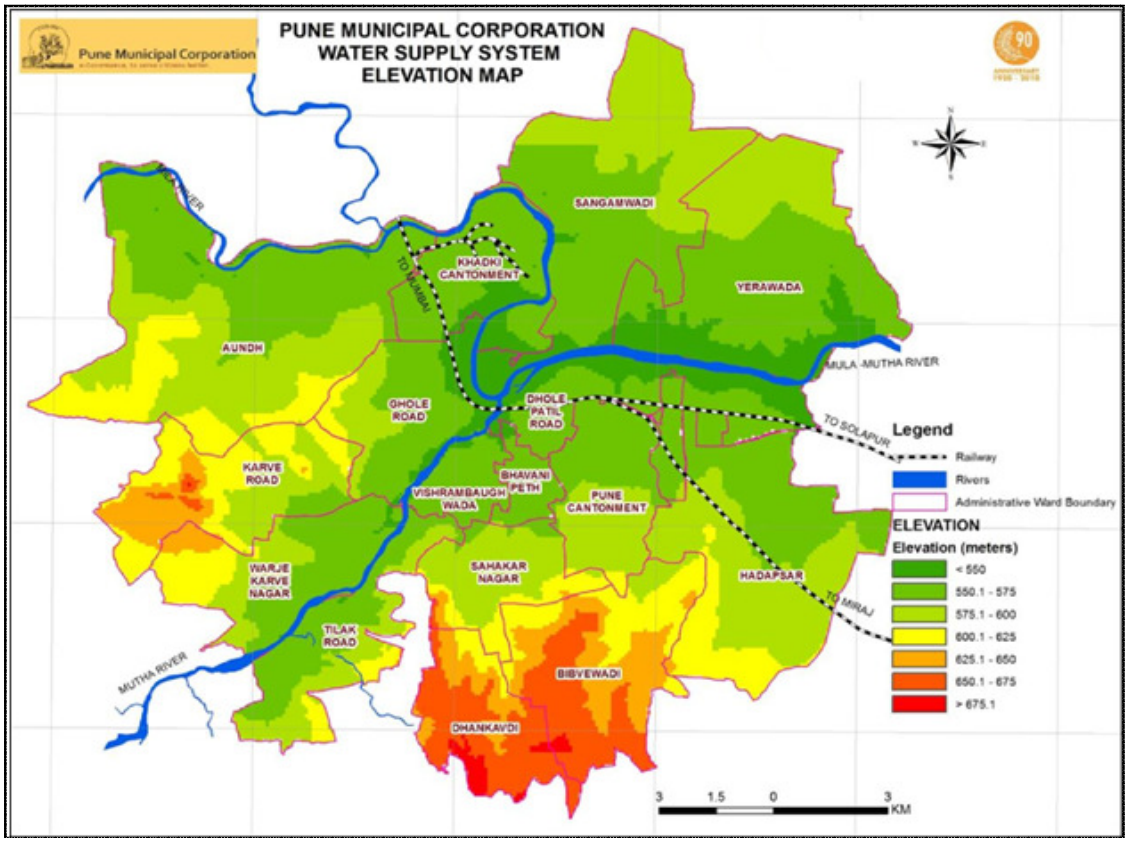
(Source: Water supply and sewerage Department, PMC)

The Table No. 5.38 also indicates that all the 9 treatment plants have adequate capacity required for the population that is being served by each of the treatment plants, considering average water supply of 210 lpcd. Hence, in the existing scenario there is no need of enhancing the water treatment Capacity of any of the 9 treatment plants, however, Parvati treatment plant and Cantonment treatment plant being older than 40 years and 120 years respectively need to be refurbished.

In Pune city, water supply distribution system has been divided into 48 zones on the basis of reservoirs and topography. Each zone has its specified service area. Presently, there are 58 storage reservoirs in the city having a total capacity of 463 ML that is 41 percent of the total

water supply which is on the higher side as per normative standard of 33 percent of total water supply that is approximately 374 ML.

The treated water is then transmitted from Water Works to Water Distribution Zones (48) as given in the map below, located in different parts of the city via 24 km transmission pipelines. At water distribution stations, the water is further treated through chlorination and chlorinated water is supplied to the consumers. The treated water is distributed from various Water Distribution Stations via distribution pipelines during supply hours.



Map No. 5.3: Elevation Map of Pune City (Source: Water Supply and Sewerage Department)

here is an issue of inequitable water supply throughout the city since the city has undulating topography as depicted in the map. The study of the map below clarifies that the in areas towards the southern part of the city especially Sahkar Nagar, Dhankwadi, Bibvewadi, Balaji Nagar and katraj, water has to be pumped because of higher elevation, varying from 600 m to 700 m. Despite water being supplied to the higher elevated areas through mechanical pumping the supply continuity is less which varies from 4-6 hours per day. Water supply in the areas located at lower elevations such as Dholepatil road, Bhawani Peth, ghole Road is distributed through gravity and the continuity of water supply is as much as 20 hours per day. Water is

supplied through a network of pipes consisting of different diameters. The lowest diameter size of pipe is 80 mm and highest diameter is 1600mm.

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Table No. 5.39: Water Sample

Description	Numbers per month
Total Number of sample tested	3689
Total number of samples that meet the specified potable water standards	3689
Total number of samples that do not meet the specific potable water standards	0

The above Table No.5.39 reflects that all water samples tested meet the specified potable standards.

5.14. Operation and Maintenance

The operation and maintenance of the source, pumping stations and water treatment plants as well as distribution system in the old PMC limits, is executed by the staff of PMC. The operation of valves in the distribution system in the fringe area is, however, outsourced to contractors. PMC employs about 1,650 persons for the O & M of the water supply system.

Complaints are registered on phone, by letter or visits in person to the ward offices or the offices of the Deputy City Engineers. The complaints are handed over to the concerned junior engineers in charge of the area, next day morning. The compliance and redressal of the complaints or report on action/repairs required to address the grievances are usually taken within 24 hours.

Table No. 5.40: Efficiency in redressal of customer complaints

Description	Complaints per Month
Total number of water supply related complaints received *	2741
Total number of water supply related complaints resolved in 24 hours	2696
Efficiency in redressal of complaints(in percent)	98.36 percent

* As per complaint register maintained by the water supply department, Pune Municipal Corporation

5.14.1. Cost Recovery in Water Supply Services

Table No. 5.41: Cost recovery in water supply services

Description	Number
Total amount operating expenses(As per budget reconciliation done for the year 2009-10 in crores)	176.41
Total revenue generated through property tax and water meters dept(in crores)	124.68
Cost recovery in water supply services(In percentage)	70.67

The above Table No. 5.41 reflects the cost recovery in water supply services of PMC which is 70.6 as compared to 100 percent in SLB.

5.14.2 Service Levels

The service levels with regard to water supply are fairly good in Pune (a gross supply of over 260 lpcd and a net supply of 194 lpcd accounts for 30 per cent distribution loss).This is well above the desired norm. In most cities, the supply level is in the range of 100-140 lpcd. In terms of coverage, about 85–88 percent of the population has access to the piped water supply system. The areas, which are not covered, are the fringe areas like Kharadi, Kondhwa, Bavdhan and other far-flung areas.

The present supply of 1123 MLD covers an estimated 39 lakhs population (86.67 percent of total population). A substantial portion of this, however, is lost due to leakage, pilferage and wastage through uncontrolled public stand posts. The loss may be in the range of 30-35 percent. The water reaching the consumer thus may be 184 to 194 lpcd. This average rate also includes the water used for non-domestic purpose by the institutions, commercial establishments and small, dispersed household industrial activity. Additionally, in uncovered and fringe areas, PMC supplies water through tankers. The gross supply to 100percent population works out to be around 261 lpcd and net supply around 194 lpcd.

In terms of service levels, per capita supply is fairly well above the desired norm. The distribution network coverage is about 70percent, indicating that in certain areas or added areas, the distribution network needs to be extension. The desired norm for storage capacity is

about 33 percent hence, additional storage capacity is required for equitable distribution of water. Road length covered by the distribution network is about 68 percent; however the current coverage is 100 percent of the developed areas. Few of the added areas are currently being catered through tanker supply. The elevated storage capacity is at 22 percent, which is lower than the desired norm of 33 percent; hence the reservoirs have to be refilled more than three times in a day.

Water is supplied twice a day. The duration varies from 3 to 4 hours, both in the morning and evening. Except for high level areas in the city and in fringe areas, pressures are reasonably high. With regard to water quality, raw water and treated water are tested regularly at the laboratory installed in Parvati Water Works. Samples are collected from the consumer taps. Daily, about 54 samples are examined for residual chlorine and MPN count.

Part-III Testing of Hypotheses

The method of testing the hypotheses has been described in Para 4.9 earlier. As explained there, many of the statistical tools used for generalization cannot be used in this study to test the hypotheses. If the replies of a majority of the respondents support a hypothesis, that hypothesis will be considered as confirmed. Otherwise, it will be considered as rejected. The data connected with the hypothesis and obtained from respondents has been used for this purpose. Conclusions of earlier studies made elsewhere may also be used to supplement the hypotheses of the study.

The following hypotheses have been tested based on the available data:

1. Inadequate infrastructure facility in water supply department of PMC.
2. There is a discrepancy in the water supply, as far as water requirement is concerned.
3. Different punishment & reward system will enhance the water supply system effectively & economically.

5.15.1. Hypotheses Testing 1(Qualitative Hypothesis)

The first hypothesis of study is as follows "**Inadequate infrastructure facility in water supply department of PMC"**

To test this hypothesis, on-site observations and interviews were conducted with higher authorities of Water Supply Department and basic facts are recorded in the tabular form. The interviews and observations focused on understanding various infrastructure facilities available in the department. All the questions are analyzed and results are discussed below.

- **Information System**

Availability of infrastructure facilities required for the maintenance of Information System. Out of six different systems like Billing system, Hydraulic Network Simulation Software, Geographical Information System, Cadastral register for system assets, Registers for repairs, defects, Rehabilitation works, Real time measurement & supervision System (SCADA) are required only for maintaining information only, Cadastral register for system assets and registers for repairs, defects, rehabilitation works exist, as per complaint registered and maintained by department and also WEB based complaint monitoring system for redressal of complaints presently in operation(Table No. 5.40). All complaints related to water supply are attended. Registers for repairs, defects, rehabilitation works exist and remaining four systems are not in existence.

This shows that as far as information system is concerned 67 percent systems (2 information systems are exist out of 6) are not in water supply department.

- **Regarding to avoid water leakages, water losses and improving efficiency of water management**

In relevance to availability of infrastructure facilities required for avoiding water leakages, water losses and improving efficiency of water supply management responses were based on following factors-

- No pressure measurement system is available.
- Absence of infrastructure facilities for network maintenance & leak detection equipment (Listening microphone, Sonic devices etc.) is not available to prevent water losses.

  or
- No prevention network inspection.
- Lack of disciplinary measures against illegal connections.
- Supply flow meters are not deployed to measure the flow and also only 29.71 percent service connections are metered.

  For supportive data (Refer Table No. 5.36)

It shows that the infrastructure does not facilitate efficient utilization of water. Hence, National water policy not in actual force.

- **Water Loss Accounting**

Lack of availability of water supply audit and accounting systems for calculation of loss of water.

The above discussion proves the inadequacy of infrastructure facilities in Water Supply Department. The parameter discussed about suffers minimum criteria for the assessment of infrastructure facilities of the water supply department. Hence, we can conclude the inadequacy of infrastructure facilities in the department and hence the hypotheses theoretically proved that is to be **accepted.**

5.15.2. Hypotheses Testing 2

The hypothesis of the study is **"There is a discrepancy in the water supply as far as water requirement is concerned".**

H0 Null Hypotheses : There is no discrepancy in the water supply as far as water requirement is concerned.

H1 Alternate Hypotheses: There is a discrepancy in the water supply as far as water requirement is concerned.

This hypothesis has been tested for the additional requirement of water in all wards of Pune city by using Chi-square test. In Pune city, 14 wards are there. In every ward, discrepancy in water supply is observed in the following table

Ward	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Yes	37	42	43	40	45	40	32	59	29	50	38	45	36	26	562
No	37	44	22	24	23	25	62	13	56	19	30	19	39	40	453
Total	74	86	65	64	68	65	94	72	85	69	68	64	75	66	1015

Calculation of Chi-Square value-

An estimate of the combined proportion of the Yes and under the assumption that the null hypothesis is true:

p1= 37+42+43+40+45+40+32+59+29+50+38+45+36+26

= 562

p2 =74+86+65+64+68+65+94+72+85+69+68+64+75+66

=1015

p = p1/p2

= 0.553

q = 1-p

= 1-0.553

= 0.447

oi	**ei**	**(oi-ei)**	**(oi-ei)^2**	**(oi-ei)^2/ei**
37	40.922	-3.922	15.38208	0.375887884
42	47.558	-5.558	30.89136	0.649551369
43	35.945	7.055	49.77303	1.384699541
40	35.392	4.608	21.23366	0.5999566
45	37.604	7.396	54.70082	1.454654186
40	35.945	4.055	16.44303	0.457449576
32	51.982	-19.982	399.2803	7.681126621
59	39.816	19.184	368.0259	9.243164959
29	47.005	-18.005	324.18	6.896713647
50	38.157	11.843	140.2566	3.675777682
38	37.604	0.396	0.156816	0.004170195
45	35.392	9.608	92.31366	2.608320072
36	41.475	-5.475	29.97563	0.722739602
26	36.498	-10.498	110.208	3.019562825
37	33.078	3.922	15.38208	0.465025
44	38.442	5.558	30.89136	0.803584

22	29.055	-7.055	49.77303	1.713062
24	28.608	-4.608	21.23366	0.742228
23	30.396	-7.396	54.70082	1.799606
25	29.055	-4.055	16.44303	0.565928
62	42.018	19.982	399.2803	9.502602
13	32.184	-19.184	368.0259	11.43506
56	37.995	18.005	324.18	8.532176
19	30.843	-11.843	140.2566	4.547439
30	30.396	-0.396	0.156816	0.005159
19	28.608	-9.608	92.31366	3.226848
39	33.525	5.475	29.97563	0.894128
40	29.502	10.498	110.208	3.735611
				$\sum\chi^2$= 86.74223

$$\chi^2 = \sum \frac{(\text{Observed Value} - \text{Expected Value})^2}{(\text{Expected Value})}$$

χ^2= 86.74223

Calculation of Degree of Freedom-

- Chi-Square Value = 86.74223
- Degree of Freedom = (c-1)*(r-1) = (2-1)*(14-1) = 13
- Table value at 13 Degree of Freedom is 36.22 at the 5% level of significance

Conclusion-

Calculated value of Chi-square for 13 degree of freedom at 5% level of significance is 86.76223 which is much greater than the table value 22.362.Hence the null hypothesis of the study stands for reject therefore, there is no discrepancy in the water supply as far as water requirement is concerned and hence alternative is accepted which means there is a discrepancy in the water supply as far as water requirement is concerned is **accepted.**

5.15.3. Hypotheses Testing 3

The hypothesis for the study is **"Different punishment & reward system will enhance the water supply system effectively & economically**"

This hypotheses is based on responses gathered from the citizens about the punishment and reward system will help to enhance the water supply effectively and economically. The responses of the respondents were collected with the help of structured questionnaire and different scale.

Following Table No.5.42 gives the details of responses about this problem.

Reponses were taken on a 5 point Likert Scales (Highly Disagree – 1; Disagree – 2; Neutral – 3; Agree – 4; Highly Agree -5).

Table No. 5.42: Different punishment & reward system will enhance water supply system

Sr.No.	Different punishment & reward system will enhance water supply system	No. of Respondent	percent	Avg. Scale
1	Highly Agree	279	27.49	4
2	Agree	555	54.68	
3	Neutral	96	9.46	
4	Disagree	75	7.39	
5	Highly Disagree	10	0.99	
Total		1015	100.00	

The percent and average scale of responses were calculated by using the ratings. It is clear that 54.68% citizens agreed that the punishment and reward system will enhance the water supply system effectively & economically.

Also the calculated value of average point rating scale is 4 which represents the majority of the citizens are agreed about the enhancement of water supply by using punishment and reward system. Therefore, it is to be concluded that, the hypotheses which is stated in the present study is **positively accepted.**

CHAPTER 6
DESIGN AND DEVELOPMENT OF GEOGRAHICAL INFORMATION SYSTEM (GIS) BASED WATER SUPPLY MODEL

6.1. Introduction

The researcher has collected data from sample 1015 citizens, of Pune city, from 14 ward offices (Includes 144 wards) and 25 PMC employees which includes Water distribution department officers, Engineers and workers of Pune Municipal Corporation of water supply and distribution department. The data has been collected through exhaustive questionnaire and it is presented in tabular and a graphical form also appropriate statistical tool has been used to process the data. The interpretation has been written by using the statistical figure which helps to reveal the final conclusion.

It is found that, city is growing very rapidly. The water is required for the cooking, washing, bathing and drinking etc. Demand of drinking water is continually increasing due to various factors. Water supply distribution is unequal in the metropolitan region. The far flung and newly added areas are not covered under the water distribution system. In some wards, water supply pressure is very low. Unequal distribution of drinking water in terms of quality and quantity leads to water stress. To analyze the existing level of service and management and try to fill the gaps by different alternative solution and to evolve solutions for the present water supply problems in a Geographical Information System (GIS) framework and EPANET Water hydraulic Model.

The fundamental objective of an urban water service is to supply adequate and safe wholesome water efficiently and effectively at an affordable price so that the citizens are released from the drudgery of seeking their daily water. Water service providers do not meet this basic objective due to an intermittent water supply, which is a piped water supply system that delivers water to its users for less than 2 hours in a day. 24×7 Water supply continuous, pressurized water supply overcomes shortcomings of intermittent supply and ensures customer convenience and benefits the people.

Stages for developing Water Hydraulic Model

Achieving continuous water supply is culmination of combined efforts of various strategies adopted for improving the water supply. Satellite image was procured and the entire city was

digitized. The map showing road network, house properties (with house ID number) etc. was prepared in AutoCAD drawing which was then used as backdrop of the hydraulic model. City Development Plan (CDP) was obtained from the Municipal Council. Water distribution network was plotted on CDP in AutoCAD which was then superimposed on the digitized map. Population was forecasted by the density method.

Each Operational Zone (OZ) is further sub-divided into 3 to 4 District Metering Area (DMA) so that each DMA contained not more than 1000 connections. Thus demand at nearest node was computed which was then compared with the earlier population figure computed by the density method. Distribution network has been simulated using latest EPANET software and hydraulic model was prepared. The data was validated and the pipe network was calibrated.

Modelling of the transformation of intermittent to 24×7 water systems is a critical part of designing for successful operations of OZ and DMAs so that the distribution system serves the community reliably, safely and efficiently 24 hours in a day. The hydraulic model gives commanding knowledge of the water infrastructure, and helps to take informed decisions. Modelling is defined as a mathematical description of a real-world system. System maps help in understanding the water distribution networks. These maps illustrate wide range of system characteristics such as pipeline alignment, elevations of nodes, location of tanks, reservoirs and valves etc. A vast data, describing real-world network system, is collected before building a model.

Water transmission pipelines were then skeletonised, marked and the positions of water treatment plants, master balancing tanks and the elevated service reservoirs and the entire distribution system in the city were plotted on the AutoCAD drawing. This drawing was then converted to the Drawing Exchange Format (DXF) format and was used as a backdrop of the EPANET scaled drawings. While making hydraulic model, various components of the network such as reservoir, tanks, pipelines and valves etc. are required to be simulated. The term simulation refers to the process of imitating the behavior of one system through functions of another. In the present approach, the term simulation represents the behaviour of the real system (model) mathematically. This study involves modeling and the various possibilities of demarcating the operation zones and DMAs. Infrastructure of entire city water supply including those of all pipelines and the valves are plotted on the backdrop drawing. Then the network is calibrated with respect to field information. Demarcating the operation zones have been carried out with respect to anticipated consumer behaviour and storage capacities.

In the course of the study, firstly the researcher has reviewed articles which are based on GIS based Water Management Utilities in India and summarize importance of such utilites.It occurred to the researcher to develop and design GIS Water Hydraulic Model for the reducing water losses, equality of water supply at all places. A conscious attempt was therefore made to construct such a model. The researcher therefore developed a **"GIS based Water Hydraulic Model"** by considering all the positive aspects of Information Technology. It is therefore presented in the following paragraph.

6.2. Study about Management of Geographical Information System based Water Supply System in India

The primary data is collected by the researcher in respect of 1015 citizens from 14 ward offices of Pune city about awareness of GIS based System. Researcher has focused on various GIS based Water Management Utility in India and found out advantages and benefits of such type of system for better Management of Water Supply. An analysis is carried out under three broad headings as follows:

1. Awareness of GIS based Water Supply System.
2. Reviews on GIS based Water Management System in India
3. Water supply Schemes in India-24X7

6.2.1. Awareness of GIS based Water Supply System

An attempt to meet objective of the study "To study the GIS technology being used in management of water supply department in India", the primary data is collected from the respondents to find out awareness of GIS based Water Supply System.

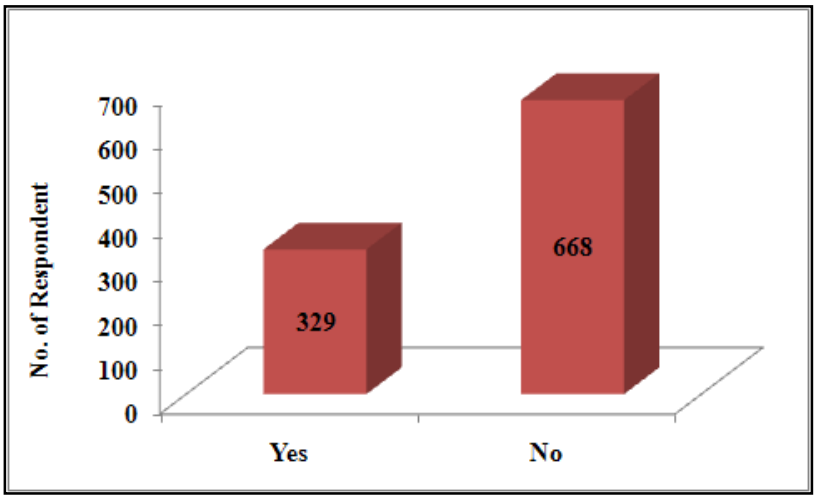
Table No. 6.1 shows the distribution of the respondents according to their awareness of GIS based Water Supply system. It is seen that 32.41 percent of the Pune citizens are aware and 67.59 percent are not aware about GIS based Water Supply system. It is seen that very few citizens aware about the new technology of GIS based Water Supply System.

Table No. 6.1 : Awareness of GIS based Water Supply System

Awareness of GIS based Water Supply System	No. of Respondents
Yes	329 (32.41)
No	686 (67.59)
Total	1015 (100)

Figures in bracket indicates percentage

Graph 6.1 : Awareness of GIS based Water Supply System



6.2.2. Reviews on GIS based Water Management System in India

Based on primary data, it is seen that most of the citizens of Pune are not aware about GIS based Water Supply System. So the researcher has focused on various GIS based Water Management Utility in India and found out advantages and benefits of such type of system for better Management of Water Supply. For that, researcher has reviewed articles in various places in India as discussed below and also reviewed a live case study on GIS based Water Management Utility in Bangalore.

6.2.2.1. Computerized Mapping, GIS Development and Utilities Computerization for Bangalore Water Supply & Sewerage Board (BWSSB), Bangalore, India [13]

The main objective of the project is to develop GIS that helps BWSSB in the planning, monitoring and development of the various functions / projects of water distribution, and also helps in the decision making process at various levels.

The Bangalore water supply and sewerage systems have grown extremely during the last 4 decades. In order to handle such a large system with large volumes of geographically related information, it was imperative to develop and give decision makers a powerful management and decision making tool. The aim of the BWSSB GIS project consisted of setting up a Geographical Information System for Water Supply and Sewerage Systems using geographical and numerical data.

The software, which integrates most of the data used by BMP(Banglore Mahanagar Palika) and caters to all the departments and different users, starts from the Commissioner to the ward officer, by department wise as well as administrative jurisdiction wise (city level, zonal level, range level, ward level etc). And also the software must have the option/utility for scaling to

accommodate more data, more departments and users and also the updating facility both spatial and attribute data.

The software also has the facility of login with password for various users and departments, so that the data can be restricted to the department wise and user wise. The updating facility also protected so that all the users cannot have access to the modification of data. The software can be built with two major modules, one is viewer module and other one is editing module. So all the user departments can access that viewer module and also from the city level to the ward level data depend on the type of user (like the Commissioner, Deputy Commissioner to the ward level officer etc).This system has many useful features for quick identification of location from the digital map. It is useful for better appreciation of the problem, as a holistic view of the network area is available.

The development of GIS for BWSSB will make a lot of difference in planning and monitoring of properties of various public, private agencies and the citizen. Accurately geo referenced data will be the biggest asset for planners and urban developers. It can be shared among different agencies to avoid duplication of data and uniformity in data can be made available. This project envisions a future where GIS is recognized, as an integral and indispensable information system for government and business, serving the integrated information needs of the citizens.

The detailed Development Phases of Bangalore Water Supply & Sewerage Board (BWSSB) refer **Annexure 7.**

6.2.2.2. GIS Based Monitoring System for Urban Water Supply System

In this article, the author has suggested monitoring system at city level. He has discussed the role of GIS and IT in the monitoring system integrated with planning and management of development of the city. Today, there is need for more detailed information that can be used to improve planning, especially to consider water flow rates, the location of demands and the quality and quantity of supplies. Inadequate budget becomes the main hurdle for smooth operation of urban water systems. Instead of continuing supply side management, more attention is required for water resources management and water demand management. For that study, researcher has taken Ghaziabad City. She has done the survey on existing water monitoring system. She found some generic issues with regard to the existing water supply situation at city level. For Details **refer Annexure 8**

Design and Application of Monitoring System for Ghaziabad's Water Supply System. Monitoring System (MS) for water supply system constitutes Population System, Land System, Water System, Finance System, Decision Making System and Decision

Implementation System. These can further be broken into smaller sub-systems which can be represented in the spread sheet. The sub-systems are described through the indicators and maps. The MS has been designed to assess functioning, performance, capacity, stress and responses. Sets of indicators have been tabulated for the water supply system of Ghaziabad City. The database generated and processed is structured in the City Monitor – Display Panels. The MS has been applied for management of water supply system with Water Resource Management, Demand Side Management and Supply Side Management. The GIS, MIS, DT are used as tools at appropriate stages to define input-processing-output for the descriptive, Diagnostic and Predictive Monitoring System. The modelling of data (population, area and supply in MLD) has been done on sample basis. Data modelling has been performed to establish the benchmarks and fluctuating line (maximum, minimum) of water supply rate (lpcd) for socio-economic groups at city level. This has been projected and used for establishing qualitative and quantitative aspects of water supply system. It is concluded that the proposed monitoring system will make efficient use of water resources and conserve for future use. It will improve the quality of service. It will help in better land use planning and urban development. It will help in pinpointing the root cause of any urban development problem. It will increase awareness among city residents and induce them to participate in better city management. It empowers the city managers to comprehend early responses for taking appropriate actions in managing the development as desired or visualized. It will enhance the existing monitoring system and integrate to develop into a powerful tool a city level.

6.2.2.3. Sewerage and Water Supply Systems Design for a city with large floating Population (Haridwar, India) using GIS.

In this article, the author has discussed the methodology of planning, design and project new pipes in water and sewer network. The infrastructure of a city, mainly the water supply and sewerage system are vital for the urbanization. The existing infrastructure is studied using the GIS tool ARCGIS, this helped in the demand estimation from the land use information which is collected and stored in the Geographic Information System (GIS). In order to get these demands, a topology operation has been made by GIS. The future demand is forecasted depending upon the Demography and land use of the study area (Haridwar, India). The programming tool EPANET is used for the hydraulic analysis of the water pipe network. However, most of the existing algorithm needs a demand at nodes and existing physical dimensions of the network to perform the calculation. This data is imported from the ARCGIS tool which is stored in the Geographical Information System;

through this the problem of sizing has been studied. This helps in completing the problem of creating new pipes for existing and future connections. The scope of the work is limited to the development of model for Water and sewer network for the City with large floating population (Haridwar).It is gathered in three main groups depending on its origin and its later usage. These groups are, basically, infrastructure information, customers' information and geographical information about both infrastructure and customers.

For the Hydraulic analysis, EPANET computer programme is used for network analysis. The Hydraulic analysis is carried for one of the zone of Haridwar using EPANET. The zone 'A 'Bhopatwala is taken for the analysis. The solution for heads and flows at a particular point in time involves solving simultaneously the conservation of flow equation for each junction and the Head loss relationship across each link in the network.

This process, known as "hydraulically balancing" the network, requires using an iterative technique to solve the nonlinear equations involved. EPANET employs the "Gradient Algorithm" for this purpose.

A network is drawn representing the Bhopatwala Zone 'A' by taking the data from the Base map prepared by ARCGIS into the EPANET.

In EPANET models, a water distribution system as a collection of links connected to nodes. The links represent pipes, pumps, and control valves. The nodes represent junctions, tanks, and reservoirs.

The ARCGIS tool of GIS is utilized to collect the information and store. In this methodology, existing infrastructure and cartographic data has been combined in GIS platform to drive for efficient analysis of water supply and sewerage network. It can further facilitate future demand estimation and network designing. The integrated programming tool kit EPANET for hydraulic calculation has proved as an efficient tool for analysis and designing of water supply systems. The topology operation made by ARCGIS has further simplified the traditional way of pipe sizing operations.

The detailed GIS based Sewerage and Water Supply Systems Design for a city with large floating Population (Haridwar, India) using GIS **Annexure 9**

6.2.2.4. **Sustainable drinking water management strategy using GIS: Case study of Allahabad City (India)**

In this article, the author has suggested to develop a methodology for sustainable drinking water management by assessing the existing state of the water supply system in the study area (Allahabad, India). An attempt is made to identify various problems and gaps in the existing system and evolve solutions for the present water supply problems in a GIS framework.

Finally, the paper proposes a conceptual framework for sustainable drinking water management.

The study was conducted in four stages. The first stage involved collection of data and background information through various primary and secondary sources including reports and publications of various organizations. This was followed by discussions with various officials of Uttar Pradesh (UP) Jal Nigam (Water Corporation), Jal Sansthan (Water Board), State Ground Water Board, Central Ground Water Board and Municipal Corporation of the city. The second stage involved field studies in a few zones of the city. The third stage involved data input and analysis on a GIS platform, and the fourth stage includes the development of a solution of the present problems and proposing a conceptual framework for ensuring sustainable drinking water management for Allahabad City.

ArcInfo 9.1 has been used as a tool for storing all types of relevant data for analysis and decision making. The various thematic maps include water supply zone map, water deficit localities map, land use map, location of tube wells, overhead tanks, zonal pumping station, ward boundaries, population map, water demand and supply map. The paper assesses the problems in the existing water supply system in Allahabad and proposes to give a GIS-based solution strategy for its sustainability. The proposed GIS-based conceptual framework would improve the current practice of drinking water management and would reduce the present problem of water crisis. The findings of the study would be useful for cities with similar problems in underdeveloped and developing countries.

6.2.3. Water Supply Systems in India-24X 7

6.2.3.1. Amravati Water Supply Scheme-24X 7

Amravati city is located on longitude 77.45 & latitude 20.56. Amravati Municipal Corporation comprises of Amravati City, Badnera Municipality & adjoining 16 villages. The present scheme is designed for 95 MLD for 1st Stage & 156 MLD for 2nd Stage. 1st stage is commissioned in the year 1994. Population for the year 200 is 549510 souls & waters supplied at the rate of 120 LPCD in zone wise manner for the period of 4-5 hrs per day. Under Sujal Nirman Abhiyan, it is decided to convert this water supply scheme into continuous water supply to the city.

Various activities carried out are listed below.

i) Satellite Image - “Quick Bird” Satellite image of Amravati city covering area 137 Sq. Km. is observed from NRSA, Hyderabad.

ii) Base Map preparation.- Digitization of image is carried out in "AutoCAD " software. Base map is prepared in DXF file format.

iii) Population Forecast - Census data for last five decades is obtained & population forecast by Density method is carried out for the year 2011 for allocating initial demands in the model.

iv) Operation Zone - Whole to part approach is adopted for 24x7 project of Amravati city. Entire city is divided into 16 operation zone. The capacities of existing ESR are verified for peak hour's demand for a estimated population of the year 2011. It is observed that capacities 13 out of 16 ESR are adequate for 24x7 water supply. Remaining three zones are rearranged as per demand. It is observed that present infrastructure is sufficiently adequate to implement the 24x7 project. Present supply to the city is 74 MLD The present maximum pumping capacity is 95 MLD.

v) Hydraulic Model - "WaterGems" software is used to build the hydraulic model of entire pipeline network from source to the distribution network up to consumer premises. The hydraulic model is prepared in house by the staff of the Division & Circle office, Amravati. Demands are allocated & model is tested. Entire model is now in working condition. 16 scenarios are created for operation zones. Each Zone is checked thoroughly by simulating the condition for 24x7 water supply.

vi) Preparation of GIS - Property survey of 125 properties of Amravati city is completed on the basis of base map prepared. The data obtained is verified for the proposed zones of Arjunnagar & Sainagar. Verification for the data obtained for other zones is underway. Database comprising of 80 fields giving various details about the property & 125 records (No. of properties) is now built. The base map is modified as per filed verification in property survey. ARCGIS software is used for preparation of GIS. The model built in WaterGems & property database obtained is imported into ARCGIS software. Exact demands for domestic, non-domestic & industrial are now available in GIS format called Geodatabase which is very useful for implementation of 24x7 projects. Thiession Polygon & load builder facility in WaterGems software is utilized to allocate exact demands in the models.

vii) Pilot 24x7 Zone Arjunnagar Zone - Initially, it is proposed to implement 24x7 water supply in ArjunNagar Population of this zone is 18000 souls 2.0 MLD water was supplied for 2.5 hrs through a pipeline network of 24.38 km in this zone. After studying hydraulic model, the Arjunnagar Zone is divided into three District Metered Areas (DMA) Pressure Gauges are also installed, data thus obtained will be utilized for calibration of the hydraulic model hourly reading of all meters are recorded, as well as readings of domestic meters are recorded by

CMU unit periodically. NRW is calculated. It is found that NRW is reduced to 22 percent. The process in underway to reduce NRW up to 15percent target.

6.2.3.2. Malkapur Water Supply Scheme -24X7

The first **complete town** to get this fate in Maharashtra, India was Malkapur, a small town of 35000 people near Karad. Here, the 4500 connections are all metered with Automatic Meter Reading (AMR) type of meters, which can be remotely, read using Radio Frequency devices by just driving along the streets. This avoids the human element in reading the meters. The readings against each of the meter number received in the handheld device are downloaded to a computer which in turn prepares the bills to be sent to the consumers every month. There is continuous 24×7 water supply since March 2009. The elements of this success are:

1. Well designed distribution system, and well laid consumer connections, both of them with least joints.
2. Leak proof material for both system and connections.
3. Achieving equal distribution through control by ferrules.
4. A completely informed and aware consumer who knows the value of water and saves every drop.
5. The best quality AMR consumer and bulk water meters which allow calculation of water balance on day to day basis.
6. The pressure sensors fitted in the network to understand the health of the system at any time against the simulated hydraulic model and most important.
7. The telescopic tariff structure which has made consumers use of water judicious. Those who use less than 55 LPCD are given a discount of 15percent in the bill and those who pay before due date are given a discount of 10percent. 60percent consumers have reduced their water bills than what they used to pay in the flat rate regime. The poor who used less water were immediately benefitted; those who used more water started reducing consumption. These demand management measures in the form of awareness and tariff have led to a sustainable 24×7 at 110 LPCD supply to the town with Non Revenue Water of 9 to 12percent, comparable to the World's best of 5 percent in Singapore.

The town has also received the "National Urban Water Award". Manohar Shinde, the Vice President of the Municipal Panchayat, played an important role in people's awareness campaign and implementation of the telescopic tariff for the first time.

6.2.4. Summary

Geographic Information System which links computerized maps i.e. location data to computerized data base which describes attributes of a particular location. By this linkage, one can easily access location and data simultaneously. Further, maps and other data may be updated quickly and accurately with the help of GIS. The spatial data of GIS can provide information to support modelling. The strength of GIS is that it is possible to process the data sets using any type of numerical analysis procedure. The digital procedure to storing and processing spatial or image data is a very much useful to analyzing the data.GIS has a wide range of use. Water Supply can use GIS in conjunction with the source water assessments to help protect the various water supply system. With an adequate database, Geographic Information Systems (GIS) can serve as a powerful analytic and decision making tool for water supply system. Furthermore, it can also be used for management and to test consequences of development**.**

6.3. GIS based Water Supply Model

Researcher has collected data related to GIS based water hydraulic model. The researcher has focused on the Middle Level Reservoir (MLR) zone. It contains 14 sub ward offices. The analysis is carried out under four categories as follows:

1. Preparation of Geo-referenced MLR water Zone maps
2. Analysis and Designing of Water Supply Network using Standard GIS Tools
3. Developing the Methodology through District Metering Areas
4. EPANET Water Hydraulic Model

6.3.1. Introduction

Design of surface water supply system concerns the locations and capacities of diversion works and storage, as well as the operations of these to meet multiple purposes and objectives. Therefore, in order to ensure the availability of sufficient quantity of good quality of water, it becomes almost imperative in a modern society, to plan and build suitable water supply schemes, which may provide potable water to the various section of the community in accordance with their demand and requirements. Due to the advent of Geographical Information Systems (GIS), it is possible to visualize, and model the entire cycle of water supply network from source to household .There has been a significant interest in the application of GIS to address the special need of water distribution department during the past several years.GIS has created a technology with considerable potential for achieving dramatic gains in efficiency and productivity for innovative Water Management application. GIS provides the hub technology for planning, deploying, operating and optimizing water distribution systems. Any large water distribution system requires a team of technical professionals and programme administrators.GIS helps coordinate this team across functional areas and geographic divisions by sharing information.GIS technology is familiar to leading system integrators and its use has been fuelled by an increase in the abundance and quality of data. This increase is due to cheaper and faster data collection tools and availability of high quality commercial data sets. In this Para, how to develop GIS in the standard GIS tools namely Arc View GIS is discussed in detail.

6.3.2. About Study Area

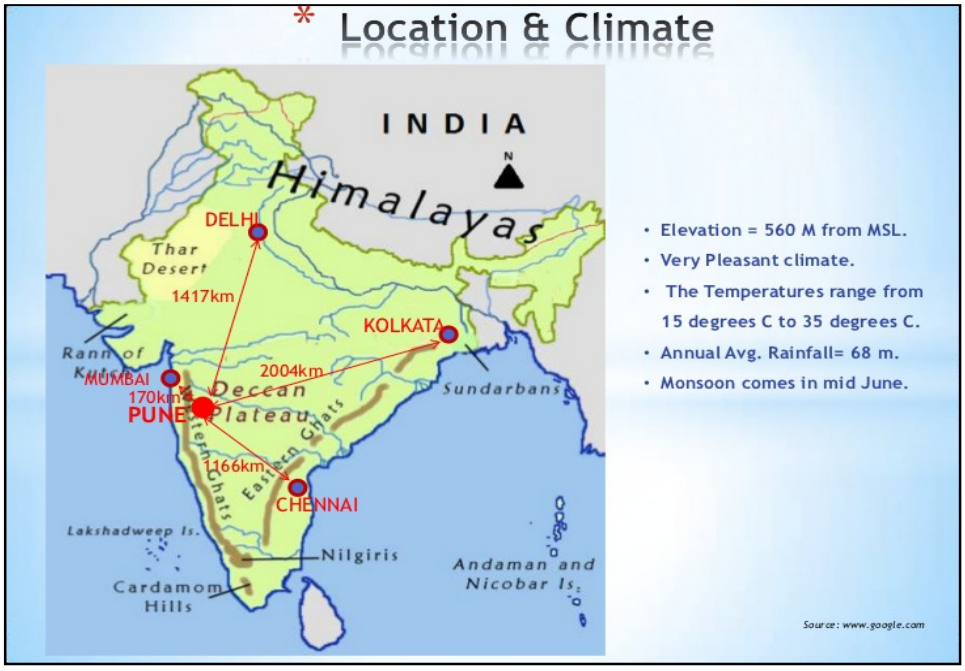
6.3.2.1.Topography:

Pune (180 31' N, 730 51' E) is a plateau city situated near the western margin of the Deccan plateau. It lays on the leeward side of the Sahyadri i.e. the Western Ghats and is hardly 50 km from the crest of the Ghat country. It is 100 km east from the Konkan i.e. the west coast. It is

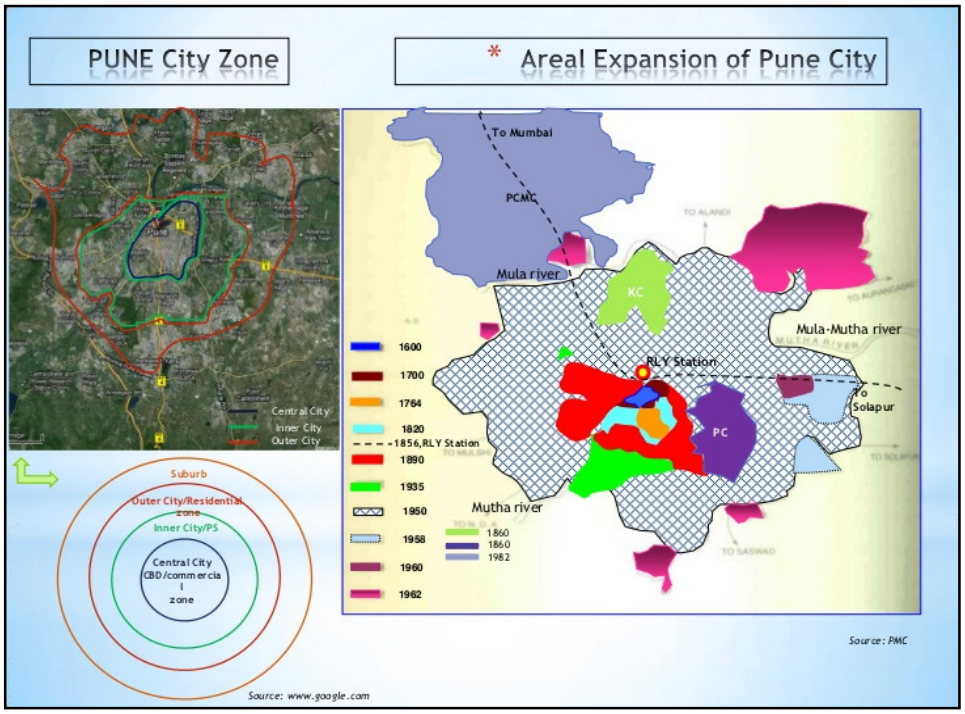
almost 160 kms southeast of Mumbai, by road. It is situated at a height of 560m above the mean sea level, near the confluence of Mula and Mutha rivers. Two more rivers, Pavana and Indrayani transverse the north western outskirts of the urban area. Mula-Mutha later empty into the Bhima River. In a sense, the city is located in the upper Bhima basin. The city is surrounded by hills on the east and the south. The Sinhagad-Katraj-Dive ghat range is the southern boundary of the urban area. The highest point within the city is the Vetal hill (800 m) whereas the highest point of the urban area is the Sinhagad fort (1400 m). The climate is typical monsoonal, with three distinct seasons- summer, rains and winter, as elsewhere in India. The height above sea level and the leeward location with reference to the Western Ghats have made the city climate moderate and salubrious. The mean daily maximum and the mean minimum temperature for the hottest month - May are 37°Celsius and 23° Celsius respectively. The evening sea breeze from west/north keeps the city summer nights at bearable levels. The same for the coldest month of December are 30° Celsius and 12° Celsius respectively. The relative humidity ranges from 36 percent in March to 81 percent in August. Three fourths of the annual rainfall of 70 cm occurs in just four months from June to September

Map 6.1 Map of Pune city-Location & Climate

Map 6.2 Areal Expansions and Zone of Pune City



Map No.6.1: Map of Pune city-Location & Climate (Source:PMC)



Map No. 6.2 : Areal Expansions and Zone of Pune City(Source:PMC)

6.3.2.2. Parvati Filtration Plant

The khadakwasla dam is filled using 3030MM diameter pipeline. This pipe line later transferred 100MLD water to Vadgaon filtrations plant. From this pipeline, around 600 to 650MLD water is useful to the citizens. The pipeline of Parvati area contains 300MLD water out of which 200MLD water comes from the canal. From Parvati area approximately 47.5 MLD water gets filtered in its plant this filtered water is being transferred to Parvati HLR, Parvati MLR, Parvati LLR, S.N.D.T. MLR respectively using pumping methods. Parvati HLR lines of 1000MM, 800MM, and 450MM diameter transfer water to the citizens which are 1.2 km Long. Daily water pumping from Parvati plant is as below in the following tables -

Table No. 6.2: Daily Water pumping details through Parvati Plant

Name of Water distribution Zone	Quantity(In MLD)
Parvati Low Level Reservoir(LLR)	132
Parvati Middle Level Reservoir (MLR)	72
Parvati High Level Reservoir (HLR (Square))	107
Parvati High Level Reservoir HLR(Circular)	71
S.N.D.T. Middle Level Reservoir (MLR)	144

Table No. 6.3: Daily Water Pumping details through Parvati Water distribution Plant

Name of Water distribution Zone	Pumping Capacity(HP)	No. Of Pumps	Total In Hours	Pumping Water (Per day) in ML
Parvati LLR	350	3	64	128
Parvati MLR	250	2	48	72
Parvati HLR (Square)	250	4	94	101
Parvati HLR(Circular)	4425	2	46	72
S.N.D.T. MLR(Circular)	500	4	96	144
S.N.D.T. HLR(square)	225	3	63	144
Wash Water		1	9.30	6.70

Parvati pumping station is open for 24 hrs a day. HLR (High Level Reservoir), MLR(Middle Level Reservoir), LLR(Low Level Reservoir) receive water from Parvati pumping plant .Overall, there are 11 tanks and sump well present.

The main focus of the researcher is on MLR water supply Zone. Therefore, the gist of this content will be on the water distribution/Supply in Pune city under MLR zone.

6.3.2.3. Main Study Area

The Parvati Middle Level Reservoir (MLR) zone consists a new as well as old tanks with capacity of 6.48 ML(Million Liters) and 13.14 ML respectively situated at the Parvati paltue. The water supply in these tanks is done by four pumps from Parvati water plants. To supply water in these tanks, there is a developed 900MM diameter MS rising main line similarly for new tank a 900 MM diameter rising main line is being developed by the irrigation project development.

Technical Specification/details of MLR tank is as in following Table No. 6.4

Table No. 6.4: Details about MLR Zone

Name of Zone	Parvati Middle Level Reservoir(MLR)
Year of Establishment	1968
Location	Laxmi Nagar
Capacity	18ML(Million Liter)
Type	C.B.Meswari
Size	36X81.50X6.48
Shape	Rectangle
Partition	No

Under MLR zone, 14 sub wards are existing as follows in Table No. 6.5

Table No. 6.5: Ward Details under MLR Zone

Ward No. and Name	Sub Ward No.	Name of Wards
BHAVANI PETH	74	Rajewadi
	75	Harkanagar
	76	General Arunkumar Vaidya Stadium
	83	Gohrpade Udyan
	84	Panch Haud Mission
	85	Mahatama Phule Samrak (Samata Bhumi)
	86	Lohiyanagar
	87	Ekbote Colony
	88	GuruNanak Nagar
SAHAKARN AGER	98	Salisaburry Park
	99	Tilak Maharashtra Vidyapeeth
	100	Parvati Darshan
	117	Mahrashinagar
KASBA PETH	82	Subhashnagar

In all 14 wards 900mm diameter main distribution pipeline is already been developed for water supply with 13 valves to switch on and off. This pipeline consists an area from Laxmi narayan to Jedhewadi via Jedhe chowk and further connected to the main network. If citizens of these 14 wards receive 135 Lits per Capita water, 40.50 ML water supply is needed.

However, there is only one main distribution pipeline that's way to distribute the water to off hours in various areas such as Kasewadi, Harkanagr,Padamji Park, Quarter Gate, Zagade Wadi, Police Vasahat, Mukund Nagar, Poona College etc. Due to main gravity, some parts at the turns get increased water supply, therefore, there is an extra water supply to their parts happening.

The MLR zone consists Mukund Nagar, TMV colony, Meera Society, nandnagar,Lohiya nagar,Gurunanak nagar, Guruwar Peth, Ghorpadi Udyan, Mahatma Phule Smarak, Ekbote Colony etc. wards. These wards use to get water between 6.00am & 9.00am and 6.00pm & 8.00pm.Since the water cutting is happening from 6.00am to 9.00am,nonetheless areas like Kasewadi, Harkanagar, Padamji Park, Quarter Gate, Zagade Wadi, Police Vasahat, Mukund Nagar, Poona College etc. and some parts of other zone gets water supply in night from 10.00pm to 2.00am.In MLR water distribution zone, total 25 valves are used for water distribution.

The water connection details of all 14 Sub Ward which is under MLR Zone is as follows in Table No.6.6

Table No. 6.6: Water Connections Details of 14 sub wards under MLR Zone

MAIN WARD	SUB WARD	Ward Name	WATER CONNECTIONS	
			DOMESTIC	NON-DOMESTIC
BHAVANI PETH	74	Rajewadi	14475	637
	75	Harkanagar		
	76	General Arunkumar Vaidya Stadium		
	83	Gohrpade Udyan		
	84	Panch Haud Mission		
	85	Mahatama Phule Samrak(Samata Bhumi)		
	86	Lohiyanagar		
	87	Ekbote Colony		
	88	GuruNanak Nagar		
SAHAKARNAGER	98	Salisaburry Park	1221	66
	99	Tilak Maharashtra Vidyapeeth	1734	113
	100	Parvati Darshan	1666	276
	117	Mahrashinagar	149	1379
KASBA PETH	82	Subahsnagar	450	NIL

In the above Table No.6.6, the Sahakar nagar ward has four wards namely Salisburry Park, Tilak Maharashtra Vidyapeeth, Parvati Darshan and Maharshinagar etc. which come under MLR Zone. The 10percent population of Salisbaurry park is depending upon on MLR zone.35 percent population depend on Tilak Maharashtra Vidyapeeth.10percent population from Parvati Darshan is depending upon MLR zone and 30 percent population from Maharashi Nagar depend on the MLR zone.

6.3.3. Preparation of Geo-referenced MLR water Zone maps

A base map displays the fundamental data set (key physical features such as, roads, railway network, rivers, neighborhood ward boundaries, schools, other landmarks etc.) that is used to render sector data more meaningful. The roads, landmarks and other places that are included in the map should be spatially related and correspond to the ground position. Displaying or analyzing the base data with the sector data assists the user in making effective and well-informed decisions.

The content of a base map depends on the user of the map and its intended use. These guidelines are for water distribution base maps that capture water and related features that are significant in planning for equitality water distribution system for PMC. The geo-referenced base map shall serve as a foundation for different mapping requirements where all other thematic maps may be overlaid for spatial analysis. Thus, it shall aid planners in preparing 24 hours water supply for city. It is important for the mapmaker and also the target custodians of this data to understand the procedural steps in the production of base maps, the hierarchy of the sources of data and the nature of the data, in addition to actual usage of the data itself.

6.3.3.1. Major components of base map:

I. Content of an appropriate base map - This includes a list of the base map features needed to be captured like, ticks/ geographic coordinates, boundaries, natural features like prominent streams, major manmade features like transport network, bridges, important landmarks/ locations and other permanent features, sources for the data, Metadata elements etc.

II. Procedure for Base map preparation using existing maps/data - This would cover general steps involved in preparing base maps from existing analogue map data. This shall guide where to look for input data, what to do with such data, and important steps involved in preparation of base map through GIS systems. This will include:

- Preparation of base maps at coarser levels using SOI maps (1:50,000) and finer scale (1: 2000 or 1:5,000 and 1:500) respectively.
- Procurement of appropriate high resolution satellite images of water distribution network of Pune city. The images (6.8 mt Resolution) available in PMC used for preparation of Base Map
- Digitization, image rectification, ground truthing and preparation of city level water distribution network.

- Listing of all water distribution network and all water entities and locating them on the base map.

III. Base map preparation (internal or by outsourcing) –

The Urban Local Body (ULB) shall have to make a self-assessment on their capability to produce the first version of a ULB base map. When it is determined that ULBs do not have in-house capacity to produce base map, help from government /private agencies to prepare base map may be obtained. In this case, the PMC shall acquire/provide the available primary or secondary data for the town, with its administrative boundary that further shows the hierarchy of secondary data to be captured.

6.3.3.2. Base map features

The basic requirement to start the water distribution network survey is to have a base map at reasonable scale for the city. In this regard, the scale of the base map for the city is recommended to be at 1: 2000, 1:5000 and 1: 10000 scale based on the availability. However, preference will be given to the available base maps larger than 1:10000 scales. However, for each slum, detailed mapping at 1:500 scales will be done through Total Station Survey using GTS benchmark. Care should be taken to ensure that these base maps at different scales will be geographically compatible with each other for seamless visualization and analysis as required under the project. The comparison of maps of different scales is given in the below Table No. 6.7.

Table No. 6.7: Comparison of maps of different scales

Scale	Application and Utility of the map	Features that can be captured	Benefits & Required resources
1:500	Micro planning (including layout plans of the water distribution network and utility mapping)	All tenements/building/ pipeline network and utility information with accuracy can be captured	Ideal for micro level planning -where detailed plans can be prepared using micro details Spatial data at this scale not easily available so has to be generated through large scale Mapping exercises. As this takes longer and dedicated manpower, the mapping of Slums in the city may be done in phases.

1:2000	All functions beginning from water network planning, area planning	Settlement boundary and Water infrastructure networks can be Captured. Tenement boundaries or building footprints are not very clearly visible at this Scale.	Detailed information can be captured required for area level mapping. Satellite maps may not be available at this scale. Maps need to be generated particularly for the utilities by superimposing the spatial information available in various forms such as paper maps and /or soft copies.
1:10000	Regional planning (city planning can be done but with limited information as at this scale many spatial features are not	Lanes and service roads may not be visible but arterial roads and settlement blocks, regional land use /land cover information would be visible	This scale is appropriate for regional planning but for city level planning the information available might not be adequate. Spatial maps /remote sensing images at this scale are

In building the GIS for water distribution network for city, there would be two forms of base maps; first in the digital form composed of different layers of digital files for each feature of the base map and other will be the printed version of the same. The layout of the printed base map should have standard maps features such as scale, north arrow, title, legend etc. Both forms of the base map (digital and printed versions) should have same features. The base map features vary with scale of mapping and hence, care should be taken to define the base map features in accordance with the scale of mapping

The following broad features are recommended to be included in the base map. The potential source of the data will be from Survey of India (SOI), State Remote Sensing Application Centers (SRSACs), Urban Local Bodies (ULBs)/ Municipalities, etc.

For illustrative list of data layers, codes and attributes required from them are as follows in Table No. 6.8

Table No. 6.8: Base map features & potential sources

Base map features	Potential source of data
Administrative boundary	
State Administrative boundary	Survey of India (SOI), Open Series of maps
Municipal and ward boundary	ULBs
Water distribution boundaries	ULBs/Municipalities, generate using satellite data, GPS based field data
Natural features	
Natural landmarks	SRSAC, ULBs, SOI, generate using satellite data ,GPS based field data
Stream, creek	SRSAC; ULBs, SOI, generate using satellite data ,GPS based field data
Man-made features	
Roads: National; City/Municipal/Slum (line segment)	SRSAC, ULBs, SOI, generate using satellite data satellite data
Railway (line features)	SRSAC, ULBs, SOI, generate using satellite data
Airport (line features)	SRSAC, ULBs or Directorate of Economics & Statistics, SOI, generate using satellite data ,
Built-up area of slums in a generalized manner	Satellite imagery, aerial photograph, GPS based field data
Other landmarks such as temples, mosques, church etc. (points or polygon)	SRSAC; ULBs, SOI, GPS based field data
Contour lines	SOI, Ground Survey
Cadastral maps	ULBs, land records and survey (LRS)

6.3.4. Prepare GIS based water distribution (Network) base map

6.3.4.1. Hands on description of preparation of base map using existing data

Obtain paper prints (heavy paper) of the base map, preferably without topography. The base map print can be a blue line or black line copy with plenty of extra space for notations. Hard copy of the latest high resolution satellite image or print of the land use map of the municipality or ULB from available database in considerably large scale may also be used. The following information should be shown on this map:

- Water Distribution Pipeline network

- Land use
- Ward Name , number, boundaries, Population, Population Density
- Valve Details such as Valve number and timings ward wise
- MLR tank Location along with all technical specification
- Water Treatment Plant along with name, specification

6.3.4.2. Steps for preparing base map using GIS Software

The following broad steps show the generic procedure in the preparation of a base map showing the various data types which the ULB should acquire under GIS environment. Data may be in two forms, the technical description and the paper map. The capture of data from the technical description involves a more direct step of encoding the numerical data into the computer, which is further converted to points or shapes. The capture of data from paper maps involves three steps as described below:

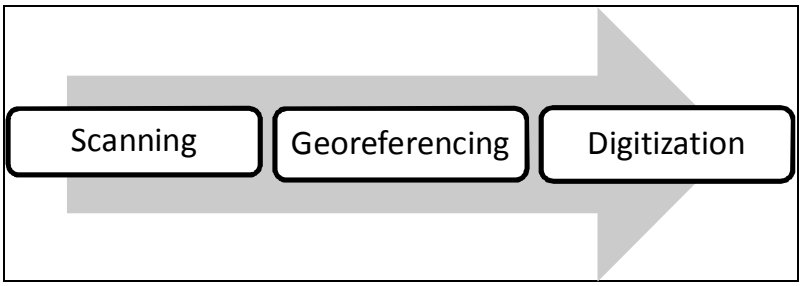


Fig 6.1 : Process of Digitization

Data captured, using GPS, will be processed directly by importing the points for appropriate storage, attributing and depiction. It is also recommended to use the Projection and Datum of the source, if already available during Geo-referencing. Re-projection should be done on the digitized layer or output vector file. When combining GIS layers from different sources, there may be discrepancies in dataset, hence care must be taken to maintain consistency with respect to output projection parameters for proper registration amongst such layers. Roads digitized from cadastral maps, even after due geo-referencing, may not coincide with the roads taken from a toposheet map, even if these layers were set to the same projection and datum, due to significant difference in mapping scale and other factors. If corrections or adjustments are done, documentation for the adjustments should be attached to the metadata. Any errors or discrepancies found on the source maps should be reported and consulted with concerned agency.

6.3.4.3. Administrative Boundaries of the MLR Water Zones

Data for administrative boundaries especially for MLR water zone boundaries may come in two forms, technical descriptions and paper maps. It is critical to identify the source of administrative boundaries of such MLR Zone. Sources available with ULBs like topo maps, PMC water distribution department and PMC city Planning Department. The output base map should not be used for property delineations or for settling legal land encroachment issues. Boundary conflicts if any, should be captured and saved in a separate layer and should be consulted with PMC employees.

i) Create the boundary using technical description/ coordinates

ULBs, municipalities and municipal corporations usually keep records and technical descriptions of MLR water zone boundaries. In cases, where geographic coordinates / grids are available, it is better to use these data and maps. When such data or descriptions are not available, field methods like Total Station Survey or GPS points needs to be used to identify legal boundaries of MLR zone of PMC.

ii) Capture the boundary using the paper maps

This procedure refers to paper maps with plotted MLR water zone boundaries. They are the plotted paper maps of the boundaries from surveys. These datasets usually come in monotone color (black ink in white paper or blueprint). If the map also includes technical description or coordinates, digitization of paper maps becomes easy. These maps need to be scanned, geo-referenced and digitized in order to convert them into the digital map. The procedure is as follows:

- Review and inspect the map. Make sure that it contains tick marks with coordinates. There should be at least 4 tick marks with coordinates, but it is often seen that they do not produce accurate results. Hence, maximum number of ticks (16 ticks) needs to be taken to ensure consistently high accuracies. Make sure that the tick marks selected are visible.
- Get familiarized with the projection and datum of the maps. If the ULBs have access to GIS facilities and have created maps using standard GIS software, a projection and datum for that ULB will have to be provided.
- Prepare maps for scanning. Smooth all folds and crumpling. Fix and align torn out portions, if any.
- Scan and save images in .jpeg/ .tiff format.
- Check for image distortions and clarity of map features and make sure that the tick

marks or reference points to be used are clearly visible on the scanned image. Rescan, if necessary.

- The process of defining the position of geographical objects relative to a standard reference grid is known as Georeferencing. It is a system that links information to a position on earth's surface. It is done by assigning map coordinates to image data for making the data amenable to GIS analysis, and to facilitate viewing in conjunction with maps. Geo-reference the scanned image using all possible tick marks as map control points. The detailed procedure along with the illustration for geo-referencing is given in **Annexure 10.**
- Crop the image. Remove areas outside the neat lines of the map with the soft-ware, if possible. Resample and save the geo-referenced image using a different name and file format which is readable by the digitizing software.
- Load the geo-referenced image using the GIS software for digitizing and perform on-screen digitization. The procedure of digitization base map using GIS software in para 6.3.4.4. georeferencing and creation of a universally compatible file, like shape file format.
- Create the municipal, zonal and ward boundaries layer as a polygon. Digitize the boundaries from the geo-referenced image. Save the file using standard file naming convention. In case of boundary conflict/disputes, create a different layer for this area, label and save it accordingly.
- Create the MLR water zone boundaries, from the same source, for the municipal boundaries. Use tools to split or append polygon if available with the software.
- Label or encode the feature name while digitization process. Ward names should be labeled as attributes. Make sure to save the slum layer, created as a different file, and do not overwrite the municipal boundary file which is used as a base layer. Follow standard naming convention. Create metadata for each feature type created.

6.3.4.4. Geo-referencing of paper maps

Once a paper map containing information in present scenario, water pipeline network of MLR zone, is scanned, save it as a digitized image. Existing water distribution base map is made available as a separate layer that can be activated. The image that is imported can be geo-referenced using any Georeferencing tool. Georeferencing of raster maps (images) involves various steps which are illustrated as an example using one of the software tools.

This also includes the procedure for CAD based paper maps or toposheets refer **Annexure 10**

6.3.4.5. Data Collection of MLR zone details using Global Positioning System (GPS):

- GPS is a simple device using which necessary field data could be collected as needed. Appropriate projection parameters as decided need to be used for mapping purpose.
- For each of the features needed, create a corresponding layer with appropriate feature type. Label or encode the feature name while it is digitized. Save the file into different files following the recommended file naming convention.
- Create metadata for each feature type created.

6.3.4.6. Digitization

The final step of digital image formation is the digitization. This means sampling the gray values at a discrete set of points, which can be represented by a matrix. Each layer of the map is geo referenced with respect to the road network, that is. Whether it is slums or canals or whatever it may be, they are geo-referenced along with road network, since the known points are taken on the road network. Hence to have a particular identity of each layer, it is to be digitized, excluding the road network. A feature on a map can be identified either by a shape of a polygon, or a line, or a point. Two types of files are available to generate such shapes.

I. Shape file II. Personal Geo Data Base (PGDB)

I. Shape File

The shape file format is used commonly in Geographic Information Systems (GIS). The format was developed by Environmental Systems Research Institute (ESRI), and is tied to their Arc View GIS 3.2 products. Shape files are simple because they store primitive geometrical data type of points, lines, and polygons. These primitives are of limited use without any attributes to specify what they represent. Therefore, table of records will store properties/attributes for each primitive shape in the Shape files. Shapes (points/lines/polygons) together with data attributes can create infinitely many representations about geographical data, and depiction provides the ability for powerful and accurate computations.

II. Personal Geo Database (PGDB):

Geo database is the latest spatial data format commonly used, with all map data stored in relational database format. The personal geo data base is built into Arc View GIS.

6.3.5. Geographical Information Systems (GIS)

Geographic Information Systems are utilized to improve efficiency, decision-making and communication by integrating various multiple and complex sets of information. The systems provide a framework for management, analysis and display of geographic information. There are three major components of a GIS: the data sets and models which represent the raw information, the maps and globes in which this information is placed, and the processing and manipulation that can be applied. For this project, the data sets are largely comprised of the home, tap stand and other important locations within the water distribution system. The maps and globes allow the 3-D setting to be more easily understood in a 2-D space, and geoprocessing can create new data and representations to interpret. One hope is to create intuitive and cognitive tools that will help people across cultures and disciplines work efficiently together. [9]

Important features for the GIS related to this project are flexibility and availability of data manipulation tools and multiple scales. There is a need to add new and updated data as the population and water system at Mae La continue to change with time. Tools are necessary to understand more about the available data. For example, if the population nearest to a particular tap stand is defined, a next valuable piece of information would be the percentage of this population that actually utilizes this tap and the frequency of use. As a result of the depth and extensive nature of geographical data, it is important for collaboration especially regarding the creation and maintenance of data sets. There exist many open forums for GIS users to collaborate as well as an international standards group, Open Geospatial Consortium, Inc., which keep users in sync with one another.

GIS provides powerful and cost-effective tools for creating intelligent maps for water.

6.3.5.1. Mapping Basics

The basic concepts essential for understanding GIS mapping are summarized in the following subsections.

- **Map Types**

There are two major types of GIS maps: vector and raster. In vector format, objects are represented as points, lines, and polygons. Examples of the vector format are maps of water mains, hydrants, and valves. Scanned maps, images, or aerial photographs are examples of raster format. Raster data is also referred to as grid, cell, or grid–cell data. In raster format, objects are represented as an image consisting of a regular grid of uniform size cells called pixels, each with an associated data value. Many complex spatial analyses, such as automatic

land-use change detection, require raster maps. Raster's maps are also commonly used as base maps. Existing paper maps that are used to create GIS maps are called source maps.

6.3.5.2. Topology

Topology is defined as a mathematical procedure for explicitly defining spatial relationships between features. Spatial relationships between connecting or adjacent features, such as a sewer tributary to an outfall or the pipes connected to a valve, which are so obvious to the human eye, must be explicitly defined to make the maps "intelligent." A topological GIS can determine conditions of adjacency, containment, and proximity. Topological relationships allow spatial analysis functions, such as network tracing, that can be used to facilitate development of hydraulic models for water and sewer systems.

Because the Earth is round and maps are flat, transferring locations from a curved surface to a flat surface requires some coordinate conversion. A map projection is a mathematical model that transforms (or projects) locations from the curved surface of the Earth onto a flat sheet or 2D surface in accordance with certain rules. Small-scale(1:24,000 to 1:250,000) GIS data intended for use at the state or national level are projected using a projection system appropriate for large areas, such as the Universal Transverse Mercator (UTM) projection. The UTM system divides the globe into 60zones, each spanning 6˚ of longitude. The origin of each zone is the equator and its central meridian. X and Y coordinates are stored in meters. Large-scale local GIS data are usually projected using a State Plane Coordinate (SPC) projection in the United States. A datum is a set of parameters defining a coordinate system and a set of control points with geometric properties known either through measurement or calculation. Every datum is based on a spheroid that approximates the shape of Earth. A coordinate system is a reference system used to measure horizontal and vertical distances on a map. A coordinate system is usually defined by a map projection. The GIS and mapping industries use either latitude/longitude- or geodetic-based coordinate grid projections. Because much of the information in a GIS comes from existing maps, a GIS must transform the information gathered from sources with different projections to produce a common projection.

6.3.5.3. Coordinate Systems

While manipulating and comprehending global spatial data, every GIS encounters a major challenge in the need to portray three-dimensional data in a two-dimensional space. Various data sources and software platforms utilize different coordinate systems and global projections. It is important to understand how these systems and projections are related in order to easily transition between sources and/or platforms, and these relations are described below.

Lines of latitude and longitude are the most common coordinate system. Surface location is defined by the angle from the center of the Earth between a given location and the plane of the equator (latitude) or Prime Meridian (longitude). Latitude and longitude coordinates can be described using two main notations:

Degree:Minute:Second (DMS) and Decimal Degree (DD). For DMS, each degree is divided into 60 parts (minutes) and each minute is further divided into 60 seconds. For DD, the minutes and seconds are represented by digits (typically four) following the major degree and a decimal. To convert between DD and DMS, multiply the decimal first by 60 to get the whole number of minutes and then multiply the resulting decimal remainder by 60 again to find seconds.

For example, for a DD of 17.8200º the corresponding DMS notation would have 0.8200 x 60 or 49.2 minutes and 0.2 x 60 or 12 seconds. Written in DMS form ,the equivalent notation is 17º49'12''. The Universal Transverse Mercator (UTM) coordinate system divides the globe into 60 zones based on an ellipsoidal model of Earth and specific locations within zones are referenced in meters[2]. For this project, the UTM coordinates are based on the World Geodetic System of 1984 (WGS 84) reference frame for the earth. WGS 84 is a coordinated global standard defined using Doppler satellite surveying and the reference frame for GPS.

As a reference, the northeast corner of the camp where the river crosses the main camp road is located, in DMS, at about 17º08'10"N and 98º22'35"E and this corresponds to a grid position within UTM zone 47N of 433633 meters east and 1894732 meters north. Direct translation from UTM coordinates to degree coordinates is not a simple task because the UTM system varies non-linearly due to the projection of spherical space onto a two-dimensional grid. Many online conversion tools exist including one by the National Oceanic and Atmospheric Administration, U.S. Department of Commerce (NOAA, 2008).

6.3.5.4. Map Scale

Map design addresses two fundamental map characteristics such as accuracy and depicted feature types. Both characteristics vary with map scale. Generally, larger scale maps are more accurate and depict more detailed feature types. Smaller scale maps, such as U.S. Geographical Survey (USGS) quadrangle maps, generally show only selected or generalized features. The map scale features are as follows-

- **Data Quality**

The famous computer industry proverb "garbage in, garbage out" conveys very well the importance of GIS data quality. A GIS map is only as good as the data used to create it. Data

quality roughly means how good the data are for a given application. Data quality is important because it determines the maximum potential of inappropriate data in a GIS map may lead to it.

- **Data Errors**

There are two types of data errors: inherent errors embedded in the source of data and operational errors introduced by users during data input, storage, analysis, and output. Inherent errors can be avoided by using the right kind of data. Operational errors can be prevented by quality control and training. A data conversion team should be aware of sources and magnitudes of data error.

6.3.5.5. Map Accuracy

A primary factor in the cost of data conversion is the level of positional accuracy. Required map accuracy and resolution depend on the application in which the maps will be used. A 2000 survey conducted by the Geospatial Information and Technology Association (GITA) [10] indicated that the water utilities were seeking more land base accuracy of 5-ft compared with other utilities, such as the 50-ft accuracy sought by the gas companies. The same survey for 2002 indicated that the water industry required the highest accuracy in their GIS projects. Among the water organizations, 27percent were using a 6-in. land base accuracy compared to electric (12percent), gas (17percent), pipeline (17percent), and telecom organizations. This data reveals that a trend toward increasing accuracy may be emerging in the water industry.

6.3.5.6. MAP TYPES

Various map types used in GIS are discussed in the following subsections.

- **Base Map**

The map layers are registered to a coordinate system geodetic control framework and a set of base information often referred to as a base map. The foundation for a successful GIS mapping project is an appropriately designed base map. The base map is the underlying common geographic reference for all other map layers. Because the base map serves as the reference layer for other layers, its accuracy can affect the accuracy of other layers. This is especially true if the base map is used to create other layers by on-screen (heads-up) digitization. Selection of an appropriate base-map scale is largely determined by the earlier choice of GIS applications. Each application inherently requires a certain minimum base-map accuracy and certain map features. For engineering and public-works applications, the required map accuracy is in the range of ±1 ft, as dictated by the need to accurately locate specific physical features, such as manholes and catch basins. Planning applications, which

most often deal with area wide themes, do not generally require precise positioning. Accuracies of ±5 ft, or perhaps as much as±40 ft, are often acceptable. Less detailed maps, showing nothing smaller than roads and buildings, for example, may be adequate for many planning applications. Whatever the range of mapping requirements, the base map must be accurate and detailed enough to support applications with the most demanding map accuracies of better than ± 2 ft. Utility asset location also requires mapping that depicts septic small features such as manholes and catch basins.

- **Digital Orthophotos**

For laypersons, digital orthophotos (or orthophotographs) are scanned aerial photos. For GIS professionals, they are ortho rectified raster images of dispositive transparencies of aerial photographs. Creation of a digital orthophoto requires more than a photo and a scanner, and includes surveyed ground control points, stereo plotters, and a digital elevation model. In fact, the digital orthophoto creation process involves many steps, which are listed below:

•Establish ground control point

•Conduct aerial photography

•Perform analytical aero triangulation

•Set stereo models in stereo plotters

•Capture digital elevation models

•Scan aerial photographs

•Digitally rectify the scanned photographs to an orthographic projection

•Produce digital orthophotos

Digital ortho photos are popularly used as base maps that lie beneath other GIS layers and provide real-life perspectives of terrain and surroundings that are not available in the vector GIS layers. Knowing whether the job will be on a busy intersection or in somebody's backyard will determine the kind of equipment, material, and personnel required for the job.

- **Planimetric Maps**

Like digital orthophotos, planimetric base maps are also created from aerial photographs. However, instead of scanning the aerial photos, the features are digitized from them. Thus, whereas digital orthophotographs are raster files, planimetric maps are vector files. Planimetric maps generally show building footprints, pavement edges, railroads, and hydrography.

6.3.5.7. GIS Mapping Steps

GIS mapping consists of five typical steps as following in Fig 6.2

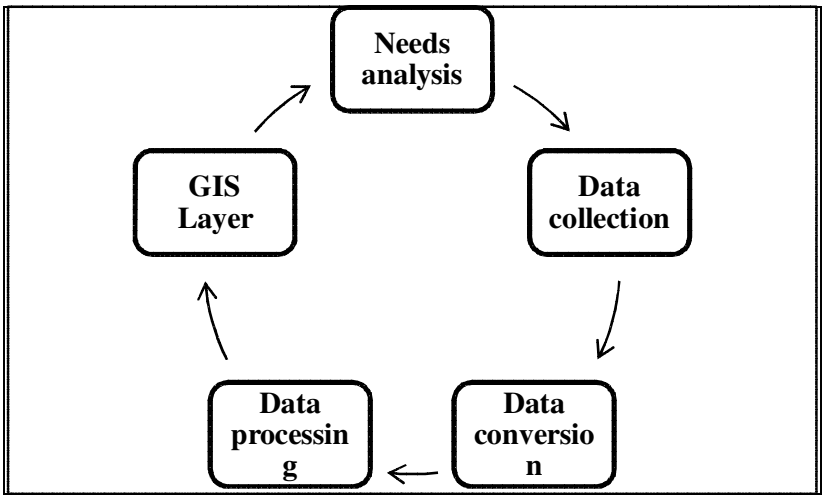


Fig.6.2 :GIS mapping Steps

- Needs analysis
- Data collection
- Data conversion
- Data processing
- GIS Layer (MAP production)

These steps are intended for GIS technicians who work in a GIS lab equipped with map-making equipment such as digitizers, scanners, and plotters. Some professionals, such as civil and environmental engineers who are users rather than creators of GIS maps, generally do not perform all of these steps.

6.3.5.7.1. Needs Analysis

The needs analysis study describes the features that should be captured during the data conversion step, mapping specifications (accuracy, resolution, scale, etc.), and source documents. For example, the needs analysis determines whether or not the customer meters should be mapped. If the answer is yes, how and to what accuracy should they be mapped. For large systems (populations greater than 50,000), a pilot project should be conducted (Needs Analysis). The pilot project allows potential fine-tuning of mapping specifications in a two- to four-sheet area before starting the map production phase.

6.3.5.7.2. Data collection

When existing maps do not exist or are inadequate, mapping data should be collected using a field survey with or without GPS. Required data is usually scattered among a multitude of different organizations and agencies. Field data collection using mobile GIS and GPS technology that employs handheld devices and tablet PCs is becoming common for collecting attributes. The question of quantity should be evaluated carefully before the data conversion

is started. Too little data limits the mapping applications. Data Conversion also referred to as the production work, this step converts hard-copy maps into digital files using digitization with or without scanning. The data conversion processes typically are the most expensive and time-consuming part of a GIS mapping project. Approximately 75percent of typical GIS costs are related to data conversion and creation.

For example, manholes are captured as a point layer, sewer pipes are captured as a line layer, and sewer sheds are captured as a polygon layer. For example, geodetic control and base-map layers should be developed first because most other layers depend on them. Data conversion includes capturing both the graphic (geometry and coordinates of features) and non graphic (attributes) data. Graphic and non-graphic data may be entered simultaneously or separately

- **Capturing Attributes**

The annotations (labels) shown on the source map are the most common source of attributes. The source document ID (e.g., drawing number) is one of the most important attributes that should always be captured during data conversion. Features such as valves and hydrants have unique IDs, which can be easily captured from labels (annotations) on source maps. The features without IDs should be assigned new IDs during data conversion. Some data conversion application software allows automatic ID creation during data conversion. Geometric properties like length, area, and perimeter of features can be internally calculated by GIS and entered as an attribute. For example, if pipe length is labelled, it can be entered as a Length_Map attribute. If pipe length is not shown, it can be automatically calculated by GIS and entered as Length_GIS (GIS-calculated) attribute. Some existing databases and tables can be linked to GIS databases to avoid manual entry of attributes. Once the linkage has been established, attributes from the linked documents are available in the GIS database for query, analysis, and thematic mapping. For example, unique hydrant IDs captured during data conversion can be used to link to a hydrant-testing database. GIS attributes can also be found in some unexpected places, such as customer billing records. With a technique called address geocoding, GIS can convert the billing records or any postal address to a point on a map.

Capturing Graphics

The data conversion methodology for capturing graphics depends on database design, source materials, and project digitization and scanning are the two most common data conversion methods.

6.3.5.7.3. Data Conversion (Digitization)

Digitization is a process of converting a paper map into a vector file by a computer using a digitizer or digitizing table (or tablet). The source map should be registered (or calibrated) to control points. Conventional table digitization is a laborious process. If a digitizer is not available but a scanner is, data conversion can be done by scanning the source maps followed by heads up digitization. The use of this process for certain specialized mapping projects, such as land-use/land-cover mapping, requires familiarity with photo interpretation techniques. For easy identification, certain utility assets that are difficult to see on the aerial photographs (e.g., valves, hydrants, manholes) can be pre-marked. Pre-marking is done by placing (or painting) targets with special symbols and colors over or adjacent to the asset to be captured. As-built or construction drawings usually have dimensional or offset information on utility assets (e.g., a sewer pipe 10 ft from the street right-of-way). This method is more accurate than digitization.

Scanning is a process of converting a paper map into a raster file (or image) by a computer using a map-size scanner. Black-and-white scanners are most common because they cost about the same as a digitizer. Colour scanners cost twice as much. Scanning is generally most efficient when converting maps for archival purposes. Sometimes, as-built drawings are scanned and linked to vector features. Because many applications (e.g., hydraulic modelling and field inspections) require the utility features in vector format, scanned images must be converted to a vector format. This can be done by heads-up digitization of the scanned maps or by using a process called Vectorization that automatically converts the raster data to vector format. Vectorization is a cost-effective data conversion method but it is based on new technology that is still improving. Complex, faded, or unclear maps may require extensive post processing and manual touch-up.

- **Data Conversion Software**

Data conversion requires GIS development software that draws objects as points, lines, or polygons or represents them as pixels. ESRI's ArcGIS® [18] and Intergraph's GeoMedia Pro ®are examples of GIS development software. For large projects, data conversion application programmes are very useful. It eliminates attribute entry and editing via command prompts or database table, which require data conversion skills. Users without prior data conversion experience can enter attributes from sources documents (e.g., as-built drawings) in a menu environment simply by clicking on points (e.g.,manholes) and lines (e.g., sewers). The ArcView version was developed using Avenue and ESRI's Dialogue Designer Extension to

support water system and sewer system map-ping needs of the ArcView 3.x users. The right window shows the form for adding and editing point and line features. The left window shows the form for editing point attributes. Data conversion is started by drawing and attributing the points. After the points are attributed, the connecting lines are added from point to point. By selecting upstream and downstream manholes to add the lines, the flow direction of a gravity sewer is incorporated into the data set, ensuring the proper connectivity of the system. Additionally, the lines are snapped to the point features, ensuring that the points of connection correspond to manholes. Data conversion applications like the water editing tool increase the speed, efficiency, and accuracy of data conversion for water, wastewater, and storm water systems. They reduce data-entry errors and can even be used to validate the input data. If desired, the applications can be modified to meet the project-specific mapping requirements. Sample water system data conversion application for ArcMap.

6.3.5.7.4. Data Processing

Data processing includes some or all of the following tasks as follows in the following Fig.6.3

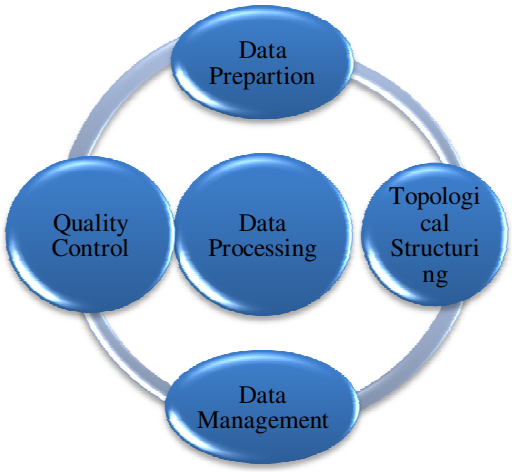


Fig.6.3.GIS Data Processing

This task makes the raw data from source maps or field/GPS surveys available for GIS use or GIS-ready. Typical activities include post-processing of captured data, changing data formats (e.g., from DXF to Shapefile), applying map projections, georeferencing the image data, and/or clipping the aerial photos. Post processing of captured data is warranted, if the source maps and the base map have different accuracy, and captured data do not align with the base map. In this case, captured data is edited (moved, stretched, or resized) to fit the base map.GIS data is stored in various file formats. GIS software cannot read all the data formats simply because there are so many formats. Although many GIS packages provide data

conversion for the most common data formats, no GIS can support all possible conversions. Many government agencies and data and software companies provide data translators for this purpose. For instance, some platforms can support better numeric precision than others. Depending on the mapping scale and the coordinate system, this could seriously affect data quality.

6.3.5.7.6. GIS Layers

- **Pipes**

Pipe layer is drawn in poly line and contains the following attribute fields: Unique ID for each pipe segment, diameter of the pipe in milli meters, material of the pipe, depth of the pipe (if known), calculated length of the pipe, pressure zone of the pipe, address information and information about the installation of the pipe. The following fig 6.4 shows GIS layers or Shape file of MLR water distribution pipe network. These attribute fields are filled from project values and field staff's knowledge but they may contain important mistakes (mostly wrong diameter and wrong material) that conflict with the reality on the fiel**d**.

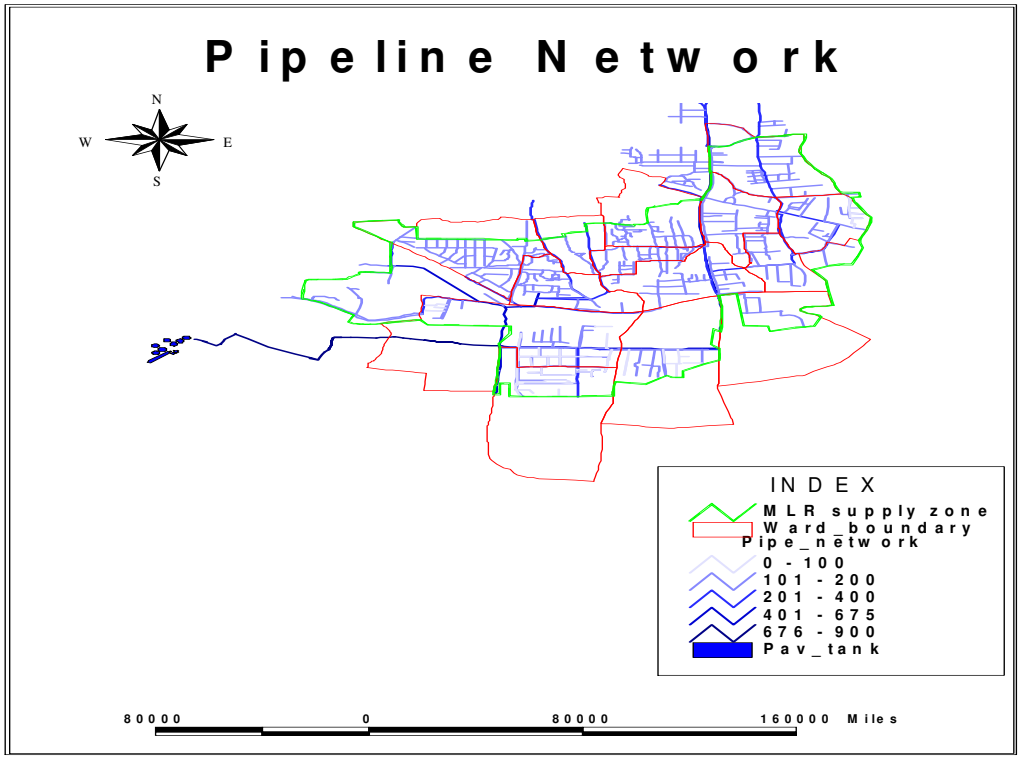


Fig. 6.4: Pipeline network for MLR zone developed using ArcView GIS

6.3.6. Analysis and Designing of Water Supply Network using Standard GIS Tools

There is a significant interest in the application to address the special needs in water management from past several years.GIS has created several technology considerable potential for achieving gain in efficiency in productivity for innovation in water management application.GIS provides hub technology for planning, operating ,deployment and optimizing the water supply management. GIS technology is familiar to leading system integrators and its use has been fuelled by an increase in the abundance and quality of data. This increase is due to cheaper and faster data collection tools and the availability of high quality commercial data sets. In this para, how to develop a GIS in the standard GIS tools namely as ArcView GIS 3.0 and ERDAS IMAGINE® Image Reader is discussed in detail.

6.3.6.1. Water Distribution Network Analysis using ArcView GIS 3.2 and ERDAS IMAGINE® Image Reader

ArcView is a useful software or desktop GIS and mapping. It is a product of Environmental Systems Research Institute, Inc. (ESRI). ArcView GIS is powerful software for visualizing, querying, exploring, and analyzing data geographically. ArcView is a powerful GIS tool that can display information (which resides locally or over a distributed network), read spatial and tabular information from a variety of data formats, access external databases, produce thematic maps (use colors and symbols to represent features as well to represent features based on their attributes), perform spatial queries, connect spatial information to database attributes, provide several analytical tools, and allows for a high degree of customization using Avenue.

6.3.6.2. Features of ArcView GIS Software

Several versions of ArcView 3.x have been released to date. This tutorial is very basic in nature and addresses general features of versions 3.0, 3.1, 3.2, and 3.3. Although no distinction will be made in this tutorial amongst the four versions of ArcView, it is important to emphasize the added options and features that were included in each subsequent release of ArcView 3.x. The following are some of the distinctive enhancements of the various releases of ArcView GIS over ArcView 3.0 (Source: ESRI White Paper):

- ArcView 3.1 introduced a wizard-based approach to accomplish a variety of more sophisticated tasks such as advanced map production and advanced geoprocessing. Task wizards, along with other updates focusing on enhancing usability, leverage the power of ArcView to help you more quickly and easily accomplish your geographic information system (GIS) objectives. ArcView 3.1 also introduced several new included extensions, specifically designed to supplement your GIS requirements. In particular, ArcView features a report writer extension that enables you to easily

generate professional reports, including embedded maps and charts, which help you more successfully, communicate the results of your GIS analysis.

- ArcView 3.2 provided both strategic updates to existing capabilities as well as new tools to facilitate your GIS operations. Specifically, ArcView 3.2 included an updated report writer and significant database access improvements. ArcView 3.2 also introduced a new shapefile projection utility, providing support for an extensive range of data projections and datum transformations, as well as support for several new data formats.
- ArcView 3.3 provides key updates to many of the tools that are part of ArcView. ArcView 3.3 includes updates to many extensions including CAD Reader, ERDAS IMAGINE® Image Reader, and the National Imagery Transmission Format (NITF) Data Reader. Also, the Projection Utility has been enhanced for greater performance. The Report Writer has been updated to include Crystal Reports™ 8.5 by Crystal Decisions. ESRI Data & Maps has also expanded to eight CDs full of new and updated data.

  Several extensions are available for use with ArcView. Many of these are commercial extensions developed by ESRI and others. Some of the commercial extensions developed by ESRI include the following:

- Network Analyst: Performs network or routing analysis.
- Spatial Analyst: Performs grid cell (raster) analysis.
- Internet Map Server: A map publishing tool for the World Wide Web.
- StreetMap: A tool for U.S. Street address geocoding and map display.
- ArcPress: Develops maps on raster plotting devices.
- 3D Analyst: Creates, analyzes, and displays surface data.
- Business Analyst: Supports business analysis.
- Image Analysis: Supports image analysis capabilities.
- Tracking Analyst: Directs feed and playback of real-time data, including data from Global Positioning System (GPS).

6.3.6.3. Base Map Digitization

R2V is an advanced raster to vector conversion system. This system combines the power of intelligent automatic digitizing technology with an easy to use menu driven graphical user interface in MC-Windows and NT environment. Each type of data, such as raster image, points, lines and text are treated differently and each has its own set of processing editing functions. Each data type can be stored in a separate file with file format.R2V supports the

concept of layer and the user can defined as many layers as needs and each layer has a name and other properties.

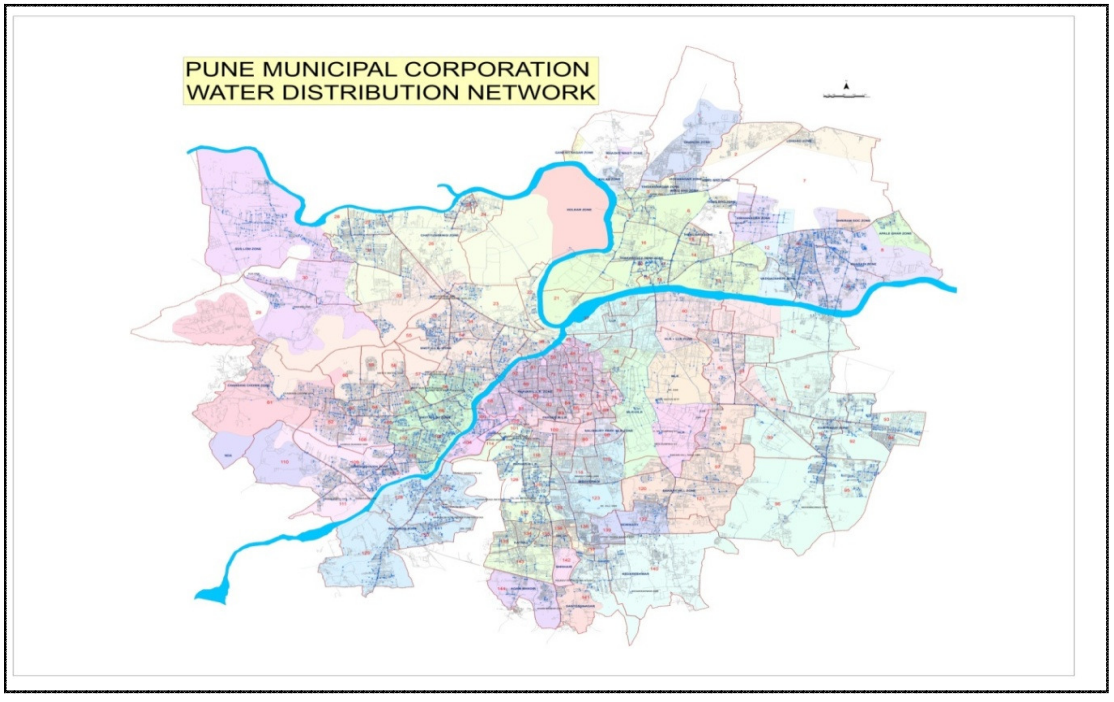
The base map is scanned using HP precision scanning software and the scanned image is stored in TIFF format and digitized using R2V software. The scanned image is opened by selecting the File/Open image of project menu. The coordinates of the control points are given according to the scale of the base map. The following commands are used for the digitization of the map:

- Layer Defined
- Lines Command
- Move Node Command
- Snap Node Command
- Split Line Command
- Point Command
- Form Polygon Command

The digitized map thus obtained by using the above commands is stored as project file with PRJ extension. The project file is exported as ARC or SHP format so that it can be used in ArcVIEW GIS respectively.

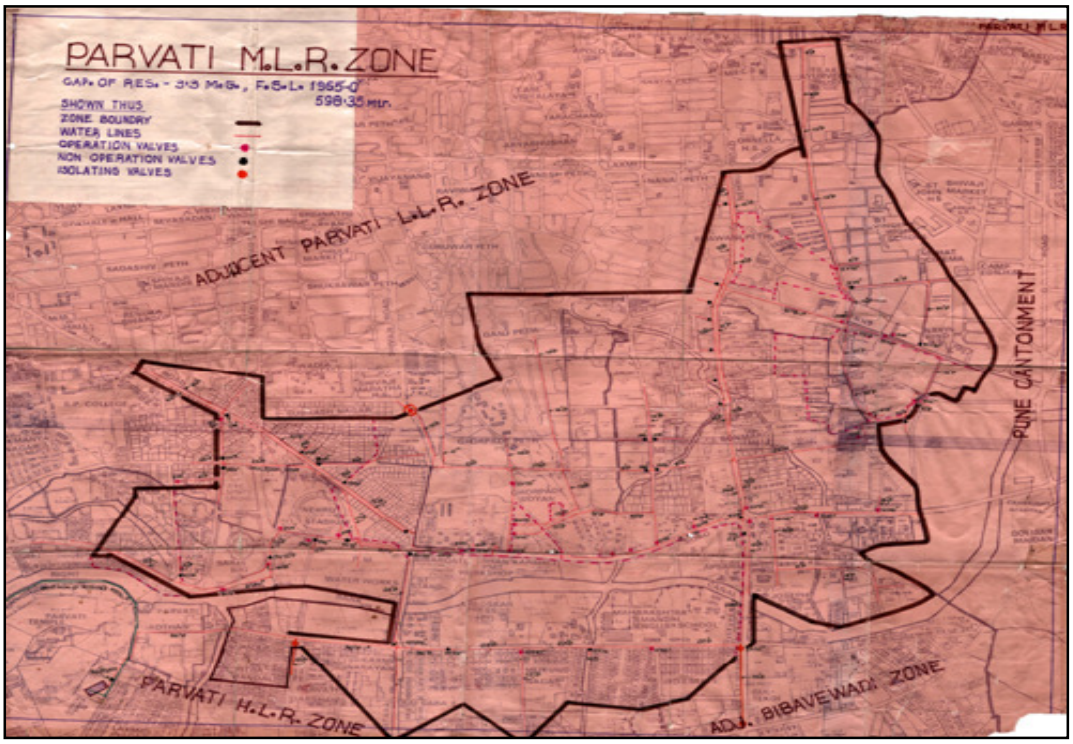
Map 6.3. Map of entire water distribution network of Pune City

Map 6.4. Digitized map of the water distribution network of MLR Zone of Pune City



Map No. 6.3: Water Distribution Network of entire Pune City

(Source: Water Distribution Department, PMC)



Map 6.4: Water Distribution Network of Middle Level Reservoir (MLR)

(Source: Water Distribution Department, PMC)

6.3.6.4. Adding Themes

For the purpose of this study, a new project is created in ArcVIEW GIS. From the PROJECT menu, a new map is created. The information is stored in different layers or themes. ADD THEME option in the view menu is used to add the spatial data to the map. The shape files created using R2V namely Operation valve , Open valve, Close Valve, Pipeline Network, Ward Boundary, MLR zone boundry,14 wards boundary, Morning valve timings, Evening valve timings etc. are imported in the map.

When the default legend setting given to the themes is changed using the LEDGEND EDITOR available in the theme menu. Using this, the legend for different themes has been changed. MLR zone Boundary and Pile line networks have been given the maximum thickness where as 14 sub wards and valves, the minimum thickness. Similarly, legend for the others themes have also been changed.

6.3.6.5.Adding Theme Attribute Tables

The tables, having the attribute data of the themes, are loaded by clicking the OPEN THEME TABLE button. By default, the attribute contains the information about the shape of the

theme whether it is a point, line or polygon and the id value. Fig 6.5 shows the various themes of map.

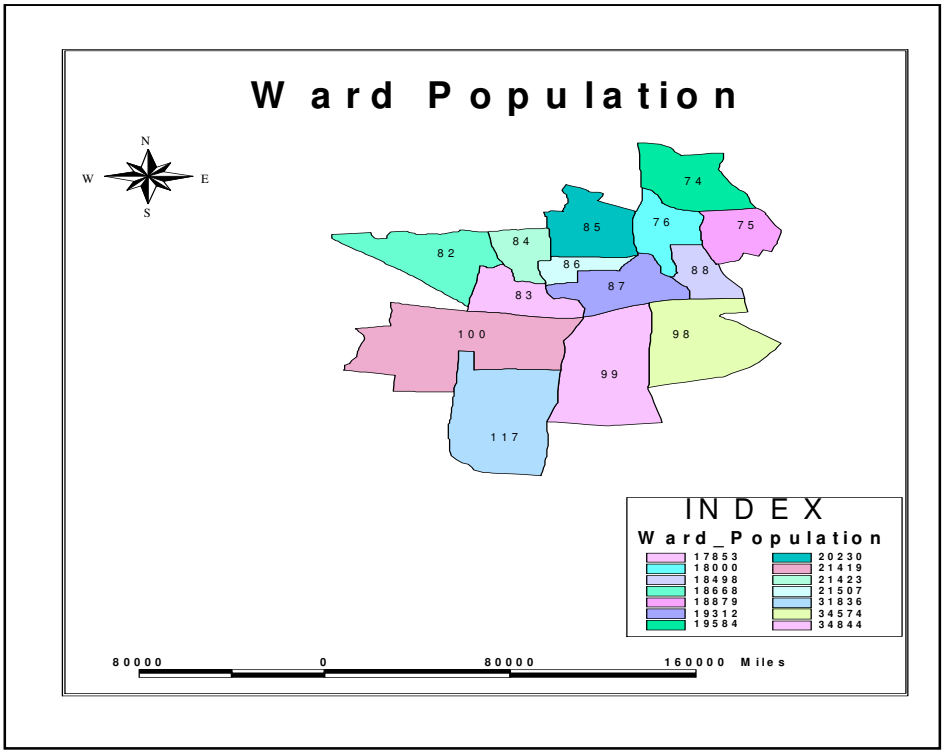


Fig. 6.5 : Ward Population under MLR zone developed using ArcView GIS

6.3.6.6. Editing Attribute Tables

The theme attribute tables are edited using the start edit option in the table menu. New fields are created using the add field option in the EDIT menu. The process of editing is done by clicking the edit menu bar and the data can be entered in the corresponding field. For example, in the layer called valve new fields are created to store the information regarding the valve type timings etc. The corresponding data can be fed in the respective fields. Similarly the attributes for the other layers are also defined.

6.3.6.7. Querry Builder

Querry is built by double clicking on these options with the mouse or by typing query directly into the query text box. By default, the querry is contained within parentheses, but the parentheses may not be required, depending on the complexity of query. If the update values choice is on, click once on a field name to list its values in the values list. The attributes of a single features on a map can be obtained by clicking on it with the identify tool in the menu bar. For example, to get the information regarding any of the religious places in the places of

worship layers, the IDENTIFY tool is clicked on the feature and the attributes of that features are highlighted in identify results window.

6.3.6.8. Merging Themes

Sometimes, two or more themes of the same shape need to be joined. The GeoProcessing Wizard tool only needs to be loaded once during a session. In the pipeline network, shape file having various diameters pipelines shape files are merged together using Merging Themes. Choose Extensions from the File Menu. Choose the GeoProcessing Wizard tool from the drop-down menu. Load the GeoProcessing Wizard by choosing GeoProcessing Wizard from the View Menu. Choose Merge themes together from the GeoProccessing screen. Click Next. There will be a new theme of the merged themes added to the project legend. The merging of various diameters pipelines are as shown in the following figure 6.6

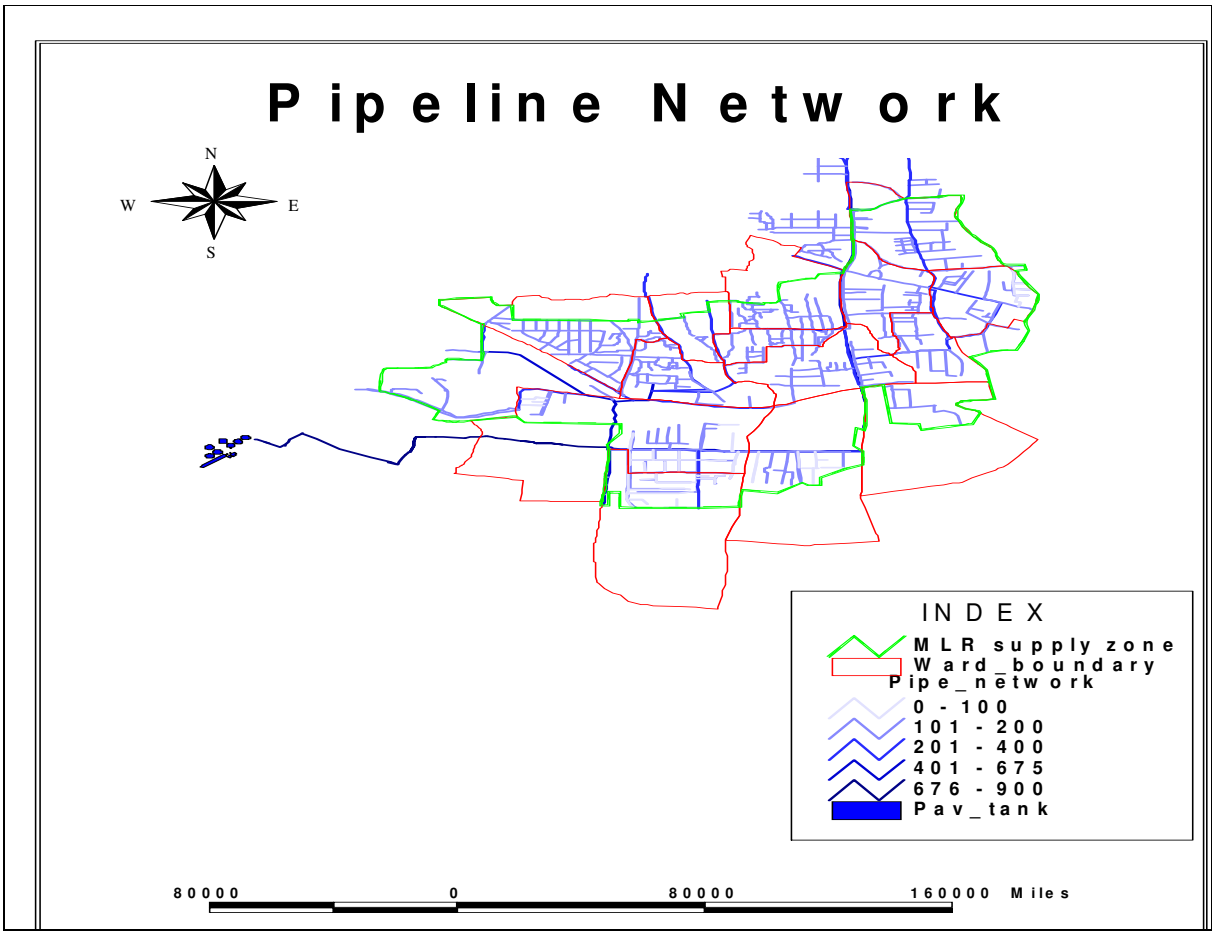


Fig.6.6: Water Distribution of Pipeline Network for MLR zone developed using ArcView GIS

6.3.6.9. Information Display Facility

Relevant icons are placed at appropriate places in the map for easy display of important locations. Important location includes main MLR zone boundary, water pipeline network, open valve, operation valve, close locations, sub ward boundaries etc. The user can customize options to view certain type of icons by selecting some option of show icons menu item and all to view all types of icons, and none option to view none. A left mouse button click on any of these icons will display the information regarding the locations represented by icons. This information includes a pictorial view of location, historical information if any, and other general information. A graphical output of information with icons displayed is as shown in the Fig. 6.7

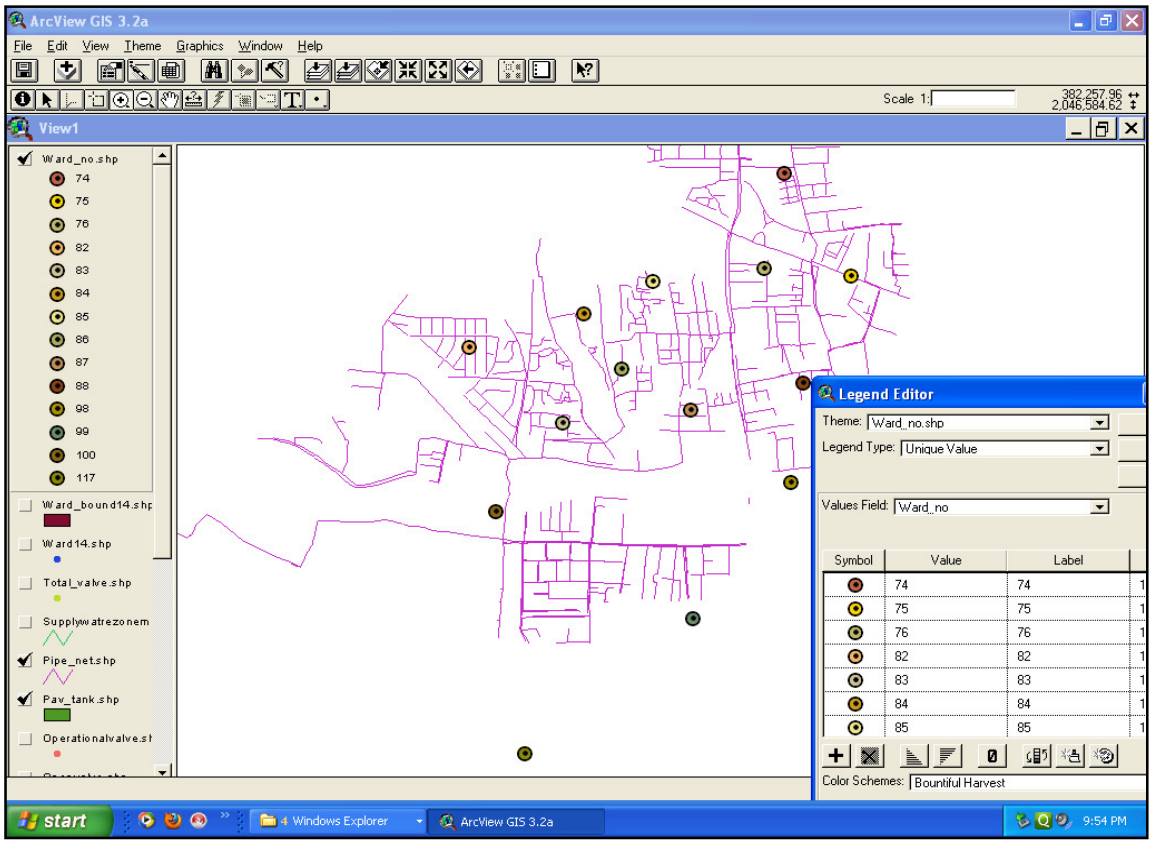


Fig. 6.7 : Graphical output of information with icons of Pipeline Network for MLR zone developed using ArcView GIS

6.3.6.10. Zooming Facilities

Zooming is an essential requirement of any GIS application because different users will appreciate between in different views. In MLR zone, the water network map can be zoomed to the required magnification or can be diminished as required by the user so the bigger map can be viewed easily. The map can be scrolled down or side by panning arrangement

provided by means of scroll bars. The user can customize his zooming options by selecting a zoom percentage. Fig 6.8 shows the enlarged view of MLR zone .Zooming options provided are 50percent,75percent,100percent,125percent,150percent,200percent,Zoom In , Zoom Out, Zoom All, Zoom Window and Enter Value.

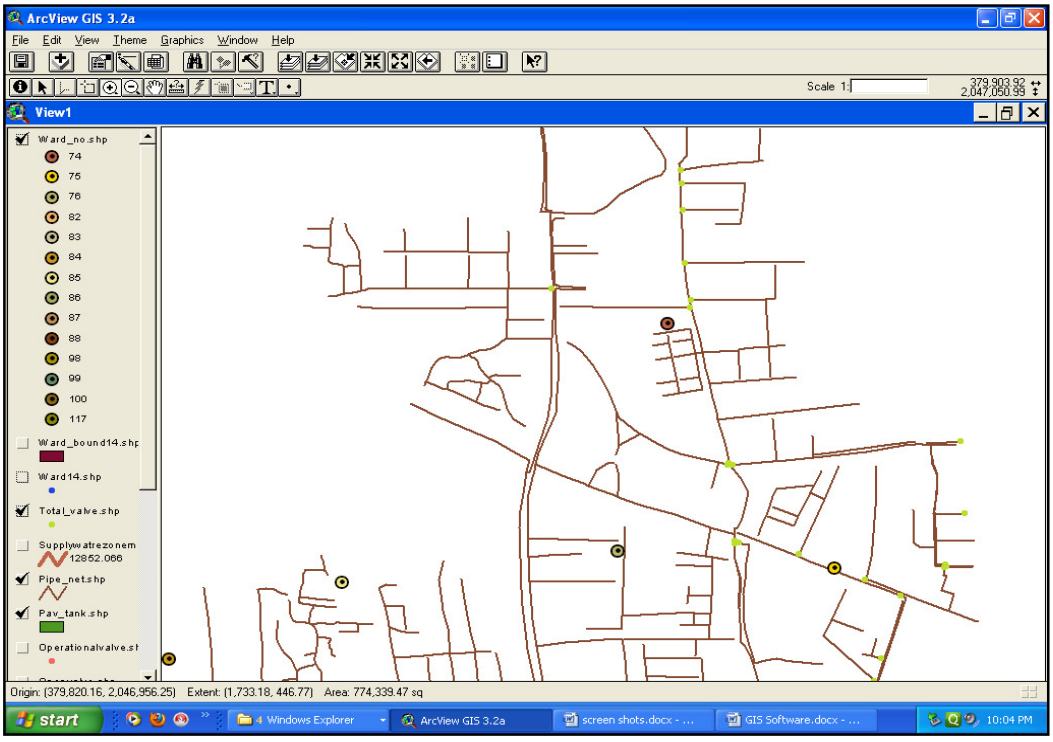


Fig. 6.8: Enlarged view of pipeline network of MLR zone developed using ArcView GIS

Sometimes, map may be required to move on the window at specified percentage in a specified direction. Thus, user can pan over without exiting a command when user is about to run off the view.

6.3.6.11. Facilities for Modification

In any GIS application, the geographically referenced data will change from time to time. Hence, it needs a mechanism to update or edit the information after intervals of time. This item provides management options such as new resources, updating relevant information and detecting the existing resources. Sub-menu items Mark Icon and Mark serves the above purposes. Change Font and Change Color options allow the user to choose font style and colour for labels shown on the map.

6.3.6.12. Valve Timing Information

Water supply user may require the information of valve timings of morning, afternoon, evening and night. This information display can be obtained y selecting valve timing shape

file available in GIS based MLR map. It will give the selected ward wise and total number of valves along with timing details, as shown in the following Fig 6.9

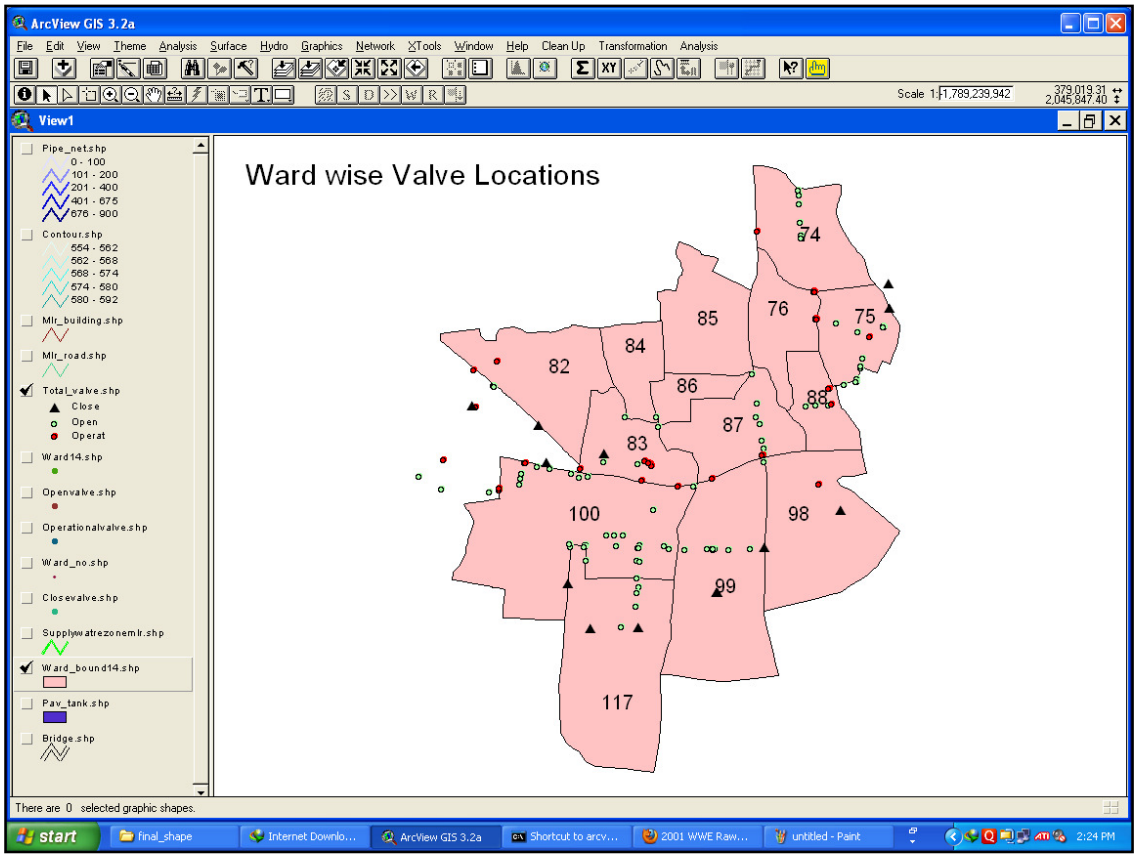


Fig. 6.9: Valve Type Information for Entire MLR Zone developed using ArcVIEW GIS

6.3.7. Developing the Methodology through District Metering Areas (DMA)

Before applying the methodology for locating water losses in a water distribution network, some minimal requirements should be satisfied. These requirements involve detailed studies on projects, investigations on field, construction works, training staff and many more subjects. Formation of a water distribution system goes through some essential phases like master planning, feasibility studies, rehabilitation studies, final design and construction. The resulting system is usually handed on to operations department. The work from now on is to operate the existing system, dealing with new consumers, repairing the failures and performing any kind of maintenance work including leak detection.

The ultimate objective is to trace any water drop from the source at the very beginning of the system to the taps of customers where it is consumed. It is possible only by having a water

distribution system that is totally under control. To achieve this goal, simple but important steps should be followed. These steps are briefly discussed below.

• Pressure zone borders have to be defined clearly (Figure 6.10). If any change in the pressure zone borders is to be made, it should not be made by combining zones having two different pressures but extending one zone up to the needed point. Defining pressure zone borders is crucial because they are the most suitable parts of the water distribution system that are open to exploits. In any case of low pressure problems, constructing new connections from a 35 upper pressure zone is used as the most practical solution. Changing pressure zone borders is one of the most harmful actions against a controlled water distribution network.

• The modern requirement of having SCADA, GIS is essential for a controlled water distribution system. SCADA is a must for measuring pressures and a discharge at various points, GIS is necessary for having an up to date knowledge of the system elements (pipes, fittings, pumps, tanks, etc.). With these three elements integrated together, a totally controlled water distribution system can be easily achieved.

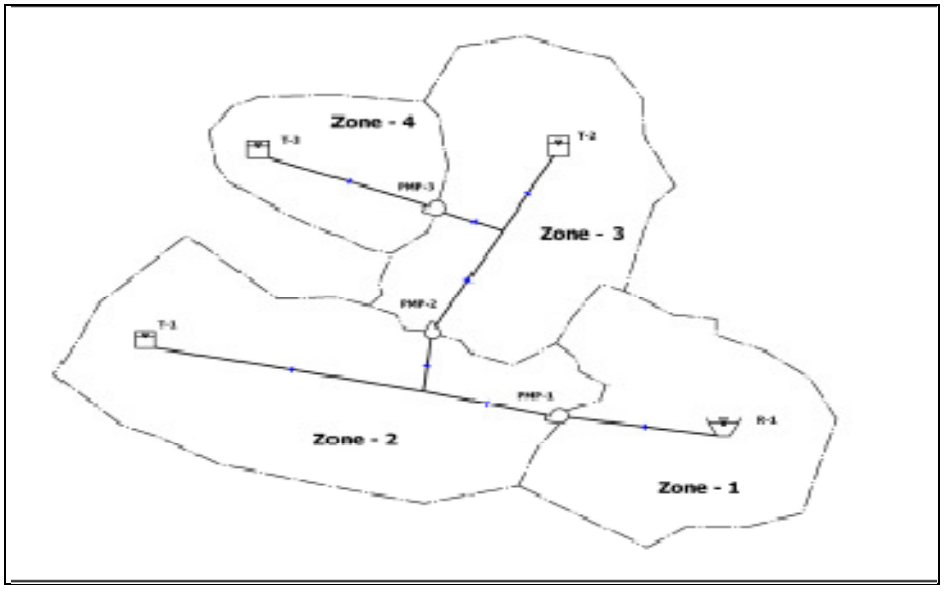


Fig. 6.10 : Defining Pressure Zone Boundaries for DMA

• To have a controlled water distribution system, it is necessary to know every element in detail.For the water distribution system elements; firstly pumps, main transmission lines (with every fitting on them) and water storage tanks should be precisely known. As a second step, distribution network should be known in detail with every fitting on them (Figure 6.11). Lastly, service pipes and customer locations should be known. These records are preferably

kept in GIS environment. Every change in the field has to be quickly reflected to the related GIS layers with enough accuracy.

• Unknown connections (connections physically existing in the network, but not drawn on as built projects) should never exist in the system. Unknown connections between networks (whether in the same zone or not) should be discovered and recorded. As a result, observations and measurements obtained from field would not meet theoretical studies done at the office.

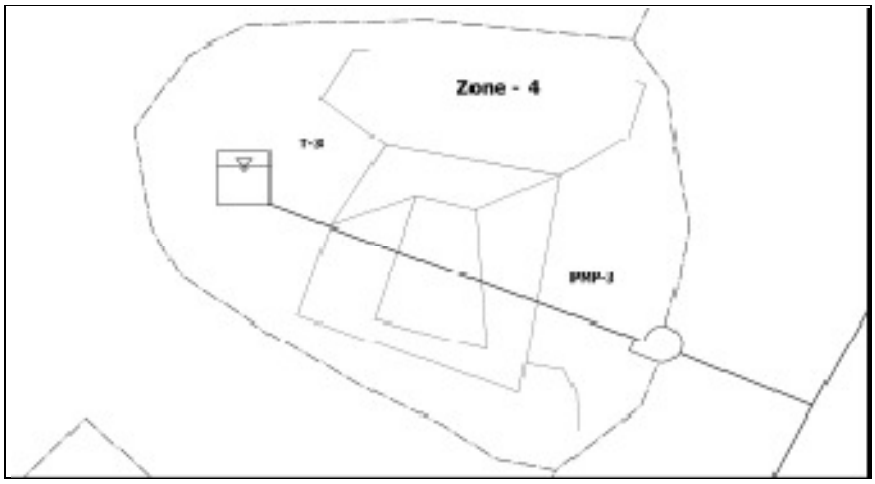


Fig. 6.11: Controlling Pumps, Tanks, Transmission and Distribution Pipes

• After detecting the routes of transmission lines, distribution network pipes with their fittings and service connection pipes, pressure zone borders should be defined with precision. The required precision is at building level (Figure 6.12). Every building (covering the customers inside) must be known with their pressure zones. Customers inside the borders of a pressure zone may be easy to determine but customers near the borders of the zone is harder to investigate. With this step, every building is assigned a pressure zone, therefore the reflection any action done on the pressure zones is known in building level.

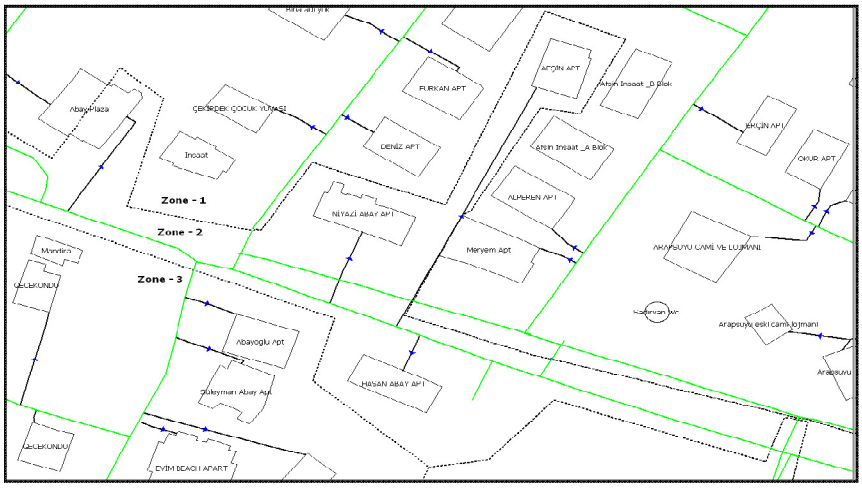


Fig. 6.12: Assigning Each Customer a Pressure Zone

•Upon completing the most necessary actions stated above, district metered areas can be formed for the purpose of water leak detection. The major purpose of completing the tasks for a controlled water distribution network is to clarify the mysteries that lie under the ground. When the infrastructure is known well enough, the working system is known in detail. Knowing the system in detail lets the water administration act consciously. Only conscious actions done on a working system leads the administration to its goals.

6.3.7.1. District Metering Area (DMA)

The concept of DMA management was first introduced to the UK water industry in the early 1980's in "Report 26 Leakage Control Policy & Practice, (UK Water Authorities Association (1980))". In this report, a DMA is defined as a discrete area of a distribution system usually created by the closure of valves or complete disconnection of pipe work in which the quantities of water entering and leaving the area are metered. The flow is analyzed to quantify the level of leakage. In this way, the leakage practitioner can determine more precisely where and when it is most beneficial to undertake leak location activities.

Beside the advances in leak detection practices and techniques (leak localizing, leak location, repair of leaks), in the 90s the District Meter Areas [6] (DMA) design was introduced in the management of the water distribution systems. A District Meter Area is an area supplied from few water inputs, into which discharges can be easily measured to determine leaks. The pressure-leakage relationship is well known, so in the DMA an effective control of the head patterns is performed, by means of pressure reducing valves to prevent the downstream hydraulic grade from exceeding a set value. Such technique is, therefore, an effective instrument to optimize the management of a water distribution system, with beneficial effects

on the water losses reduction and probably also on the pipe failure rates and rupture frequencies.

The District Metering Areas (DMA) design is an innovative methodology of water networks management, based on the pressure patterns control and on the water flows monitoring, in order to reduce water losses and to optimize the water systems management. A District Meter Area is an area supplied from few water inputs, into which discharges can be easily measured to determine leaks. So, the DMA design represents an alternative to the traditional approach based on heavy looped distribution network.

Water District Metering (WDM) is one of the most efficient techniques for water loss detection and pressure management and consists in partitioning a water network into subsystems called District Metering Areas (DMA).The division of the network in hydraulically independent districts can be obtained by installing flow meters and boundary valves. Pipe closure can compromise original water system performance because it reduces the network reliability. In this work, an original approach to define the Water District Metering, based on graph theory principles, is put forward.

A DMA is based on the principle of measuring and monitoring total flows within a hydraulically discrete pre-defined area, which is segregated from the rest of the network Customer complaints on water pressure and scarcity are reduced to nil once DMAs are implemented.

The DMA design can be chosen in alternative to the traditional approach [3] of heavy looped distribution networks. These systems on the one hand offer a remarkable level of reliability but on the other hand, they involve a less effective control of the water network and greater difficulties in the leakage management activities.

6.3.7.1.1. District Metering Area (DMA) Procedure

After the network was calibrated, several hypotheses of designing and implementing DMA to reduce physical losses were performed, according the following procedure:

- **District Meter Areas and the transmission mains connecting them to the network were identified**. Each District Meter Area had similar elevation, few connections with the remaining part of the network, and served a population of 10.000 to16.000.
- **Implementing each zone with intercepting valves and/or pressure reducing valves**.
- **Preliminary analysis of the district metered network was performed to provide adequate operating pressure of the system**. A minimum head pressure of 25 m was guaranteed with peak demands, as 5-6 storied buildings were present. The network served

as well 8 insulated tower buildings, which were supposed to be served with their own on site pumps.

- **Many numerical simulations** were performed to guarantee adequate head pressure for:
  - Daily demand, especially for peak hour's demand
  - Break of transmission mains
  -Fire hydrant service. Peak demands due to fires were estimated by assuming a concentrated flow of 30 l/s, requiring a minimum head pressure of 5 m.

The integrity of the DMA boundary as well as plant and equipment, i.e. it involves checks on the accuracy of meters and secondary instrumentation.

6.3.7.1.2. DMA Boundary maintenance includes

•Recording changes to the supply area and customer base

•Making sure that boundary valves are clearly marked and in the correct status

•Educating staff as to the purpose of closed valves and ensuring that, if operated, they are returned to the correct status.

6.3.7.1.3. Constraints in Designing DMAs:

There are a few constraints to designing DMAs:

• Traditional engineering design criteria and reluctance to close valves;

• Too many closed valves;

• Low network pressure and critical points;

• Intermittent supply;

• Creating dead-ends can reduce water quality.

Most of these constraints can be overcome by introducing DMAs in pilot areas; restoring supply temporarily in areas of intermittent supply; using a network model or pressure loggers to assess the effect on customer service levels; and by education and awareness training. Water quality problems can be overcome by a regular flushing programme or by re-designing the DMA boundary.

6.3.7.1.4. Formation and Evaluation of District Metered Areas[1] (DMA)

Every leak occurring in a water distribution network can be defined as a unique case. Type of the network, material of the pipes, workmanship, soil type of the region and operating pressures are just some of the uncertainties that can make the case unique. In order to take action against these kinds of unique cases, proper, standardized, methodological steps must be followed. Flows must be accurately measured in the distribution network for the grand purpose of tracing the input water from the source to the consumer. Most of the time,

metering is only done in two stages of the water distribution cycle. First metering is done at the water treatment plant, where the treated water is supplied to the system and last metering is done at the consumers at the billing stage. Without having any middle metering stages, any calculated lost water will be the representative amount for the whole distribution network area. Forming district-metered areas (DMA) will guide the water utilities to decide to focus on smaller segments of their distribution networks. By these establishments, water utilities will have the opportunity to watch over their networks not just as a big one-piece mechanism but also as a big mechanism that consists of several smaller living parts. Metering of the DMAs, continuously with SCADA systems or by routine metering with portable equipment helps the water utility to take control over the metered area.

DMA realizations should have some limitations in size. DMAs that are small in size but large in quantity may have a high initial cost to the water utility, but controlling smaller DMAs may be easier. On the other hand, large sized DMAs will have low initial cost. However, as the area gets larger in size to take control over the area will be harder. These boundaries may be in terms of area, pipe length or number of consumers. In some cases, natural topographic limitations may force the utility for a DMA design.

According to Butler[5], He suggest typical DMA sizes in UK in terms of property counts. The given limitation is areas having properties between 1000 and 5000. This can be used as a guideline for limiting the size of the DMAs. Assuming every property having 5 people living, the limits become 5000 to 25000 people. DMAs containing properties less than 1000 mean too small areas. When the area gets smaller, it will be easier to manage the water losses, and every detail in the network could be better investigated. On the other hand possibly too many dead ends will be created in the network.

When DMAs contain more than 5000 properties, the area becomes too big to manage. It will take too much time to scan the area for water losses. In addition, it will be easy to miss the unknowns in the network (unknown connections, forgotten valves left closed, etc.). At the absence of population and building number data, DMA sizes can be defined considering the lengths of distribution network pipes. If an example in terms of pipe lengths is to be given; DMA's total pipe lengths should not be less than 5000 meters and should not exceed 25000 meters. DMA formation can be studied in two points of view. One is forming the DMA before the construction of the water distribution network. The other is to divide and isolate the divisions in an existing water distribution network to form DMA.

DMA formation has to be done with valve closing operations in order to divide the area into smaller areas. This may have some disadvantages while the operations are applied to the field

like, not properly working isolation valves or unknown connections (pipes and/or valves) within the network.

Second point of view deals with DMA formation in existing networks. As stated above the existing network will be either in the form of a branching system, a grid system or a combination of these two.

The solution for purely branching systems may be to make each and every branch a DMA (measuring at points A and B), which may be an expensive solution, or place metering points at some predefined points on the water distribution mains and use differences between these metered values for the branches between metering points (at points C, D and E). An example for this case can be seen in Figure 6.13. As a rule of thumb, forming a DMA can be stated as drawing a closed border around the network without crossing any of the pipes; except the pipe that is both the starting and ending point.

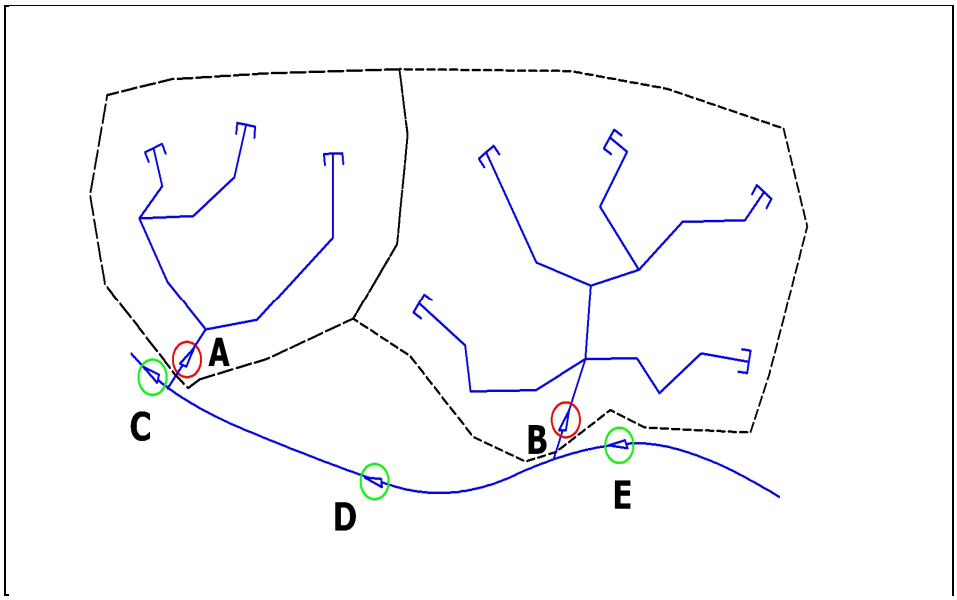


Fig.6.13: Forming DMA in a Branching Network

When it comes to form DMA regions in a grid or a grid and branch combined system, valves and their locations on the network becomes extra important. A sample DMA formation for grid systems can be seen in Figure 6.13. Measuring points are located at A and B. The advantage is ability to define different DMA areas by a few valve operations. The disadvantage may rise in a hydraulics problem in which the defined and applied DMA may suffer from low water pressures in peak consumption hours. The solution to this problem can be found in defining the DMAs only for short terms. Here, short term is defined as applying the DMA and necessary valve operations only for the hours of minimum usage (mainly night hours until early morning) while actively working on the field for leak detection. DMAs that

are not suffering this kind of problems can be left as permanent areas, so need for valve operations becomes unnecessary.

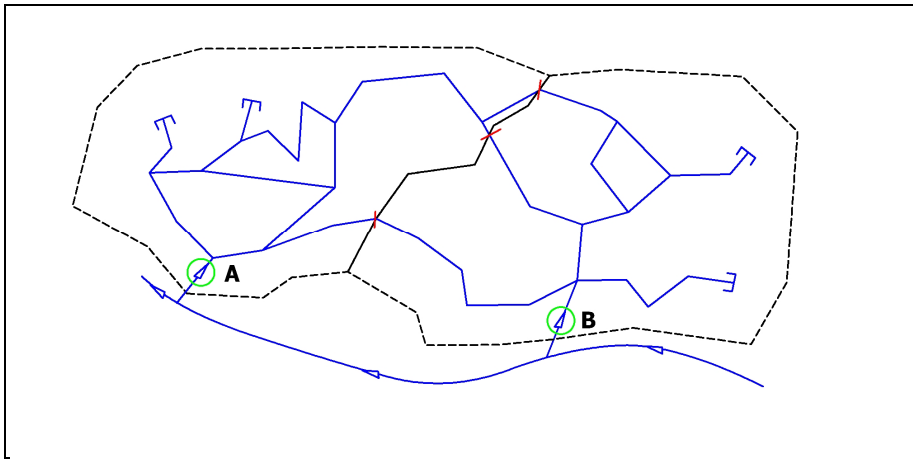


Fig.6.14 : Forming DMA in a Branching Network in a Grid Network

A procedure to be followed for DMA formation can be given like this:

• Clearly identify the transmission mains and their branching points to the secondary pipes.

• Obtain maximum knowledge about paths of the secondary pipes and the valves placed on them.

• Keep all valves in operating condition.

• Define the desired limits for DMA size.

• Use the largest diameter branching pipe as the entrance for the aimed DMA.

• Draw the borders of the DMA around the area within the desired size by crossing pipes only on the points of isolation valves.

• Place the discharge-metering device (water meter) on the entrance branch pipe.

• Keep the isolation valves closed whenever DMA is in use.

A valve at the entrance of the area can be useful for testing the validity of the DMA. After isolating the area from the rest of the network, the entrance valve can be closed and the area can be observed if there is an unknown source entering the system. Normally, with this operation all the consumers should have a shortage of water within some time. This means that the border drawn in office is valid on the field too. If there are some consumers still not affected from closing of the entrance valve, it shows either an isolation problem or an unknown connection from neighboring zones.

6.3.7.1.6. Formation of Sub-DMAs

Dividing DMAs into smaller regions using valves can be used to determine the starting point for water leak detection. In practice, the DMA is divided into smaller sub-DMAs, which

consist of only a few streets. Therefore, with operations like step testing, it might be possible to choose the weakest places of the DMA. This step can be preferred for quick analysis of large DMA areas where maximum benefit is aimed within limited time.

Sub-DMAs are formed just like forming DMAs. It should be carefully checked that unknown connections should not exist between isolated sub-DMAs. In such a case, it is not possible to form the needed isolated area. The technique whereby a leak or leaks are detected by making temporary successive valve closures to reduce the size of a district or sub-district (generally called a Leakage Control Zone) and typically may contain 500 to 1500 connections is often known as Step Testing. The valves are closed for a short duration whilst simultaneously measurements of the rate of flow are being made. If the resultant reduction is greater than anticipated, taking into account the number and type of customers in the section isolated, it is an indication of a leak. Step tests are generally undertaken during the period of minimum night flow (often between 02.00 a.m. and 04.00 a.m.). Carrying out such a test at this time avoids causing supply problems to the majority of customers.

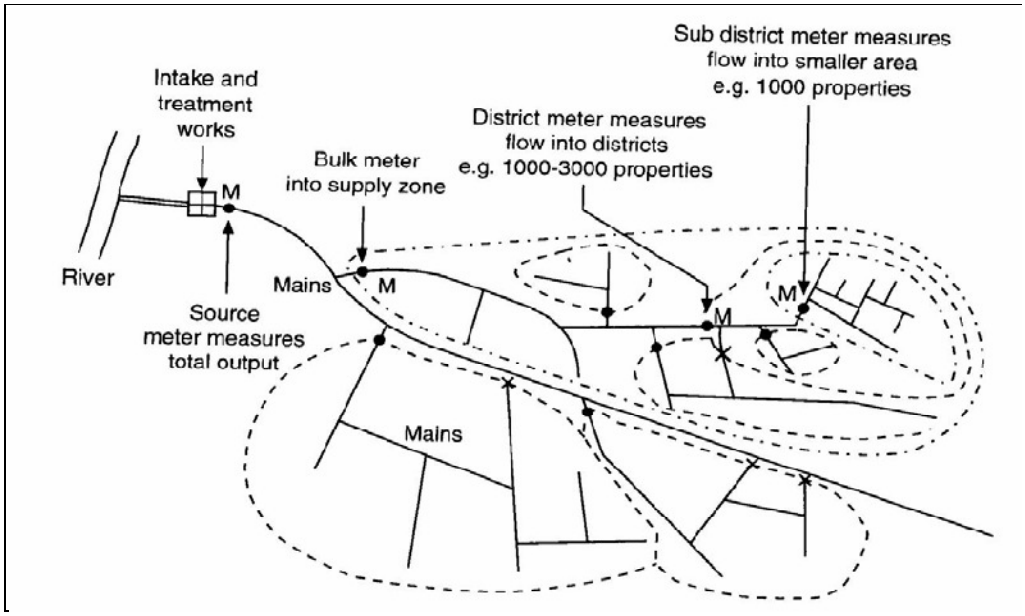


Fig. 6.15 : Layout of Districts and Sub-districts

A step test needs to be carefully planned in order that it can be carried out during the period of minimum night flow. Therefore, the number of valves that need to be operated needs to be carefully considered. The size of the individual steps does depend on the size of the Leakage Control Zone. In an urban zone of 1500 connections a step size of approximately 150 connections. In practical terms, it is advisable not to have fewer than 10 steps but this may be determined by the location of existing valves.

Forming sub-DMAs inside a DMA may have advantages in terms of taking control over the network. Keeping a valve just behind the sub-DMA entrance enables the field operator to control a few street pipes by using only one valve.

To use one valve to control a whole DMA requires little investment and maintenance, as there is only one valve to keep an eye on. This provides a superficial control over the network of the DMA. This means that only rough experimental actions can be applied to the network (shutting the whole DMA). When sub-DMAs are formed, all the necessary valves behind sub-DMA entrances should be kept usable. This step requires more investment and maintenance. However, a better level of control over the network is provided. As a result, much more flexible operations over the network may become available (shutting any combinations of sub areas inside the DMA). If an ultimate degree of control is required over the network, all of the valves at each street intersection should be kept usable. As a result, an in-depth control over the network is guaranteed, meaning very precise operational actions over the network can be made (shutting any street level pipe combinations). The three different situations can be explained with fictitious valve numbers. Low Control (*1/50 valve*): If a DMA is known to have 50 valves installed, but only the main valve at the entrance is kept ready for usage it is an example for the first situation. In this case, only shutting the whole DMA can be performed. Medium Control (*20/50 valve*): It may be any number between 1 and 50 but to be similar with the case study, it is given as 20 of the 50 valves are being used. In this case, a few sub-DMA regions can be defined, and step tests can be performed. Sub-DMAs can be shut down without disturbing other parts of the DMA.

High Control (*50/50 valve*): Each water distribution network should reach this ideal situation. In this case, all of the installed valves are being used. Sub-DMA formation concept can be ignored by some water loss operators that do not prefer to prioritize the area instead prefer to search for leaks covering the whole area.

6.3.7.1.6. Design District Metering Area for Middle Level Reservoir Zone

There are 14 sub wards in the MLR zone. Researcher has created DMA design for entire MLR zone. The following Figure shows the Pipeline network for Ward No.83 and DMA design for Ward No.83. DMA design for all wards refer **Annexure 12.**

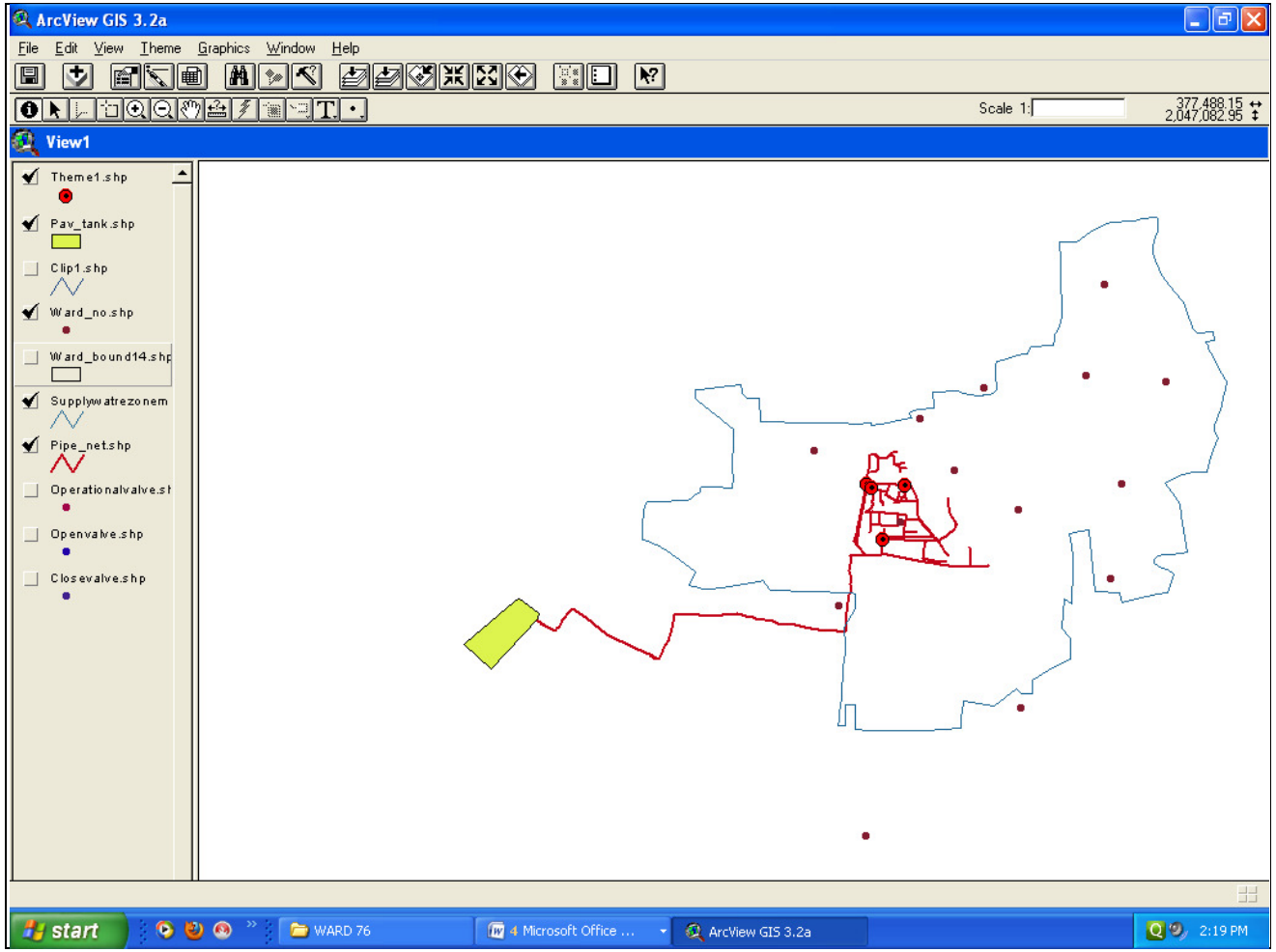


Fig.6.16: Pipeline Network for MLR zone of Ward No: 83 Ward Name: Ghorpade udyan developed using ArcView GIS

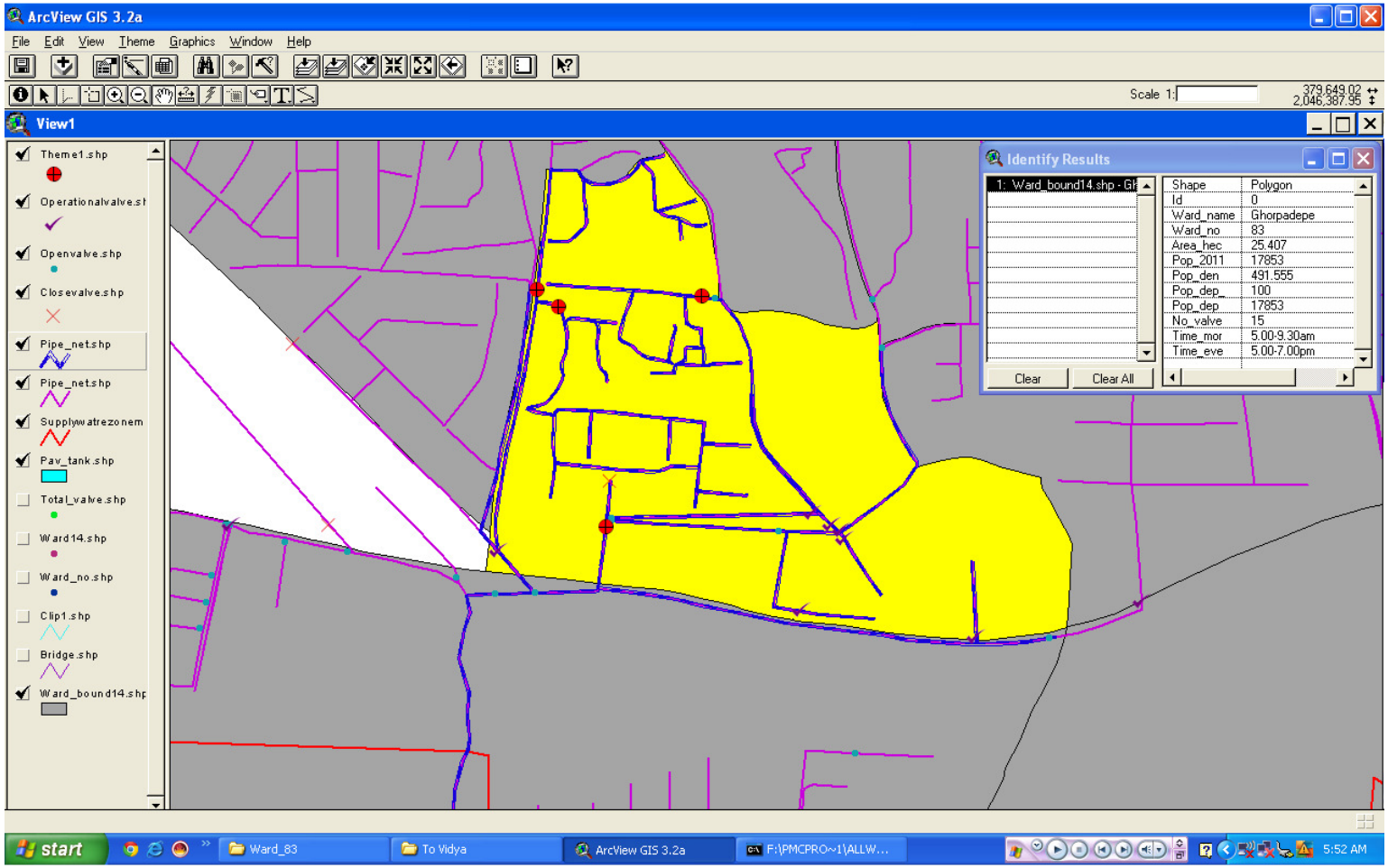


Fig.6.17 :DMA design for MLR zone of Ward No: 83 Ward Name: Ghorpade udyan developed using ArcView GIS

6.3.7.1.6. Leakage monitoring in DMAs

The technique of leakage monitoring is considered to be the major contributor to cost effective and efficient leakage management. It is a methodology which can be applied to all networks. Even in systems with supply deficiencies, leakage monitoring zones can be introduced gradually. One zone at a time is created and leaks detected and repaired, before moving on to create the next zone. This systematic approach gradually improves the hydraulic characteristics of the network and improves supply. Leakage monitoring requires the installation of flow meters at strategic points throughout the distribution system: each meter recording flows into a discrete district which has a defined and permanent boundary. Such a district is called a district metered area (DMA).

In some cases, the flow meter installation will incorporate a pressure-reducing valve (PRV). Figure 6.18 shows an example of the configuration of several DMA types within "water into supply" (WIS) zone boundary, and the DMA recording system. The DMA meters are sometimes linked to a central control station via telemetry, so that flow data are continuously recorded. DMA has progressively and consistently increased, indicating a burst or undetected leakage.

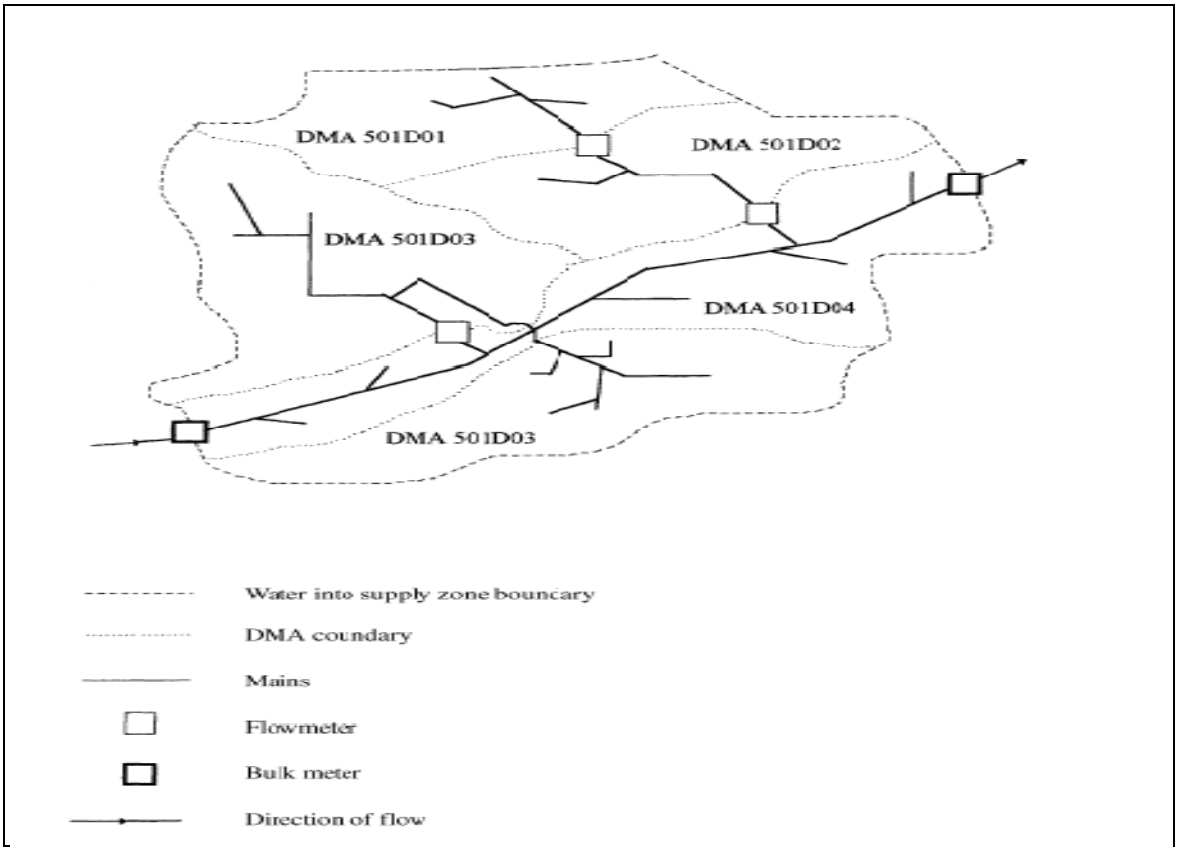


Fig.6.18: District Metering Area types in Water Supply Boundaries

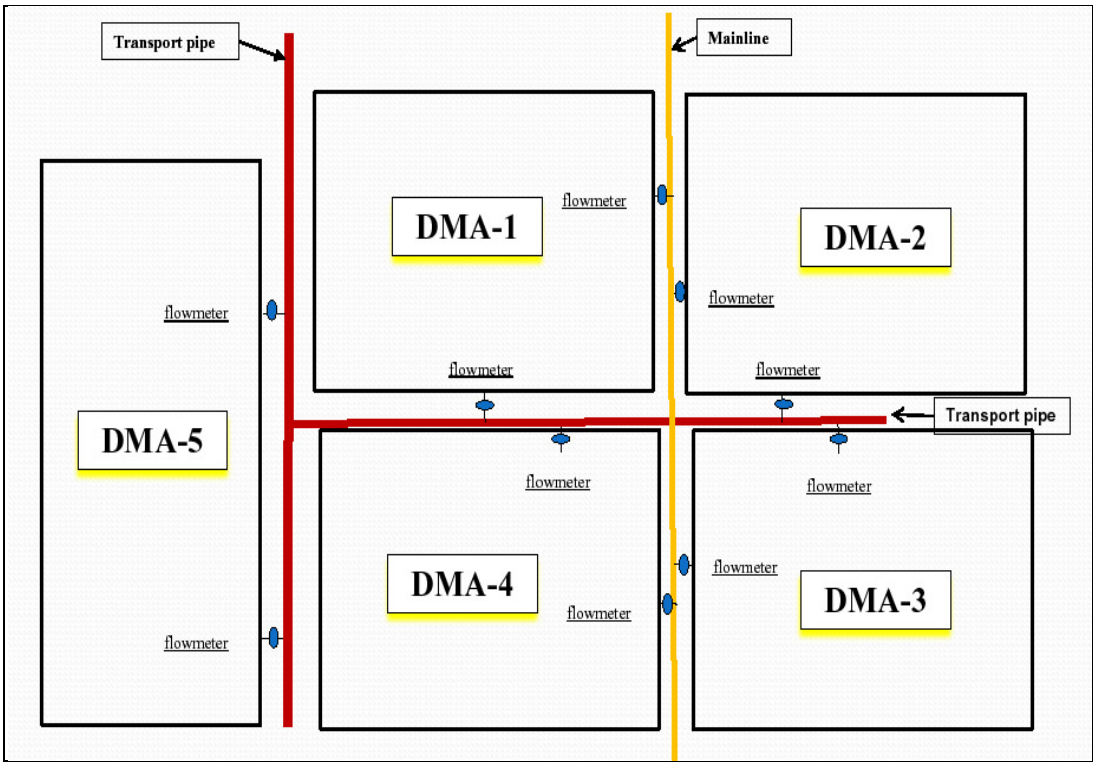


Fig.6.19: Typical DMA Design

The above fig. 6.19 shows the typical DMA Design. DMA maintenance is crucial to maintain the accuracy of the data. It includes maintaining the integrity of the DMA boundary as well as plant and equipment, i.e. it involves checks on the accuracy of meters and secondary instrumentation.

6.3.7.1.6.1. Leak localizing

Once the network is divided into DMAs, those showing a greater volume of night flow per connection than the others, can then be inspected more thoroughly by carrying out a leak localizing exercise. Inspectors can then be deployed to locate the precise leak position in the culprit section of pipe. Examples of these are:

• Step test – a technique which requires the progressive isolation of sections of pipe by closing line valves, beginning at the pipes farthest away from the meter and ending at the pipe nearest the meter. During the test, the flow rate through the meter is observed, and the times when each section of pipe is isolated are noted. A large decrease in flow, or "step", indicates a leak in the section of pipe which has just been isolated.

• Correlator survey;

• Acoustic logger survey (sometimes combined with correlation).

6.3.7.1.6.2. Leak location

Leak location is carried out using one or more of the following pieces of equipment:

• Basic sounding stick- The basic instrument is the sounding stick, which is used either as a simple acoustic instrument or one which is electronically amplified. This technique is still widely preferred by the majority of practitioners, and is used for:

- blanket surveys, sounding on all fittings;
- sounding on valves and hydrants;
- Confirming the position of a leak found by other instruments.

• Electronic sounding stick

• Ground microphone (or an "array" of microphones laid along the line of the pipe)

• Leak noise correlator -The leak noise correlator is the most sophisticated of the acoustic leak location instruments. Instead of depending on the noise level of the leak for its location, it relies on the velocity of sound made by the leak as it travels along the pipe wall towards each of two microphones placed on convenient1y spaced fittings. The instrument is portable, and so can be operated by one person, and it has the capability for frequency selection and filtering.

6.3.7.1.7. Water Loss Calculation

The water Loss calculation is calculated by using the following formula,

The Hazen–Williams equation[12] is an empirical formula which relates the flow of water in a pipe with the physical properties of the pipe and the pressure drop caused by friction. By using this formula, we can calculate head loss in pipes and tubes due to friction.

SI units

When used to calculate the head loss with the International System of Units, the equation becomes: [15]

where:

$$h_f = \frac{10.67 \quad L \quad Q^{1.85}}{C^{1.85} \quad d^{4.87}}$$

- h_f = head loss over a length of pipe, m (head pressure)
- L = length of pipe, m (meters)
- Q = volumetric flow rate, m^3/s (cubic meters per second)
- d = inside pipe diameter, m (meters)
- *C* =factors used in design [11] which take into account some increase in roughness as pipe ages are as follows

Material	C Factor low	C Factor high
Asbestos-cement	140	140
Cast iron new	130	130
Cast iron 10 years	107	113
Cast iron 20 years	89	100
Cast iron 30 years	75	90
Cast iron 40 years	64	83
Cement-Mortar Lined Ductile Iron Pipe	140	140
Concrete	100	140
Copper	130	140
Steel	90	110
Galvanized iron	120	120
Polyethylene	140	140
Polyvinyl chloride (PVC)	150	150
Fiber-reinforced plastic (FRP)	150	150

Water loss calculation for all wards are calculated refers **Annexure 13**.

6.3.7.1.7.1. Water loss calculation through DMA Implementation

DMA implemation precess and water loss calculation is as follows:

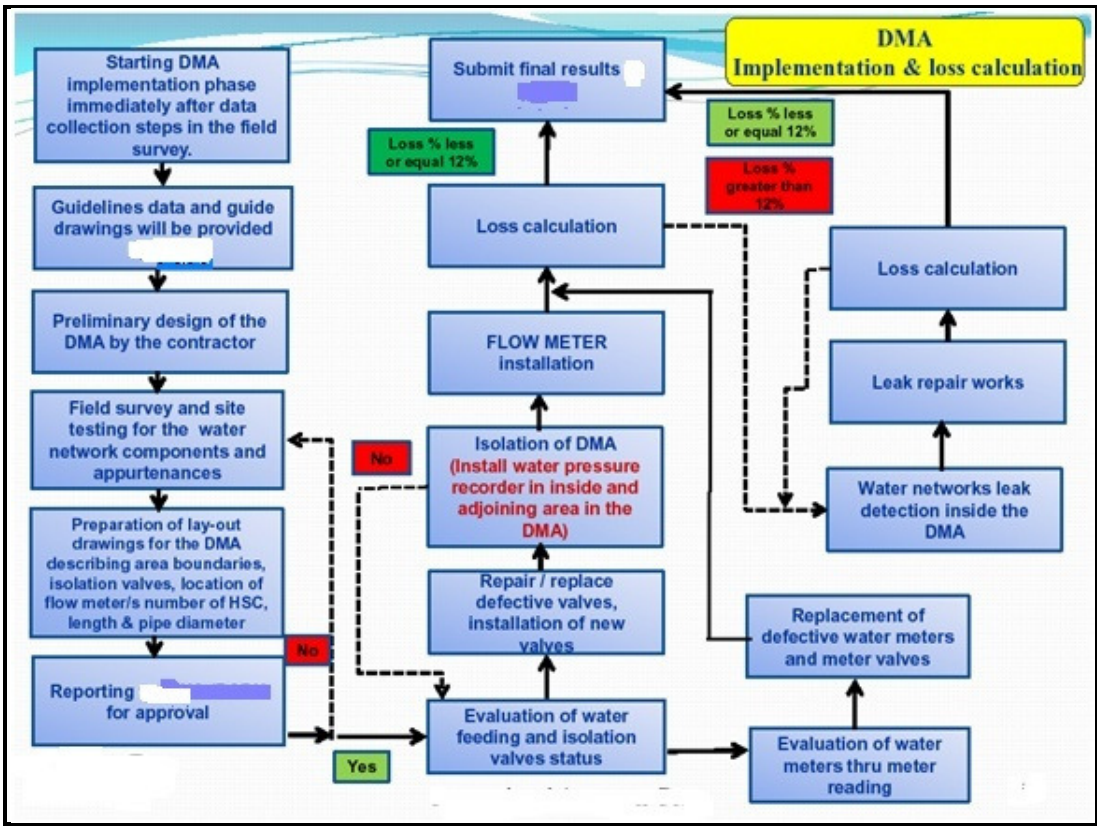


Fig.6.20: DMA Implementtaion & Water Loss Calculation

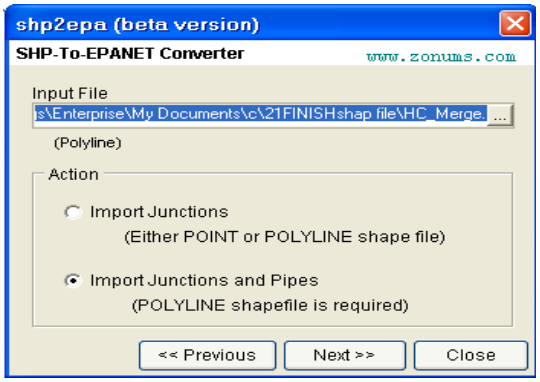
6.3.8. EPANET Hydraulic Water Model

The basic function of a water supply system is to deliver water from sources to customers. Moving water from source to customer requires a network of pipes, pumps, valves, and other appurtenances. Storing water to accommodate fluctuations in demand due to varying rates of usage or fire protection requires storage facilities, such as tanks and reservoirs. Pipes, pumps, valves, storage, and the supporting infrastructure together comprise a water supply system. A hydraulic network model is a mathematical model of a water supply system in which the physical components of the system are represented as nodes and links. Hydraulic network analysis utilizes the physical and operational properties, topology, and demands of a water supply system as basic input data, and calculates pressures at nodes and flows in links. Hydraulic network analysis can be used to predict pressure and flow conditions in a water supply system under different operational scenarios to ensure that sound, cost-effective engineering solutions can be implemented in the design, planning, and functioning of the water supply system.

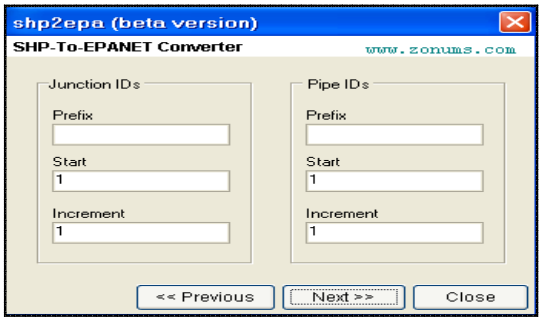
This section provides a brief introduction of hydraulic network analysis. The basic methodology for hydraulic network analysis is introduced. The EPANET hydraulic simulation models are described for Ward No. 82 & 83 under MLR Zone.

6.3.8.1. Conversion data from .shp files to .Epa files

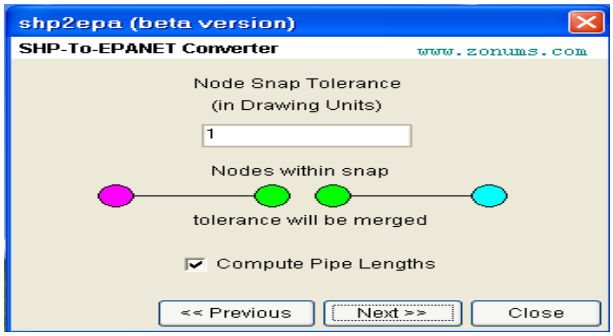
Step I:



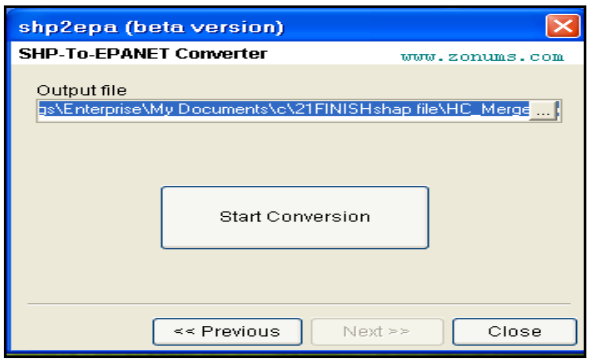
Step II:



Step III:



Step IV:



6.3.8.2. Components in Hydraulic Networks

In general, a hydraulic network model consists of two basic classes of elements: nodes and links. The nodes represent facilities at specific locations in a water supply system, and the links define relationships between nodes. Typical nodal elements include junctions and storage nodes, and typical link elements are pipes. Other components, such as valves and pumps, can be modelled as either links or nodes, depending on different modelling techniques. The primary modelling purpose of each physical element is briefly described below.

- **Junctions**: represent locations where links intersect and where water enters or leaves the network.
- **Storage nodes**: represent locations of storage reservoirs and tanks. The pressures at storage nodes are known and treated as boundary conditions to solve flow equations. In contrast to tanks, which have limited storage capacity and for which the volume of stored water varies with simulation time, reservoirs represent external water sources with unlimited storage capacity, such as sources from lakes, rivers, or ground aquifers.

- **Reservoirs:** The reservoir works as a drain or as a water source. It is a good idea to use one when working with Epanet, to avoid error warnings. The volumetric mains constant regardless of water input or output because of its huge size incomparison to the system. In order to picture what they could be like, think of rivers, lakes, and aquifer.
- **Pipes:** represent links conveying water from one node to another.
- **Pumps:** represent elements adding energy to flowing water in the form of an increased hydraulic grade. A pump can be modeled as either a node or link.
- **Valves:** represent elements controlling water flow or pressure from one node to another. A valve can be modeled as either a node or link. There are different types of valves with different functions, such as check, pressure reducing, flow control, throttle control, air release, and vacuum breaking valves.

These physical components are interconnected to form a network and operate together under some operational rules. Typical operational rules include the change of the status of pipes, pumps, and valves under certain conditions. For example, the status of a pump is typically controlled by the water level of the tank it serves. When water in the tank is lower than a certain level, the pump is opened to boost water to the tank. When water in the tank is higher than a certain level, the pump is closed and the tank supplies water to customers. The operational rules give a water supply system the ability to work efficiently under different operation scenarios.

6.3.8.3. EPANET Hydraulic Model for Ward No.82 & 83 under MLR Zone

Many commercial software packages are available in the market for hydraulic network analysis. Among them, EPANET, developed and distributed by the US Environmental Protection Agency (EPA) [17], is one of the earliest and most widely used. Because EPANET contains a state-of-the-art hydraulic analysis engine and its source code is freely available to the public, a family of software packages including WaterCAD [22], MIKENET [14] , H2ONET, and others, use the EPANET analysis engine and develop their own products around it.

EPANET was designed to be a research tool for improving the understanding of the movement and fate of drinking water constituents in water distribution systems. It has two major capabilities: hydraulic and quality modelling for water in a pressurized pipeline network. The water quality modelling is beyond the scope of this study, and therefore, only the hydraulic modelling capabilities of EPANET are discussed.

EPA uses Windows-based software called EPANET to model water distribution piping systems [21]. EPANET is a computerized simulation model which was developed by the National Risk Management Research Laboratory to help water utilities meet the growing need to better understand the movement and transformations undergone by treated water that is introduced into their distribution systems in order to meet regulatory requirements and customer expectations. EPANET performs extended period simulation of the hydraulic and water quality behaviour within pressurized pipe networks [21]. It predicts dynamic hydraulic and water quality behaviour within a drinking water distribution system operating over an extended period of time[20].

6.3.8.3.1. EPANET

EPANET is a Windows -based programme that performs extended period simulation of the hydraulic and water quality behaviour within pressurized pipe networks. The software is available free to the public. "EPANET [16] was developed to help water utilities maintain and improve the quality of water delivered to consumers through distribution systems. It can assist in evaluating alternative strategies for improving water quality, such as altering source use within multi-source systems, modifying pumping and tank filling/emptying schedules to reduce water age, using booster disinfection stations at key locations to maintain target residuals, and planning cost-effective programmes of targeted pipe cleaning and replacement [17] ".

Distribution system networks consist of pipes, nodes (pipe junctions), pumps, valves, and storage tanks or reservoirs. "EPANET tracks the flow of water through each pipe, the pressure at each node, the height of the water in each tank, and the concentration of different chemicals throughout the network during a simulation period". The software provides an integrated computer environment for editing network input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats including color-coded network maps, data table, time series graphs, and contour [17] plots.

EPANET provides an extended-period hydraulic analysis package that can handle systems varying size, compute friction head loss using the Hazen-Williams, the Darcy Weisbach, or the Chezy-Manning head loss formula, including minor head losses for bends and fittings. It can model constant or variable speed pumps, compute pumping energy and cost, model various types of valves and storage tanks of different shapes. It can consider multiple demand categories at nodes, each with its own pattern showing variation with time variation, model pressure-dependent flow from emitters and base system operation on simple tank level or timer controls as well as on complex rule-based controls [17].

EPANET can be used to plan and improve a system's hydraulic performance and assist with pipe, pump, and valve placement and sizing. It can also be used to determine ways for minimizing energy usage; conduct fire flow analyses; vulnerability studies; and operator training programmes[17]. EPANET [20] has a water quality analyzer that can model the following:

- The movement of a non-reactive tracer material through the network over time.
- The movement and fate of a reactive material as it grows or decays over time.
- The age of water throughout a network.
- The percent of flow from a given node reaching all other nodes over time.
- The reactions both in the bulk flow and at the pipe wall.
- Growth or decay reactions that proceed up to a limiting concentration.
- Global reaction rate coefficients that can be modified on a pipe-by-pipe basis.
- Time-varying concentration or mass inputs at any location in the network.
- Storage tanks that are complete mix, plug flow, or two-compartment reactors.

EPANET's Windows user interface provides a network editor that simplifies the process of building piping network models and editing their properties. Various data reporting and visualization tools such as graphical views, tabular views, and special reports, and calibration are used to assist in interpreting the results of a network analysis.

6.3.8.3.2. EPANET Hydraulic Modelling Capabilities

• No limit on the size of network that can be modeled.

• Computes friction head loss using either Hazen-Williams,Darcy-Weisbach, or Chezy-Manning equations.

• Includes minor head losses for bends, fittings, etc.

• Models constant or variable speed pumps.

• Computes pumping energy and cost.

• Models various types of valves including shutoff, check, pressure regulating, and flow control valves.

• Allows storage tanks to have any shape (i.e., diameter can vary with height).

• Considers multiple demand categories at nodes, each with its own pattern of time variation.

• Models pressure-dependent flow issuing from emitters (sprinkler heads).

• Base system operation on both simple tank level or timer controls and on complex rule-based control.

EPANET's Windows user interface provides a network editor that simplifies the process of building piping network models and editing their properties. Various data reporting and visualization tools such as graphical views, tabular views, and special reports, and calibration are used to assist in interpreting the results of a network analysis.

6.3.8.3.3. EPANET Hydraulic Network Components

An EPANET hydraulic network model consists of various physical components, which are the mathematical representations of physical objects in a real water supply system. Mathematical representations are also used for operational components that control the behavior and operational properties of the physical components.

6.3.8.3.4. Physical components of the network model

EPANET models a water distribution system as a collection of links connected to nodes. The links represent pipes, pumps and control valves while the nodes represent junctions, tanks and reservoirs. The figure 6.21 below shows the physical components of a distribution system.

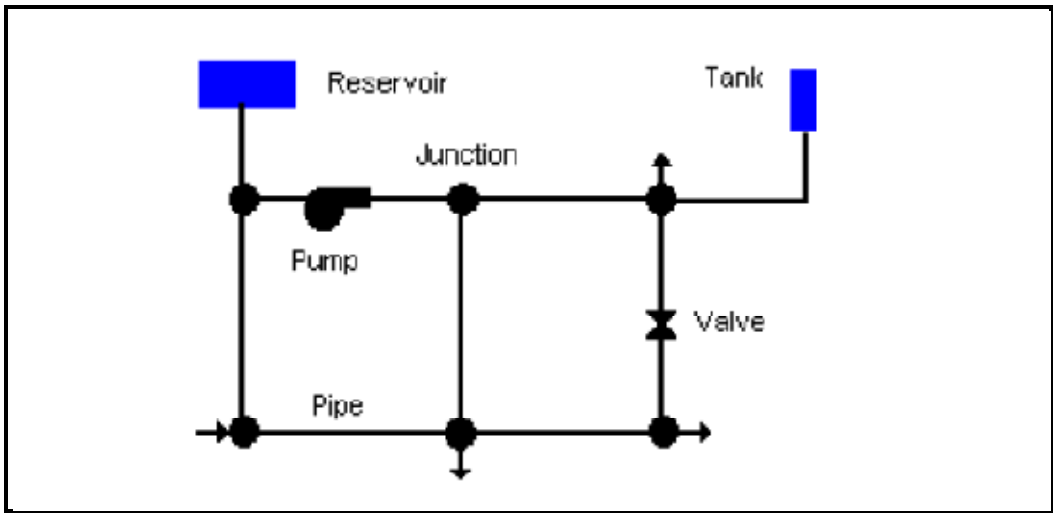


Fig. 6.21: Physical components in a distribution system

(Source: Rossman, L.A. (2000))

Junctions are points where links join together or where water enters or leaves the network. The model requires elevation, usually the mean above sea level, water demand and initial water quality as input parameters and it outputs hydraulic head, pressure and water quality for each node. Junctions can have varying demands, have multiple categories of demand assigned, have negative demand implying that water is entering the network, and be water quality sources where constituents enter the system or contain sprinklers that make outflow rate dependent on pressure[17] .

Reservoirs are nodes that represent an external source of water to the network. They are used to model such things as lakes, rivers and ground water aquifers. They also serve as water quality source points. Reservoirs are boundary points to the network and their head and water quality cannot be affected by what happens in the network. However, the head at the reservoir can be set to vary with time[17] . Tanks are nodes that have storage capacity. The volume stored can vary with time during simulation. The input parameters for tanks are the bottom elevation where the water level is zero, the diameter, the maximum and minimum water level and the initial water quality.. Tanks are required to operate between their maximum and minimum levels and EPANET[17] will stop inflow at the maximum level and outflow at the minimum level.

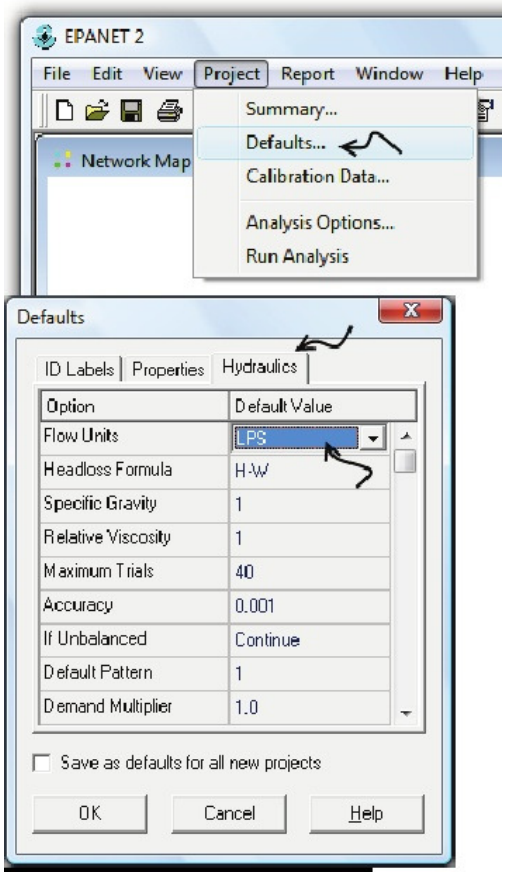
Pipes are links that convey water from one point in the network to another. EPANET assumes that all pipes are full all the time. Flow direction is from the end at higher hydraulic head to the end with lower hydraulic head. The hydraulic input parameters for pipes start and end nodes, diameter, length, roughness coefficient and Pumps are links that impart energy to a fluid, thereby raising its hydraulic head.

The input parameters are the start and end nodes and the pump curve which represents the combination of heads and flows that the pump can produce. The output parameters are flow and head gain. Flow through pumps is unidirectional and EPANET will not allow a pump to operate outside the range of its pump curve. The input parameters for valves are start and end nodes, diameter, setting and status. EPANET outputs are flow rate and head loss[17] .

6.3.8.3.6. Project Setup

• Setting default values in EPANET

In order to do this, click on Project and, in the drop-down menu, select Defaults. The rest of these instructions are given in the manual by means of routes. The route for this action would be: > Project / Defaults.



In the menu that appears, click on the Hydraulics tab and make sure that you put LPS. Choosing this option implies that the following units are used:

•Flow Units: liters/second

•Pressure: MWC1

•Diameter: millimeters

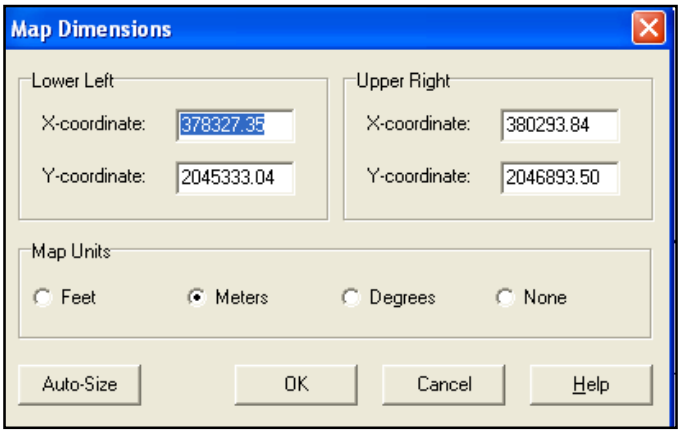
•Length: meters

•Height: meters

•Dimensions: meters

- **Setting dimensions**

Before drawing our network, we should insure that our map scale settings are acceptable. Select **View >> Dimensions** to bring up the Map Dimensions dialog. Note the default dimensions assigned for a new project. These settings will suffice for this example, so click the **OK** button.



6.3.8.3.6. Setting Object Properties

i) Entering data for pipes

For designing EPANET Model you need to consider mainly two groups of pipes:

a) Metal pipes.

They have greater friction, they absorb chlorine, their diameter is decreased by build-up and scaling on the inside of the pipes and they are more expensive. They include galvanized iron and cast-iron.

b) Plastic pipes are smoother, don't absorb chlorine, and they accumulate less build-up and are cheaper. They include PVC and polyethylene (PEAD).The introduction of data for pipes is much easier.

The 3 first parameters are given by EPANET automatically. Although you can change the ID of a pipe, this is a big waste of time. If you still really feel you want them to follow certain logic wait until the network is working properly so you don't have to keep modifying the pipes in the model. When you make modifications, the junctions' IDs keep changing. The last 7 are read once the model has been analyzed. Until then, they will show up "#N/A".

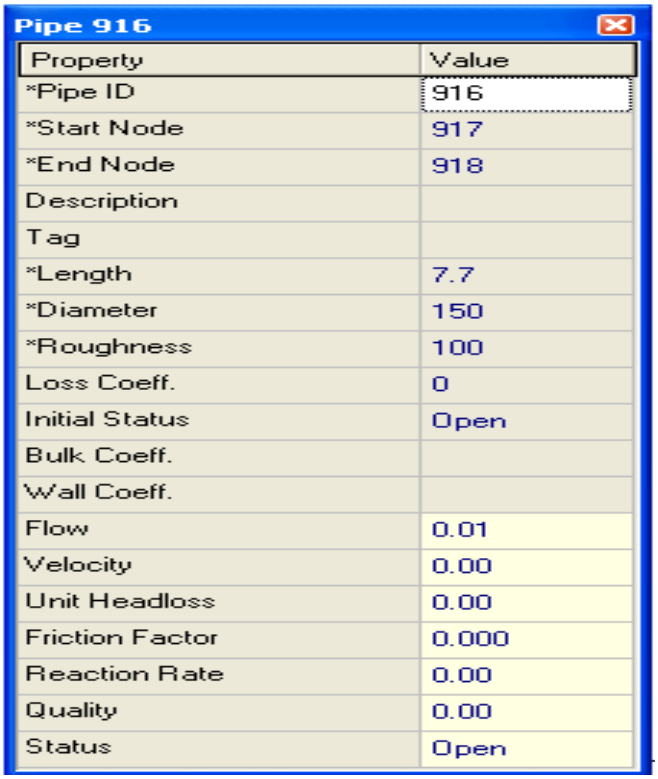
Length

With a calibrated image, the length will be determined by EPANET in the auto-length mode. If you do not have a background image, you will have to enter the lengths pipe by pipe from the topographic survey.

Diameter

Metal pipes are specified by the internal diameter. A 57 mm pipe has 150 mm of inside diameter, and this is the diameter that is entered when modelling them. In contrast, plastic

pipes (PVC and PEAD) are classified by their outside diameter. The inside diameter is calculated by taking the outside diameter less the thickness of the wall.



Pipe 916

Property	Value
*Pipe ID	916
*Start Node	917
*End Node	918
Description	
Tag	
*Length	7.7
*Diameter	150
*Roughness	100
Loss Coeff.	0
Initial Status	Open
Bulk Coeff.	
Wall Coeff.	
Flow	0.01
Velocity	0.00
Unit Headloss	0.00
Friction Factor	0.000
Reaction Rate	0.00
Quality	0.00
Status	Open

Roughness

The roughness coefficient depends on the formula that is used to calculate the system hydraulically. The two main options are as follows:

a) If you use the Darcy-Weisbach equation, which is largely used in Europe, this coefficient is f and it takes values with decimals.

b) If you use the Hazen-Williams, as used in America, this coefficient takes values like 100, 120, etc. The bigger the coefficient, the smaller the friction of the pipe. I would recommend you to always use Hazen-Williams, because it is more intuitive. The coefficient has no decimals, and moreover, this coefficient does not depend so much on the diameter or velocity.

The following figure 6.22. Shows EPANET model Along with pipe data.

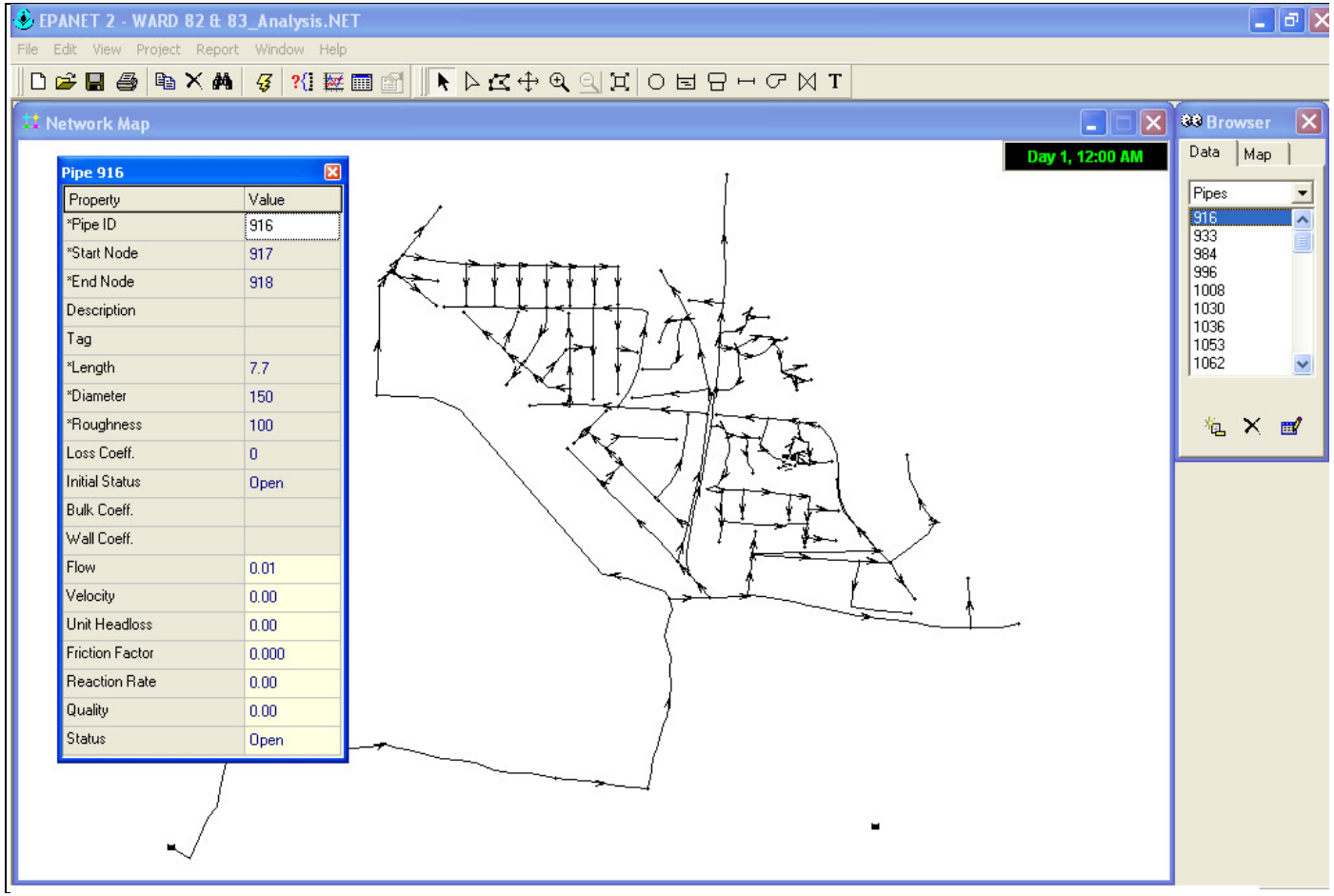


Fig.6.22 : EPANET Design for Ward No. 82 & 83 along with Pipe data

ii) Entering data for junctions

Now we have drawn the network, it is time to go over the data we will need. As you will know from the tutorial, when double-clicking on an object a dialog box opens and shows its properties. In this box, you can read some things and modify others but cannot modify all of them. This is the complete dialogue box for a junction, with all its properties. Those which are shown inside the red square (above), with the exception of description or tag, can be modified, but will acquire an automatic value when the object is drawn. These properties are self- explanatory and the tag has little use in black (underneath), is calculated data which is read-only. Any required data comes with an asterisk which in the case of a junction would be elevation and name. Focus on the parameters in the centre:

1.Elevation

2.Base demand

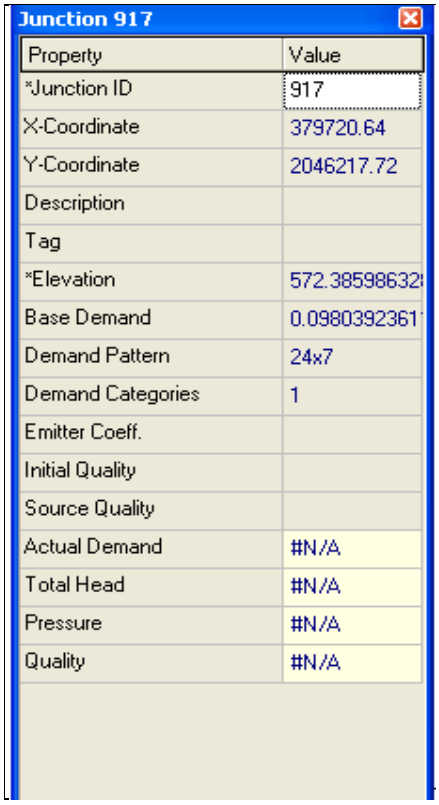
3.Demand Pattern

4.Demand Categories

6.Emitter coefficient

6.Initial quality

7.Source quality



The following fig 6.23.shows entering data in Junctions

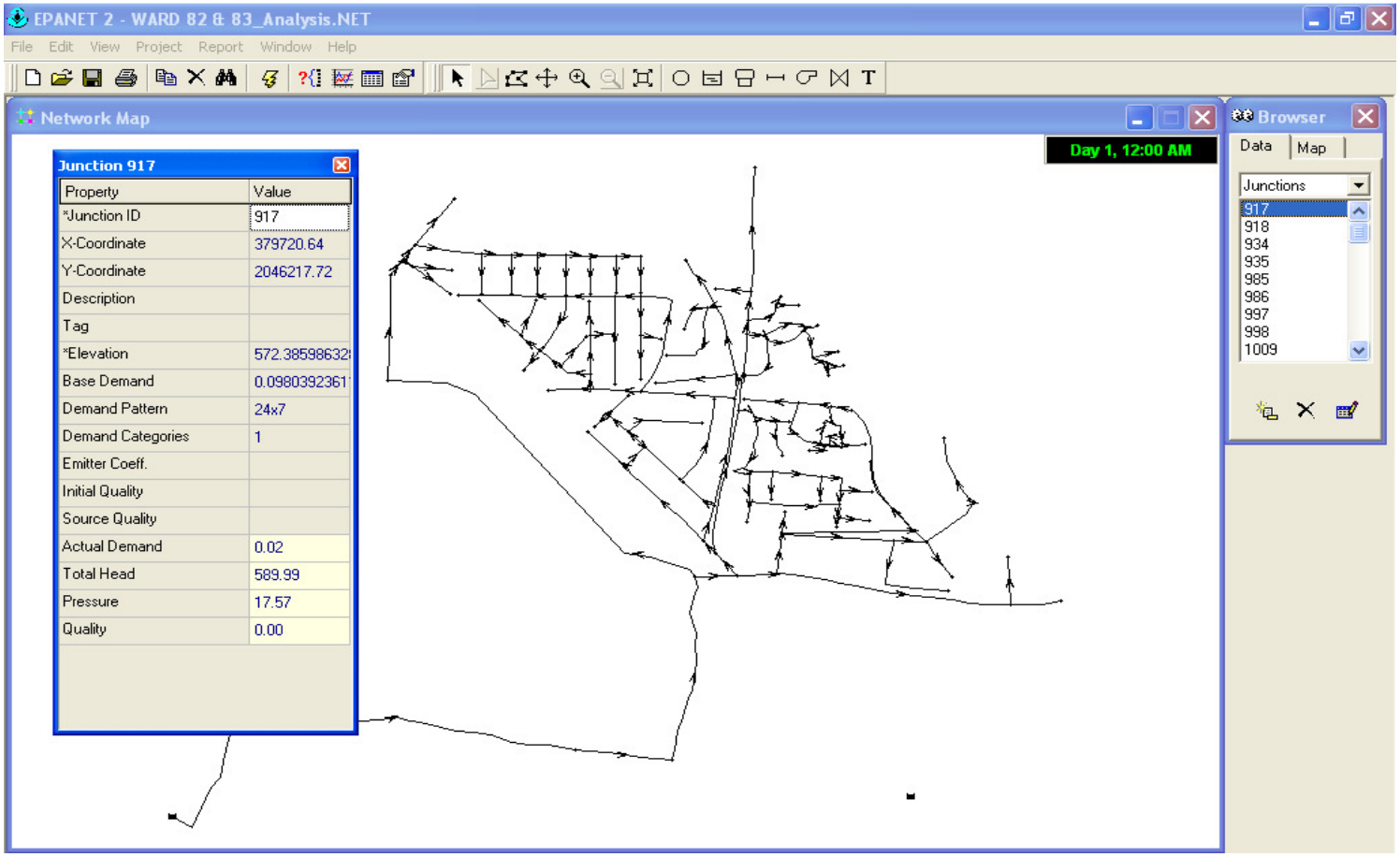


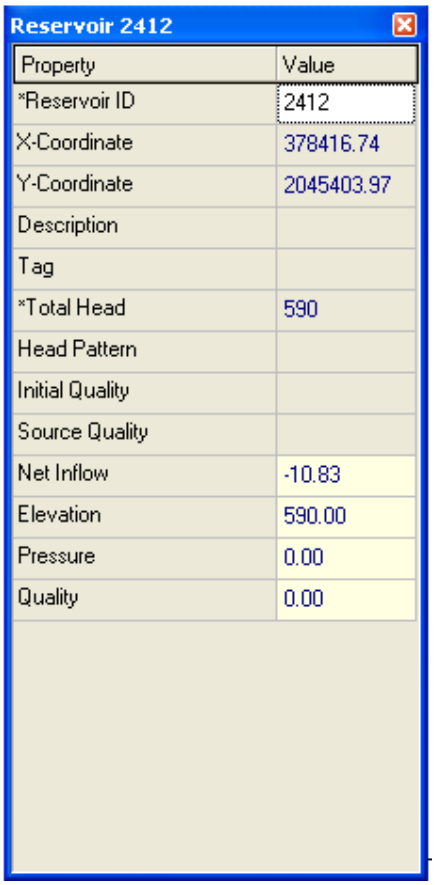
Fig. 6.23: View Junction Data for Ward No.82 & 83 developed using EPANET

iii) Entering data for reservoir

- **Elevation/ Total Head**

This is the height of the water level. In some cases it can be tricky to determine. Besides a river or lake, the most frequent case in development is a borehole.

As you pump from an aquifer, the water level goes from rest (static level) to a much lower one (dynamic level) as is shown in the image. Broadly, a depression cone is formed, similar to the one that is created when pulling the plug out from the sink. The bigger the discharge, the greater the depression cone is. This cone makes the water level much lower inside the borehole and this is the level that needs to be entered. For example, if the borehole cap is at 30m height, and static water level is 10m under the ground, and when the pump is activated the equilibrium is reached at 50m from the cap, the level of this "reservoir" will be 30m - 50m, and so on.



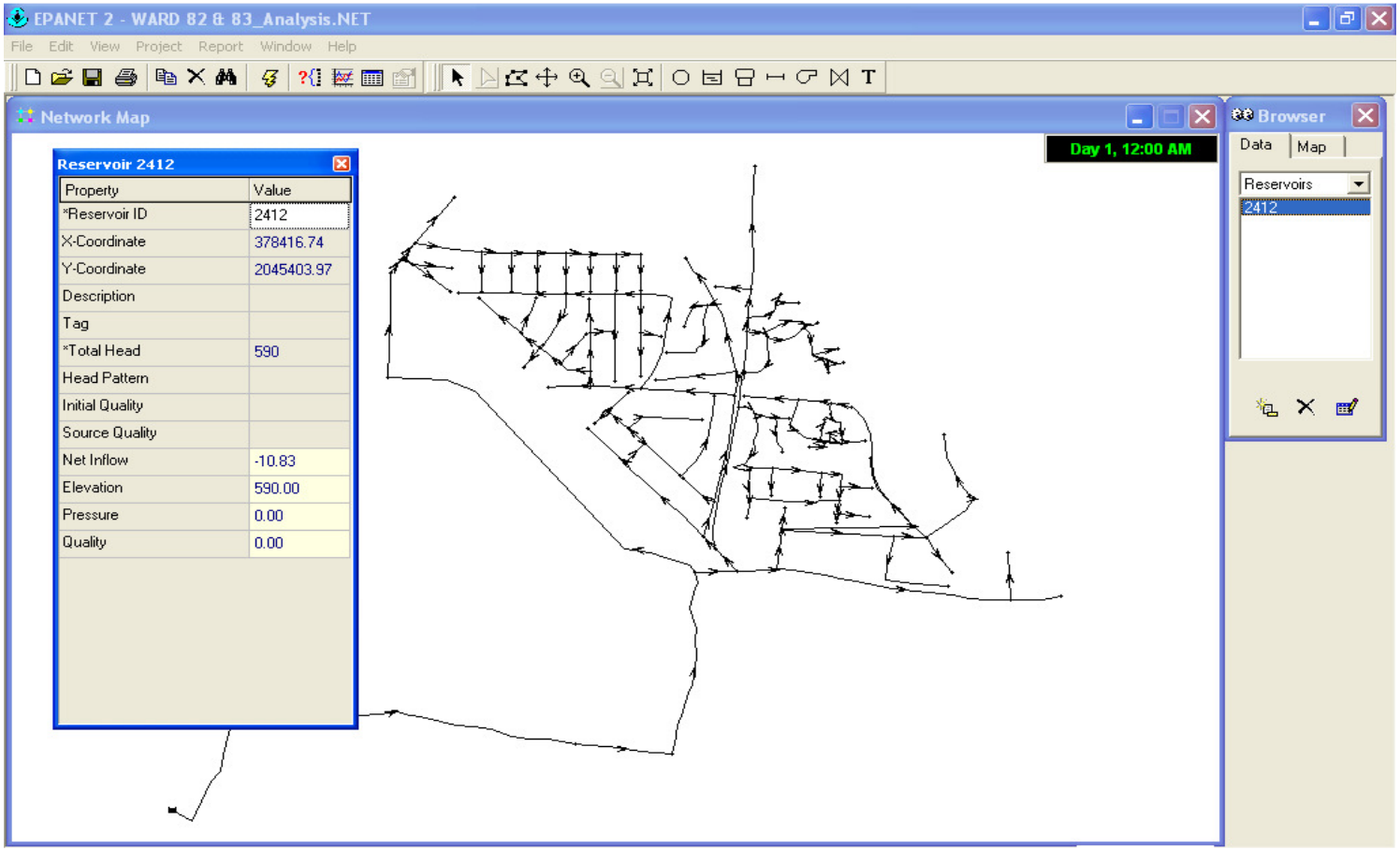


Fig. 6.24: View Reservoir Data for Ward No.82 & 83 developed using EPANET

6.3.8.4. Future Water Supply Network

Any water distribution system must be designed to adequately satisfy the water requirements for combination of domestic, commercial and industrial purposes that are placed on it at all times during the design period. The population increases and the growth of the city during the last period have an effect on the existing network. The increasing of water demand and the improvement in socio-economic conditions and standards of living has increased the need for more water supplies. Since a future distribution system is expected to provide effective service for many years (in this project taken as 30 years.), the future water demands should be based on estimated future requirements such as future population and future per capita water demands rate.

6.3.8.4.1. Water Demand calculation for each node of Ward No. 82 and 83:

To estimate the demand we need the following data:

- Water Consumption : Water consumption per capita
- Area of each node : from AutoCAD
- The area for each zone in AutoCAD drawing is equivalent to the area of the houses served by the nodes
- Factor(Population density) : this factor equals to the population rate per square meter of homes
- Ward density: Ward Population / Developed area
- Factor of losses = (1/ (1- losses %))
- Loss: is the difference between the quantity of water delivered to the system and the quantity registered by the water meters of the consumers .
- Losses from the network take from the data .For this calculation 15% losses is considered.

Water Demand = factor * zone area (m^2) * WaterConsumption

The water demand calculation for Ward No.82 and 83 as follows in the following Table No.6.9, Table No.6.10 & Table No.6.11.

Table No 6.9. : Gross water demand Calculation of Ward No.82 and 83

Ward_ No	Ward Name	Ward Population (2011)	Developed Area	Ward Density	Total demand (Lit)	Total demand (ML)
82	Subhasnagar	14104	43.52	324	2488941	2.488941
83	Gohrpade Udyan	12402	25.41	488	2188588	2.188588
Total		**26506**	**68.931157**		**4677529**	**4.677529**

Table No. 6.10 : Gross water demand Calculation of Ward No.82 Subhashnagar

Sr.No.	ELEMENT ID	AREA (SQM)	AREA (HA) [AREA (SQM)*10^4]	DENSITY (PERSONS/HA)	POPULATION [AREA* DENSITY]	DEMAND (LPD) [(POPULATION/PER CAPITA)* 0.085]
1	1230	23334.21084	2.333421084	324	756	133411.7647
2	1603	2250.457658	0.225045766	324	73	12882.35294
3	1405	8062.71802	0.806271802	324	261	46058.82353
4	1601	3920.437786	0.392043779	324	127	22411.76471
5	1796	22258.72983	2.225872983	324	721	127236.2941
6	1706	2839.651933	0.283965193	324	92	16236.29412
7	1384	2810.750937	0.281075094	324	91	16058.82353
8	1339	11937.7241	1.19377241	324	387	68294.11765
9	1486	7101.556752	0.710155675	324	230	40588.23529
10	1912	5063.547269	0.506354727	324	164	28941.17647
11	1953	5793.748199	0.57937482	324	188	33176.47059
12	1800	3209.581889	0.320958189	324	104	18352.94118
13	1157	3764.748479	0.376474848	324	122	21529.41176
14	1156	3706.955384	0.370695538	324	120	21176.47059
15	1369	8857.38056	0.885738056	324	287	50647.05882
16	1636	2519.813853	0.251981385	324	82	14470.58824
17	1367	3859.027713	0.385902771	324	125	22058.82353
18	935	996.7225196	0.099672252	324	32	5647.058824
19	934	1346.383992	0.134638399	324	44	7764.705882
20	1038	16520.04204	1.652004204	324	535	94411.76471
21	1465	11931.21832	1.193121832	324	387	68294.11765
22	1569	2573.345331	0.257334533	324	83	14647.05882

23	1622	5386.910292	0.538691029	324	175	30882.35294
24	1352	7366.608721	0.736660872	324	239	42176.47059
25	1351	1652.940125	0.165294013	324	54	9529.411765
26	1328	10789.72505	1.078972505	324	350	61764.70588
27	1327	11531.10912	1.153110912	324	374	66000
28	1721	2546.902818	0.254690282	324	83	14647.05882
29	1668	2330.589115	0.233058911	324	76	13411.76471
30	1773	5046.127266	0.504512727	324	163	28764.70588
31	1344	3604.897615	0.360489762	324	117	20647.05882
32	1343	2200.078609	0.220007861	324	71	12529.41176
33	1341	17120.47283	1.712047283	324	555	97941.17647
34	1233	2709.611943	0.270961194	324	88	15529.41176
35	1232	4242.993596	0.42429936	324	137	24176.47059
36	985	2447.882971	0.244788297	324	79	13941.17647
37	1658	4664.118864	0.466411886	324	151	26647.05882
38	1398	1896.693181	0.189669318	324	61	10764.70588
39	1397	6017.277052	0.601727705	324	195	34411.76471
40	1654	2826.00064	0.282600064	324	92	16236.29412
41	1867	11337.96724	1.133796724	324	367	64764.70588
42	1652	3264.08038	0.326408038	324	106	18706.88235
43	1113	4966.011953	0.496601195	324	161	28411.76471
44	1648	3758.593806	0.375859381	324	122	21529.41176
45	1646	2798.068536	0.279806854	324	91	16058.82353
46	1428	2918.020911	0.291802091	324	95	16764.70588
47	1962	3152.302783	0.315230278	324	102	18000
48	998	5948.103733	0.594810373	324	193	34058.82353
49	997	2349.310553	0.234931055	324	76	13411.76471
50	2172	1086.564275	0.108656428	324	35	6176.470588
51	1208	2942.486869	0.294248687	324	95	16764.70588
52	1207	2426.524441	0.242652444	324	79	13941.17647
53	1312	4699.375356	0.469937536	324	152	26823.52941
54	1311	2192.386865	0.219238687	324	71	12529.41176
55	1631	3210.639648	0.321063965	324	104	18352.94118
56	1037	3867.222323	0.386722232	324	125	22058.82353
57	1415	2156.073081	0.215507308	324	70	12352.94118
58	986	4261.13659	0.426113659	324	138	24352.94118

59	1627	11676.66363	1.167566363	324	378	66706.88235
60	1990	2618.986631	0.261898663	324	85	15000
61	1263	1881.504564	0.188150456	324	61	10764.70588
62	1729	2883.348693	0.288334869	324	93	16411.76471
63	1817	26449.24061	2.644924061	324	857	151236.2941
64	1833	5572.627887	0.557262789	324	181	31941.17647
65	1565	6309.35297	0.630935297	324	204	36000
66	1614	2296.466788	0.229646679	324	74	13058.82353
67	1292	6576.370305	0.657537031	324	213	37588.23529
68	1291	4531.824964	0.453182496	324	147	25941.17647
69	1718	6143.732769	0.614373277	324	199	35117.64706
70	1370	11850.03589	1.185003589	324	384	67764.70588
71	2035	26528.33835	2.652833835	324	860	151764.7059
72	1710	3547.765868	0.354776587	324	115	20294.11765
Total		**435236.8225**	**43.52368225**		**14104**	**2488941.176**

Table No. 6.11: Gross water demand Calculation of Ward No.83 Ghorpade Udyan

Sr.No.	ELEMENT ID	AREA (SQM)	AREA (HA) [AREA (SQM)*10^4]	DENSITY (PERSONS/HA)	POPULATION [AREA* DENSITY]	DEMAND (LPD) [(POPULATION/PER CAPITA)* 0.085]
1	1346	3662.452021	0.3662452	488	179	31588.24
2	1759	2677.689449	0.2677689	488	131	23117.65
3	1031	2203.294691	0.2203295	488	108	19058.82
4	1064	2654.366031	0.2654366	488	130	22941.18
5	1063	2747.902954	0.2747903	488	134	23647.06
6	1272	2832.809945	0.283281	488	138	24352.94
7	1271	2783.918097	0.2783918	488	136	24000
8	1055	3109.677509	0.3109678	488	152	26823.53
9	917	979.2713037	0.0979271	488	48	8470.59
10	1695	11572.53812	1.1572538	488	565	99706.88
11	1694	8201.156489	0.8201156	488	400	70588.24
12	2227	9180.7175	0.9180718	488	448	79058.82
13	1154	2689.553961	0.2689554	488	131	23117.65

14	1258	1247.545597	0.1247546	488	61	10764.71
15	1482	5666.089661	0.566509	488	276	48706.88
16	1469	5381.971842	0.5381972	488	263	46411.76
17	2252	3619.58937	0.3619589	488	177	31236.29
18	1675	5436.63988	0.543664	488	265	46764.71
19	1032	1856.950654	0.1856951	488	91	16058.82
20	1245	2946.386401	0.2945386	488	144	25411.76
21	1244	5406.20297	0.5405203	488	264	46588.24
22	2205	2323.173928	0.2323174	488	113	19941.18
23	918	313.6663368	0.0313666	488	15	2647.06
24	1880	5361.524599	0.5361525	488	262	46236.29
25	1130	1073.443288	0.1073443	488	52	9176.47
26	1337	4139.607854	0.4139608	488	202	35647.06
27	1978	7171.353341	0.7171353	488	350	61764.71
28	1439	8216.189177	0.8216189	488	401	70764.71
29	1010	1654.284823	0.1654285	488	81	14294.12
30	1009	10717.62277	1.0717623	488	523	92294.12
31	1114	2641.158721	0.2641159	488	129	22764.71
32	1325	1076.514498	0.1075514	488	52	9176.47
33	1074	2803.008695	0.2803009	488	137	24176.47
34	1748	10077.95844	1.0077958	488	492	86823.53
35	1744	31400.34877	3.1400349	488	1532	270352.94
36	1306	6426.390089	0.642539	488	314	55411.76
37	1091	873.8149144	0.0873815	488	43	7588.24
38	1090	2053.381227	0.2053381	488	100	17647.06
39	1410	2853.501544	0.2853502	488	139	24529.41
40	1054	963.8125462	0.0963813	488	47	8294.12
41	2478	14307.66205	1.4307662	488	698	123176.47
42	2049	5366.928312	0.5366928	488	262	46236.29
43	1879	13430.34283	1.3430343	488	655	115588.24
44	1617	3106.966124	0.3106966	488	152	26823.53
45	1294	2469.853671	0.2469854	488	121	21352.94
46	1147	998.5202781	0.099852	488	49	8647.06
47	1183	4586.44132	0.4585441	488	224	39529.41
48	1289	3374.069067	0.3374069	488	165	29117.65
49	1288	6438.357108	0.6438357	488	314	55411.76

50	1073	1664.859139	0.1664859	488	81	14294.12
51	1071	5282.918563	0.5282919	488	258	45529.41
52	1605	4056.366301	0.4056366	488	198	34941.18
Total		**254074.7648**	**26.407476**		**12402**	**2188588.26**

6.3.8.4.2. Calculation of Future population:

Many methods used to predict future population: [7]

1. The mathematical method -$P = P_o + AT$
2. The engineering method- **Pf = Pp(1+i)^n**
3. Approximate graphical method.
4. Graphical Method.

As per provisional reports of Census [3] India, population of Pune in 2011 is 3,115,431. The population growth rate in this area is considered as (2.5percent) according to Pune Population Department**.** The future population in Pune city after 10 years 2021 will be approximately calculated by using engineering method is as follows:

$$\mathbf{Pf = Pp(1+i)^n}$$

Where:

Pf : Future population.

Pp : present population.

I : Population growth rate in percent (2.5 percent).

N : Design period in years (30 years).

$P_{2021}=P_{2011}*(1+0.025)^{10}$

$= 3115431 *(1.025)^{10}$

$= 3115431 * 1.280085$

$= 3988015$

In other words, the population after 10 years is expected to reach 3,98,8016.

EPANET Water hydraulic model Results and Graphs,Table as shown in **Annexure 13.**

References

[1] A thesis by Hayrettđn Onur Bektas on ,"Developing A Methodology For Finding Network Water Losses Using Information Technologies: A Case Study" Dec,2011

[2] ArcUser, 2008

[3] Artina S., Bragalli C., Giunchi D., Liserra T., "Stima delle perdite idriche proposta dal DM 99/97 e da IWA con monitoraggio in telelettura", Atti del I Convegno Nazionale di Idraulica Urbana-Acqua e Città, Sorrento, 2006.

[4] Bajpai, P. and Bhandari, L. (2001). Ensuring Access to Water in Urban Households. Economic and Political Weekly, Sept. 29: 3774-3778.

[5] Butler, D. (2000) Leakage Detection and Management, Palmer Environmental, UK.

[6] Cheong L.C., International report on "Unaccounted for water and economics of leak detection",IWA World Conference Budapest, October 1993

[7] Dr. H. Ramesh, L. Santhosh and C. J. Jagadeesh on "Simulation of Hydraulic Parameters in Water Distribution Network Using EPANET and GIS", International Conference on Ecological, Environmental and Biological Sciences (ICEEBS'2012) Jan. 7-8, 2012 Dubai

[8] Environmental report 2008-09,PMC

[9] Esri International User Conference Proceedings ,2006

[10] GITA2003,ConferenceProcedding (http://www.gita.org.au/2003_Event_programme.html)

[11] Hazen-Williams Coefficients, Engineering ToolBox, http://www.engineeringtoolbox.com/hazen-williams-coefficients-d_798.html, retrieved 7 October 2012

[12] http://en.wikipedia.org/wiki/HazenpercentE2percent80percent93Williams_equation

[13] http://www.bwssb.org/

[14] MIKENET Software (2005), http://www.dhisoftware.com/mikenet/

[15] Robert Pitt University of Alabama and Shirley Clark Penn State by"Comparison of Pipe Flow Equations and Head Losses in Fittings",New York: Mc Graw Hill. pp. 6.29. ISBN 0-07-007247-7 (http://rpitt.eng.ua.edu/Class/Waterpercent20Resourcespercent20Engineering/M3epercent20Comparisonpercent20ofpercent20methods.pdf. Retrieved 2008-12-06.)

[16] Rossman, L. A. (2009) EPANET 2 Users Manual; Accessed August 24, 2009 at http://www.epa.gov/nrmrl/wswrd/dw/epanet/EN2manual.PD

[17] Rossman, L.A. (2000). EPANET 2 Users Manual. National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH.

[18] Shasmi "GIS Tools for Water, Wastewater, and Storm water Systems", 375 pages, ASCE Press, August 2002

[19] The world health report 2003 - shaping the future

[20] US Environmental Protection Agency, 2000: EPANET user manual September 2000 (http://www.epa.gov/NRMRL/wswrd/dw/dsr.htm)

[21] US Environmental Protection Agency, 2008: Distribution System Research; Accessed August 24, 2009 at http://www.epa.gov/NRMRL/wswrd/dw/dsr.htm

[22] WaterCAD (2005), http://www.hasetad.com/software/watercad/

CHAPTER 7
FINDINGS, SUGGESTIONS AND SCOPE FOR FURTHER RESEARCH

7.1 Introduction

This chapter first presents the important findings of the study. Next, the conclusion and suggestions arising out of the study are presented. It was observed during the course of the study that published research material on the subject of the study was strictly limited and a number of areas and aspects require wider and in-depth research in future. The scope for further research is therefore briefly discussed before concluding the chapter. For ready reference and convenience, referent table numbers of the study are given in brackets in the concerned paragraph of the chapter.

7.2. Findings

The findings set forth in the following pages constitute a recapitulation in a short form, of what has been attempted at length in earlier chapters. This study mainly relates to the current water supply system in Pune city , in terms of their source and treatment capacities, distribution network, level of services and key issues with regard to water supply operations, water consumption pattern ward wise as well as individual wise, awareness regarding the water conservation and appliances of water conservation at home among the citizens. Opinion about water billing system either annually or metering system focuses on various water conservation ways for storing water for future. To design District Metering Areas for problematic wards and measure water losses and design and develop Water Hydraulic model. Five objectives and three hypotheses lay primary emphasis on this subject. All objectives focus on Entire Water supply system, problem regarding water supply, water conservation, suggest GIS based framework for water supply. The researcher of this study has considered it necessary and useful to also look at GIS phenomenon at national as well as international level. This unique approach has provided new insights, added to the important conclusions and enriched this study.

The researcher has analyzed the primary data to study the infrastructure arrangement for water supply system, problem with respect to citizens and PMC and designs and development of GIS based Water hydraulic Model. Citizen's views about water consumption, problems, conservations based on analysis of the data is presented in Part I, PMC water infrastructure is presented in Part II, reviews on GIS based development in water supply in India discussed in Part III and GIS based water model for Pune city is presented in Part IV.

7.2.1. Part I: Pune Citizens

Pune city has been known as Oxford of the East & it is the second largest city of the state. It is situated on the banks of Mula and Mutha. Pune is a highly developed city as it is a centre for many industrial activities as well as top educational institutes and universities. It is also growing in terms of software and IT developments. In Pune city, the demand for water is increasing day by day but the supply is insufficient and here comes the water crisis problem but have you ever thought about how much water you need in a day and how much water you are using. Actually, if you analyze your daily water consumption you will realize that you are actually wasting a lot of water. It has become a challenge today to meet the rising demand for water because of our negligence. Majority of the respondents are female and House wives. The major findings of Pune citizens drawn from this study are as follows-

i) About Water Consumption & problems faced by citizens with respect to water supply system

Problems of the citizens with respect to water supply are studied by checking the parameters as per capita water consumption, various water resources, and frequency of water supply, water pressure, and additional water requirement at different ward. First, water consumption per person is found out at different places. Also, for different uses how much is the consumption per person at different area is found out, to know disparity in the use of water requirement at ward level.

- It is revealed that there is 9.26 percent per capita water usage from Tilak Road where as usage of per capita water within the range of 6 to 8 percent is from other ward offices. It is to be concluded that the usage of water on an average

from all ward office is the same i.e. overall; consumption of water in all ward offices is more or less equal. (Table No. 5.2)

- It is seen that, Maximum average utilization of water is 49.35 for cleaning and minimum average utilization of water is 8.64 for gardening purpose. Maximum variance of water usage is 546.25 for cooking and drinking where as minimum variance of water usage is 64.42 for miscellaneous purpose. (Table No. 5.3)
- For most of the citizens (45.6 percent) who are getting water supply through tap was available for once in day. (Table No.5.4 & 5.5)
- 21.30 percent of the households are getting water supply through tap for 24 hours, while 29.90 percent citizens said that water is available only for more than once in a day. Further 45.60 percent get it for once in day, and 3 percent citizens said that water is available only once in two & three days. (Table No.5.6)
- 45 percent citizens are getting sufficient quantity of water at houses and 55 percent citizens are not getting sufficient quantity of water at houses. (Table No. 5.7).
- It revealed that, 81.94 percent people require additional water in Sahakar nagar ward and Maximum additional requirement of water (105 Lit) at ward Karve road.(Table No. 5.8& 5.9).
- 93.89 percent of the households use municipal tap water supply,47.19 percent citizens depend upon bore well,9.46 percent citizens get water through public tap,0.7percent citizens get water from well and 3.45 percent citizens depend upon the tankers provided by municipal corporation.(Table No.5.10).
- In the absence of municipal water supply, most of the citizens (61.72 percent) depend upon another alternative source of water supply i.e.bore well. (Table No. 5.11).
- 10 percent citizens are getting water through public tap or public stand post. Maximum 90 percent citizens are having their own water connection. (Table No. 5.12).
- 82.29 percent are staying in rented house such as Chwal, slum areas etc. So they don't have individual water connection. It is a show that, 42.70 percent

citizens who are saying water connection fee is too high. It is not affordable to them from economical point of view. Further 41.66 percent citizens are saying that water connection facility is not available in the area.10.41 percent citizens feel monthly/yearly charges are too high are not affordable.5.20 percent citizens believe present arrangement is satisfactory.(Table No.5.13).

- 4.10 percent citizens are getting a Very Low water pressure due to topographical disparity of Pune city. It's followed that, 43.40 percent citizens who also get water at Low pressure level. (Table No. 5.14)
- Most of the citizens believe that they are getting enough quantity of water but they still facing the problems such as leakages, low pressure, illegal water connections, misuse of water, insufficient water quantity etc. (Table No. 5.15)
- 55.40 percent citizens are not satisfied with current water supply system given by PMC. There is a lot of water loss in Pune city due to old pipeline; as a result citizens are not getting enough water. Reasons are many, but difference in the percent ratio between satisfaction and dissatisfaction amongst citizens is less. It necessitates improvisation in water supply system. (Table No.5.16)
- Majority of the citizens (36.85 percent) preferred Meter water billing system and 63.15 percent citizens preferred annual basis water billing system. Ratio is high for annual basis because citizens are willing to pay water charges only once in year or annual basis. (Table No.5.17).
- 36.85 percent citizens preferred Meter water billing system , out of 86.90 percent citizens are agreed that meter system makes optimal use of Water, 84.76 percent agreed that meter system helps for Water Loss Reduction and 69.79 percent citizens agreed that there is need to Conserve the water for future. (Table No.5.17 & 5.18)
- 63.15 percent citizens preferred Annual water billing system, out of 93.60 percent citizens agreed that annual water billing system is economically feasible. In Pune city, citizens are paying water tax which is included in property tax either once or twice in a year and also it is affordable. (Table No. 5.17, Table No.5.19)
- 82 percent citizens feel punishment system will help in reducing wastage of water and 18 percent citizens are not feeling the same way. (Table No. 5.20)

- 77.06 percent respondents agree with Penalty on Water bill. It is followed by 43.50 percent respondents agreeing with cutting water connection. It is seen that majority of the respondents agree for penalty on water bill so as to reduce wastage of water. (Table No. 5.20, Table No. 5.21).
- Most of the citizens (82 .46 percent) feel reward system will help in reducing wastage of water and 18.54 percent citizens do not feel the same way. (Table No. 5.22)
- The reward system for the reducing wastage of water and optimal usage of water is highly appreciated by respondents and as per the survey it is seen that 83.95 percent citizens are agreeing for giving discount on water bills as they are economically benefited. (Table No.5.23).
- It is observed that the majority of the citizens (54.68 percent) agree that if both the systems are applied then citizens will reduce the wastage of water and conserve water for future. (Table No.5.24).

ii). Awareness of Water conservation and appliances for future use and suggestions on various ways for conservation.

- 84.83 percent citizen s understand importance to conserve water for future use. (Table No. 5.25)
- 79.70 percent citizens are aware about rain water harvesting and which is most known water saving appliance. (Table No. 5.26)
- 80.20 percent citizens agreed to rainwater harvesting method. Nowadays while sanctioning building plans. Nowadays, while sanctioning building plans, PMC makes it compulsory for every builder to do the rainwater harvesting. (Table No. 5.27)
- 56.16 percent citizen get motivated for water conservation because of water shortage.55.67 percent citizens because of insufficient rain fall and 48.70 percent citizen due to lack of water resources. Also very less percent of citizen get motivated for conservation of water just because metering system made compulsory and due to which increase consumption will lead to higher water bills. (Table No. 5.28)

- Most of the citizens (63.15percent) are not willing to contribute more to community towards water conservation, because they feel that it is the duty of Pune Municipal Corporation & they are also not confident about any positive change after contribution. (Table No. 5.29)
- 65.02 percent want to implement various ways for improving water supply system to reduce wastage of water.62.76 percent citizens want to improve water supply system to implement development and utilization of new resources. (Table No. 5.30)

7.2.2. Part II: PMC Infrastructure for Water Supply system

i. Natural Sources of Water Supply

- In Pune City Various natural resources for water supply are rivers, lakes, dams and ground water.
- Ground water has emerged as an important source to meet the water requirements of various sectors. There are around 399 dug wells & 4820 bore wells.
- Water Storage Capacity of dams like Khadakwasla, Panshet, Warasgaon and Temghar dams is 31.01 TMC whereas 29.14 TMC is Usable Capacity in Pune city.

ii. Situational analysis of Water Supply System

- No. of Distribution Zones – 48 , Chlorinators – 24 and Water Treatment Plants - 9
- Whereas No. of Pumping Stations – 20 and No. of GSR (Gravity Storage reservoir) & ESR(Elevated Service Reservoir) – 47
- Total Length of pipelines - 2474Km.

iii. Water supply Service Delivery and Service Level Benchmark

- For Water Supply Service Delivery, Nine Performance Indicators are considered which are Coverage, Connections, Per capita supply, Extent of metering, Continuity, NRW Reduction, Quality, complaints Redressal , service recovery Cost, and Efficiency in collection of water charges

iv. Extent of metering of water connections

- 122643 are number of direct service connections and stand posts (Unmetered Connections)
- 37000 are number of metered connections in which 36564 are functional metered connections and 436 are metered public stand posts.(70 % unmetered Connections where as 30 % metered Connection)
- 1123MLD is total Water Supply to Pune City. In which 937938 Households served through water connections, 57793 Household without connections and 14000 are Commercial Water connections.

v. Extent of Non Revenue Water (NRW)

- Treated water supply to Pune city is 1123 MLD. 786 MLD billing to consumer and 337 MLD NRW water

vi. Quality of Water Supplied in Pune City

- Parvati water works – 537 MLD, Vadgaon water works -125 MLD and Cantonment water works – 380 MLD
- 1318 MLD Installed Capacity of water supplied in Pune city.

vii. Operation and Maintenance

- 2741 complaints are registered in PMC office regarding water supply and out of which 2696 complaints are resolved within 24 hours.(98% complaints solved per month)
- Operating expenses are Rs.176.41 crores and Rs.124.68 crore is recovery cost in water supply services
  (70 % cost recovery)

i) Institutional Key issues concerning water supply operations in PMC

PMC is also plagued with issues concerning inefficiencies in service delivery and low consumer satisfaction. Moreover, the existing legal and regulatory framework does not allow the proportion to work on commercial principles. It is thus essential to identify the root cause of inefficiencies in terms of the institutional issues and develop a strategy to address the same. It is also a good approach for transition to a commercial orientation of PMC. Though at the city level, all the indicators reveal that service levels are well above the desired norms, certain issues with regards to the water supply system in Pune emerge.

- **Method of Withdrawal of Raw Water**

The Parvati water works receive raw water, partly from the direct pipeline and partly from the canal. The variation in water level in Khadakwasala dam affects the discharge from the pipeline. PMC is forced to lift about 30 percent water directly from the canal. The quality of water is affected due to the large-scale pollution of canal water by people living along the City Development Plan. The raw water rate, to be paid to the Irrigation Department, is much higher for canal water than that for the water drawn directly from the dam. (Table No.5.31 & 5.32)

- **Inequitable water distribution**

While the average rate of water supply in the Pune city appears satisfactory, the distribution is not equitable. While, some areas receive water supply round the clock, some areas hardly get water for an hour. Some high level areas do not get water through the pipe network and tankers need to be deployed in these areas. There is a wide disparity in the water supply rate and pressures. The inadequate service storage, small and leaking old pipes and unfavourable topography result in inequitable distribution.

- **Unaccounted for Water**

The distribution network in the old city is old. There are heavy leakages through the pipelines; faulty plumbing at households and uncontrolled public stand posts. A very substantial portion of water, supplied in the city, is lost due to leakage.

- **High Consumption of Energy**

Though the source of water supply is close to the city and a substantial quantity of raw water flows by gravity up to the intake point, energy accounts for a major chunk (almost 60 percent) of the O & M expenditure. Recognizing the need to improve efficiency in energy consumption, PMC has already taken up energy audit of some pumping stations.

- **House Connections**

The number of house connections is low, compared to the total number of properties in the city. The house connections are not metered and water tax is included in the property tax, based on Annual Rental Value. There is no incentive to control the use of water. (Table No.5.36)

ii) SWOT(Strengths, Weaknesses, Opportunities, and Threats) /PEST(Political, Economical, Social and Technical)Analysis

A SWOT/PEST approach is used for identifying the critical issues facing PMC in both the short term and the long term. This section aims in introduce the SWOT and PEST concept and identifying the key issues. However, it is proposed that a SWOT /PEST analysis be carried out with the PMC staff during interviews and observations and to develop the detailed SWOT /PEST matrix.

a) Introduction to SWOT/PEST

SWOT/PEST is an acronym for Strengths, Weaknesses, Opportunities, and Threats where as PEST is an acronym for Political, Economical, Social & Technology. The SWOT/PEST analysis is an extremely useful tool for understanding and decision-making for all sorts of situations in business and organizations. Table No. 7.1 explains the framework for analysis.

The SWOT analysis approach seeks to address the concept of strategy formulation from a twofold perspective: from an external appraisal (threats and opportunities in an environment) and an internal appraisal (of strengths and weaknesses within the organization). The SWOT/PEST analysis template is normally presented as a grid shown below:

Table No. 7.1. SWOT /PEST framework

• **A strength**: resource or capacity organization can use effectively.	• **A weakness:** a limitation, fault or defect in the organization that will keep it from achieving its objectives.
• **An opportunity**: any favourable situation in the organizations environment.	• **A threat**: any unfavourable situation in the organization's environment that is potentially damaging to its.
• **Political** factors are basically to what degree the government intervenes in the economy.	• **Economic** factors include economic growth, interest rates, exchange rates and the inflation rate. These

Specifically, political factors include areas such as tax policy, labour law, environmental law, trade restrictions, tariffs, and political stability.	factors have major impacts on how businesses operate and make decisions
• **Social** factors include the cultural aspects and include health consciousness, population growth rate, age distribution, career attitudes and emphasis on safety.	• **Technological** factors include technological aspects such as R&D activity, automation, technology incentives and the rate of technological change.

Due to its many advantages, it is proposed to use it for the purpose of strategy formulation for Pune city. The major issues of concern have been identified to guide the discussion and brainstorming for the SWOT/PEST analysis.

b) Key Issues for SWOT/PEST Analysis

Key issues have been identified under various broad headings

1. Lack of policy guidelines for service delivery

2. Legal framework

3. Organizational structures

Based on survey, it was found that, there is a lot of scope for further progress towards in accountability and transparency on the part of employees of PMC. There is also a complete lack of civil society in the planning and implementation of programmes. The current institutional structure makes it practically impossible to have customer orientation and improved efficiencies. It is thus imperative to review the existing framework with an objective of having specialized cells for customer grievance, GIS, MIS etc.

4. Internal Management

One of the weaknesses of the PMC is the complete lack of internal procedures and information management including financial management. Further the planning capacity, human resource development and financial management functions are not adequately developed, as a result of which these are operating inefficiently.

5. Operational Aspects

There is a lack of information on consumption of water in the city, the length of the distribution network, pressure in the pipelines etc. This is due to the fact that all connections (Domestic/ Commercial/Institutional) are unmetered and the available information on the production and supply of water in the city is improperly recorded.

6. Infrastructure

• A large amount of the existing infrastructure for the operations and management of water supply is poorly maintained. Further, there is an urgent need to modernize the infrastructure especially for data recording and transmission. There is also no policy in place for ensuring regular up gradation or replacement of old and out-dated infrastructure.

• Modernization and upgrading of systems and procedures in city management through equipment, skill-enhancement and application, and updating of manuals and codes (e.g. GIS and MIS) have not been carried out to meet the current and emerging challenges.

7. Staff Capability/motivation

The Municipal Corporation is technically sound with a work force constituting mainly of engineers. Though the Municipal Corporation has a technically competent staff comprising mainly engineers, most of the staff of the municipal corporation was found woefully unaware/lacking in modern skills of water management. Further, the staff lacks basic public interaction, financial management and social skills. Based on limited interaction with the municipal employees, it can be inferred that the motivation levels and job satisfaction is very low due to the following reasons:

- The poor working condition and multiple pressures from community, department and politicians.
- Political intervention in the PMC also reduces the motivation and performance of the employees.

8. Public participation/ consumer interface

- One of the major issues facing PMC right now is to improve its civil society interface and emerge as a responsible customer oriented organization.

- One of the major issues facing PMC right now is to improve its civil society interface and to emerge as a responsible customer oriented organization.
- Pune Municipal Corporation has taken the initiative to formulate a citizen's charter. The existing citizen charter for water supply provides only a listing of services provided, the contact persons for malfunctioning services and the time lines for addressing such complaints.

There is a low level of expectation of the consumers but also low willingness to pay for piped water supply. Water is still considered as a social good and not an economic good. There is a lack of awareness about the economic costs of water. This can be attributed to low awareness among the citizens regarding the costs involved in the delivery of water services.

c) Results of SWOT Analysis

Results of SWOT analysis carried out by PMC during the interviews and observations are given in the following Table No. 7.2 as follows.

Table No.7.2. SWOT/PEST Analysis

SWOT/ PEST	Strength	Weakness	Opportunities	Threats
I)Institutional and Governance Level				
Political aspect	• Qualified & competent Staff • Top Management very Co-operative, helpful	• High level of political interference • Operational Staff is insufficient • Administrative approval is very difficult in case of emergency	• Willingness for collection and revenues realization • Immediate sanction of scheme through PMC • Exposure to training programmes and updated knowledge.	• Forcibly taking illegal connections • High level of political interference • Lack of consumers' co-operations • Undulating topography resulting in the problem of low water pressure in some areas. • Threat of scarcity of potable water to cater the projected population after 2031
II)Financial				
Economic Aspect	• Low Cost	• Low tariff • Poor revenue realization • Inability to procure digital data products and carry out surveys for collection of attributed data.	• Approval for various Government Scheme for augmentation of water supply by PMC	• Unwillingness to pay.
III)Technical				

Social Aspect	• Sufficient distribution network through service reservoirs as well tube wells in sufficient numbers • Sufficient sources of water available • Experienced lower level staff(field level staff) • Water flows by gravity from Source to treatment	• Water losses 25-30 percent • Water loss in transmission and distribution due to old pipelines. • No water auditing • No accounting of water losses • Lack of awareness regarding water conservation among the citizens. • Only 29 percent coverage of metered connection	• Resources available for technical up gradation • Private sector participation in service delivery	• No Threats
	IV) Information System			
Technological Aspect	• Uninterrupted power supply ('Express Feeders') for WTPs • On-line complaint registration system • E-governance implementation	• No telescopic tariff for water consumption. • Lack of appropriate base maps necessary for micro-level and utility planning • Limitation on availability and digitization of certain data products. • Underground leakage detection equipments not available • No data on operational parameters • Lack of GIS facilities	• 100 percent metering will lead to 100 percent collection of water taxes thereby increasing the revenue income of Municipal Corporation. • Opportunity of availing 24X7 water supply should be tapped under JNNURM	• Lack of rain water harvesting facilities • Groundwater depletion

iii. Observations:

The following observations are drawn from the PMC office and visit to the various sites of Pune city.

- Pune Cantonment, Khadaki Cantonment & Commercial premises are metered. Phase wise metering in PMC area is under consideration.
- Telescopic tariff structure for water billing as per consumption of water is under consideration.
- Metering at all key nodes such as WTP's, ESR's, Junctions and Bulk supply points 80percentcompleted and remaining 20percent in progress.
- WEB based complaint monitoring system for redressal of complaints presently in operation.
- All complaints related to water supply are attended on priority basis.

Reduction of wastage of water from distribution system through systematic leak detection and control has not received serious attention of water supply authorities. Some of the problems leading to this situation may be identified as under:

1. Lack of appreciation and awareness of the economic and public health significance of waste assessment, leak detection and control by water supply department.
2. Non-existence of staff with training and experience in leak detection.
3. Lack of recognition and incentives to the staff of leak detection units which have to work mostly at night.
4. Due to road cognition and lack of provision in existing system of leak detection.
5. Difficulties in procuring imported equipment such as pipe locators, valve box locators and leak detectors.

iv. General Findings/Observation about water management in Pune city

- **Rainwater Harvesting:**
  - Mapping aquifers is a critical step to planning rain water harvesting, which can be more effective if implemented through a comprehensive area based approach.

- Though the PMC has made RWH mandatory for new buildings, there is no monitoring to check if the system is in place and functioning. These systems need to be monitored, just like elevators are monitored.
- For a phased program, initially rainwater harvesting should be made mandatory for big buildings and complexes like government offices, shopping malls, movie theatres, industries, colleges and schools as well as open parks and water bodies under the PMC. The owners/ managers of these building should be given a deadline of one to two years to achieve functioning RWH systems, with publicly declared
- Information how they do that and consequences to follow for those who do not achieve this in stipulated time and manner. The system should be monitored after two years for its efficiency and steps should be taken against defaulters.
- Pune city population is more than 35 Lacs, Out of 25 lacs people are staying in 5000 Society and remaining population near about 10 lacs are staying in individual houses, slums etc. Pune receives more than 700 mm rainfall annually. This means that a building with a roof area of 1000 sq feet has a runoff of 70000 liters annually. Considering 40000 liters of water is actually harvested, this can suffice water use of two people for an entire year (at around 150 lpcd). This is to indicate the potential of RWH, which is currently unexplored in Pune. According to GSDA report, groundwater levels in the city have been dropped by more than 8.75 meters. Recharging groundwater by recharging the existing 5000 bore wells and 400 open wells through rainwater harvesting can help conjunctive water use in the city.

Calculation of Water Saving Through RWH for Society Level-

- **Average Rainfall i**n Pune city=**700mm**
- If we consider a Society having 10 Buildings with 1000 sq.ft. Terrace area, we can harvest 7**, 00,000 liter** of water through rain water harvesting.
- If this water infiltrate in a soil then as an average we can get 5 times more water.
- Means 1 society will get **35, 00,000 liter** water through RWH.
- Considering 5000 societies in Pune city

- We will get **1,75,000 lac liter water** (35,00,000 * 5000) and be used for **agriculture and industry purpose.**
- 1,75,000 lac liter water = **0.65 TMC**
- Approximately 0.65 TMC water will be saved after implementation of RWH in Pune city.
- Capacity of Khadakwasla is =1.97 TMC
- **Water Saving through RWH=0.65 TMC means 1/3rd of Khadakwasla DAM.**

Calculation of Water Saving Through RWH for Slums and Individual Houses-

- Population of Pune city which are staying in Slum areas:**10,00,000**
- Out of 30 percent children & Old age People=**3,00,000**
- Actual population which will save water through RWH=**7,00,000**
- Suppose single person saves single bucket (20 Lits.) water for miscellaneous purpose then,
- Approximate water saved= **7,00,000 * 20 liter** (per day)=**140,00,000 L**iter will be save d through RWH.
- **Rebate on Property Tax**: 5 percent

- **Waste Water Treatment and reuse:** Pune produces more than 744 Million liters of Sewage every day of which less than 30% is treated. All of the 7 Sewage treatment plants run at less than 50% of their designed capacity in addition to huge quantity of sewage which flows in the river directly. Pune has been spending huge amounts on setting up Sewage Treatment Plants. There is no credible external audit of the efficiency and functioning of these sewage treatment plants. Why is there no transparent, accountable, participatory governance mechanism for each of the STP?
- **Water Losses:** It has been estimated that wastages and leakages in Pune's water supply system amount to more than 40%. The PMC Water Supply Department had agreed that it does not have the figures of water wastage and leakage and no projects have been undertaken regarding this for past 4 and a half years. Pune did not have functioning bulk water meters then and it was nearly impossible to comprehend where losses came from. Pune urgently needs to adopt metering system and follow examples of towns like

Amravati where the city with Maharashtra Jeevan Pradhikaran overhauled its ageing water system and set up District Metering Areas (DMA), each with 500-2500 connections per **DMA and a bulk water meter at the entrance of each DMA, making it easier to monitor water supply and leakages** and ensure supply efficiency and auditing water use. This can be done without any privatization or huge loans from international financial institutions like the World Bank, as is being proposed for Pune.

- **Demand Side Management** Pune also needs to assess the water consumption by various sectors and sections and see where it is possible to reduce the unnecessary, wasteful use. Also those who use higher than minimum quantity needs like Water Parks, swimming pools, etc., to be made to pay for the water they consume. Hotels, Malls, multi storey offices, and such other users can also be asked to put in their own STPs to recycle maximum possible quantity of water in a time bound manner.
- **Democratic Water Governance:** Accountable water governance where the citizens are participant and aware of the investments and projects can monitor progress and question the functioning of departments is a necessity for efficient water use in Pune city.

  Keeping all these factors in mind, it is entirely unjustified, immoral and unacceptable for a city like Pune, which has not worked seriously on any of the options for reducing and reusing its water.

  Pune faces a number of challenges, but there are a number of opportunities in the situation as well. With political will, transparent administration and citizen's participation, the current crisis can be transformed into an opportunity for the city to take sustainable, wise decisions about managing its water resources not only for the present, but for the coming generations.

7.2.3. Part III: Reviews of GIS based Water Management Study in India

Majority of citizens (67.59 percent) are unaware about GIS based Water Supply system. It is seen that very few citizens are aware about the new technology of GIS based Water Supply System. From these findings, researcher has reviewed GIS based Water Supply system live cases of India and reviews as follows.

Geographic Information System which links computerized maps i.e. location data to computerized data base which describes attributes of a particular location. By this linkage, one can easily access location and data simultaneously. Further, maps and other data may be updated quickly and accurately with the help of GIS. The spatial data of GIS can provide information to support modelling. The strength of GIS is that it is possible to process the data sets using any type of numerical analysis procedure. The digital procedure of storing and processing spatial or image data is very much useful to analyze the data.GIS has a wide range of use. Water Supply can use GIS in conjunction with the source water assessments to help protect the various water supply system. With an adequate database, Geographic Information Systems (GIS) can serve as a powerful analytic and decision making tool for water supply system. Furthermore, it can also be used for management and to test consequences of development**.**

The key benefits from introducing 24x7 water services can be summarized as follows:

- **Increased universal** access to water
- Improved services to citizens
- **Conservation of water** resources
- I**ncreased cost recovery**
- **Reduction** in operating costs.
- **Reliable services to the** urban poor community
- Reduction in water consumption
- **Enhanced** asset life

7.2.4. Part IV: GIS based Water Hydraulic Model

- ❑ Design criteria for water network system
- It would be ideal if the future design for the WDN satisfies the acceptable range of pressure and velocity for each node, so that the network works in it is maximum efficiency and capacity.
- The velocities here are in the range of (0.01-2) m\s.
- The pressure limits are in the range of (0-25) m.

- ❑ Problems found in the current situation of the network

- Low pressure at nodes: 1288 1289 1337 1245 1410 1074 1439 1346 1244 1073 1469 1010 1009. These nodes run in negative pressure so water takes time before it reaches to household and that why people who want to get water install small pump at their
- High pressure at nodes: There are some nodes having high pressure because they are locating in low-laying areas. So it is troublesome if any leakages occurs in network which can even lead to corrosion in the network.
- High velocity in pipes: No high velocity pipes were found in the network.
- Low velocity in pipes : In general most of the network pipes have low velocity, almost 40 percent of the pipes have velocity less than 0.01 m/s; because of the dead ends.

The analysis of the current situation is then used to design the rehabilitation needed for both present and future scenarios.

i) Benefits of DMA formation for water network

- Allowing the user to maximize water loss control and to optimize the water network, enabling the operator to reduce the volume of **Non Revenue Water** (NRW) with a more accurate view of District Metering Areas.
- To enable efficient control of recoverable losses, DMAs are being used both to identify and reduce recoverable leakage in the short term and then to monitor and control leakage in an ongoing manner.
- Remarkably reducing water losses.
- Reducing the number of maintenance operations, after reducing the operating pressure of the system.
- Easy finding the most vulnerable areas of the network.
- Making quick maintenance and repair in the network.

ii) Reducing Non-Revenue Water

The benefits of reducing NRW include:

- Need for less water to be produced, treated, and pumped, translating into the postponement of the expansion of capacity, producing less water also translates immediately into cost savings on O&M, due to savings in energy and treatment costs.

- Reduction in apparent losses, which will result in more water being billed and more revenue for utilities. It has also been shown that water metering and adequate rates reduce wasteful consumption, which will likely decrease total consumption;
- Adequate understanding of consumption patterns, which will allow utilities to optimize distribution systems.
- Better knowledge of real consumption, which will improve demand projections;
- Reduced sewage flows and pollution. These benefits depend on adequate pricing of water resources and services.

iii) After implementation of DMAs, the operational benefits from leakage monitoring as follows

- Reducing the run-time of a leak.
- Reducing the man hours spent searching for leaks.
- Focusing on looking for leaks in the areas with leaks. Increasing knowledge of the network.
- Raising awareness of a leak when it occurs and before it becomes a major incident.
- Reducing the amount of night-work and over-time.
- Finding quiet leaks that are inaudible during the day or are masked by smaller leaks.
- Saving every drop of water including customer leakage.
- Reducing repair costs through earlier intervention.
- Improving public relations

iv) Proposed 24X7 Water Supply System

24x7 continuous, pressurized water supply overcomes shortcomings of intermittent supply and ensures customer convenience and benefits the poor. Continuous high quality water supply system reduces contamination level as the pipes are under positive pressure and entry of contaminants into the pipes is restricted. Life of distribution networks increases as steady pressure in the pipes causes less damage to the pipes. A better demand management is possible due to elaborate metering and effective leakage control. It also results in less storage

of water or none at all, which in turn reduces wastage of water. Continuous supply of pure water boosts the economy and attracts more industries and businesses.

- **Improvements in delivery time and services**: Water is made available to the taps anytime it is opened 24x7. This has totally removed the constraints of attending to irregular and meager water supply services and thus the citizens of Pune will relieved of the problem of irregular and unpredictable water supply.
- **Quality of water:** The quality of the water delivered to the citizens through the tap is guaranteed as the pipes are pressurized throughout the day and night i.e., 24x 7 supplies.
- **Decrease in waterborne diseases in children:** A survey conducted by PMC indicated that the water borne diseases in the children have been reduced remarkably to near zero level.
- **Reduction in wastage of water:** Wastage of water is remarkably reduced because of telescopic tariff structure and the reduction is to an extent of 30percent. The number of hours of pumping the water has been reduced from 19-20 hours to 13-14 hours per day.
- **Shifting of the distribution system from valve man to the consumer:** As no valves are required to be operated in the distribution network, consumer can open the tap and get the water at any time of the day.
- **Simplification of billing procedure:** As the AMR type meters are installed, reading can be done remotely by driving through the streets using hand held devices and radio frequency and thus meter reading procedure is simplified. The earlier annual billing system is replaced by monthly billing and thus the cash flow of the Municipal Council has been improved.
- **Saving in electricity:** As the pumping of water to the water tank on terraces is not required, use of electricity is reduced. The energy saved is equivalent to reduction in 450 tons of carbon dioxide in the atmosphere. As 11 bore wells with power pumps of MC and many power pumps and small pumps have been stopped to lift water from ground to terrace, electricity consumption has been reduced.

- **Reduction in operation cost:** The system of automation like operating the raw water pumps from water treatment plant using GSM technology has reduced the cost of operation.
- **A successful Pilot:** Many Municipal Councils, MLAs and others aspiring to implement 24x7 water supply system are visiting the town to understand the methodology.

v) Benefits of GIS based Water Hydraulic Model

- **Better quality water for public health**

High levels of bacterial contamination are experienced in the first 10 minutes of repressurization of an intermittent system, in some cases persisting for up to 20 minutes. Maintaining full pressure removes that risk.

- **Better service to all consumers**

Access to clean water with improved quantity, timing, and pressure, including effective service to supply pipe 'tail ends'.

- **Service to the poor**

Consumers can access more water for improved health and hygiene while saving time in queuing and carrying, and gainfully using the time thus saved for employment opportunities.

- **Household coping costs into resources for the service provider**

Coping costs that consumers need to incur are reduced; they pay for a better service.

- **Reduces the burden on water resources.**

Continuous supply reduces water wastage arising from overflowing storage systems and open taps. It saves on stored household water that is discarded when new supply comes in. Because the network is renewed where needed, it also reduces losses arising from leaks in the old pipes.

- **Effective 'supply management' and 'demand management'**

Continuous supply makes possible the effective management of leakage through pressure management and flow measurement. Water conservation is also encouraged through metering and price signals via a volumetric tariff to consumers.

- **Improved efficiency of service provision**

Operational efficiencies are achieved because of a reduced need for valve men, and a conversion of these jobs into more efficient ones of meter reading and customer care. It also makes possible the management of illegal connections.

vi) Benefits to the Water Utility

- **Economic Benefits**

Continuous water supply benefits the Utility because of the following:

1. Providing service over 24 hours rather than only 1 to 4 hours means that smaller pipes can be used and still deliver the same quantity of water per day.
2. Providing continuous pressure over 24 hours means that there will be few sudden jerks (water hammer effects) on the pipe lines and thus the pipes, joints, and valves will last longer.
3. Providing better service to the customer creates better willingness to pay and higher revenues.
4. 24X7 supply makes it easier to detect leaks and thus reduce water losses and Non-Revenue Water (NRW).
5. Completion of the transmission mains linking the water treatment plants improves the distribution and reliability of the water supply around the city. The distribution system provides access to piped water to many urban poor families at reasonably low cost. Access to affordable and reliable water means more water available for personal use, leading to health and hygiene benefits.

- **Environmental Benefits**

Continuous water Supply benefits the environment in many ways:

1. Providing continuously pressurized piped water reduces the need for in-home "booster pumps" and thus reduces energy consumption and global warming. In some cases "carbon credits" may be available.
2. Improved leak detection and repair combined with demand management can lead to the same or possibly even more water provided to the consumer with little or no increase in resources.

7.3. Conclusion

In the present study, the various aspects of the water supply system are discussed, specifically problems and issues related to the Pune city. The problems have been identified and the feasibility of the various development options to tackle the problems has been computed.

- Water is essential for survival and is required in adequate quantity to remain healthy. Although recycled by the nature, fresh water is a limited resource. The high water consuming economic activities and population explosion are responsible for declining per capita water availability.
- To consume more is emerging main goal of societies, more so of the 'privileged', thus putting further pressure on this diminishing natural resource.
- The coverage of population by water supply has improved steadily over the years and in the present survey it has reached 95 per cent. However, it still falls short of the target of covering 100 per cent of the population by water supply.
- Coverage by itself is not sufficient to ensure that adequate quantity of water is available to all at the required pressure and for adequate number of hours in a day. Therefore, coverage has to be seen against the quantity of water available, duration of supply and quality of water supplied.
- To improve the supply, not only are finances required to fund new schemes for water supply, but also efficiency in operations and cost recovery are also required.
- Water is supplied only for a limited number of hours daily in almost all the wards. A round the clock supply, though desirable, is not possible in many cases due to inadequate water at source.
- Unaccounted for water (UFW) is another major problem that needs to be plugged. The PMC does not have adequate capacity to detect and plug these leakages, be physical or financial. The estimation of UFW is also very poor in PMC, mainly because all connections are not metered and this makes leakage detection a difficult task.
- In order to estimate UFW more accurately and reduce losses, leakage detection programmes need to be undertaken in corporation. Reducing water losses will effectively increase water availability and will reduce the requirement of funds for future investments.

- Most of the citizens agreed that if punishment and reward system apply, they will reduce wastage of water and conserve it for future.
- Amongst different water saving appliances, the most widely known appliance is Rainwater Tank.
- As per citizen's point of view, rainwater harvesting method is the most popular method for water conservation.
- Citizens will motivate for water conservation due to water shortage.
- Pune Citizens were not willing to additionally pay to community towards water conservation.
- Increasing population, growing water demands, pollution of nearby water sources and depletion of sources due to over exploitation have all contributed to the current crisis of potable water. It is thus time to take stock of the situation and initiate remedial measures to avoid the impending crisis. Water requirements change with income levels, economic activities, social habits and technology. Revising norms periodically will make planning for water more realistic.

  The demand for water will continue to increase in future due to increasing population and also due to changing non-domestic water requirements. To improve the situation, not only are additional finances required but also efficiency of operations needs to improve. Water rates are still very low in many states and not sufficient to cover the expenditure on the service. Additional capital investments in water supply are required to cover the presently uncovered population by water supply and also cover the population that will be added to the PMC.
  As water distribution planning plays a crucial role in densely populated city, it has to be carried out with a qualitative focus on the analysis of the spatial and non-spatial data. The water network planner needs an awareness of the ground realities for the analysis.
  Key issues in water supply system are:
    - Availability of **reliable water** sources till 2031
    - **Inadequate pressure** in certain areas.
    - Old **water supply distribution network**
    - Supply timings at **odd hours, highly inconvenient to all.**

- **Lack of awareness** regarding water conservation
- **No telescopic tariff** for water consumption.
- **Power cuts / load shedding** affecting water supply
- Undulating **topography** resulting in the problem of **low water pressure**
- Large number of **unauthorized connections,** leading to unsafe water.
- Common **stand posts** with/without **leaking taps** and continuous water wastage during supply hours.

The major observations drawn from the study are:

(a) It is observed that water consumption in Pune city is far lower than the norms laid down by Bureau of Indian Standards. The lower consumption results mainly because the water supply not keeping pace with population growth and increasing needs of users.

(b) It is interesting to observe that though a majority of households consume water below the specified norms, they, by and large, show satisfaction with the available supply. This is mainly because they have delimited their aspiration and requirements of water in relation to available supply from the concerned municipalities or water authorities.

(c) Some household activities, like washing clothes, bathing, using toilets, and washing dishes and utensils are the most water consuming activities in the city under focus. It has also been found that in Pune, a majority of the households perceive the above activities as most water wasting activities. This shows that given appropriate and affordable technologies to save water in specified activities, the households would be willing to adopt them. In fact, there exists a large scope of reducing water consumption in washing clothes by adopting appropriate machines; and in toilets by changing and modifying the flushing system. An awareness campaign about the best practices in these activities can play a big role in saving precious water.

(d) As expected, the availability and mode of use of water varies across the socio-economic classes within the cities. But, surprisingly, the difference is not very high.

(e) The municipal corporation supplies water to majority of households once in two days. Water tankers and bore-wells compensate the deficiency of municipal water in the city.

(f) Twenty four hour water supply on municipal taps is a dream for a majority of households in the large cities of the country. The study reveals that only about 21% of the total households in these cities get 24 hours municipal water supply. The erratic and limited duration of supply of water has become a common phenomenon in these cities. This has forced the households, in majority of the cities, to depend on groundwater and other sources of water, like the private vendors who supply water through tankers and drums. These, in turn, are leading to depletion of groundwater due to over withdrawal by the burgeoning population and emerging water markets. In fact, during the summer season private water vendors have their hay-days in these cities.

(g) The much talked co modification of water and water services is also making dent into the otherwise role of government departments as the key supplier of water in cities. It is also true that so far none of these cities have permanently handed over the task of supply to their citizens (NGOs) or the private sector.

The traditional methods of planning have suffered for want of location based outputs and this has made the updation of network very difficult and at times even impossible. Another disadvantage of the traditional methods is the impossibility of visualizing the impact of any measures, before its implementation. This is due to the fact that superimposing of one or more map outputs is not possible in the traditional method of planning. Whereas the availability of overlay concepts in GIS will help in superimposing of maps. Moreover GIS based water supply system planning and decision making have the added advantage of viewing the map outputs in combined form.

The most significant aspect of GIS water supply planning and decision making is that it is highly cost-effective. It will help the planner by way of saving cost in terms of time required to view the various forms of the output.

If a fault happens in the network and if the concerned engineer knows the place of fault, he can obtain all the information about the network by querying GIS and can rectify the problem at the earliest. The traditional methods on the other hand are time consuming, because one has to undergo the delayed process of referring to the tabular form of outputs. In addition,

the involvement of excessive manpower makes the conventional methods a wasteful exercise. Also, the new GIS based Water Supply System's, applicability in city planning specifically for Infrastructure Management has been evaluated and the proposals are made. Finally, the study concludes with the recommendations at various levels of planning for Pune. Therefore, substantial gains in time, manpower, cost reduction and effective integration of data are achieved through the implementation of GIS based water supply system.

GIS is the best tool for the planner because:

- The data is well created such that upgrading is easier.
- It reduces manpower and speeds up planning.
- It saves time in preparation of alternative plans.
- It helps to visualize the outputs in a better way.
- User can quickly identify features
- Using a GIS, you can enter new data or modify existing data. This example shows a GIS interface that allows easy editing of geographic data and the display of related documents.

GIS Water Hydraulic model will be helpful for-

- Information about pipelines, sewerage connections and their diameters.
- The system will also help the PMC and find out the volume of water used by its consumers.
- It will be able to monitor water pressure hourly.
- It will be able to find out the optimum supply, the water quality, monitor how the water is brought from the reservoirs as well their storage levels and capacity.
- It will reduce 30 to 35 percent leakages.
- It will save around 20 per cent of the water.
- It will need less staff to monitor it.

Through this, model is developed for MLR area, the present study reveals that it can efficiently be used in entire Pune city as well as in other Indian cities.

To conclude, it can be stated that the supply of water in Pune city is going to be a big challenge in future. The rapid increase in population in these cities, depleting water resources

and enhanced consumer needs are going to create a difficult situation. The market oriented development is creating new needs in sectors like entertainment industry and tourism, building industry, adapted new technologies pushing up water needs, more supply in shopping malls, and so on. Simultaneously, the alarming rise in pollution levels in surface water bodies and even in groundwater is going to add to the situation. Therefore, an urgent need is felt for a comprehensive water policy for cities which is suitable and satisfactory to growing needs of citizens.

7.4. Suggestions and Recommendations

Based on the survey following suggestions have been made.

i) Suggestions for water distribution department of PMC

The suggested mission statement for water supply services is "**Water for all and 24 x 7 supplies with focus on safety, equity, and reliability**". To achieve this target, additional schemes need to be designed for sourcing more surface water.

In the interests of reducing transmission and distribution losses, PMC should refurbish the old distribution system, conduct leak detection studies, identify illegal water connections and discourage public stand posts (PSP).

All households should be provided with metered connections to increase coverage to 100% and volumetric billing should be introduced to discourage wastage. Finally, PMC can control its operational expenses by conducting an energy audit, which accounts for the bulk of its operational expenses. There are some key areas where PMC can take initiative –

- **From Water Distribution Department perspectives for planning and policy**
  - Metering of connections, both for bulk supply and retail distribution, must be encouraged. Standard meters should be made available, at reasonable cost, to the city for this purpose.
  - Tariff is a major concern in the water sector. Tariff should be increased at certain given intervals, indexed to inflation and power tariff.
  - The local governments should be given sufficient autonomy to decide on increase in water tariff required to cover at least O&M costs.
  - Improving cost recovery should be linked to giving grants. Financial incentives could

be given to PMC showing improved cost recovery. Technical assistance and guidance should also be provided to local authorities to improve financial performance.

- Conduct an energy and water audit.
- Rainwater harvesting should be made compulsory for all new building projects to supplement the ground water.
- The metering must be as per the usage and not on the basis of water supply.
- Water supply should be metered and moved towards full cost recovery.
- Water supply in added areas to be improved.
- Since per capita is very high, use a separate pipeline for drinking water to reduce cost of service and wastage of treated water.
- Protect catchments of the Khadakwasla reservoir and protect Right Bank canal.
- Contamination develop a comprehensive watershed management plan for the Pune city including details of groundwater availability, usages , potential and develop a policy and legal framework to use and replenish groundwater
- Make land reservations for zones that are good for water recharge and water conservation.
- Ensure that high-volume non-domestic users compulsorily fit ISP meters.
- Promote individual water supply House Service Connections(HSCs) even in slum locations and discourage PSPs as a policy measure and to increase accountability.

❑ **From Water Distribution Department perspectives for Technology and methodology implementation**

- Steps should be taken to initiate capacity building in PMC for estimation of UFW. Financial assistance should also be provided to the water supplying agencies to equipping with the instruments for estimating UFW.
- Getting surface water from distant sources is proving to be very expensive. Ground water depletion can be controlled by undertaking rainwater harvesting in the entire city. Specific programmes/ schemes should be initiated for aquifer re-charge.
- Reduce transmission and distribution losses.

- Conduct a water audit and leak detection study to identify leaks, UFW and worn out networks for refurbishment.

❑ **From Employees perspectives in Water Distribution Department**

- Identify illegal water connections and discourage public stand post.
- Conduct a study to check the quality of water being supplied.
- In slum areas, there are several places wherein there is a PSP and the nearby households have water connections. Such PSPs must be removed.
- It is possible that the water is getting polluted as water from a nearby sewerage line seeps in. Such potential and existing polluting sources need to be checked. Systems refurbishments shall be taken up.
- Prepare an asset inventory and map the water supply systems for effective monitoring.
- Public stand post to be removed from slums where they are fully covered with individual house service connections.
- Facilitate regular checking of internal plumbing and storage systems at the consumers' end by licensing service provider
- Identify potential and existing polluting sources.
- Stop 24hrs water to slum areas and charge some amount to people staying there. Control on leakages of pipelines.
- Proper uses of bore wells and protect natural resources of Pune city.

ii) Recommendations to Water Distribution Department of Pune Municipal Corporation(PMC)

The solutions to the water crisis could be dealt at three levels:

- Empowering, training and strengthening the existing corporation
- Forming a core committee in the corporation to deal and find solutions to the crisis
- Decrease slums

Efficiency enhancement in transmission and distribution network:

- Reduce physical losses, analyze leakage data by mapping.
- Carry out study for rehabilitation of network and suggest rehabilitation projects and adopt / introduce system for leakage detection.

- Prepare pipeline maps on GIS.

b) Achieve Equity in distribution:

- Regulate quantity and pressure over various regions and uses.
- Analyze data of low pressure complaints, consumption by various regions, various users.
- Periodically check the correctness of valve operations.
- Install pressure gauges to collect data on leakages / malfunctioning. And suggest re-routing, re-structuring of transmission / distribution network or rehabilitation of pumping equipment.

c) Achieve financial recovery

- Tariff should be increased at certain given intervals, indexed to inflation and power tariff. Suggest metering policy, meter types, metering methodology etc.
- Improving cost recovery should be linked to giving grants. Financial incentives should be given to staff for recovering tax from citizens. Technical assistance and guidance should also be provided to local authorities to improve financial performance.
- Analyze efficiency and correctness of meters.

d) Awareness for water conservation

- Develop content for water conservation campaign.
- Devise communication strategy (target groups, methods etc.).
- Conduct seminar/workshops etc. with the help of NGOs, schools, colleges, etc. – competition and events related to water conservation.
- Create posters, pamphlets, radio jingles, TV scrolls, hoarding designs related to water conservation.

e) Periodic water audit (Every 3 years)

Water audit has to be done at three levels .At the primary level, audit is from the water source to the treatment plant, the secondary water audit is done from reservoirs supplying water to the city to the treatment plants, elevated storage reservoirs built in various parts of the city for supply and also from these reservoirs to the pipelines. The tertiary water audit is done from the pipelines to the end users in homes, shops and industries. Audit helps water

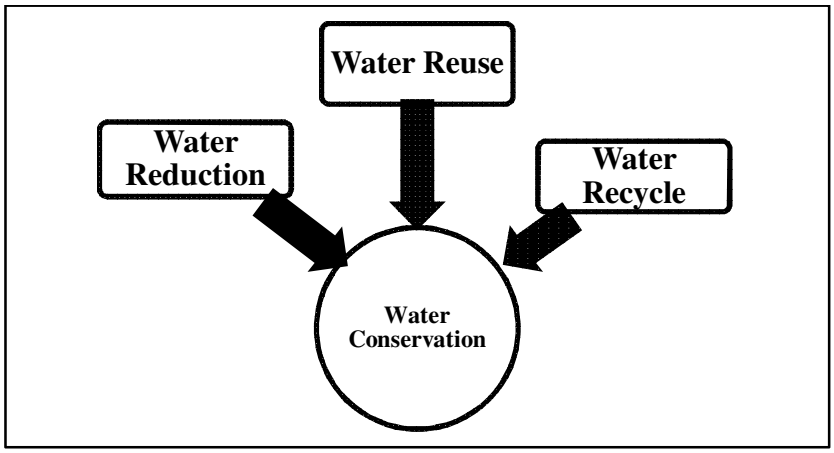
department to evaluate bids and award work of water audit, liaise between auditor and department / zones ,follow up action on water audit reports

f) Implementation of efficiency and equity measures as per requirement

- Rehabilitation / augmentation of network (Replacement of pipelines, increase or modify valves, re-route distribution network, introduce ESRs etc.) and rehabilitation of pumping equipments.

iii) Expectation from the citizens related to various Services of water supply provided by PMC.

- Water is life. Do not waste water unnecessarily.
- Do not use drinking water for gardening or other domestic purposes.
- Do not draw water in an unauthorized manner like installation of pumps in municipal connection.
- Get the repair after proper intimation to corporation and under the supervision of corporation engineering staff.
- Pay water charges/ bills and other dues regularly.
- Conserve rainwater by installing rainwater-harvesting structures in buildings/ houses, which would also contribute in increasing the groundwater table.
- Keep the house taps and public stand posts closed to avoid any wastage.
- Inform about water leakages and theft of public stand posts.
- Inform to the Municipal Corporation about illegal water connections in any area.
- Do not tamper with water supply connection.
- Do not take illegal connection.
- Use of Three R's -



iv) Areas identified for improvement Performance

- House to house survey is being carried out to identify connections.
- 100% metering will be achieved in coming year.
- For reducing NRW -
  - i) PMC is implementing recycling of filter bed back wash water.
  - ii) Metering at trunk mains and ESR's.
- Adopting SCADA system for equitable distribution of water supply and monitoring of water quality through reports.
- Telescopic tariff structure for water billing for recovering O&M charges of water supply services.
- Powers delegated to a special committee to improve collection efficiency of water charges.
- Designing distribution network for newly developed planning & areas for equal distribution of water.
- Additional close pipeline from Khadkwasla dam to Parvati & Cantonment WTP for reducing losses, contamination & cost of raw water.
- Refurbishment of old WTP's at Parvati & Cantonment.
- Replacement of old Pre stressed line with MS line to prevent frequent leakages.
- Effective use of ground water sources.
- Use of dual flush & plumbing fittings to be made compulsory for newconstructions to reduce wastage of potable water.

- Citizens' Awareness Programme at various levels to be taken up for preventing the wastage of potable water.
- Individual household metering for individual flats to be proposed for new constructions.

v) Corporate Governance Initiative for Social responsibilities

As a part of its effort to improve the quality and promptness in the delivery of civic service – water to the citizens of Pune. Citizens' participation through the involvement of Community Based Organizations and N.G.Os in improving the delivery of civic services.Form steering Committee that will be support to get civic services to everybody. This Committee will be responsible for streamlining public services and informing the citizens regarding their rights and responsibilities and achieve a **STAR** System.

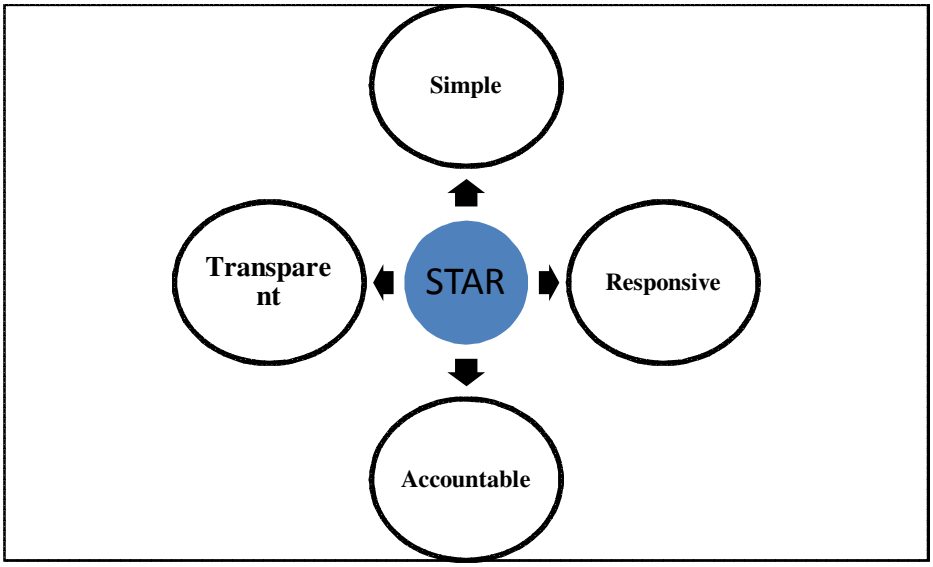


Fig. 7.1.STAR System

1. Simple 2. Transparent 3. Accountable 4. Responsive

STAR will help to develop proper understanding and co-ordination between Citizens' Groups, elected ward members and Municipal Officials for achieving timely-and efficient delivery of municipal services and bringing about a better physical environment at the local level by creating awareness among citizens about their civic rights and responsibilities.

This committee should be consist of one representative from Central Water Commision,Statelevel Water Commission,Municipal Commissioner,Head of Water,Distribution department, Ex. Engineer from Water Maintenance & Water works, Ward office/ward

representative etc.This committee should provide all important information to the citizens about the services being delivered by PMC and the concerned departments such as

- Create **public awareness** regarding the **rights and responsibilities** of the citizens with regard to various municipal functionaries.
- Create a **network of service centers for public** grievances and **redress the same qualitatively and time limit.**
- Solicitate the **mutual trust and confidence** in citizens to make them **aware of their duties towards** community.
- Being **fair, efficient, citizen friendly and outcome** oriented.
- Providing **all important information** to the Citizens about the services being delivered by the Municipality.
- Citizen interaction with us **easy, simple, hassle free** and efficient, at the same time ensuring **accountability and transparency.**
- **Conveyance and distribution of water** for private and public uses.

Needed Cooperation From Citizen:

- Avoid wastage of water. Do not use drinking water for gardening and other similar purposes
- Do not draw unauthorized water or through installation of pumps in municipal connection
- Get the repairs attended after proper intimation to corporation and under the supervision of Municipal engineering Staff.
- Pay water charges and other dues promptly and avoid disconnection
- Conserve rain water and install Rain Water Harvesting structures in all buildings.
- Keep the tap closed both in the house and in public stand post to avoid pollution and wastage or Report water leakage, theft as a public service
- Do not tamper with water supply connection or meters.

vi) Water Saving Chart For Everyone

WATER SAVING CHART	LITRES SAVED PER		
	Day	Month	Year
In the kitchen:			
· Wash vegetables and fruits in a bowl, not under tap	10	300	3650
· Select only one glass for the day	2	60	730
· Fill one basin with soapy water and one with rinse water for hand-washing dishes	4	120	1460
· Don't rinse dishes before loading dishwasher	70	2100	25550
· When buying a new dishwasher, consider purchasing a water-saving model	10	300	3650
In the bathroom:			
· Use a mug to rinse your razor, not running water	2	60	730
· Turn off running water while brushing your teeth	20	600	7300
· Turn off running water while shampooing	6	180	2190
· Take shorter showers (e.g. from 10 to 5 min)	30	900	10950
· Install a water-saving showerhead	27	810	9855
· Place a bottle filled with pebbles in the toilet tank	2	60	730
· Fix toilet leaks	130	3900	47450
In the laundry room:			
· Wash laundry only when the machine is full	130	3900	47450
· Replace a top-loader washing machine with a front-loader one	30	890	10830
· Recycle clothes-washing water for mopping the floor or flushing the toilet	20	600	7300
Everywhere:			
· Turn off dripping taps	30	900	10950
· Install aerators in all taps	15	450	5475

(Source: h2opune.com)

7.4. SCOPE FOR FUTURE RESEARCH

Technology has played a crucial role in this endeavor. The design has been worked out with EPANET hydraulic model that utilizes the information on the use of water at different times of the day, special information available from Geographical Information System (GIS) and household surveys. Minimization of leakage and duration of the network has been achieved with HDPE pipes. In this study, we want to develop GIS water supply model that will design entire MLR water network.

Simulation of the real world network involves modeling of the entire city network, its complex operations and the present behaviour of the hydraulic systems. Further, it is essential to study the entire networks for suitable zoning and sub-zoning. Thereafter, the critical analysis for improving the system through various measures needs to be modelled under numerous.

Future development will include enhancements to the programmes to increase operation speed, so as to make it functional in one environment and decrease reliance on user input.

The city of Pune was provided with the results of the case study along with the programmes and information required using the system and analyzing different alternatives.

Dissemination of basic information about the water supply and city could be achieved quite effectively. Addition of GIS driven maps would enhance the utility of such information service.

Economic analysis can be carried out to find the benefits from the proposed study. Updating of the network which is undergoing by the PMC of water distribution department is needed. But this needs to be integrated with the land information system (LIS) of the city as well as information on hydraulic flow of the water network. Operation and maintenance data including pressure records need also be integrated spatially with the network. Therefore, introducing geographic information system (GIS) is timely as it may facilitate the updating of the networks and support to perform related spatial analysis. The recently prepared digital elevation model (DEM) of the city may support to divide the network in to manageable smaller hydraulic zones or district meter areas.

The other issue addressed in the analysis was that of the impact of pipe age on water loss. On the one hand, the loss was found to be higher in the sub-system where pipes of relatively older age are located. This signifies that besides to the loss caused as a result of leakage, other non-

physical losses may also be expected to be higher. To this effect, as illegal connection is not noticed as major problem, loss due to meter errors especially under recording of meters is expected to be higher. From the above explanations, the main causes of the water loss may be characterized as being caused by leakage and customer billing errors.

There is a lot of scope for continuous improvement and efforts are being taken to reduce the NRW from 30% to15% in planned period of three years. Continuous efforts for leak detection and reduction are planned to achieve this goal. By reducing the losses, more area will be brought under coverage of 24x7 Water Supply System. The goal is to supply 24x7 water to entire Pune city consumers in near future by replicating the experiment. The necessary planning and implementation measures for remaining Pune city area required take up in hand.

However, from the quality of the available data and the complex nature of the water loss and leakage, this conclusion could only be taken as suggestive findings to be a base for further studies. A researcher has studied this concept and wishes to file the patent for further research.

Bibliography

- **Books**

1. Buckley David J., " The GIS Primer- An Introduction to Geographical Information System" Corporate GIS Solutions Manager, Pacific Meridian Resources, Inc.(http://bgis.sanbi.org/gis-primer/page_25.htm)
2. Burrough P.A., 1986"Principles of GIS", Oxford, Clarendon Press GIS Science Publications, (Wilson J.P., Mitasova H., Wright D.J., 2000)
3. Burrough P.A., 1986"Principles of GIS", Oxford, Clarendon Press
4. C.R.Kothari , "Research Methodology Methods & Techniques", New age International Publication, New Delhi.
5. Donald R. Cooper and Pamela S. Schindler,"Business Research Methods", Tata McGraw Hill , Delhi
6. Dr. S. P. Gupta, "Statistical Methods", Sultanchand & sons Publication, New Delhi.
7. GIS Tutorial Workbook for ArcView 9, Second Edition Wilpen L. Gorr and Kristen S. Kurland ISBN: 9781589481787
8. GIS: Fundamentals, Applications and Implementations, Elangovan,K.,Year:2006 ISBN: 8189422162
9. Howard, J, K. Larson, D. White, and E. Wentz ,"The Use of GIS as a Decision-Support Tool by Water Managers in Phoenix, Arizona"
10. Prof. Dhaygude M.G., "Mathematical Methods", Everest Publishing House, Pune.
11. Shamsi, U. M. (2001). "GIS and Modeling Integration." CE News, 13(6).
12. The Advanced Learner's Dictionary of Current English, Oxford Publishing, Delhi.

- **Journal and Magazines**

1. Abaje I.B.,O.F. Ati, and S. Ishaya ,"Nature of Potable Water Supply and Demandin Jema'a Local Government Area of Kaduna State, Nigeria" ,Research Journal of Environmental and Earth Sciences 1(1): 16-21, 2009 ISSN: 2041-0492
2. Alaguraja Yuvaraj .D, P Sekar.M, Muthuveerran.P, Manivel .M " Analysis of drinking water problem in Coimbatore City Corporation Tamil nadu, India using Remote Sensing and GIS tools". International Journal Of Environmental Sciences Volume 1,

No1,2010 ISSN 0976 – 440 2

3. Asadi S. S., Vuppala Padmaja and Reddy M. Anji, "Remote Sensing and GIS Techniques for Evaluation of Groundwater Quality in Municipal Corporation of Hyderabad (Zone-V), India" International Journal of Environmental Research and Public Health 2007, 4(1) ISSN 1661-7827
4. Bo Yan; Xiaorong Su; Yiyun Chen; , "Data Management of Urban Water Supply Network Based on GIS," Computing, Communication, Control, and Management, 2008. CCCM '08. ISECS International Colloquium on , vol.3, no., pp.353-357, 3-4 Aug. 2008 doi: 10.1109/CCCM.2008.370
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4609856&isnumber=4609776
5. C. Jun a, *, J. Koo b and J. Koh c , M. Tabesh, A. H. Asadiyani Yekta and R. Burrows " An Integrated Model to Evaluate Losses in Water Distribution Systems" (Journal-waterresourcemanagement,ISSN-0920-4741,VOL-23FEB-2009,477-492 (http://www.springerlink.com/content/w38x3680276r3111/
6. Dewi Rogers and Alessandro Bettin on "Saving the World's Most Precious Resourc Sustainable Development – Education, Business and Management – Architecture and Building Construction – Agriculture and Food Security"(7/03/2012)
7. E.Manoli,G. Arampatzis,E. Pissias,D. Xen Os, And D. Assimacopoulos ""Water Demand And Supply Analysis Using A Spatial Decision Support System" Global Nest, the International Journal Vol 3, No 3, pp 199-209, 2001
8. Garaci Mike "Simplified GIS for Water Pipeline Management" Journal of Water Resources Planning and Management, Vol. 119, No. 2, March/April 1993, pp. 412-419) http://cedb.asce.org/cgi/WWWdisplay.cgi?80147
9. I. Mouratidis, G. Dimopoulos, T. Astaras, S. Savvidis ,"Sustainable Water Resources Management Through The Use Of GIS Technologies" Global Nest Journal, Vol 12, No 2, Pp 140-151, 2010
10. Ifatimehin, O.O. and Musa, S.D,"The Prospects Of Sustainable Management Of Domestic Water Supply And Sanitation In Kogi State.".Geo-Studies forum: An International Journal of Environmental and policy issues volume 4:1812.2008

11. Labadie John W.,Margaret T. Herzog ,“Optimal Design of Water Distribution Networks with GIS” Journal of Water Resour. Plann. Manage. 122, 301 (1996); doi:10.1061/(ASCE)0733-9496(1996)122:4(301) (11 pages)
12. Prof. Gavekar Vidya S., ”Enhancement of water supply system through GIS”, CIIT,International Journal of Artificial Intelligent Systems and Machine Learning, July 2009
13. Rao N. H., Brownee Sheena M. and Sharma P. B. ,“GIS Based Decision Support System for Real time water demand estimation in canal irrigation systems” Current Science Journal, Vol. 87, No. 5, 10 Pg.629-637
14. Reddy Anji,” Impact Assessment of Water Conservation Measures: A GIS Approach” Environment Science & Technologies Centre for Environment, Jawaharlal Nehru Technological University, Hyderabad, AP, India.
15. Robert Pitt University of Alabama and Shirley Clark Penn State by"Comparison of Pipe Flow Equations and Head Losses in Fittings",New York: Mc Graw Hill. pp. 6.29. ISBN 0-07-007247-7 (http://rpitt.eng.ua.edu/Class/Water%20Resources%20Engineering/M3e%20Comparison%20of%20methods.pdf. Retrieved 2008-12-06.)
16. Rosenthal, W. D., R. Srinivasan, and J. G. Arnold. 1995. Alternative river management using a linked GIS hydrology model. Transactions of the ASAE. 38(3): 783-790.
17. Satti Sudheer R., Jacobs Jennifer M. “A GIS-based model to estimate the regionally distributed drought water demand”, Dept. of Civil & Coastal Engg., University of Florida, Gainesville, USA ,Journal of Agricultural Water Management DOI:10.1016/j.agwat.2003.10.003
18. Shasmi “GIS Tools for Water, Wastewater, and Storm water Systems”, 375 pages, ASCE Press, August 2002
19. Suchith Anand , Dr K. Vairavamoorthy ,“GIS in Design and Asset Management of Intermittent Water Distribution Systems”(Map Asia, 2002) (8th annual WD symposium EPA Cincinnati, August 27-30, 2006)

20. Tabesh M. , Asadiyani Yekta A. H. and R. Burrows, " An Integrated Model to Evaluate Losses in Water Distribution Systems" (Journal-water resource management,ISSN-0920-4741,VOL-23FEB-2009,477-492 (http://www.springerlink.com/content/w38x3680276r3111/)WaterResources Management Volume 23, Number 3, 477-492,)
21. Tabesh M., M. R. Delava,A. Delkhah "Use of geospatial information system based tool for renovation and rehabilitation of water distribution systems" Int. J. Environ. Sci. Tech., 7 (1), 47-5 8, Winter 2010,ISSN: 1735-1472
22. United Nations Development Programme (UNDP) (2003), Human Development Report 2003: Millennium Development Goals - ACompact Among Nations to End Human Poverty, published by UNDP.
23. Usali Norsaliza & Mohd Hasmadi Ismail " Use of Remote Sensing and GIS in Monitoring Water Quality" (www.ccsenet.oo rg/jsd Journal of Sustainable Development Vol. 3, No. 3; September 2010)
24. Wilson J.P., Mitasova H., Wright D.J.," Appl;ications of GIS in Water Resources" GIScience Publications,23/03/2000.

- **Reports**

1. A report by Government of India (2002), The National Water Policy, Ministry of Water Resources, New Delhi.
2. A report by Ministry of Urban Development, Central Public Health and Environmental Engineering
3. A Report by Ralph A. Wurbs Texas A&M University,Department of Civil Engineering Environmental, Ocean and Water Resources Division on "COMPUTER MODELS FOR WATER RESOURCES PLANNING AND MANAGEMENT" July 1994
4. A report by United Nations Development Programme (UNDP) (2003), Human Development Report 2003: Millennium Development Goals - A Compact Among Nations to End Human Poverty, published by UNDP.
5. A Report by Wurbs Ralph A. Texas A&M University, Department of Civil Engineering Environmental, Ocean and Water Resources Division on "COMPUTER MODELS FOR WATER RESOURCES PLANNING AND MANAGEMENT" July 1994

6. A report on " Water Resources Management for Himanchal Pradesh " prepared by INRM Consultants & Technology House Consortium ,New Delhi.
7. A Report on City Development Plan -2010-11,Pune Municipal Corporation
8. A report on Excellence in Water Management 2008 -Confederation of Indian Industry) by, Kirloskar Brothers Limited, Kirloskarwadi Plant
9. A Report on Government of India & Central Water Commission Training Program on "Applications of GIS in Water Sector" dt.7-18 June,2010 Organized by National Water Academy, Pune.
10. A report on Impact Assessment of Water Conservation Measures: A GIS Approach by Anji Reddy, Environment Science & Technologies Centre for Environment, Jawaharlal Nehru Technological University, Hyderabad, AP, India.
11. A report on Water conservation in India Pune Submitted by Water Conservation Advisory Council, December 2008
12. A Report on Water Resources Management for Himachal Pradesh for INRM consultants & Technology House Consortium ,New Delhi, Project Sponsored By Council for Science, Technology and Environment,Government of Himachal Pradesh,March 2006.
13. A thesis by Hayrettđn Onur Bektas on ,"Developing A Methodology For Finding Network Water Losses Using Information Technologies: A Case Study" Dec,2011
14. Annual Report on Water Distribution system ,PMC, Pune
15. Blacksburg, "Overview and Introduction to. Geospatial Technologies" VA. July 24th – 30th, 2010. (http://gep.frec.vt.edu/VCCS/materials/PDFs/1.1-Clayton_Intro2GIS.pdf)
16. Butler, D. (2000) Leakage Detection and Management, Palmer Environmental, UK.
17. Case Study on "Excellence in Water Management 2008 "(Confederation of Indian Industry) by, Kirloskar Brothers Limited, Kirloskarvadi Plant
18. CGWA (Central Ground Water Authority). 1999. Ground water situation status of development and proposed
19. Cheong L.C., International report on "Unaccounted for water and economics of leak detection",IWA World Conference Budapest, October 1993
20. City Development Plan,PMC (2006-2012)

21. Durmus Cesur ,"GIS as an information technology framework for water modeling", Journal of Hydroinformatics | 09.2 | 2007 Q IWA Publishing 2007(http://www.iwaponline.com/jh/009/0123/0090123.pdf)
22. Environmental report 2008-09,PMC
23. Government of India & Central Water Commission Training Program on "Applications of GIS in Water Sector" dt.7-18 June,2010 organized by National Water Academy, Pune.
24. Government of India (2002), The National Water Policy, Ministry of Water Resources, New Delhi.
25. Hazen-Williams Coefficients, Engineering ToolBox, http://www.engineeringtoolbox.com/hazen-williams-coefficients-d_798.html, retrieved 7 October 2012
26. Henriette Tamasauskas*, L.C. Larsen, O. Mark, "Using GIS In Water Supply And Sewer Modelling And Management"DHI Water and Environment report http://www.cjk3d.net/DHIPaper/urban/15.pdf
27. Rossman, L. A. (2009) EPANET 2 Users Manual; Accessed August 24, 2009 at http://www.epa.gov/nrmrl/wswrd/dw/epanet/EN2manual.PD
28. Rossman, L.A. (2000). EPANET 2 Users Manual. National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH.
29. SLB Report by PMC-2010-11
30. The world health report 2003 - shaping the future
31. US Environmental Protection Agency, 2000: EPANET user manual September 2000 (http://www.epa.gov/NRMRL/wswrd/dw/dsr.htm)
32. US Environmental Protection Agency, 2008: Distribution System Research; Accessed August 24, 2009 at http://www.epa.gov/NRMRL/wswrd/dw/dsr.htm
33. Vairavamoorthy K., "Guidelines for design of Intermittent Water Distribution Systems", DFID, UK, Waterlines, Volume 21, Number 1, 1 July 2002 , pp. 19-21(3)
34. WaterCAD (2005), http://www.hasetad.com/software/watercad/

35. WHO,2000,World Health Organization, Global Water Supply & Sanitation assesment 2000 report

- **Conference Proceedings**

1. Abdollah Ardeshir, Mehdi Saraye, Farhad Sabour, and Kourosh Behzadian "Leakage Management for Water Distribution System in GIS Environment" ASCE Conf. Proc. doi:http://dx.doi.org/10.1061/40856(200)27
2. Anderson, J. L., Lowry, M. V., and Thomte, J. C. (2001). "Hydraulic and Water Quality Modeling of Distribution Systems: What are the Trends in the US and Canada." AWWA Annual Conference, Washington,DC.
3. Artina S., Bragalli C., Giunchi D., Liserra T., "Stima delle perdite idriche proposta dal DM 99/97 e da IWA con monitoraggio in telelettura", Atti del I Convegno Nazionale di Idraulica Urbana-Acqua e Città, Sorrento, 2005.
4. Bahadur Rakesh, Pickus Jonathan, Amstutz David and William Samuels "A GIS-based Water Distribution Model for Salt Lake City, UT"21st Annual Esri International User Conference, July9-13,2001,PaperNo-173 (http://www.proceedings.esri.com/library/useconf/proc01/professional/papers/pap173/p173.htm)
5. Bajpai, P. and Bhandari, L. (2001). Ensuring Access to Water in Urban Households. Economic and Political Weekly, Sept. 29: 3774-3778.
6. Bartolin Hugo J., Martinez Fernando have published article on "Modelling and Calibration of Water Distribution Systems. A NewGIS Approach" 21st Annual Esri International User Conference, July 9-13, 2001 ,Paper No-126
7. Bo Yan; Xiaorong Su; Yiyun Chen; , "Data Management of Urban Water Supply Network Based on GIS," Computing, Communication, Control, and Management, 2008. CCCM '08. ISECS International Colloquium on , vol.3, no., pp.353-357, 3-4 Aug. 2008doi: 10.1109/CCCM.2008.370
8. Bo Yan; Xiaorong Su; Yiyun Chen; , "Functional Structure of Urban Water Supply Network Based on GIS," Computing, Communication, Control, and Management, 2008. CCCM '08. ISECS International Colloquium on , vol.3, no., pp.348-352, 3-4 Aug.2008 doi:10.1109/CCCM.2008.369

9. Breiling Meinhard ,“The Use of Geographic Information Systems (GIS) in Local Planning and Possible Contributions to Integrated Water Management in Sweden” Paper to Conference “Water Savings Strategies in Urban Renewals“February 1 to 3, 1996, Schloß Wilhelminenberg, ViennaEuropean Academy of the Urban Environment, Berlin Interdisciplinary Institute of Environmental Economics and Management, Vienna
10. Chen Yuli; Wang Zhihong; Tu Yu; Wang Shen; Sun Wen; , "Application analysis on the information management system for water supply network in Guangzhou," Electric Technology and Civil Engineering (ICETCE), 2011 International Conference on , vol., no., pp.5758-5763, 22-24 April 2011doi: 10.1109/ICETCE.2011.5774622URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5774622&isnumber=5774181S
11. D.Hardwick and, G. Maree “You are here”: Marking the progress of GIS in river conservation planning”, Conference & Proceeding,26 November,2006, Map Africa 2006
12. Dr. H. Ramesh, L. Santhosh and C. J. Jagadeesh on “Simulation of Hydraulic Parameters in Water Distribution Network Using EPANET and GIS”, International Conference on Ecological, Environmental and Biological Sciences (ICEEBS'2012) Jan. 7-8, 2012 Dubai
13. Esri International User Conference Proceedings ,2006
14. F. DE SMEDT, L. YONGBO and S. GEBERMESKEL , 2000, Hydrologic modeling on a catchment scale using GIS and remote sensed land use information, Department of Hydrology and Hydraulic Engineering, Free University Brussels, Belgium..16)
15. Fifty Years of Dryland Research in India, eds. H. P. Singh, Y. S. Ramakrishna, K. L. Sharma and B. Venkateshwarlu. Hyderabad, India: Central Research Institute for Dryland Agriculture. Pp. 301-313.
16. GITA2003, Conference Proceeding (http://www.gita.org.au/2003_Event_programme.html.
17. Guizuo,Liliang Ren,Tianfang Fang,Jinping Zhang “The Study and Application of GIS-based distributed Hydrological Model” 2008 International Workshop on Education Technology and Training & 2008 International Workshop on Geoscience Issue Date: 21-22 Dec. 2008 ,Volume: 2 ,On page(s): 223 - 227 ,ISBN: 978-0-7695-3563-0
18. Hussain Jama Ismail Bait-Ishaq , Philip Burden ,“GIS Implementation in the Ministry of Water Resources in Oman” User Conference 2003,

http://www.gisqatar.org.qa/conf97/links/e2.html (3 of 8)8/20/2003 3:27:39 AM

19. Ingeduld, Zdenek Svitak, Pradhan Ajay, Tarai Ashok “Modelling Intermittent Water Supply Systems with Epanet”, 4th Asia Pasific DHI Software Conference,2008
20. Kui Chang, Jinliang Gao, Yixing Yuan, Wenyan Wu ,"Establishment of the Scheduling Training System of Water Distribution Network Using Virtual Reality” Information Science and Engineering, International Symposium on, vol. 2, pp. 625-628, International Symposium on Information Science and Engineering, 2008.
21. Leigh Eric and Dr. Guy Fipps ,“Use Of Geographical Information Systems (Gis) In Defining Municipal Water Supply Networks” Third International Conference on Irrigation and Drainage, Water District Management and Governance, U.S. Committee on Irrigation and Drainage, San Diego, March 2005
22. LIAO Xiao-yu,”A GIS-based Decision Support System for Water Resources Management of Song-LiaoRiverBasin”College of Urban and Environmental Science China http://www.gisdevelopment.net/application/nrm/water/overview/ma04042abs.htm
23. Lin Ji-Hao has published article on “Scenario Simulation of Water Supply Network “Asian Conference on Remote Sensing (ACRS) proceedings,2007
24. Madhavan K.D. ,“Mapping & Maintenance of Water Distribution System and Sewer Collection System Network using Remote Sensing and GIS” 8th Annual International Conference on Map India 2005 Geomatics 2005 at New Delhi.
25. Martínez-Solano, F. Javier; Pérez-García, R. & Iglesias-Rey, P.L. “Water Mains Creation Using GIS”, 5th AGILE Conference on Geographical Information Science, Palma (Balearic Islands, Spain) April 25th- 27th ,2002
26. Molden, D.; Sakthivadivel, R. 1999. Water accounting to assess uses and productivity of water. Water Resources Development 155, No.1 & 2: 55-71.
27. Narain, P.; Khan, M. A. 2002. Water for food security in arid zone of India. Indian Farming 52 (7): 35-39.
28. Pickard Brian D. and Levine Audrey D. “Development of a GIS Based Infrastructure Replacement Prioritization System: A Case Study” Water Distribution Systems Analysis Symposium 2006 Proceedings of the 8th Annual Water Distribution Systems Analysis Symposium, held in Omaha, Nebraska, May 22-25, 2006

29. Roy P.S. and Rao V.V. Indo-US Workshop on “Innovative E-technologies for Distance Education and Extension/Outreach for Efficient Water Management”, March 5-9, 2007, ICRISAT, Patancheru/Hyderabad, Andhra Pradesh, India
30. S. Mohan and K. Danimon, India K. Vairavamoorthy , UK ,“Development of GIS based contamination risk assessment in water distribution systems” 30th WEDC International Conference, Vientiane, Lao PDR, 2004
31. Saxena Praveen Raj , Prasad N.S.R., “Integrated Land & Water Resources Conservation and Management –Development Plan Using Remote Sensing & GIS of Chevella Sub-Watershed “, Professor, Dept. of Applied Geochemistry, Osmania University, Hyderabad , India.(http://www.isprs.org/proceedings/XXXVII/congress/8_pdf/7_WG-VIII-7/01.pdf)
32. Shakoor, A.; Shehzad, A.; Asghar, M.N.; , "Application of Remote Sensing Techniques for Water Resources Planning and Management," Advances in Space Technologies, 2006 International Conference on , vol., no., pp.142-146, 2-3 Sept. 2006 doi: 10.1109/ICAST.2006.313815URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4106426&isnumber=4106396
33. Shandas Vivek, Alberti Marina, Gibson John ,Steve Moddemeye, Jacqueline Meijer-Irons, “A GIS based Water Demand Analysis for Municipal Application” 6th Annual International conference MAP INDIA 2003, Seminar on Muncipal GIS
34. Tao Song, Kyehyun Kim ,“A Study Of Developing Gis-Based Water Quality Management System Of Rural Area “ Asian Conference on Remote Sensing (ACRS) proceedings,2006
35. Tian Yu; Ma Liya; Lei Xiaohui; Jiang Yunzhong; , "Construction of water supply pipe network based on GIS and EPANET model in Fangcun District of Guangzhou," Geoscience and Remote Sensing (IITA-GRS), 2010 Second IITA International Conference on , vol.2, no., pp.268-271, 28-31 Aug. 2010 doi: 10.1109/IITA-GRS.2010.5604123 URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5604123&isnumber=5601975
36. Toleti Rao B.V.M., Chaudary , B.S. “Integrated Ground Water Resources Mapping in Gurgaon District, (Haryana) India using Remote Sensing and GIS Techniques” , Asian Conference on Remote Sensing, MAP INDIA 2000. http://www.gisdevelopment.net/aars/acrs/2000/ts2/water0002.shtml

37. Vairavamoorthy K., J.M. Yan, H. Galgale UK, S.Mohan, India and S.D. Gorantiwar, UK ,"A GIS based spatial decision support system for modeling Contaminant intrusion into water distribution systems"30th WEDC International Conference, Vientiane, Lao PDR, 2004 People-Centered Approaches To Water And Environmental Sanitation
38. Vairavamoorthy K., Jimin Yan a, Galgale Harshal M., Gorantiwara Sunil D., "IRA-WDS: A GIS-based risk analysis tool for water distribution systems", International Journal of Environmental & Science Technology, Vol. 22, No. 7. (2007), 951-965.
39. Wasi-Ullah; Chakravarty, A. K.; Mathur, C. P.; Vangani, N. S. 1972. Effect of contour furrows and contour bunds on water conservation in grasslands of western Rajasthan. Annals of Arid Zone 11(3/4):1709-182.
40. Werner de Schaetzen and Paul F. Boulos, "Optimal Water Distribution System Management Using ESRI MapObjects Technology" 22nd Annual Esri International User Conference, July 8–12, 2002.
41. Xiao-Li Cao; Chao-Yuan Jiang; Si-Yuan Gan;, "Leakage monitoring and locating method of water supply pipe network," Machine Learning and Cybernetics, 2008 International Conference on , vol.6, no., pp.3549-3551, 12-15 July 2008doi: 10.1109/ICMLC.2008.4621019 URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4621019&isnumber=4620933
42. Zhao-Shun Wang; Zu-Kuan Wei; Qian Yin; , "The design of water supply network based on GIS," Cybernetics and Intelligent Systems, 2008 IEEE Conference on , vol., no., pp.209-213, 21-24 Sept. 2008doi: 10.1109/ICCIS.2008.4670974 http://ieeexplore.ieee.org/stamp/stamp.tp=&arnumber=4670974&isnumber=4670728
43. Zorkeflee Abu Hasan , Nuramidah Hamidon , Norazazi Zakaria , Aminuddin Ab.Ghani and Leow Cheng Siang, "INCOPERATING GIS IN WATER RESOURCES MODELLING: Application of SWAT 2005 Model in Sungai Kurau, Perak and CCHE2D Model in Tasik Harapan USM, Penang"http://www.infogigi.com/redac.eng.usm.my.html

- **Websites**

1. http://bgis.sanbi.org/gis-primer/page_06.htm
2. http://en.wikipedia.org/wiki/Geographic_information_system
3. http://en.wikipedia.org/wiki/Hazen%E2%80%93Williams_equation

4. http://en.wikipedia.org/wiki/Municipal_corporation
5. http://en.wikipedia.org/wiki/Pune(11/7/2008)
6. http://en.wikipedia.org/wiki/Pune(11/7/2008)
7. http://government.wikia.com/wiki/
8. http://government.wikia.com/wiki/PMC_Electoral_Ward_Administration (20/6/2009)
9. http://www.ArcUser.com 2008
10. http://www.bwssb.org/
11. http://www.census2011.co.in
12. http://www.census2011.co.in(1/1/2012)
13. http://www.dhisoftware.com/mikenet/MIKENET Software (2005)
14. http://www.epa.gov/surf/).
15. http://www.esri.com
16. http://www.geospatialmedia.net/publications.htm
17. http://www.gis.com
18. http://www.gisdevelopment.net
19. http://www.h2opune.com
20. http://www.informationsoftwaresystems.com/
21. http://www.isro.com
22. http://www.jiyainfotech.com/products.htm
23. http://www.maharashtrafireservices.org/pdf/ pune_mitigation_plan.pdf(23/09/2009)
24 http://www.mapsofindia.com/maps/maharashtra/pune.htm(23/07/2008)
25. www.bgis.sanbi.org/gis-primer/page_25.htm
26. www.gep.frec.vt.edu/VCCS/materials/PDFs/1.1-Clayton_Intro2GIS.pdf (Lo, 2002)
27. www.punecorporation.org

28. www.punecorporation.org/pmcwebn/informpdf/PMC_DPR_ver8.0.pdf
29. www.punediary.com
30. www.virtualpune.com

- **News Papers**

1. Sakal Times,Saturday,March 9,2013
2. Times of India, 8th April,2012
3. Times of India July 19,2011
4. Times of India, 4th Aug 2009
5. Times of India, Thursday, April 15, 2010 at 01:04:05 AM
6. Times of India, Dec 21, 2010
7. Times News Network 02/10/2010
8. Times of India, 4th Aug 2009
9. Times of India, Dec 21, 2010
10. Times of India, Jul 22, 2010, 02.14am IST
11. Times of India,8th September 2010
12. Times of India, Wed, 07/01/2009 - 06:59.

- **Visited Places**

1. Central Water Power Research Station(CWPRS), Pune
2. Ground Water Survey Development & Agency(GSDA), Pune
3. National Water Academy(NDA), Pune
4. Society For Promoting Participative Ecosystem Management(SPPEM), Pune
5. Gomukh Trust, Pune
6. Surshti Eco Research Institute, Pune
7. Water Distribution Centre, PMC, Pune
8. Water Treatment Plants, PMC, Pune
9. Symposium on “Issues in Water Sector in India” on dt 23rd -24th March,2013,Karve Shikshan Sanstha,Pune

Annexure 1

Drinking Water Standards As Per Bureau Of Indian Standards (BIS 10500: 1991)

Sl. No	Substance or Characteristic	Requirement (Desirable Limit)	Permissible Limit in the absence of Alternate source
ESSENTIAL CHARACTERISTICS			
1.	Colour Hazen units, Max	5	25
2.	Odour	Unobjectionable	Unobjectionable
3.	Taste	Agreeable	Agreeable
4.	Turbidity NTU, Max	5	10
5.	pH Value	6.5 to 8.5	No Relaxation
6.	Total Hardness (as CaCo3) mg/lit., Max	300	600
7.	Iron (as Fe) mg/l,Max	0.3	1.0
8.	Chlorides (as Cl) mg/l, Max.	250	1000
9.	Residual free chlorine mg/l, Min	0.2	--
DESIRABLE CHARACTERISTICS			
10.	Dissolved solids mg/l, Max	500	2000
11.	Calcium (as Ca) mg/l, Max	75	200
12.	Copper (as Cu) mg/l, Max	0.05	1.5
13.	Manganese (as Mn) mg/l, Max	0.10	0.3
14.	Sulfate (as SO4) mg/l, Max	200	400
15.	Nitrate (as NO3) mg/l, Max	45	100
16.	Fluoride (as F) mg/l, Max	1.9	1.5
17.	Phenolic Compounds(as C 6 H5OH) mg/l, Max.	0.001	0.002
18.	Mercury (as Hg) mg/l, Max	0.001	No relaxation
19.	Cadmiun (as Cd) mg/l, Max	0.01	No relaxation
20.	Selenium (as Se) mg/l, Max	0.01	No relaxation
21.	Arsenic (as As) mg/l, Max	0.05	No relaxation
22.	Cyanide (as CN) mg/l, Max	0.05	No relaxation
23.	Lead (as Pb) mg/l, Max	0.05	No relaxation
24.	Zinc (as Zn) mg/l, Max	5	15

Sl. No	Substance or Characteristic	Requirement (Desirable Limit)	Permissible Limit in the absence of Alternate source
25.	Anionic detergents (as MBAS) mg/l, Max	0.2	1.0
26.	Chromium (as Cr^{6+}) mg/l, Max	0.05	No relaxation
27.	Polynuclear aromatic hydro carbons (as PAH) g/l, Max	--	--
28.	Mineral Oil mg/l, Max	0.01	0.03
29.	Pesticides mg/l, Max	Absent	0.001
30.	Radioactive Materials		
	i.Alpha emitters Bq/l, Max	--	0.1
	ii.Beta emitters pci/l, Max	--	1.0
31.	Alkalinity mg/lit. Max	200	600
32.	Aluminium (as Al) mg/l,Max	0.03	0.2
33.	Boron mg/l, Max	1	5

BACTERIOLOGICAL STANDARDS

I. Water entering the Distribution system

Coliform count in any sample of 100 ml should be Zero. A sample of the water entering the distribution system that does not conform to this standard calls for an immediate investigation in to both the efficacy of the purification process and the method of sampling.

II. Water in the distribution system

1. Ecoli count in 100ml of any sample should be zero.
2. Coliform organisms not more than 10 per 100 ml in any sample.
3. Coliform organisms should not be present in 100 ml of any two Consecutive samples or more than 5% of the samples collected for the year

Annexure 2

Guidelines Recommended By Central Public Heath & Environmental Engineering Organization As Recommended By World Health Organization (WHO)

S.No.	Characteristics	*Acceptable	**Cause for Rejection
1	Turbidity (NTU)	1	10
2	Colour (Units on Platinum Cobalt scale)	5	25
3	Taste and Odour	Unobjectionable	Objectionable
4	pH	7.0 to 8.5	<6.5 or >9.2
5	Total dissolved solids (mg/l)	500	2000
6	Total hardness (as CaCO3) (mg/l)	200	600
7	Chlorides (as Cl) (mg/l)	200	1000
8	Sulphates (as SO4) (mg/l)	200	400
9	Fluorides (as F) (mg/l)	1.0	1.5
10	Nitrates (as NO3) (mg/l)	45	45
11	Calcium (as Ca) (mg/l)	75	200
12	Magnesium (as Mg) (mg/l)	~ 30	150
13	Iron (as Fe) (mg/l)	0.1	1.0
14	Manganese (as Mn) (mg/l)	0.1	0.5
15	Copper (as Cu) (mg/l)	0.1	1.5
16	Aluminium (as Al) (mg/l)	0.0	0.2
17	Alkalinity (mg/l)	200	600
18	Residual Chlorine (mg/l)	0.2	>1.0
19	Zinc (as Zn) (mg/l)	5.0	15.0
20	Phenolic compounds (as Phenol) (mg/l)	0.001	0.0002
21	Anionic detergents (mg/l) (as MBAS)	0.2	1.0
22	Mineral Oil (mg/l)	0.0	0.0
	TOXIC MATERIALS		
23	Arsenic (as As) (mg/l)	0.01	0.05
24	Cadmium (as Cd)(mg/l)	0.01	0.01
25	Chromium (as hexavalent Cr) (mg/l)	0.05	0.05
26	Cyanides (as CN) (mg/l)	0.05	0.05
27	Lead (as Pb) (mg/l)	0.05	0.05
28	Selenium (as Se) (mg/l)	0.01	0.01
29	Mercury (total as Hg) (mg/l)	0.001	0.001
30	Polynuclear aromatic hydro carbons (PAH) (µg/l)	0.2	0.2
31	Pesticides (total, mg/l)	Absent	Refer to WHO guidelines for

RADIO ACTIVITY +			
32	Gross Alpha activity (Bq/l)	0.1	0.1
33	Gross Beta activity (Bq/l)	1.0	1.0
Notes:			
*	The figures indicated under the column 'Acceptable' are the limits upto which water is generally acceptable to the consumers		
**	Figures in excess of those mentioned under 'Acceptable' render the water not acceptable, But still may be tolerated in the absence of an alternative and better source but up to the limits indicated under column "Cause for Rejection" above which the sources will have to be rejected.		
+	It is possible that some mine and spring water may exceed these radio activity limits and in such cases it is necessary to analyze the individual radio-nuclides in order to assess the acceptability to otherwise for public consumption		
	BACTERIOLOGICAL GUIDELINES		
	Bacteriological Quality of Drinking Water		
	Organisms	Guideline value	
	All water intended for drinking		
	E.coli or thermo tolerant coliform	Multiple not be detectable in any 100-ml sample	
	Treated water entering the distribution system		
	E.coli or thermo tolerant coliform bacteria	Must not be detectable in any 100-ml sample	
	Total coliform bacteria	Must not be detectable in any 100-ml sample. In case of large supplies, where sufficient samples are examined, must not be present in 95% of samples taken throughout any 12 month period	

Source: WHO guidelines for Drinking Water Quality (Vol.1-1993.)

Standards Prescribed for Drinking Water in India

Sr.No.	Substance / Characteristics	Desirable/ Essential	Highest desirable Limit (ppm)	Highest desirable Limit (ppm)
1	Calcium	Desirable	75	200
2	Magnesium	Desirable	30	100
3	Iron	Essential	0.3	1
4	Chloride	Essential	250	1000
5	Sulphate	Desirable	200	400
6	Nitrate	Desirable	45	100
7	Fluoride	Desirable	1	1.5
8	Total Dissolved Solids	Desirable	500	2000
9	pH	Essential	6.5-8.5	No relaxation
10	Total Hardness	Essential	300	600

Source: Bureau of Indian Standards: IS 10500

Existing Water Tariff Structure

Sr.No.	Type of Consumer	Water Charges
1	Residential -Metered	Rs. 3.00 per KL
2	Residential – un metered	
	If taxable amount is <1000	Rs. 75 per month
	If taxable amount is 1000-3000	Rs. 83 per month
	If taxable amount is >3000	Rs. 92 Per Month
3	Pune & Khadki CB	Rs. 5.00 per KL
4	Commercial and Industrial	Rs. 33 per KL

Annexure 3

Ward Office wise Distribution of Citizens

Ward Office No.	Ward office Name	No. of Respondents
1	Aundh	74
2	Karve Road	86
3	Ghole Road	65
4	Yerwada	64
5	Sangamwadi	68
6	Bhavani Peth	65
7	Tilak Road	94
8	Sahakar nagar	72
9	Hadapsar	85
10	Bibwewadi	69
11	Dhanakwadi	68
12	Dhole Patil Road	64
13	Warje Karvenagar	75
14	Kasba Vishrambaug	66
Total		1015

Annexure 4

Questionnaire for Citizen's

NOTE: Water is the most significant natural resource, potentially useful to Human, Agricultural, Industrial, Household, Recreational and Environmental activities. Water is life and little drops of water can create mighty ocean. So it's our duty to save every single drop of water and utilize it more efficiently. The Researcher is an Academician, who is carrying out a survey of water supply system in Pune city for better utilization of the precious resources.

The information given by the respondent would be treated as confidential.

1. Name(Optional) _____

2. Location /Area _____

3. Ward Office Name: (Tick Mark the Option.)

1) Aundh	2) Karve Road	3) Ghole Road	4) Yerwada
5) Sangamwadi	6) Bhavani Peth	7) Tilak Road	8) SahakarNagar
9) Hadpsar	10) Bibwewadi	11) Dhanakwadi	12) Dhole Patil Road
13) Warje Karvenagar		14) Kasba Vishrambaug	

4. How many members are in your family? _____

5. What is the approx quantity of water utilized at your residence (In Buckets/In Liters)?
(1 Bucket=10-14Lit)

Sr.No	**Usage of Water**	**Average Consumption of Water Daily**	
		In Buckets	**In Liters**
1	Cooking & drinking		
2	Cleaning & washing		
3	Bathroom		
4	Toilet		
5	Gardening		
6	Miscellaneous		
Total			

6.

Sr. No	Water Sources	House Hold (PMC) Connection	Bore Well	Public Tap	Well	Pond	River	Tanker	Canal	Any Other
i)	Sources of water available in your area	☐	☐	☐	☐	☐	☐	☐	☐	
ii)	Sources of water for your household uses	☐	☐	☐	☐	☐	☐	☐	☐	

7. Do you use any alternative option in case of unavailability of corporation water supply?

1. Bore Well ☐ 2. Well ☐ 3. Tanker ☐ 4. Dam ☐ 5.Any other_____

8. What is the frequency of water supply?

1. 24 hours supply ☐ 2. Once in a day ☐ 3. More than once in a day ☐

4. Once in two days ☐ 5. Once in three days ☐ 6. Any Other_____

9. How many hours of water supply per day? _____Hrs.

10. Do you feel that the required quantity of water supply to your house is sufficient?

Yes ☐ No ☐

i) If Yes, Water availability

1. Sufficient all year ☐ 2.Insufficient during dry season ☐

3. Sometimes insufficient ☐ 4. Insufficient mostly ☐

ii) If Not, How much water is required to fulfill your daily needs? (In Liter)

☐ 50-100 Lit ☐ 100 -150 Lit ☐ 150 -200 Lit ☐ 200-250 Lit ☐ As above_____

PUBLIC TAP

11. Do you have water supply through Public Tap?

Yes ☐ No ☐

If Yes, **Answers the following questions from Q.12 to Q.15.**

12. How far (in meters) is the public tap from your house? _____

13. Consumption (liter/day) _____

14 Collecting time (minutes/day) _____

15. What are the reasons for not having the water connection inside the house?

1.Connection fee is too high ☐ 2. Monthly/Yearly charges are too high ☐

3. Connection facility is not available ☐ 4. Present arrangement is satisfactory ☐

5. Rented house ☐ 6. Waiting list ☐

7. Any Other, specify_____

16. Water Pressure. (Select any one option)

Very Low ☐ Low ☐ Neither Low Nor High ☐ High ☐ Very High ☐

17. Are you satisfied with current water supply?

Yes ☐ No ☐

If Not, What are the water supply problems you face? (For each problem give only one rating between 1-5)

Sr. No	**Problems of Water Supply**	**Rating (1- Low 5- High)**				
		1	**2**	**3**	**4**	**5**
1	Insufficient Water quantity	☐	☐	☐	☐	☐
2	Electricity Problem	☐	☐	☐	☐	☐
3	Insufficient Connections in your area	☐	☐	☐	☐	☐
4	Low Pressure	☐	☐	☐	☐	☐
5	Impurity of water	☐	☐	☐	☐	☐
6	Inconvenient Water Timings	☐	☐	☐	☐	☐
7	Costly	☐	☐	☐	☐	☐
8	Leakages	☐	☐	☐	☐	☐
9	Water contamination	☐	☐	☐	☐	☐
10	Misuse of water	☐	☐	☐	☐	☐
11	Illegal water connection	☐	☐	☐	☐	☐
	Any Other (Specify)	_____				

18. On what basis are you paying the water supply charges?

Mater Basis ☐ Annual Basis ☐

i) If Meter Basis, choose appropriate option -

Individual Meter ☐ Group Meter ☐

ii) Are you satisfied with the current Meter system for usage of water?

Yes ☐ No ☐

If No- Why _____

19. Which type of billing system you preferred? (Tick Mark the Option)

Meter basis ☐ Annual Basis ☐

i) If Meter Basis, Why?

Optimal use of Water ☐

Water Loss Reduction ☐

Conserve the water for the Future ☐

Any Other_____

ii) If Annual Basis, Why?

Economically Feasible ☐

Unlimited water supply ☐

Faulty Meter ☐

Irregularity in meter checking ☐

Any Other_____

20. On a scale of 1 to 5, how important is water conservation to you? Pls. circle your answer?

1 2 3 4 5

Not at all important very important

21. What would motivate you to contribute more to conserve water?

Metering system made compulsory ☐ Increase in charges for water consumption ☐

Water shortage ☐ Drought Season ☐

Insufficient rain fall ☐ Lack of water resources ☐

22. To conserve the water for future, which options you will choose from the following?

Rain Water Harvesting ☐ Leakages of Tap ☐ Control on Illegal Connection ☐

Recycling of Waste Water ☐ Tree Plantation ☐ Optimal use of water in summer season ☐

GIS(Geographical Information System)based water Supply System ☐ Any Other (Specify):_____

23. Are you willing to pay and support additional conservation of water in our community?

Yes ☐ No ☐

24. Are you aware about the following water saving appliances? (If Yes, Please Tick Mark the Option.)

Sr.	Device name	Yes/No

No		
a)	Low flow shower heads	☐
b)	Spray taps	☐
c)	Kitchen Faucet Aerator	☐
d)	Toilet water diverter	☐
e)	Dual flush toilet	☐
f)	Rain Water Tank	☐
g)	Grey water use	☐

25. What do you consider to be the best solution for improving the water supply system?

Development & utilization of new resources ☐ Water loss reduction ☐

Metering System ☐ Reducing wastage of water ☐

26. In your opinion, will a reward system help in reducing wastage of water?

Yes ☐ No ☐

If Yes, Reward preferred

Discount on Water Bill ☐ Recognition in Newspaper & web site ☐

Supply of extra water in dry season ☐ Supply of extra water for agriculture purpose

Any Other_____

27. In your opinion, will a punishment system help in reducing wastage of water?

Yes ☐ No ☐

If Yes, Punishment preferred

Penalty on Water Bill ☐ Close water connection ☐ Any other:_____

28. Regarding the statement "Different Punishment & reward system will enhance the efficiency of Water Supply System" What is your opinion?

a) Strongly Agree b) Agree c) Neutral d) Disagree e) Strongly Disagree

29. Please write your comments or suggestions about water supply system and wastage of water?

Annexure 5

List of points for Interviews with Water Distribution & Supply Department Of PMC

1.	What are raw water resources available in Pune City?		
	☐ Dam ☐ River ☐ Canal ☐ Bore Well ☐ Well ☐ Pond ☐ Any Other_____		
2.	Details of Raw water sources -		
	Water Sources	Daily Raw Water Supply (MLD)	
	Dam		
	River		
	Canal		
	Well		
	Pond		
	Bore Well		
3.	Dam Details		
	Name of Dam	Storage Capacity(T.M.C)	Usable Capacity(T.M.C)
	KhadakWasla		
	Panshet		
	Warasgaon		
	Temghar		
4.		Quantity	Capacity/Specification
	Reservoir		
	Junctions		
	Pumping Station		
	Valves		
	Fire Hydrants		
5.	Total Water Distribution network length -_____Km		
6.	Water Connection Details -		

1.	Number of water Purification Plant:-_____				
2.	Name of Water Purification Plant :-_____				
3.	Location:-_____		4. Establishment Year:-_____		
5.	Total Capacity of the Plant:-_____				
6	Details of treatment plant drawing water from the various dam or other resources.				
	Location/Sources of DAM to WTP	Raw Water Supply Qty	Raw Water Supply Method	Treated Water Supply Qty.	Treated Water Supply Method
7.	Water supply network from WTPs To near DAM				
	Pipe Specification (between DAM to WTP)	Pressure	Length of network	Pipe diameter(Distribution Line)	
8.	Technical details of the treatment Plant of Pune Municipal Corporation.				
	Sr.No	Component Name	Technical Specification		
9.	What is the amount of treated water supply distribution across different centre?				
	Sr.No.	Distribution Centre	Treated Water Supply Qty(MLD)		
	1	Swargate			
	2	S.N.D.T			
	3	Contonment			

WATER TANKER DETAILS					
1.	Total Number of Water Tanker :-_____				
2.	Capacity of Tanker:-_____				
3.	Details of water supply through Tanker-				
	Season	Area	No of tanker per day	Quantity	
4.	Charges for Tanker:-_____				

Annexure 6

Interviews of Water Connections Department of PMC

Customer category Domestic	**No. of connections**	**Customer category Non-domestic**	**No. of connections**
(½")		**(½")**	
(¾")		(¾")	
(1")		1")	
Industrial		**Public stand posts**	
(1-1/2")		**Religious places**	
(2")		**(½")**	
(3")			
(4")			

(Note-%age Contribution of each consumer category to total revenue)

Category	**Contribution of revenue by each category to the total revenue from tariff (% age)**
Domestic	
Non-Domestic	
Industrial	
Public Standposts	
Worship Places	
Bulk Consumers	
Total	

Year	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**
Additional Connections (%)					
Additional connections					

Annexure 7

Interviews of Employees of Water Distribution Department of PMC

SECTION I – GENERAL INFROMATION

This Section focuses on general information regarding Water Supply System & Distribution department.

1.Name:_____ 2.Designation:_____

3. Does your system use computerized tools / information systems, such as a:

• Billing system	□ Yes	□ No	□Don't No
• Hydraulic network simulation software	□ Yes	□ No	□Don't No
• Geographical Information Systems (GIS)	□ Yes	□ No	□Don't No
• Cadastral register for system assets	□ Yes	□ No	□Don't No
• Register for repairs, defects, rehabilitation works	□ Yes	□ No	□Don't No
• Real time measurement & supervision system (SCADA)	□ Yes	□ No	□Don't No

4. Please tick which of the following statements apply to your system:

• A national water policy exists which aims at reducing water losses	□ Yes	□ No
• A water loss reduction program is implemented	□ Yes	□ No
• Benchmarks for reducing water losses exist and are followed up	□ Yes	□ No
• System flow meters are installed to measure the system input	□ Yes	□ No
• Approx. % of the service connections are metered		
• Pressure Management is used to reduce water losses	□ Yes	□ No
• A network maintenance/ rehabilitation program is implemented	□ Yes	□ No
• Preventive network inspections are done	□ Yes	□ No
• A leak detection program is implemented	□ Yes	□ No
• Measures to fight illegal connections are applied	□ Yes	□ No

5. How the meter reading and billing is performed?

□ Monthly □ Quarterly □ Yearly

6. What would be the obstacles for solving the water supply problems?

• Political situation	□ Yes	□ No	□ Can't Say
• Departmental situation	□ Yes	□ No	□ Can't Say
• Lack of financial means	□ Yes	□ No	□ Can't Say
• Lack of appropriate technologies	□ Yes	□ No	□ Can't Say
• Maintenance system	□ Yes	□ No	□ Can't Say
• Public Interference	□ Yes	□ No	□ Can't Say

SECTION II-WATER LOSS ACCOUNTING

This Section focuses on how you currently account for or compare the relative amounts of water consumed to that produced and calculate is commonly known as "**water loss**" or "**unaccounted for water**."

7. What is the loss of water after purification & distribution of water?

□ Greater than 25%	□ Less than 25% but greater than 20%	□ Less than 20% but greater than 15%
□ Less than 15% but greater than 10%	□ Less than 10% but greater than 5%	□ Less than 5%
□ Do not calculate water loss		

8. Do you have following system for maintaining water loss?

Name of System	Yes	No	Don't No
Water Audit	□	□	□
Water Accounting	□	□	□

9. Which of the following best describes to calculate water loss that you perform to get the figure reported in Q.5 of this section?

a. The difference between total water sales to the customer and the total water supplied to the system is the water loss.

b. The difference between total water sales plus some other metered or unmetered water uses and the total water supplied to the system.

c. The detailed water use audit that includes all unmetered & metered water uses and all other identified water uses.

d. Do not know exactly what is in the water loss calculation

e. Any other_____

10. After you have done the system water use calculations or analysis, how do you use the results?

□ Compare with past results	□ Compare the results to general benchmarks for % water loss
□ just enter them into the records	□ None of the above

SECTION III - WATER LOSS MINIMIZATION EFFORTS

This section focuses on gathering information about your water loss maintenance efforts. It takes into account your efforts to reduce water loss through such practices as leak detection, system repairs and water accounting procedures.

11. Which of the following best describes your system Leak Detection and Repair Program?

□ Periodic system surveys	□ Leaks are fixed when discovered by us.
□ Reported by customers.	□ A Leak Detection Program that includes various detection equipment.
□ Any Other _____	

12. Do you use of leak detection equipment? (Ex. listening microphones, sonic devices, or other equipment incorporated into your system to detect leaks.)

□ Yes □ No

13. Does your system have any specific programs or procedures where you fix leaks on the customer service lines?

□ Yes □ No

14. Please tick marks all other water loss control measures that you currently implement in your ongoing operations:

□ Systematic distribution line replacements or	□ Pressure management to reduce volumes of loss

rehabilitation	
□ Search for and enforce against illegal connections	□ Leak or pressure analysis through hydraulic modeling
□ Any Other _____	

15. Do you keep an organized leak repair log?

□ Yes □ No

If Yes, mark all that is included?

□ Pin or marked maps that visually show problem areas	□ Classify leaks based on size and location
□ Nature and cause of leak	□ Pipe material and replacement parts
□ Estimate of water lost during repair	□ Do not have a leak log or keep specific repair records

16. What is the average time it takes to fix a small or large leak at a valve or service line after it is reported or found?

□ Less than one day (1) □ Two to Three days (2-3)

□ More than three days □ Any Other_____

Annexure 8

1. Computerized Mapping, GIS Development and Utilities Computerization For Bangalore Water Supply & Sewerage Board (BWSSB), Bangalore, India

Implementing agency: Bangalore Water and sewerage board

Place **:** Bangalore India

Scope of work **:** Implementation of a complete GIS/MIS solution for water & sewerage management.

Name of the Project **:** Bangalore Information System on Networks

Date **:** 1999 – 2002

1.1. Hardware & Software Requirement of BWSSB:-

The GIS Hardware/Software setup at BWSSB is as below:

BWSSB Head Office is connected to all its Divisional Offices through LAN/WAN provide high-end equipment and computers to BWSSB Head Office and its Operational divisions.

- Supply and Installation of Computers, Networking Products and Peripherals for BWSSB head office and divisional offices
- Windows NT Server, Windows NT, Workstations
- Oracle 8i Server and Clients, Oracle ,Developer 2000
- Spatial Database Engine (ArcSDE)
- Microsoft Exchange Server
- Visual Basic Pro 6.0, Visual C++ 6.0
- Firewall CA Le Guardit
- Map Objects Lite
- Software provided for Database and other Application Development
- ArcInfo Products: ArcInfo, ArcFM, ArcView, ArcEdit, ArcCOGO,ArcNetwork, ArcSCAN, ArcEXPLORER, ArcPRESS, AutoCAD

Head Office – One Server with 5 PIII workstations, One Plotter, Scanner and A3 Colour Printer, with ArcInfo 8.1, Arc SDE (Spatial Database Engine), ArcView 8.0, ArcPress and Oracle 8i RDBMS

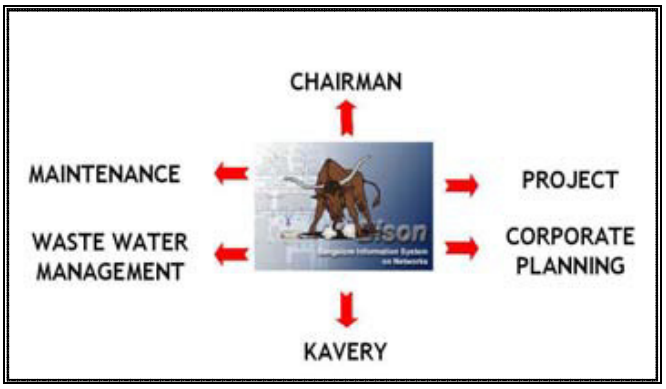
Divisional – One Server with 2 PIII workstations and A3 offices Printer,

Software - Arcview 3.1 and Oracle RDBMS

Service Stations – One Desktop PC with Printer

User Requirement:

Fig. No. 1: A Multi-User Corporate GIS oriented accessible in 60 different locations

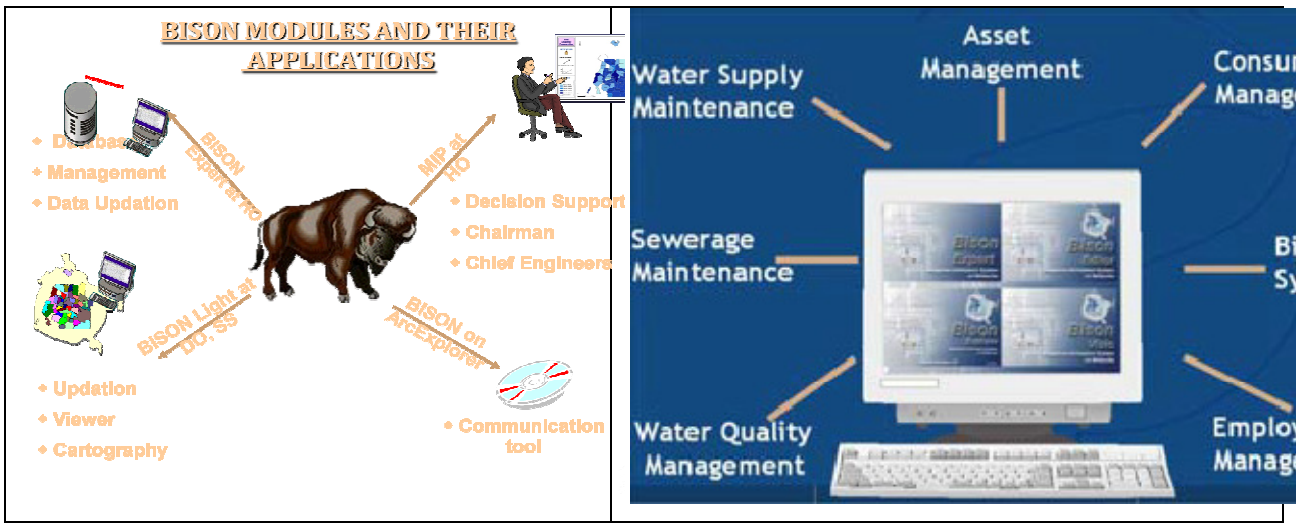


Key decisions Makers: Chairman and the 5 Chiefs engineers

- 5 Departments (Maintenance, Project, Corporate planning, Cauvery etc.)
- 6 divisions, 55 Service Stations

1.2. BISON (Bangalore Information System on Networks) MODULES AND THEIR APPLICATIONS

Fig. No. 2: BISON (Bangalore Information System on Networks) MODULES AND THEIR APPLICATIONS

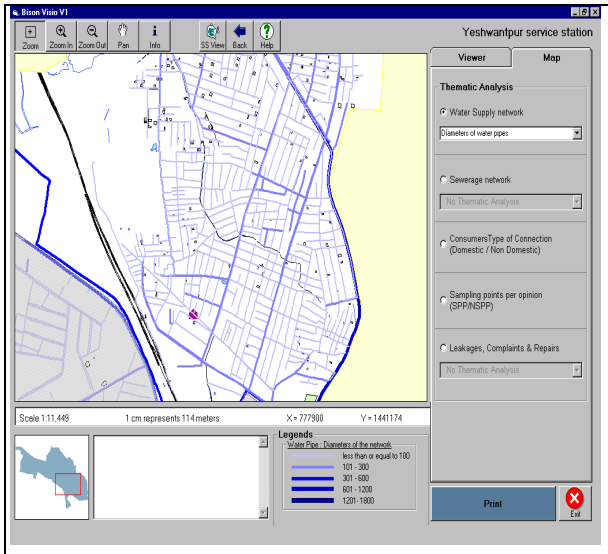


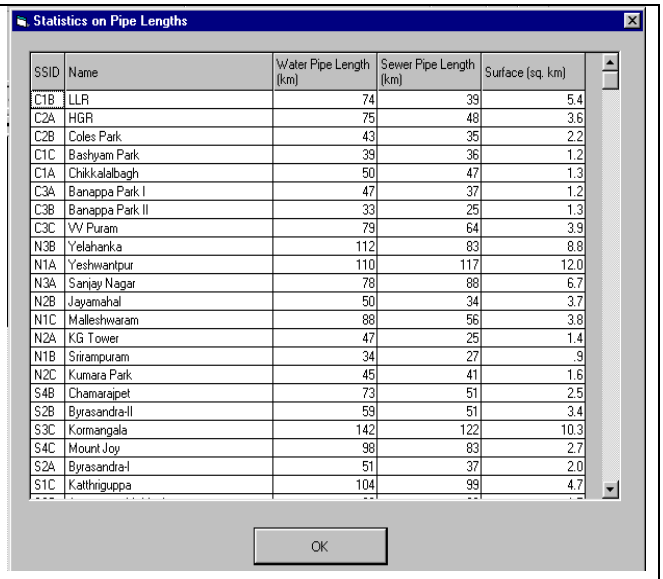
1.3. GIS Based Development Phases for BISON:

1. Preparing Base Maps.
2. Digitizing the base Maps
3. Georeferencing the Maps
4. Equipment procurement and installation
5. Detailed water supply and sewerage systems analysis
6. User Requirement assessment
7. GIS Design
8. Graphical and Alphanumerical Data Collection
9. Data Integration
10. Development and Testing of Front End Application
11. Training of staff

1.4. Sample Screen Layout of Bangalore Water Supply & Sewerage Board

Fig. No. 3: Layout of Bangalore Water Supply & Sewerage Board





SSID	Name	Water Pipe Length (km)	Sewer Pipe Length (km)	Surface (sq. km)
C1B	LLR	74	39	5.4
C2A	HGR	75	48	3.6
C2B	Coles Park	43	35	2.2
C1C	Bashyam Park	39	36	1.2
C1A	Chikkalalbagh	50	47	1.3
C3A	Banappa Park I	47	37	1.2
C3B	Banappa Park II	33	25	1.3
C3C	VV Puram	79	64	3.9
N3B	Yelahanka	112	83	8.8
N1A	Yeshwantpur	110	117	12.0
N3A	Sanjay Nagar	78	88	6.7
N2B	Jayamahal	50	34	3.7
N1C	Malleshwaram	88	56	3.8
N2A	KG Tower	47	25	1.4
N1B	Sriramputam	34	27	.9
N2C	Kumara Park	45	41	1.6
S4B	Chamarajpet	73	51	2.5
S2B	Byrasandra-II	59	51	3.4
S3C	Kormangala	142	122	10.3
S4C	Mount Joy	98	83	2.7
S2A	Byrasandra-I	51	37	2.0
S1C	Kathriguppa	104	99	4.7

Fig. No. 3:GIS layer for Complaint related Water Leakages

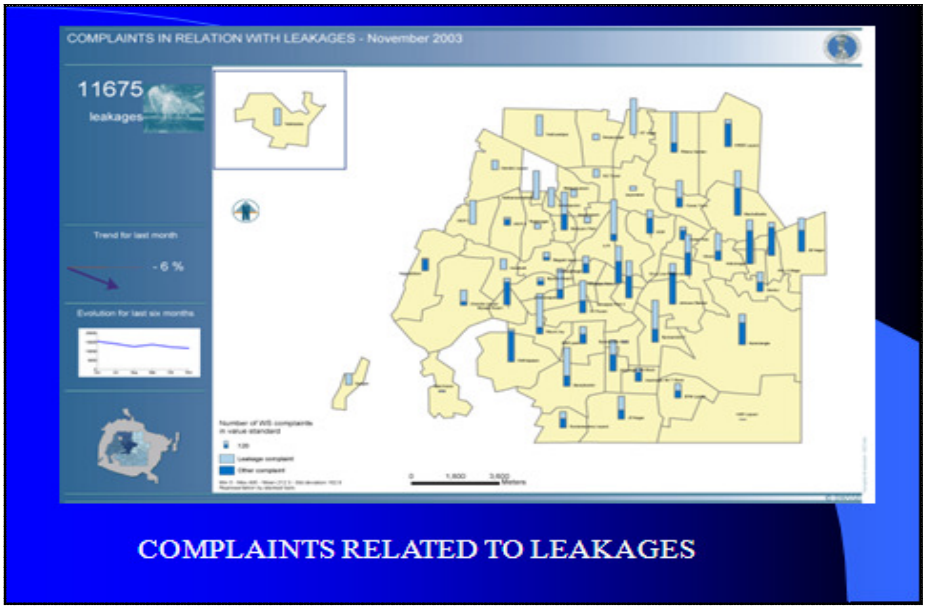


Fig. 4:Water Network of Bangalore Municipal Corporation Developed by using ArcGIS

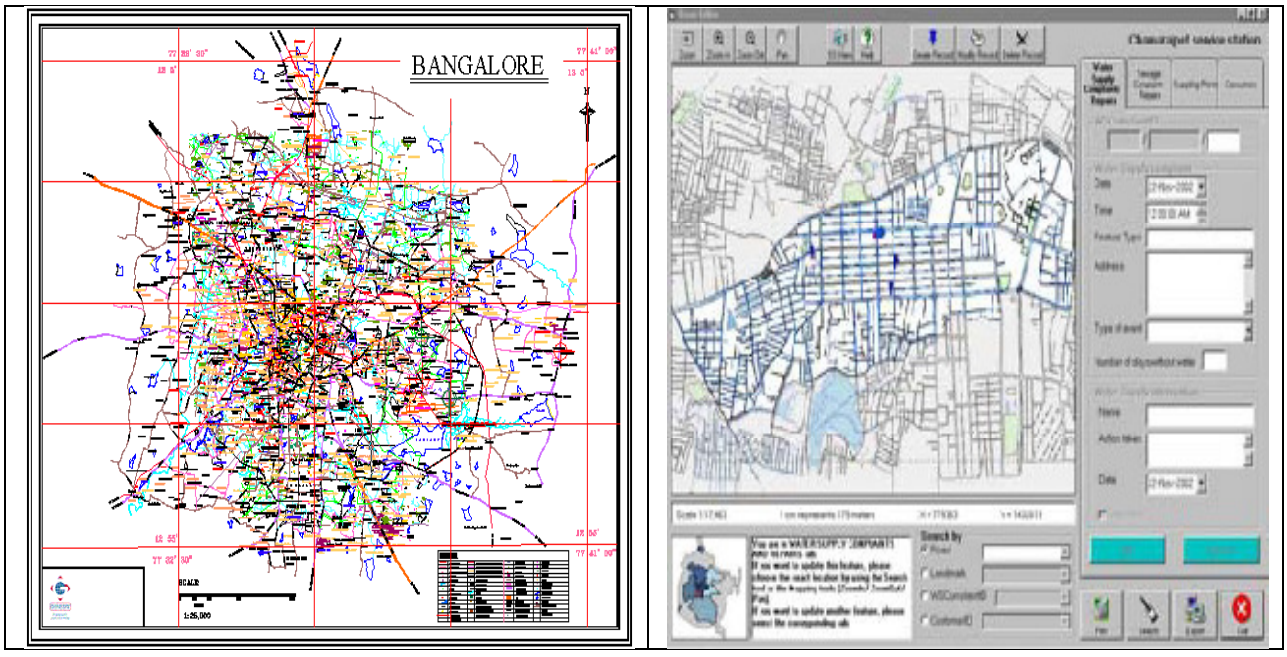
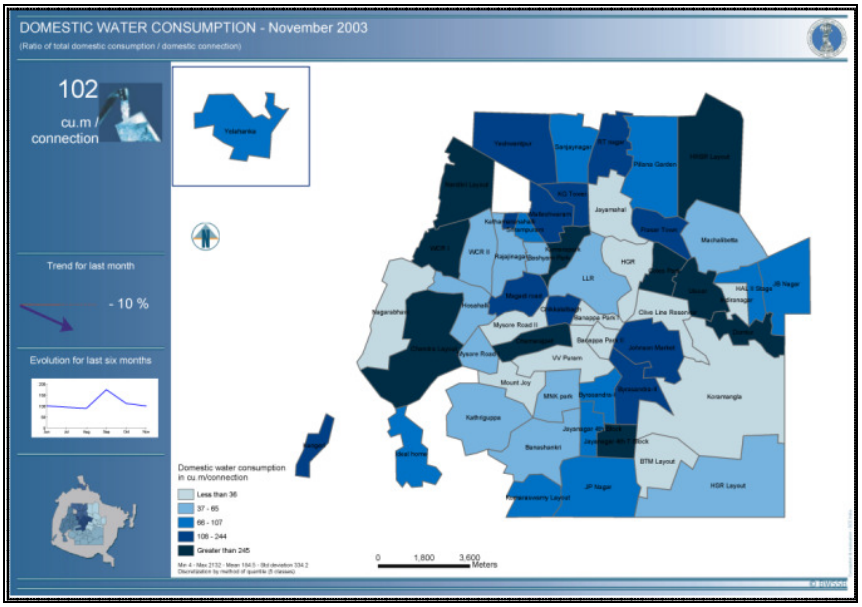


Fig. 6: Domestic Water Consumption map of Bangalore



Annexure 9

1. Sewerage and Water Supply Systems Design for a city with large floating population (Haridwar, India) using GIS

1.1 GIS based System Outputs-

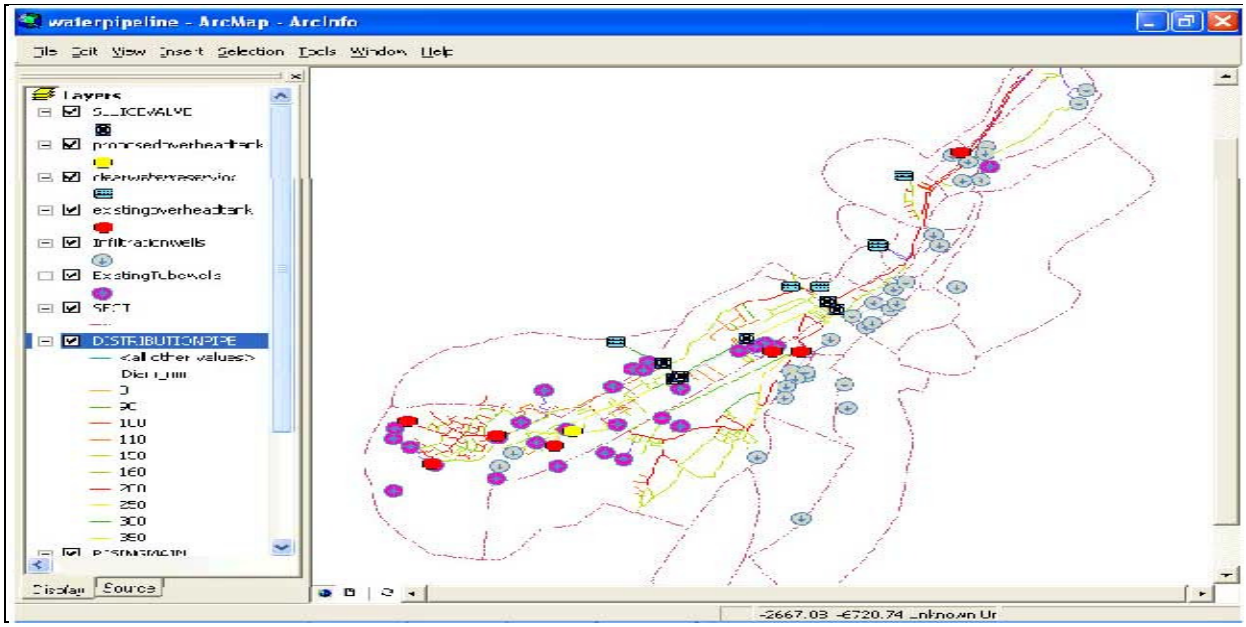


Fig. 1: Water Pipeline Map developed using ArcMap

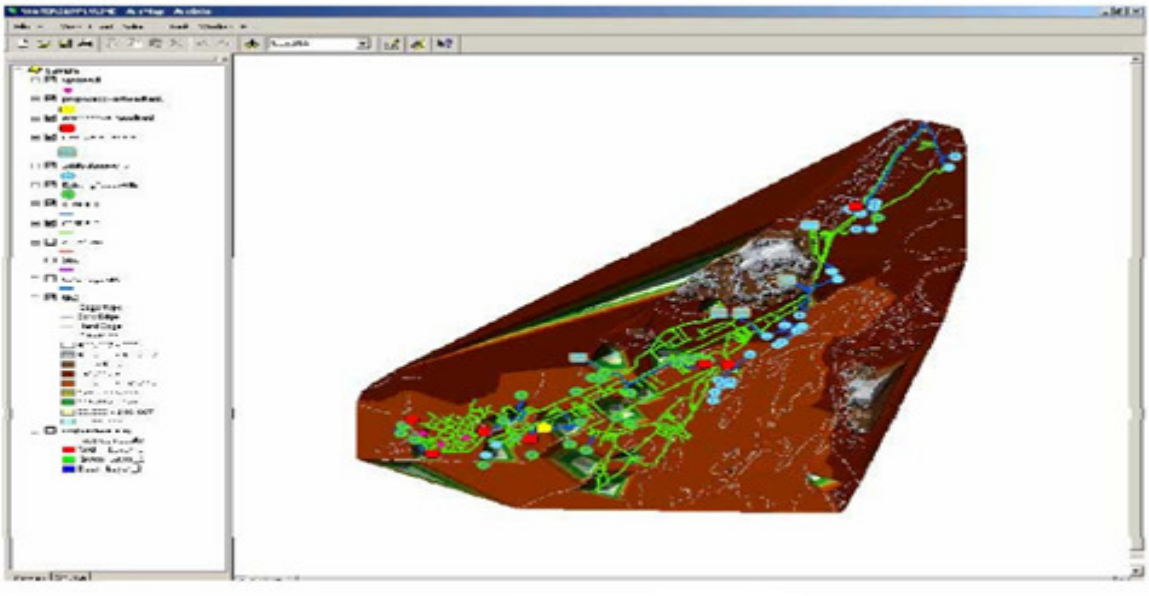


Fig. 2: ARCGIS window showing water system on a Tin Surface

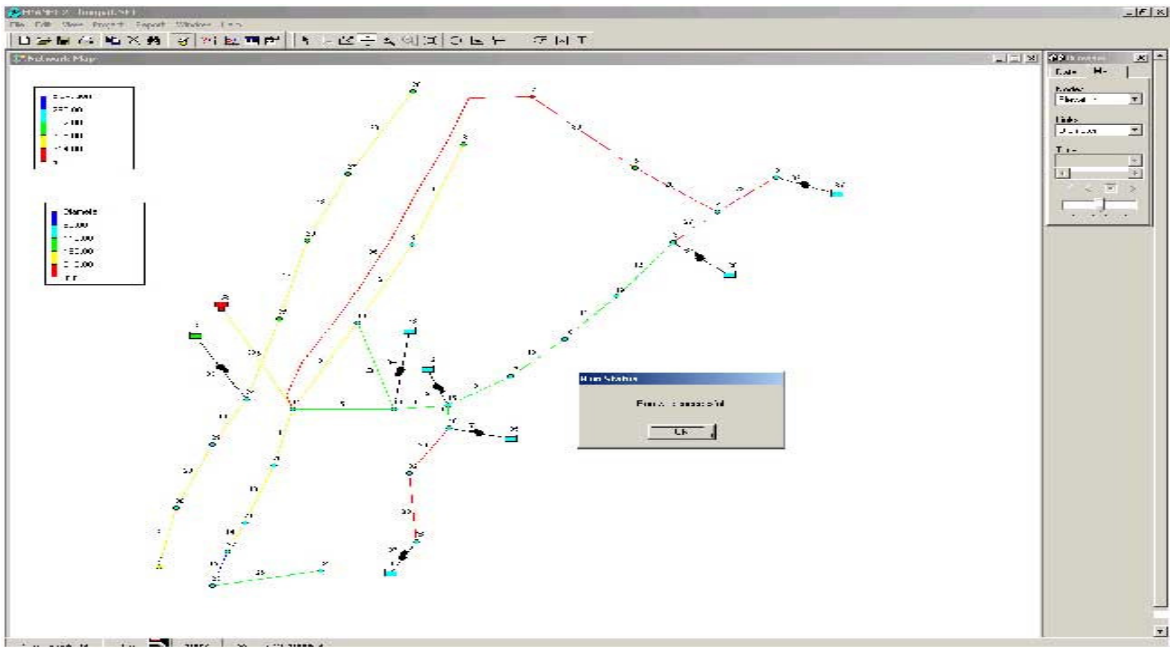


Fig. 3: EPANET window Showing the Pipe network, wells, Tank and pumps of the Bhopatwala Zone

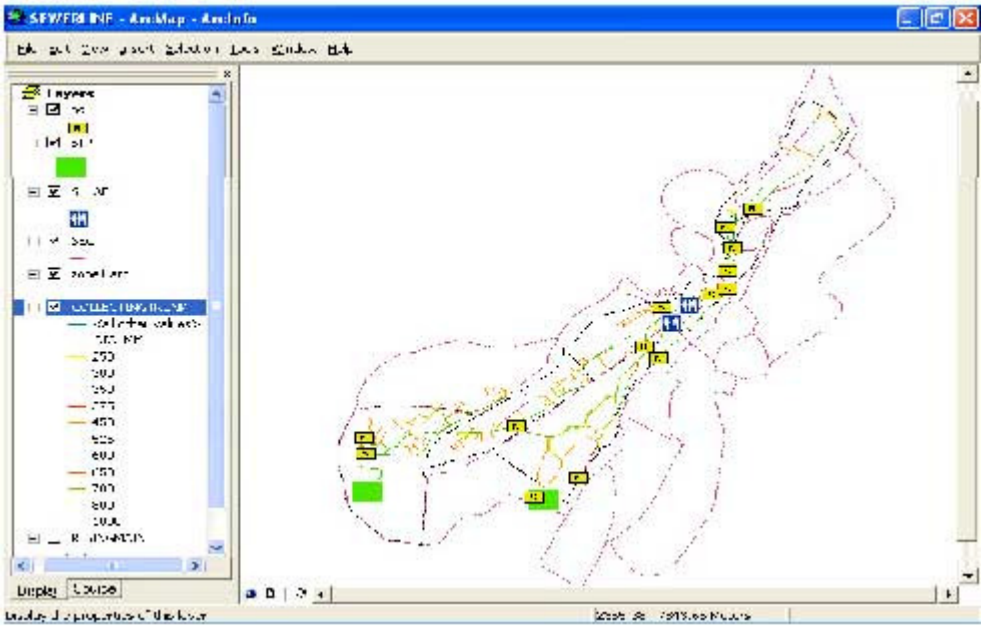


Fig. 4: The ARCGIS Window Showing the Details of Existing Sewerage System of Haridwar, Sewage Pumping Stations (SPS) Sewage Treatment Plant (STP) Sewer Network

Annexure 10

1. GIS Based Monitoring System for Urban Water Supply System

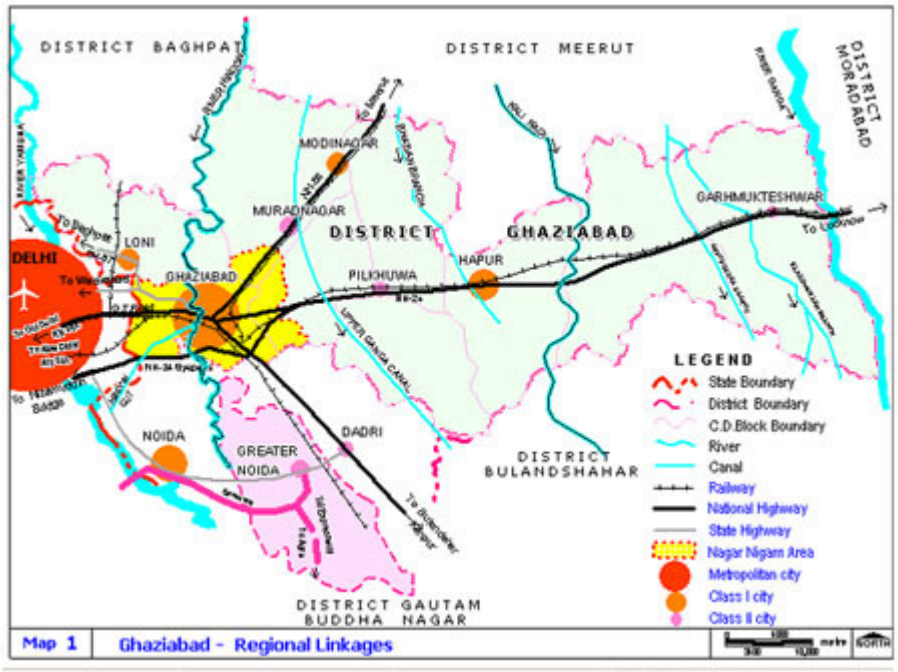


Fig. 1: Existing Ghaziabad City Map

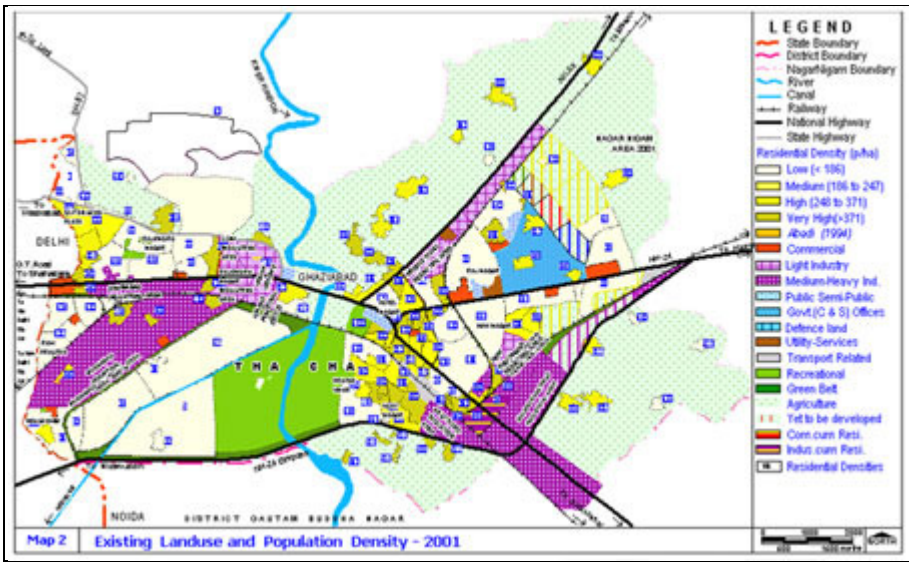


Fig. 2: Existing Land use and Population Density Map

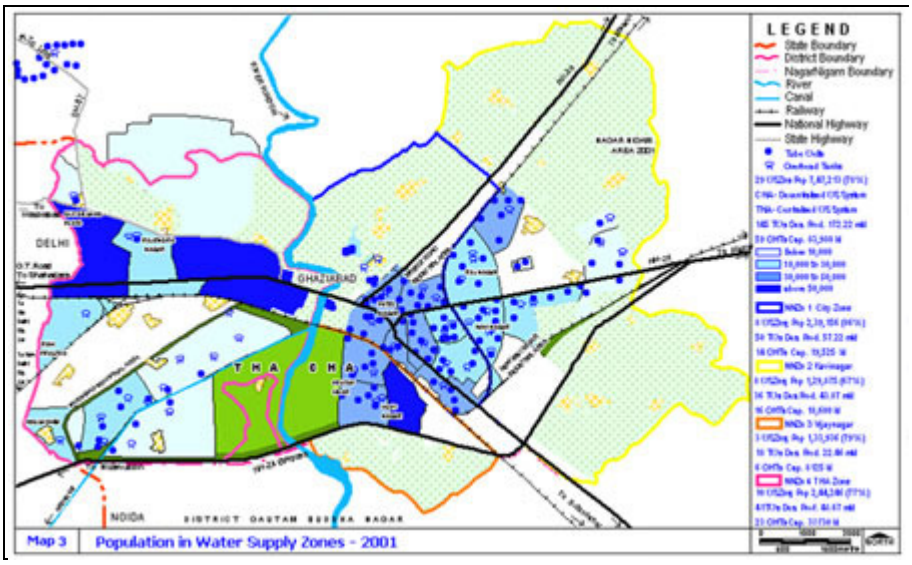


Fig. 3: Population in water supply zone wise Map



Fig. 4: Water Supply Rates in Water supply Zone wise.

Annexure 11

Illustrative examples for using paper maps for GIS

i) Identification of Ground Control Points (GCPs) on existing maps:

A set of GCPs could be identified on maps such as four corners of a Toposheet (not limiting only to 4 corner points), which provides information of latitudes and longitudes at the four corners. For better results, additional known control points could be identified and mapped. These points should ideally be spread over the entire map. In the following example, the longitudes and latitudes of four corners are as indicated (For the sake of understanding, geo-referencing procedure is illustrated for only four corners points of a toposheets).

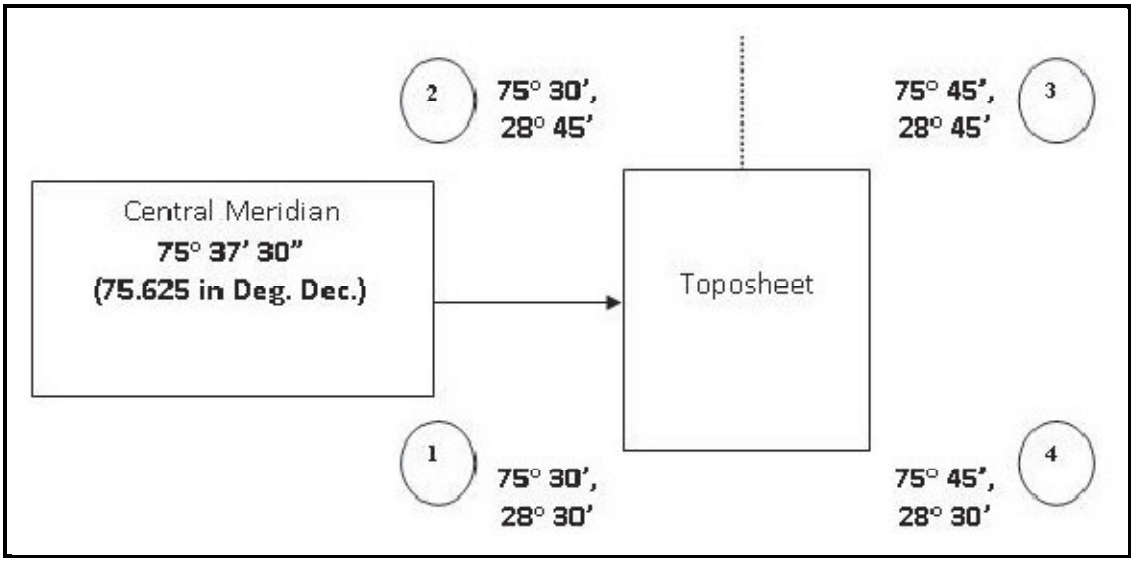


Fig. 1 : Longitude and latitude of TopoSheet

Values in Degree Minutes Seconds need to be converted into Degree Decimals. The four points would have following values respectively for points marked (1) to (4).

The step-by-step guide is given below of using ERDAS- Geo Rectification of Topo Sheet as an example.

ii) ERDAS- Geo Rectification of Topo Sheet

Geometric Correction or Geo-Rectification of a Topo graphical sheet. Topographic maps are also commonly called contour maps or topo maps, are large-scale detail and quantitative representation of relief usually called contour lines in modern mapping.

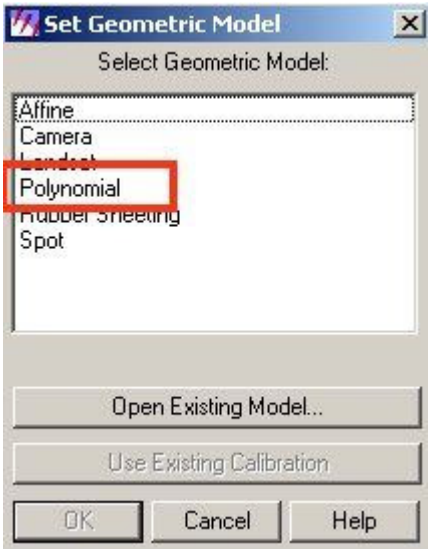
Steps to achieve Geometric Correction in ERDAS

Basic Procedure:

- Display files
- Start Geometric correction tool
- record Geometric(ground) Control Points(C+GCPs)
- resample the image
- Verify

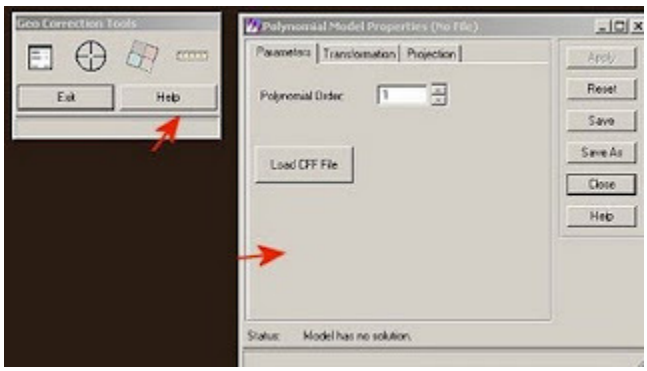
Begin by opening the file which you wish to georegister and display it and "fit" it in a viewer. As your mouse moves within the display window note that the coordinates displayed in the lower left of the viewer are in "row" and "column".

- Start the Geometric Correction tool from the viewer displaying the file to be retified.
- Select RASTER > Geometric Correction from the viewer's menu bar and Polynomial from the dialog box.



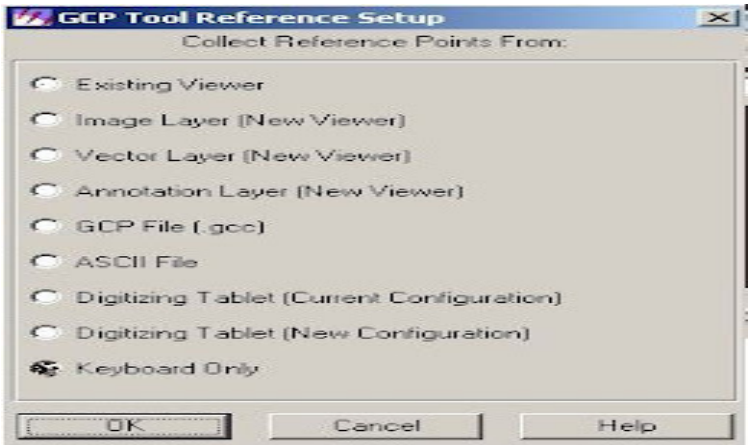
- Each of these geometric models relate to specialized tasks. The polynomial model has the most general application.

Two dialogs boxes will appear. The Geo Correction Tool menu will be used now.



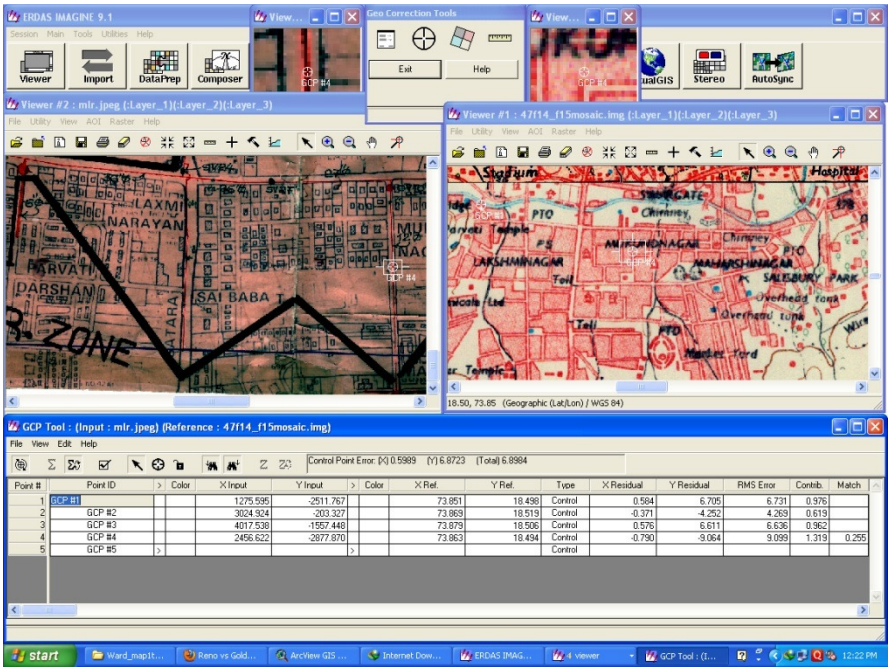
- The first one is Geo Correction Tools Window and the other is Polynomial model properties
- From the Polynomial model properties click on Projection Tab-->click on Add/Change projection.
- Select Datum--> Geographic Lat/Long
- Spreriod--> Everest 1956
- Datum name--> India Nepal

Click on GCP tool Reference Setup from the Polynomial model properties. You would observe the following dialog box:



- Select the option Keyboard Only. This option differs when you are Georectifying Image/Topo sheet from an existing geometrically corrected Image/Topo sheet.
- Click on Ok

You are now ready to begin assigning real world coordinates to the non-geographic registered image.



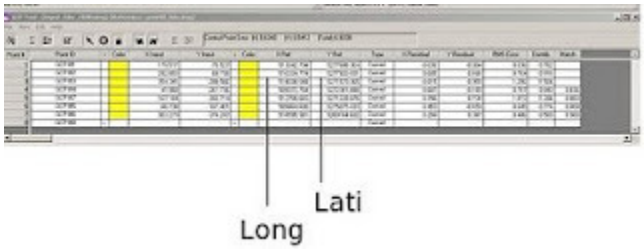
- First, each viewer now has it's own "zoom" window above it. The zoom window display that part of the image which is inside the "box" (some time called the link box). The Ground Control Points (GCPs) are the small targets which are place on the image using the GCP tool .As you observer there are two viewers , one in which the image to be rectified is displayed and in the other a magnified part of the image is displayed.
- In the Viewer1 you would observe a magnifier box pointing to some area and the respective area is visible in the Viewer2 at a best zoom level.
- Now adjust the Maginifer box in the viewer to the top left corner of the topo sheet where you can see a cross hair mark having coordinates.
- From the GCP tool bar, select GCP tool and click on the cross hair in the Viewer1(Top Left Corner).
- As soon as you click on the viewer paper coordinates are added to the GCP control. You have to manually add the Geographic coordinates to the control, i.e, longitude and Latitude.

Note: In ERDAS Imagine you have to first add Longitude and later Latitude.

You need not convert Geographic coordinates which are in Degree Min Sec to Decimal coordinates.

Ex:17045'50"

Add them as 17 45 50 in the table provided X and Y Reference, they will be added as Decimal Coordinates.

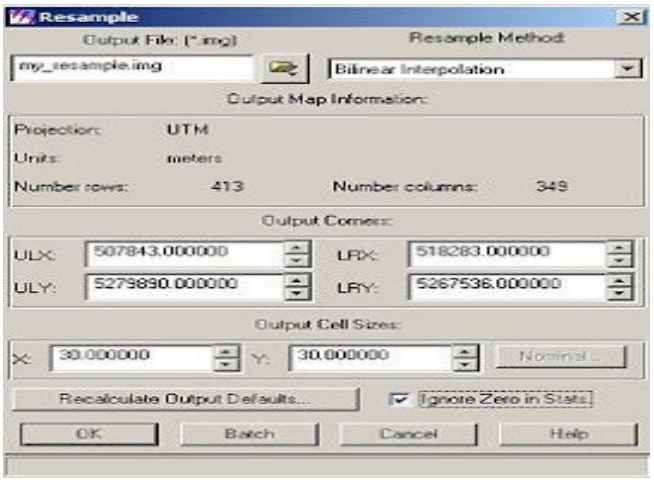


- Repeat this for Top-Right, Bottom Left and Bottom Right Corners in the Topo sheet(Anti clock wise direction)

Save the Input from the table file menu

- Our next task is to resample the image. Resampling is the process of calculate in the values for the rectified image and creating the new file. All of the raster data layers (all bands) in the source file are resampled. The best known algorithms for resampling are Nearest Neighborhood, Bilinear Interpolation, and Cubic Convolution. We'll use the Nearest Neighborhood algorithm.

- Click on the resampling icon from the Geo Correction Tool Menu  . The resample dialog opens. Enter a file name for the output (know where on the drive you will put the file) - select the Nearest Neighborhood resampling method - click to exclude zero file values in the statistics.



A job status dialog opens to let you know when the processes is complete.

- Verify the rectification by displaying the new image in a viewer and Geo. Link the reference image with the new image and use an Inquire Cursor to check that they are georegistered to each other.

Find the below video file recorded while performing Geometric Correction in ERDAS for a Topo sheet

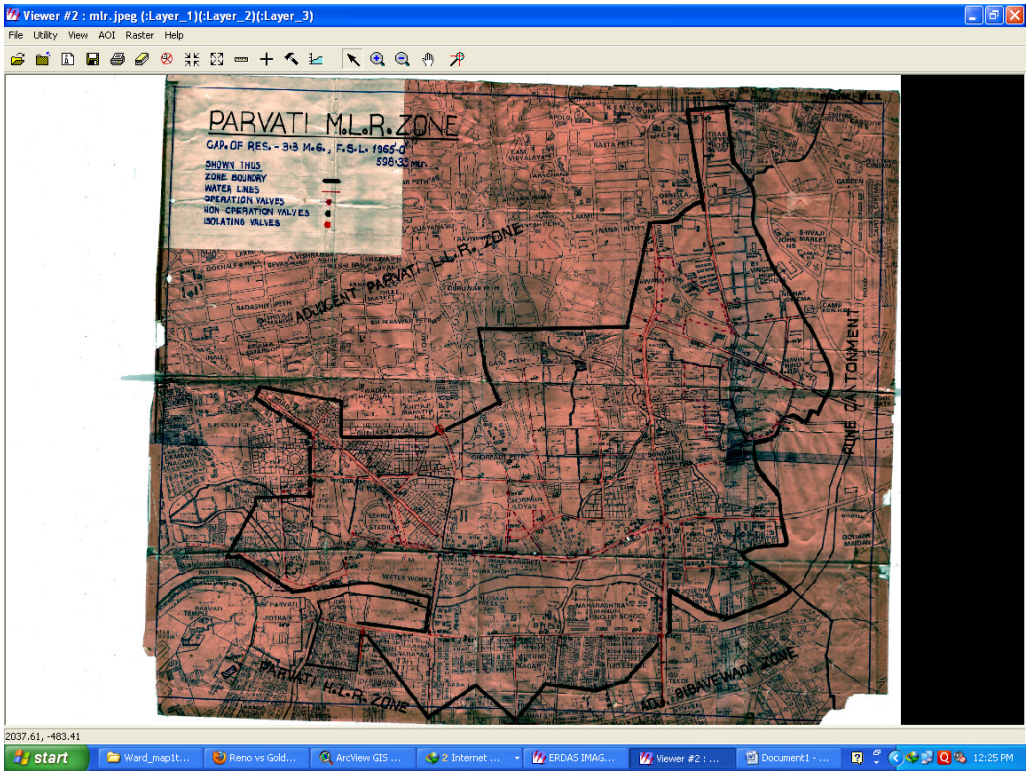


Fig. 2: MLR map from PMC in ERDAS Imagine 9.1

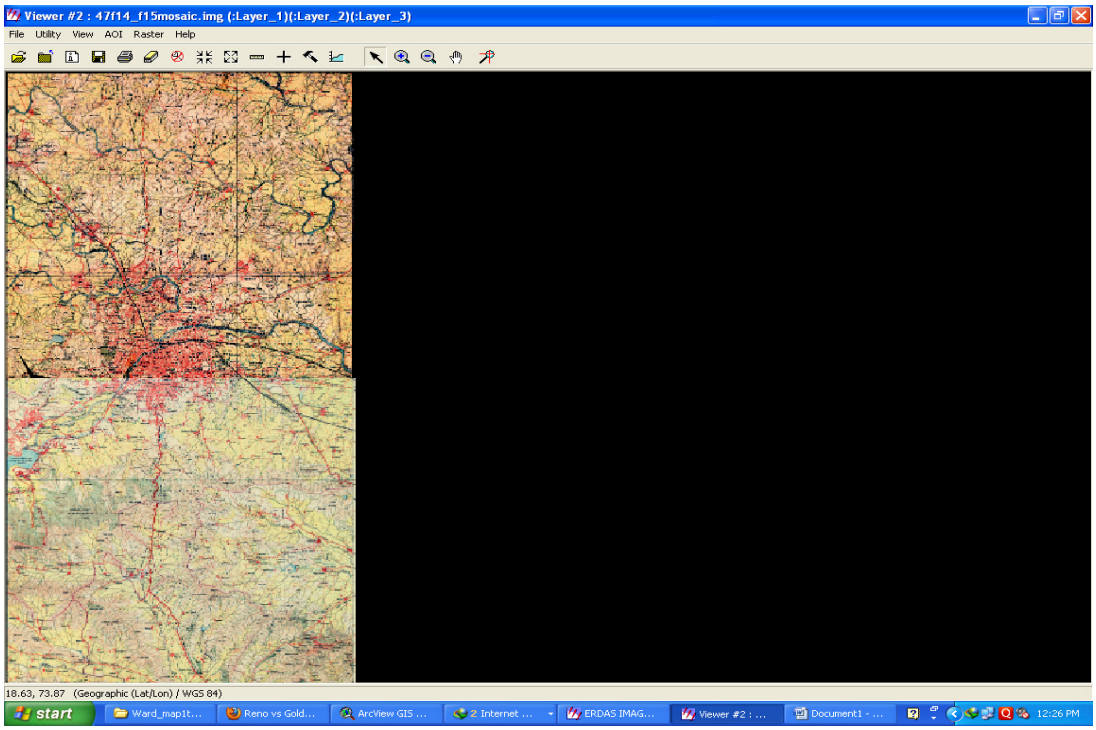


Fig. 3: Toposheet of Pune city

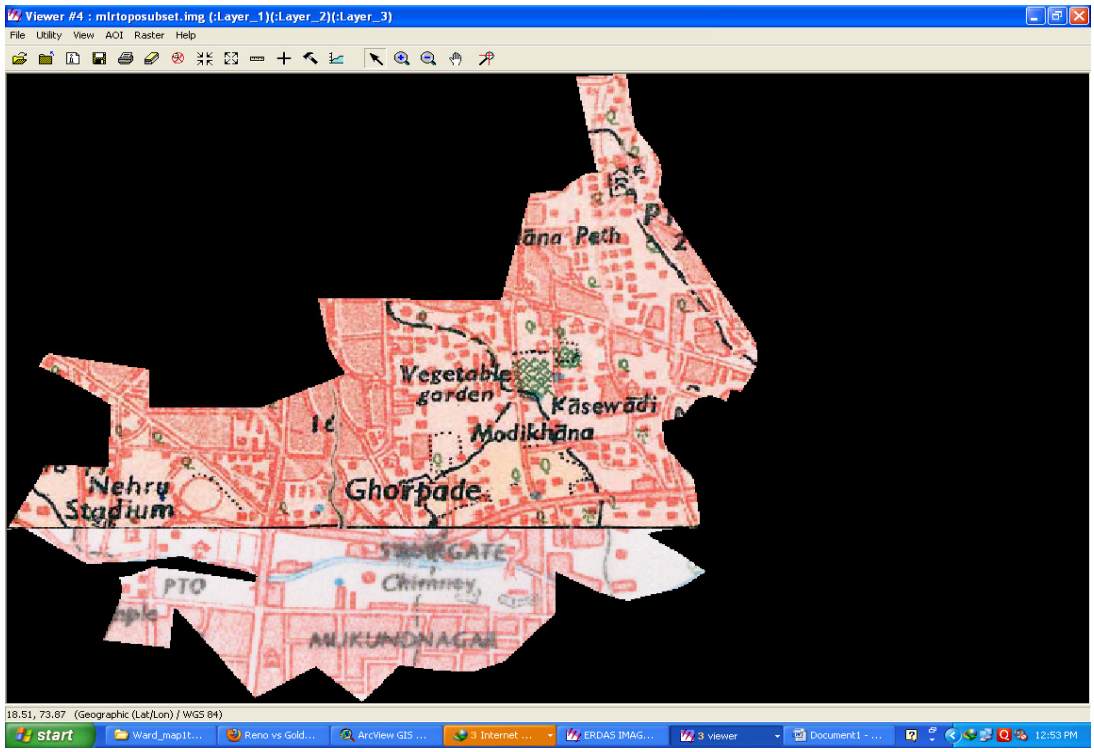


Fig. 4: Capturing Boundary image of MLR Zone through Toposheet

Annexure 12

DMA Design for MLR Zone

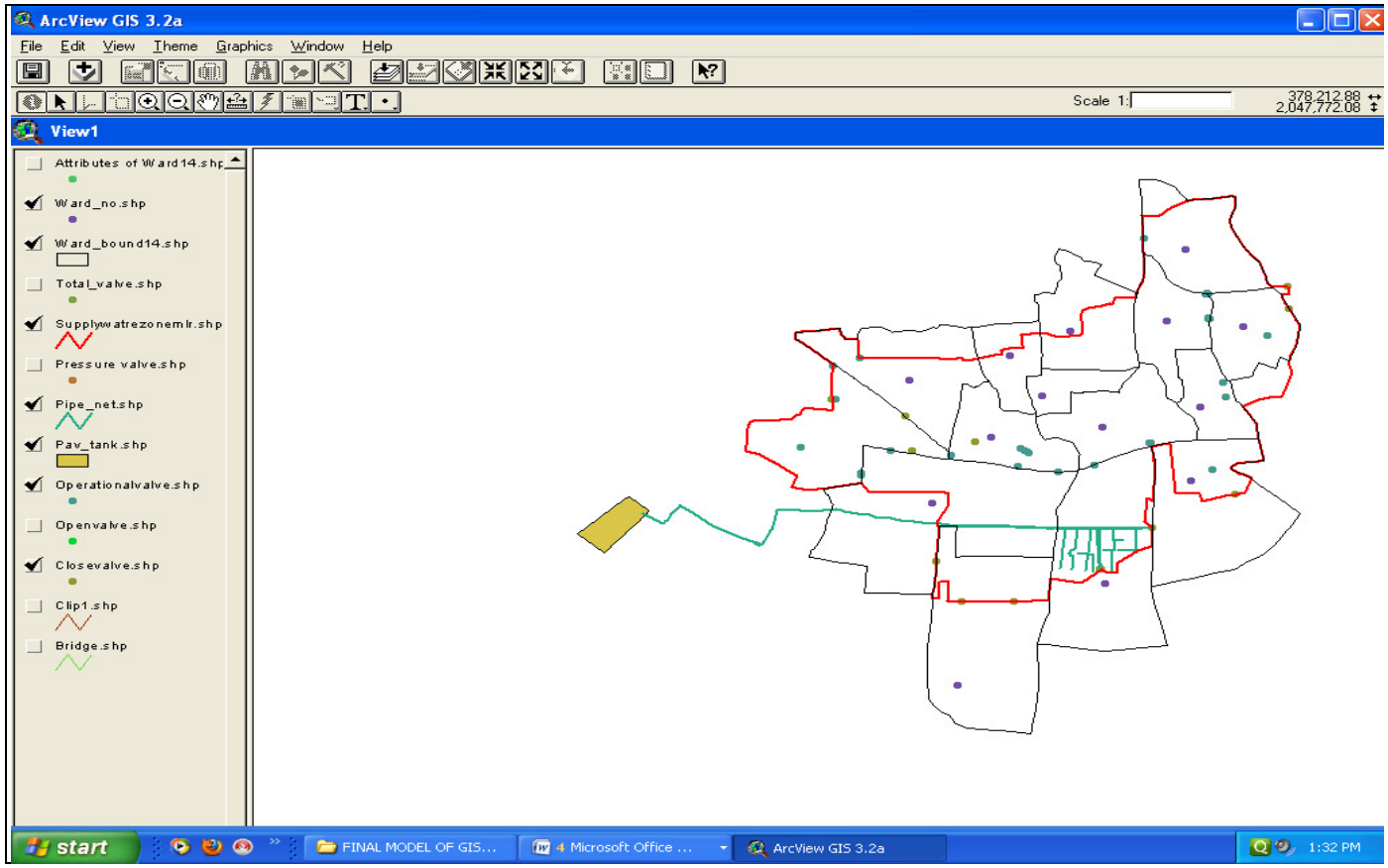


Fig.1: Pipeline Network for MLR zone of Ward No-99 and Ward Name: Tilak Maharashtra Vidyapeeth developed using ArcView GIS

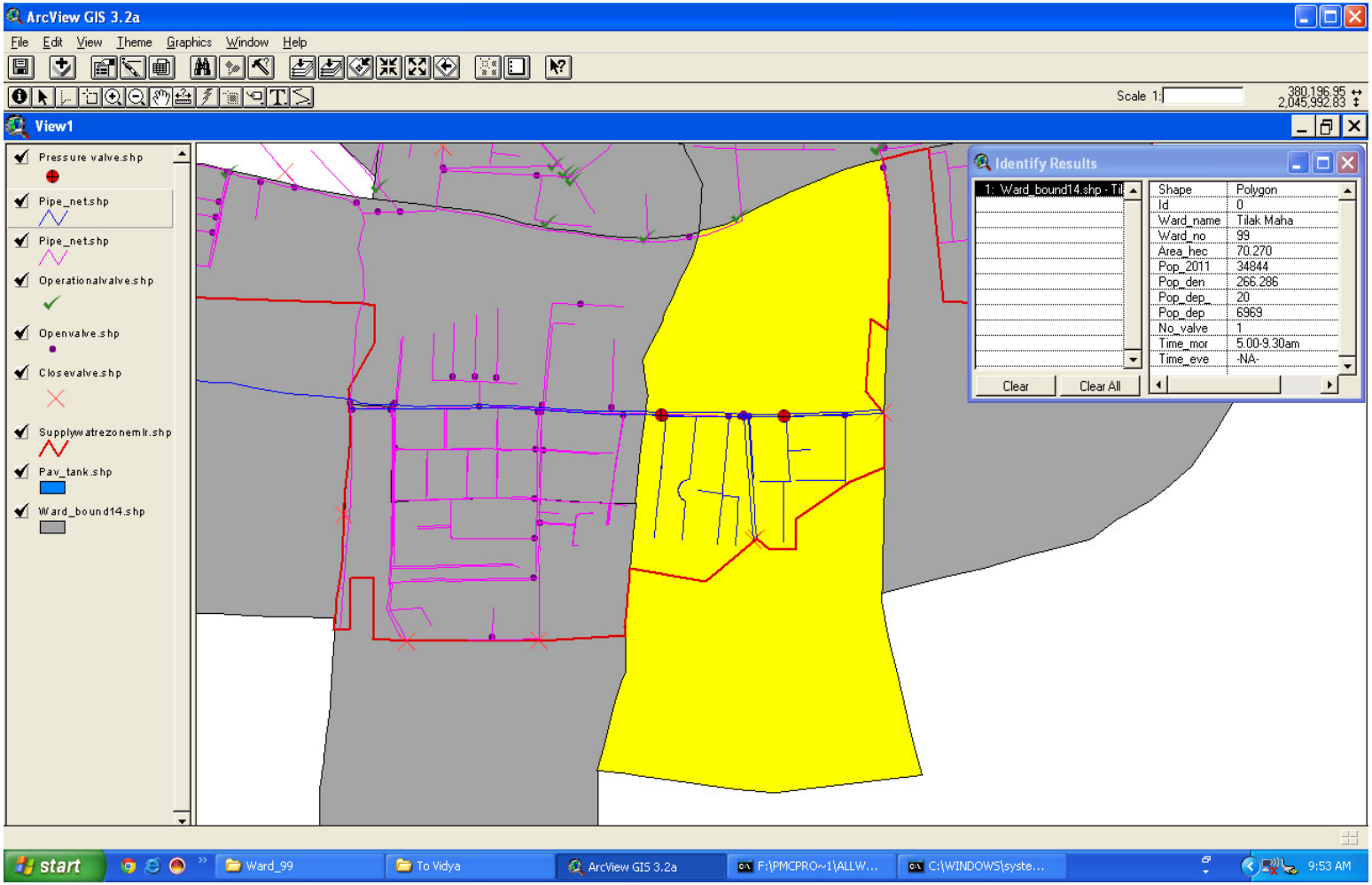


Fig.2: DMA design for MLR zone of Ward No-99 and Ward Name: Tilak Maharashtra Vidyapeeth developed using ArcView GIS

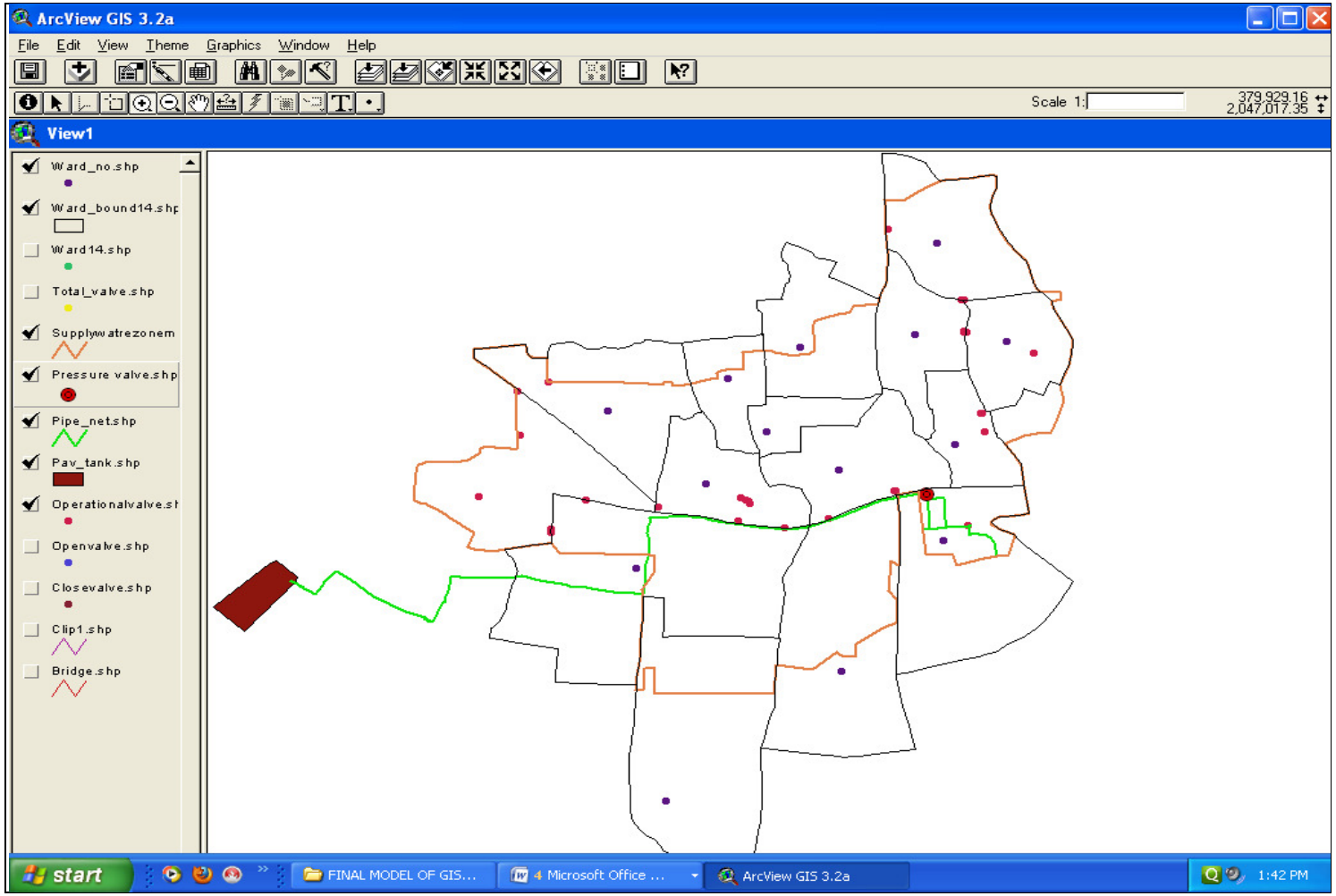


Fig.3: Pipeline Network for MLR zone of Ward No:98 Ward Name: Salisbury Park developed using ArcView GIS

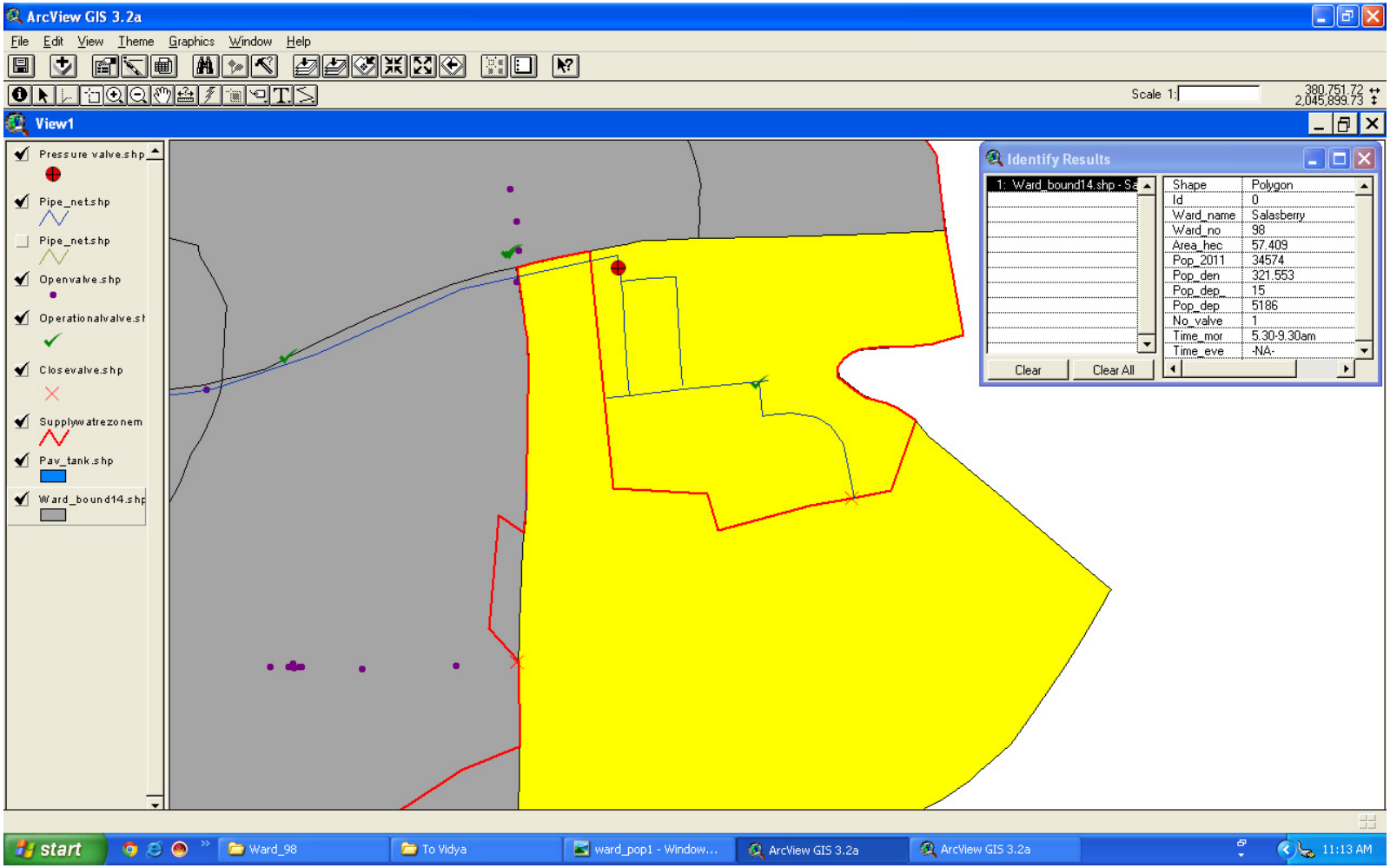


Fig.4: DMA design for MLR zone of Ward No:98 Ward Name: Salisbury Park developed using ArcView GIS

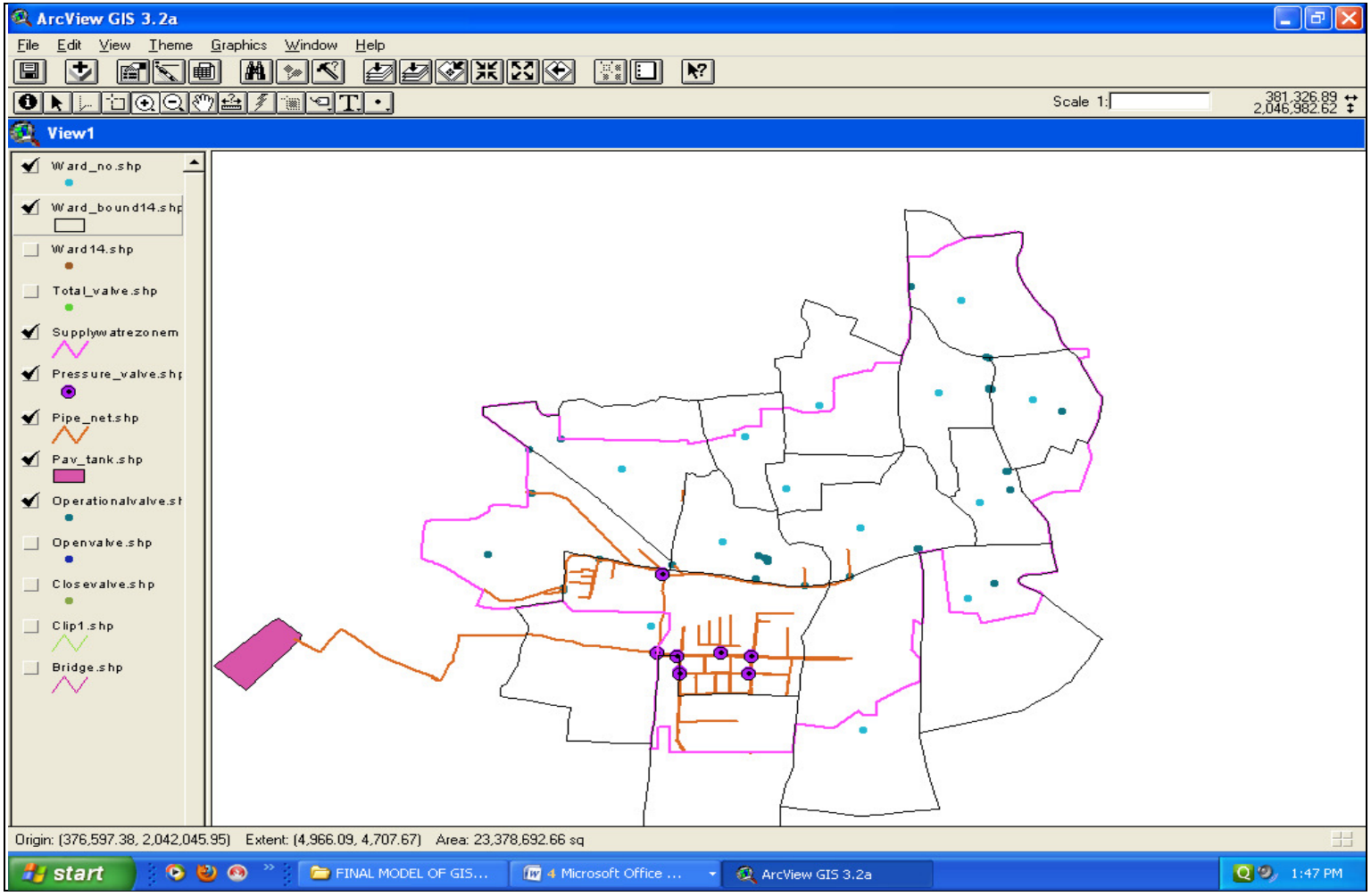


Fig.5: Pipeline Network for MLR zone of Ward No:100 Ward Name : Parvati Gaon developed using ArcView GIS

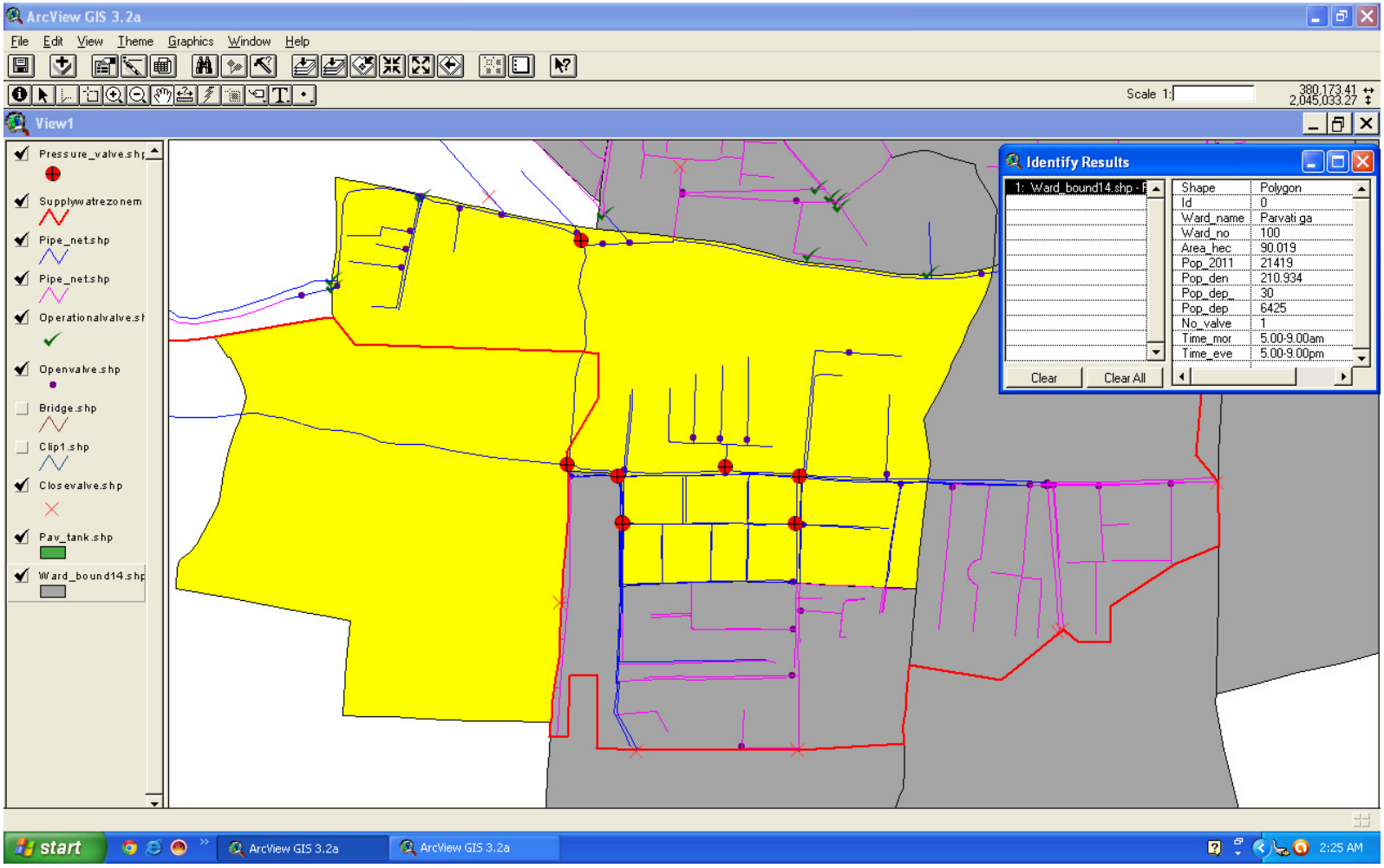


Fig.6: DMA design for MLR zone of Ward No:100 Ward Name : Parvati Gaon developed using ArcView GIS

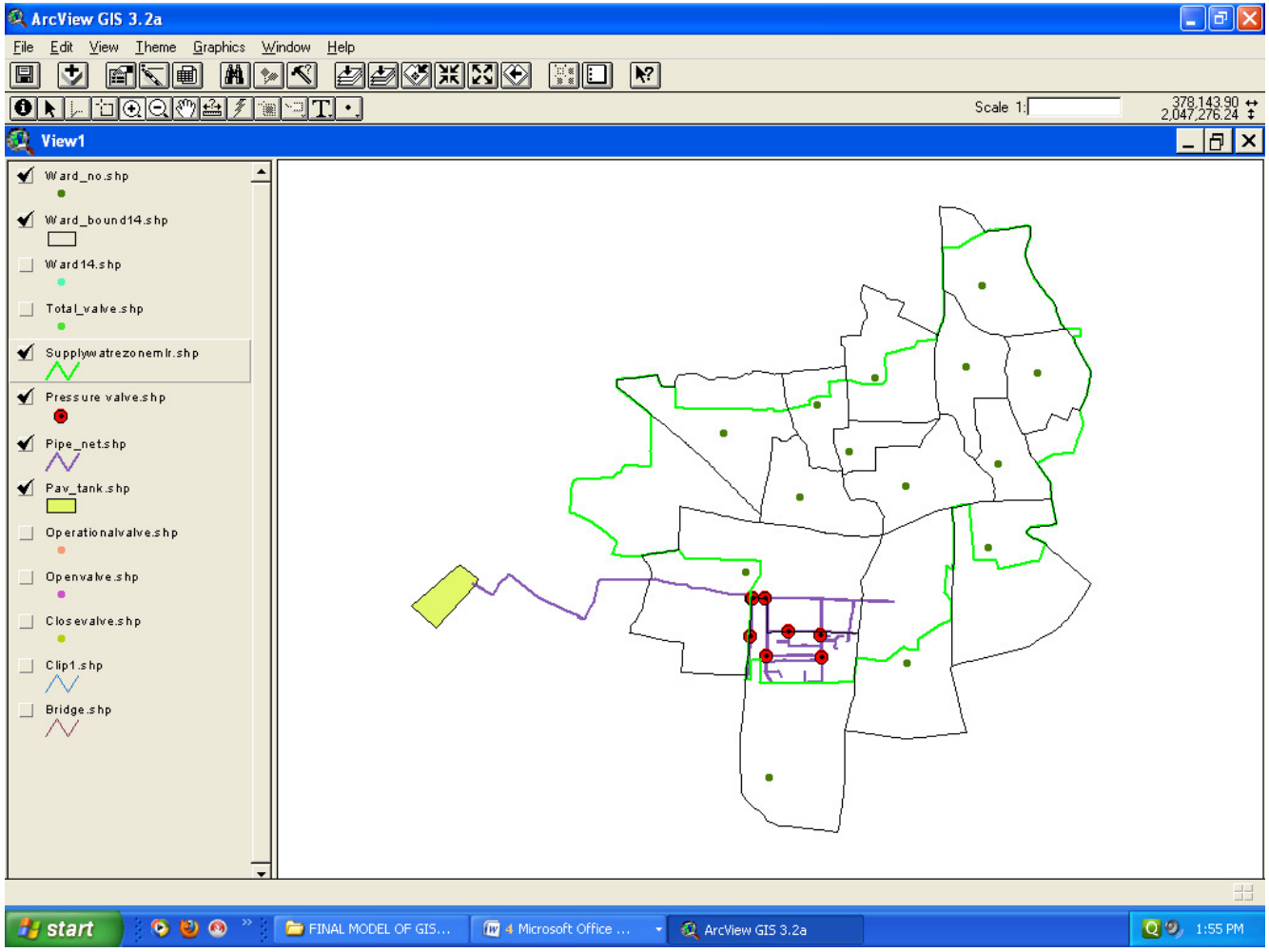


Fig.7: Pipeline Network for MLR zone of Ward No: 117 Ward Name: Maharshi Nagar developed using ArcView GIS



Fig.8: DMA design for MLR zone of Ward No: 117 Ward Name: Maharshi Nagar developed using ArcView GIS

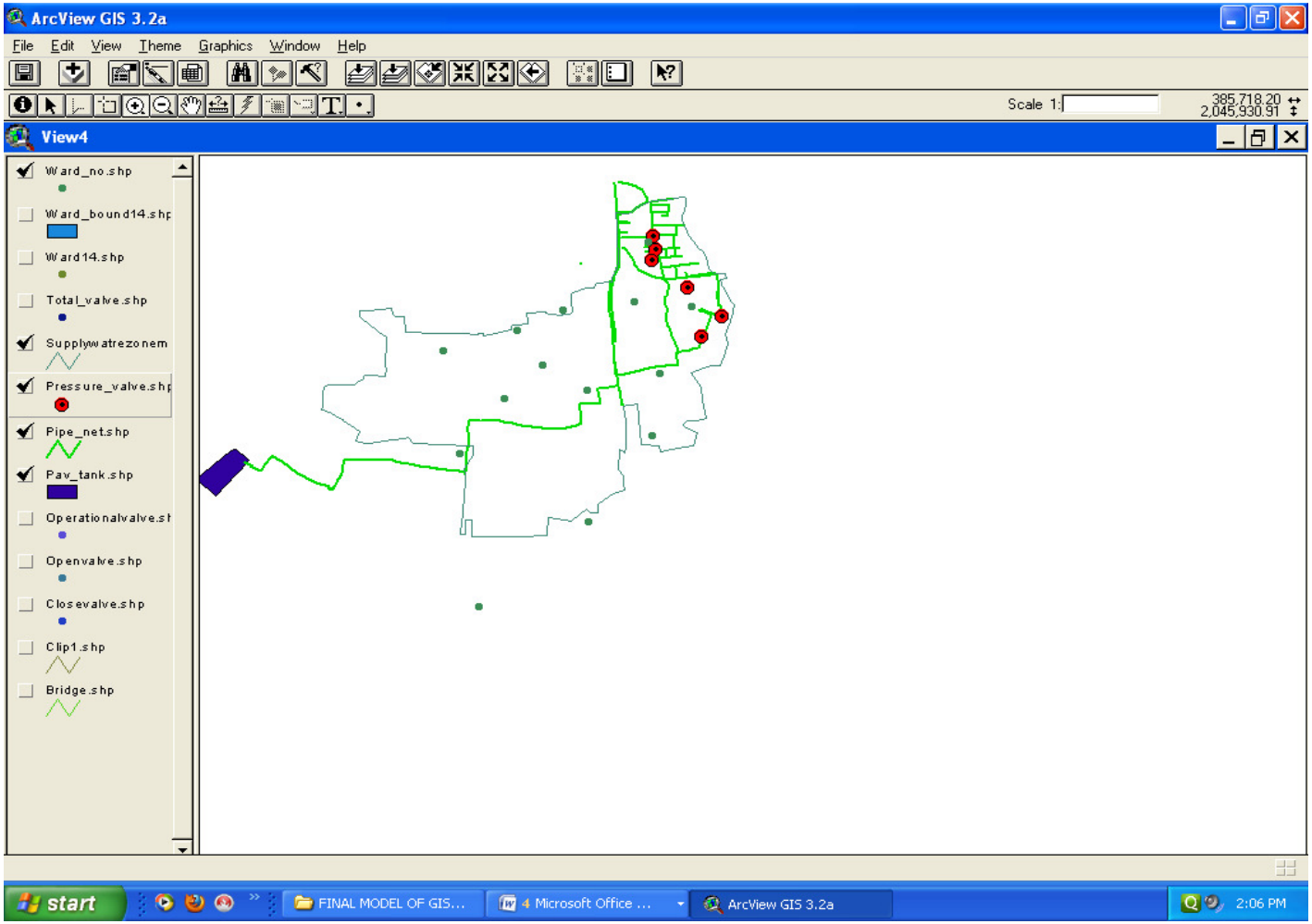


Fig.9: Pipeline Network for MLR zone of Ward No: 74 Ward Name: Rajewadi developed using ArcView GIS

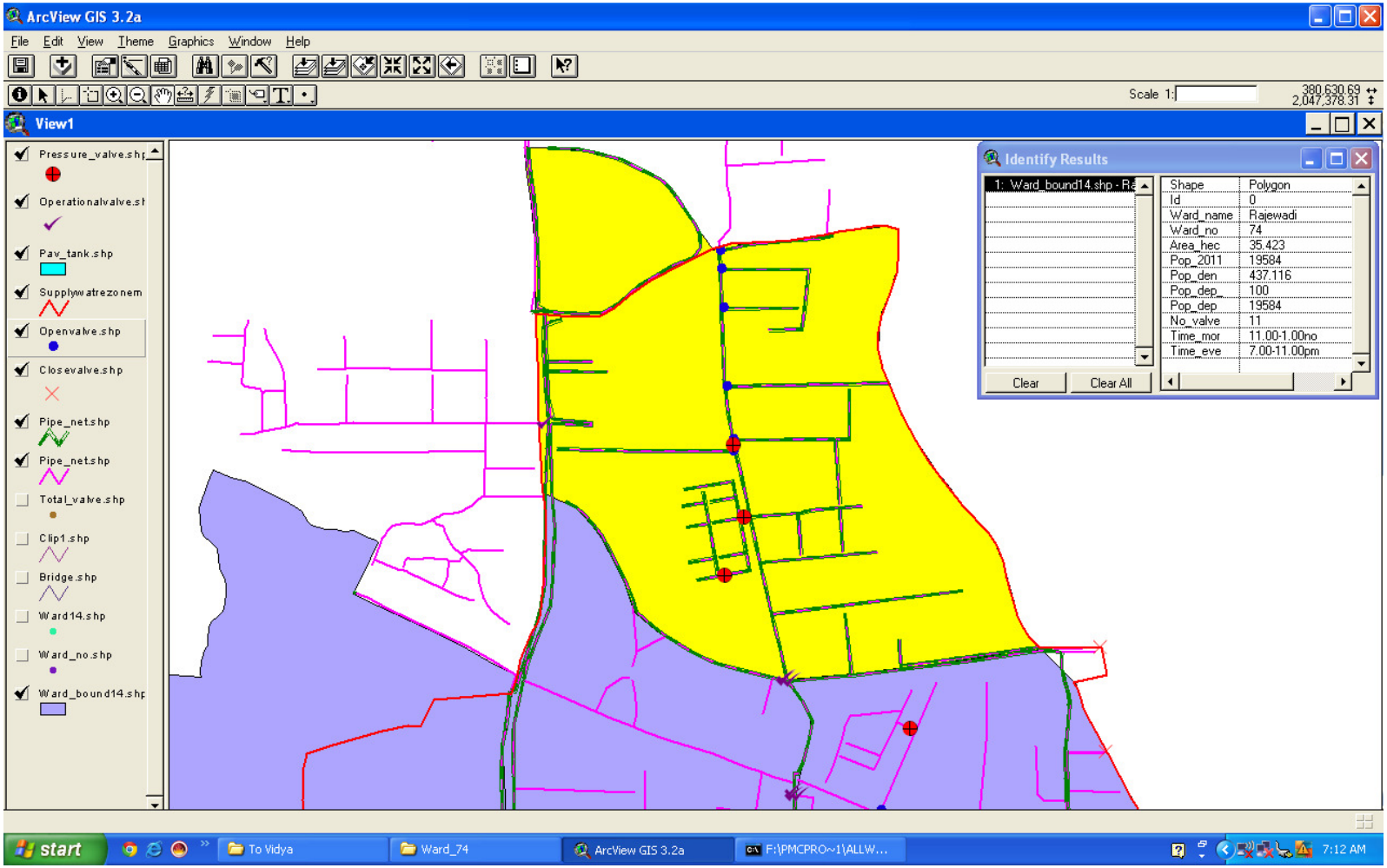


Fig.10. DMA design for MLR zone of Ward No: 74 Ward Name: Rajewadi developed using ArcView GIS

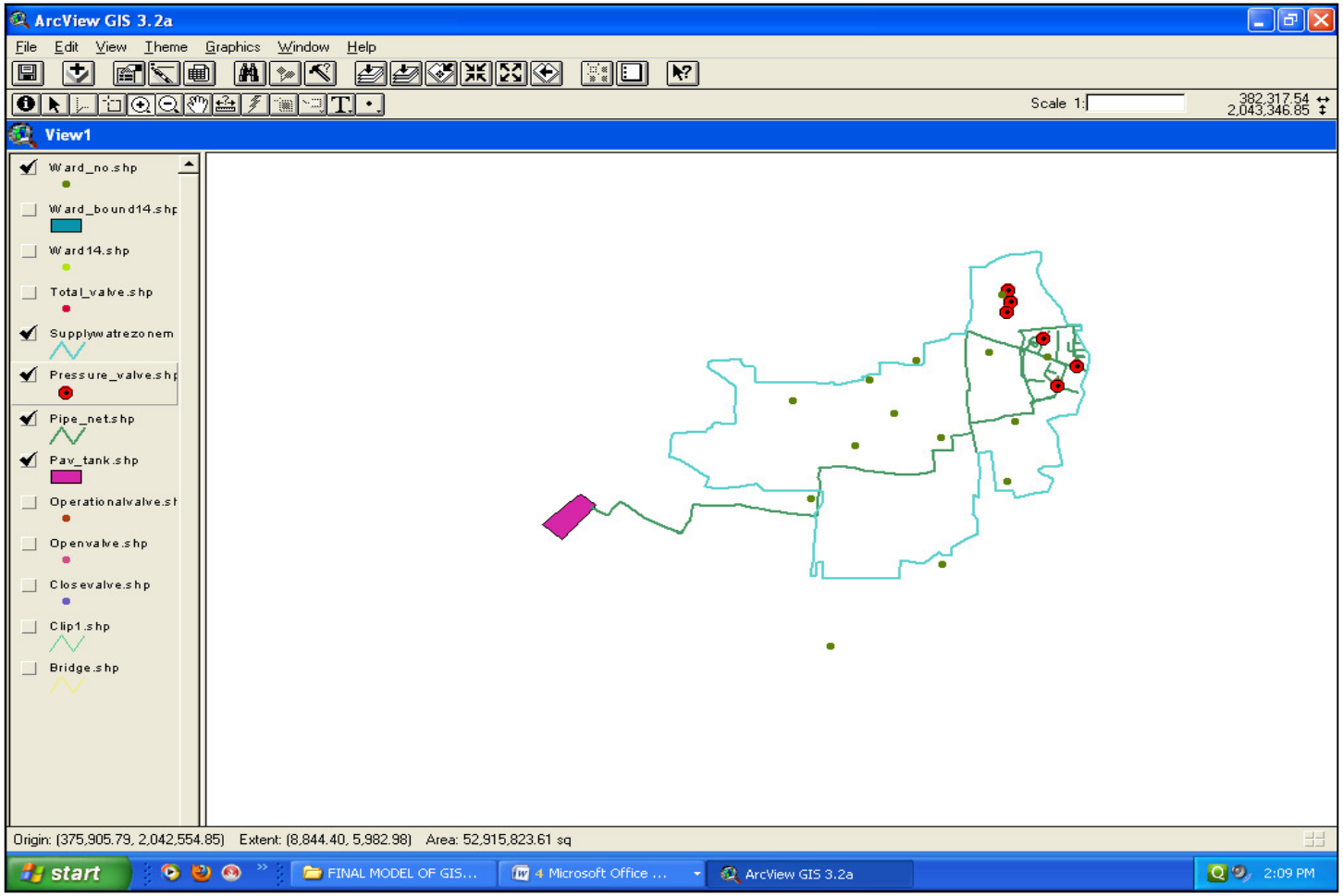


Fig.11: Pipeline Network for MLR zone of Ward No: 75 Ward Name: Harkanagar developed using ArcView GIS

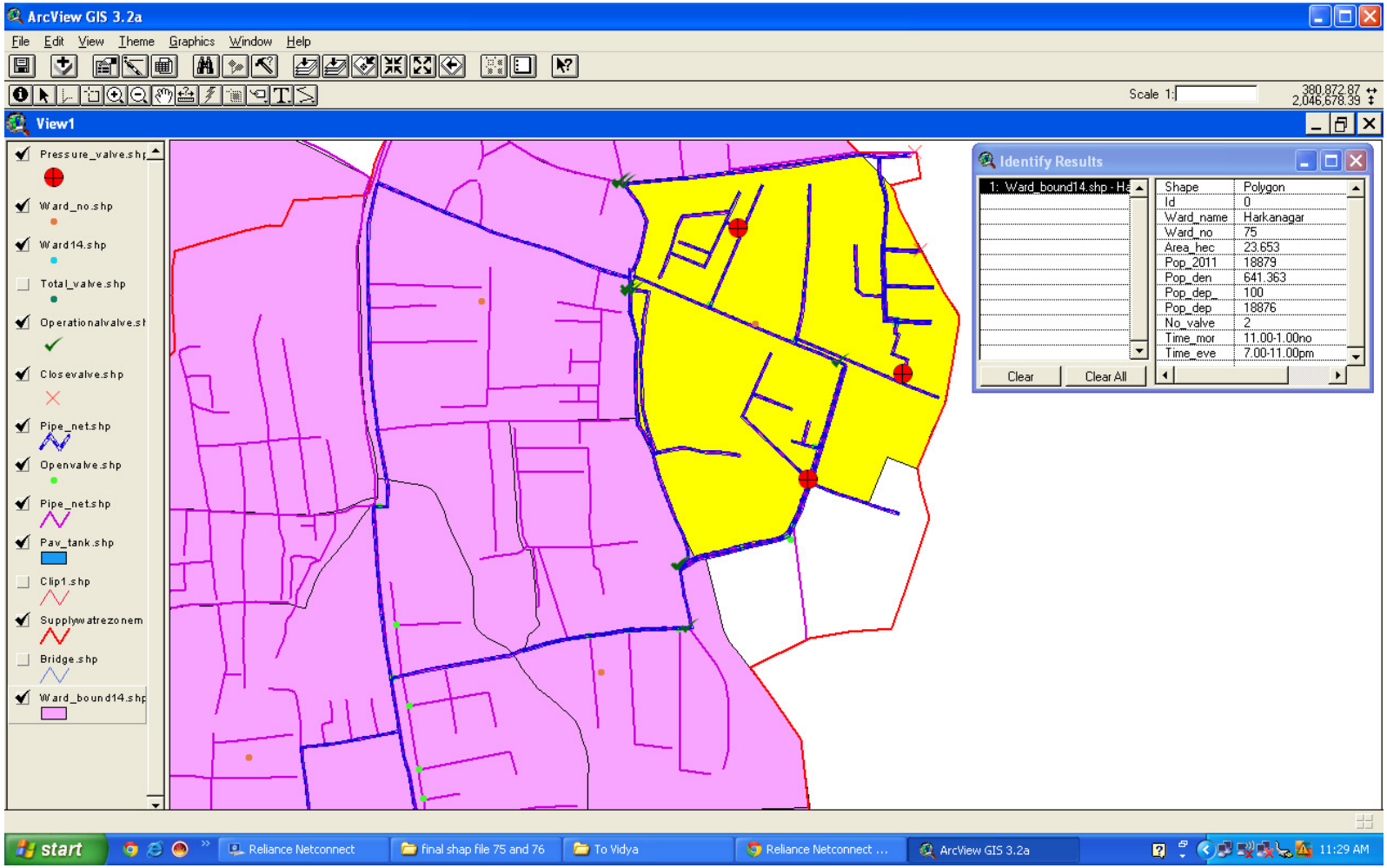


Fig.12. DMA design for MLR zone of Ward No: 75 Ward Name: Harkanagar developed using ArcView GIS

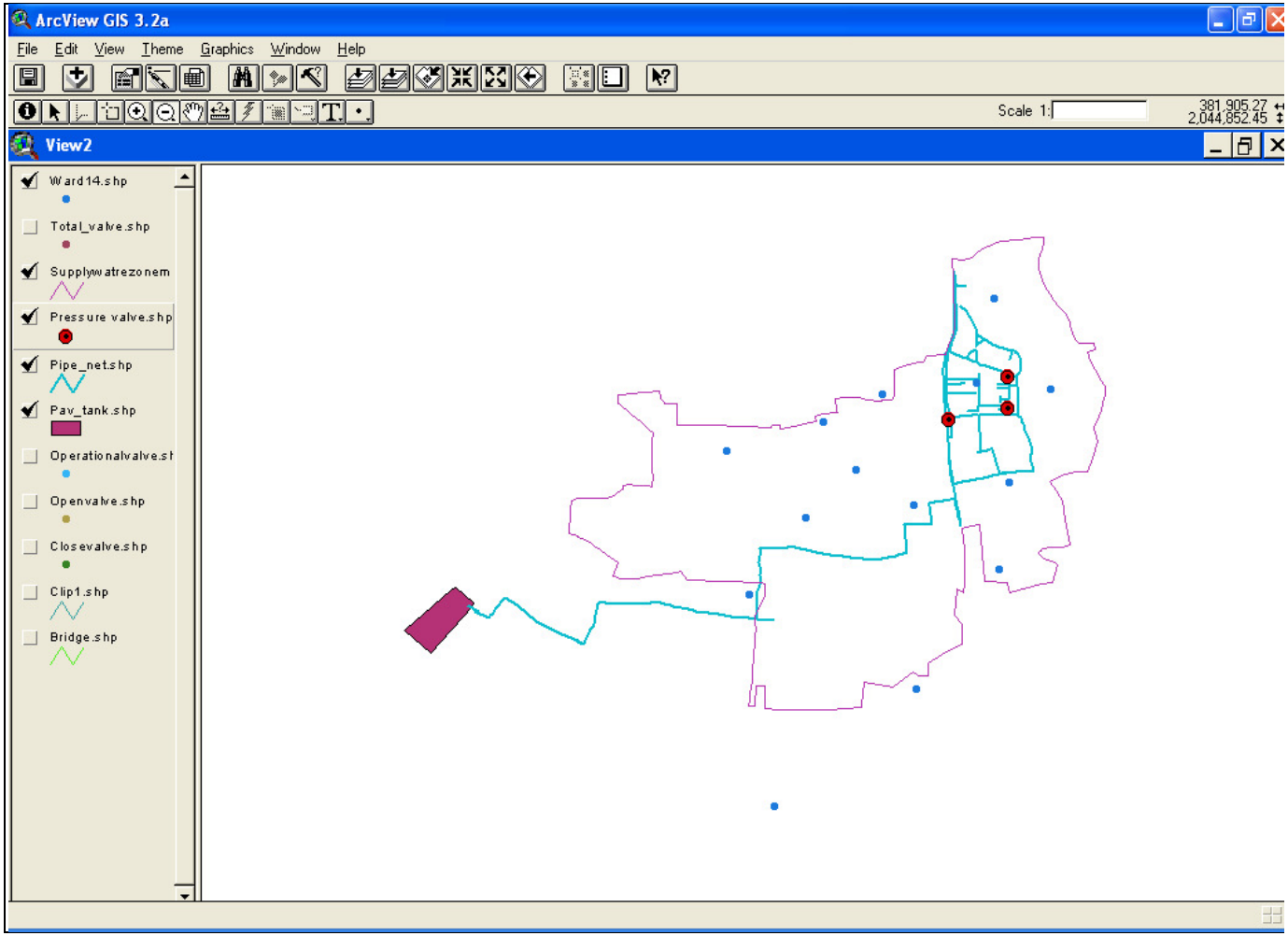


Fig.13: Pipeline Network for MLR zone of Ward No: 76 Ward Name: Gen Arun Kuma developed using ArcView GIS

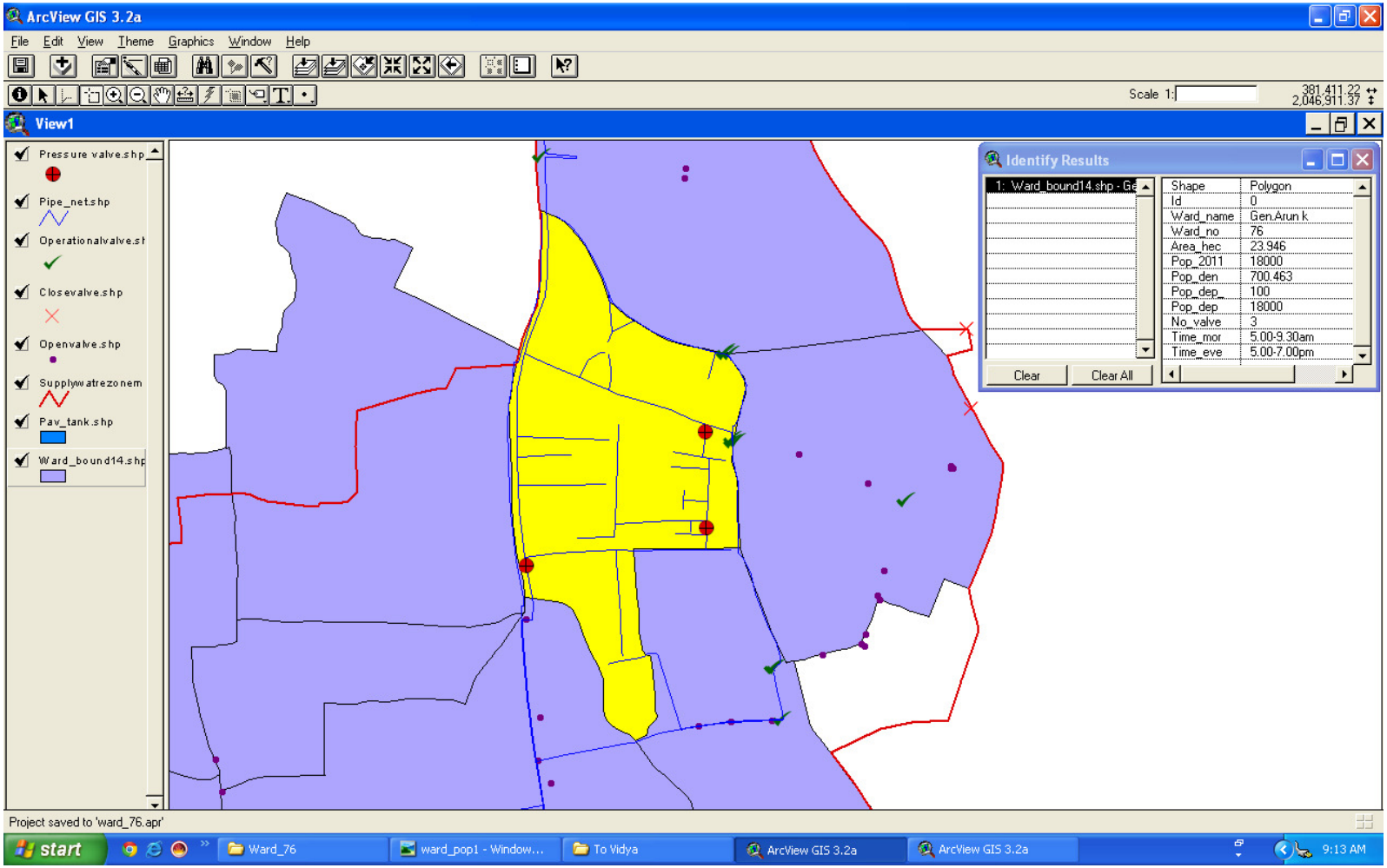


Fig.14. DMA design for MLR zone of Ward No: 76 Ward Name: Gen Arun Kumar developed using ArcView GIS

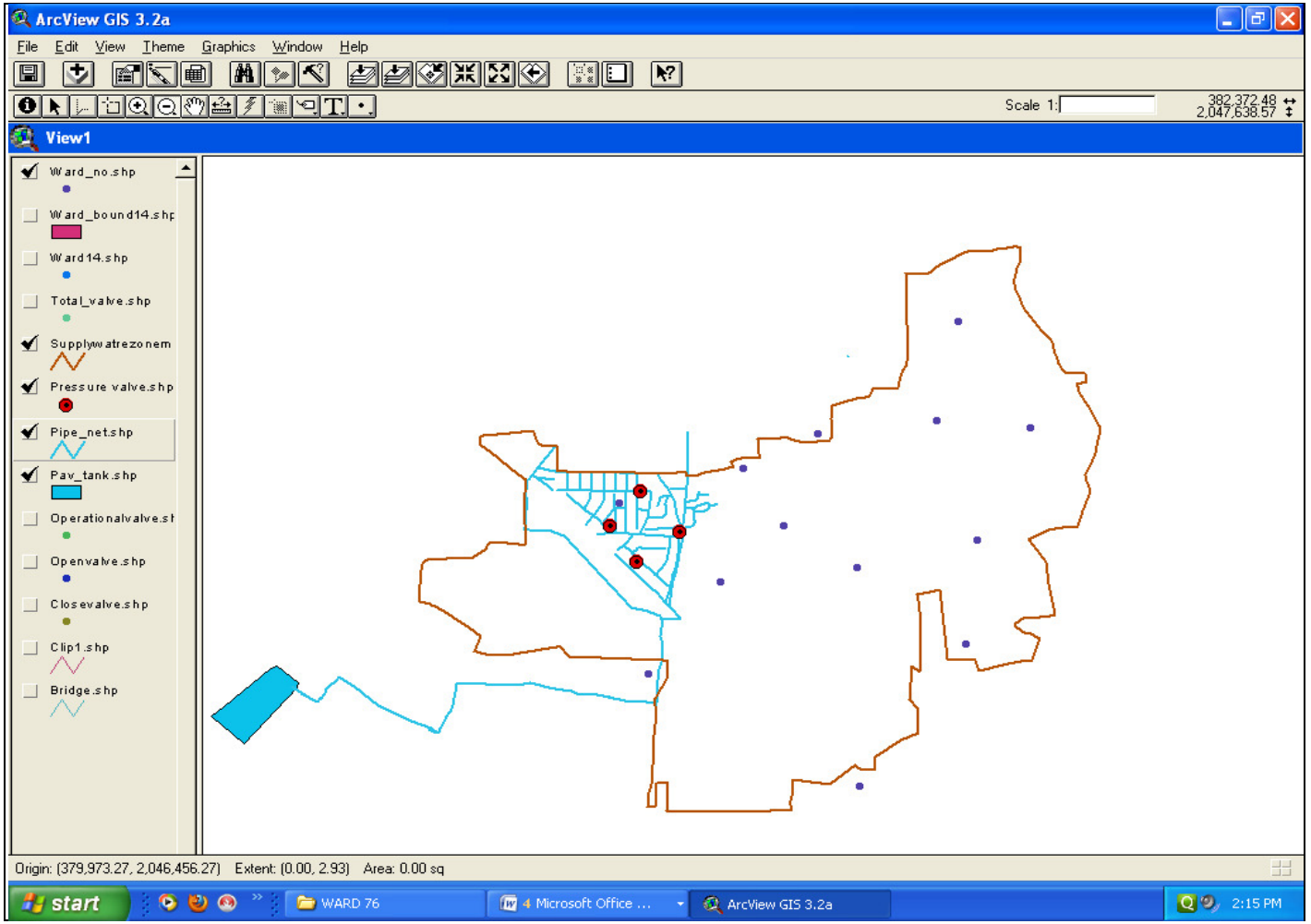


Fig.15: Pipeline Network for MLR zone of Ward No: 82 Ward Name: Subhash Nagar developed using ArcView GIS

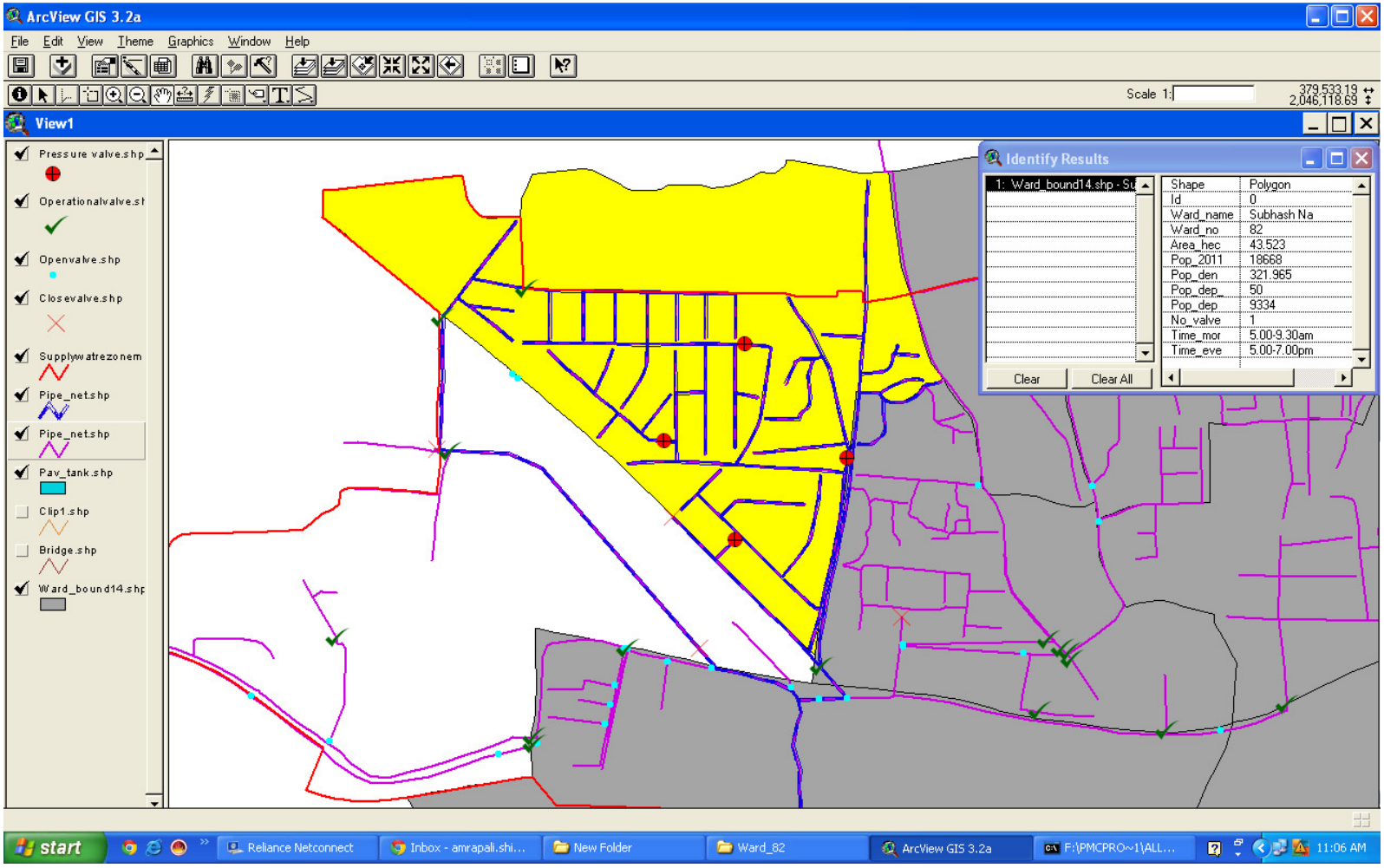


Fig.16. DMA design for MLR zone of Ward No: 82 Ward Name: Subhash Nagar developed using ArcView GIS

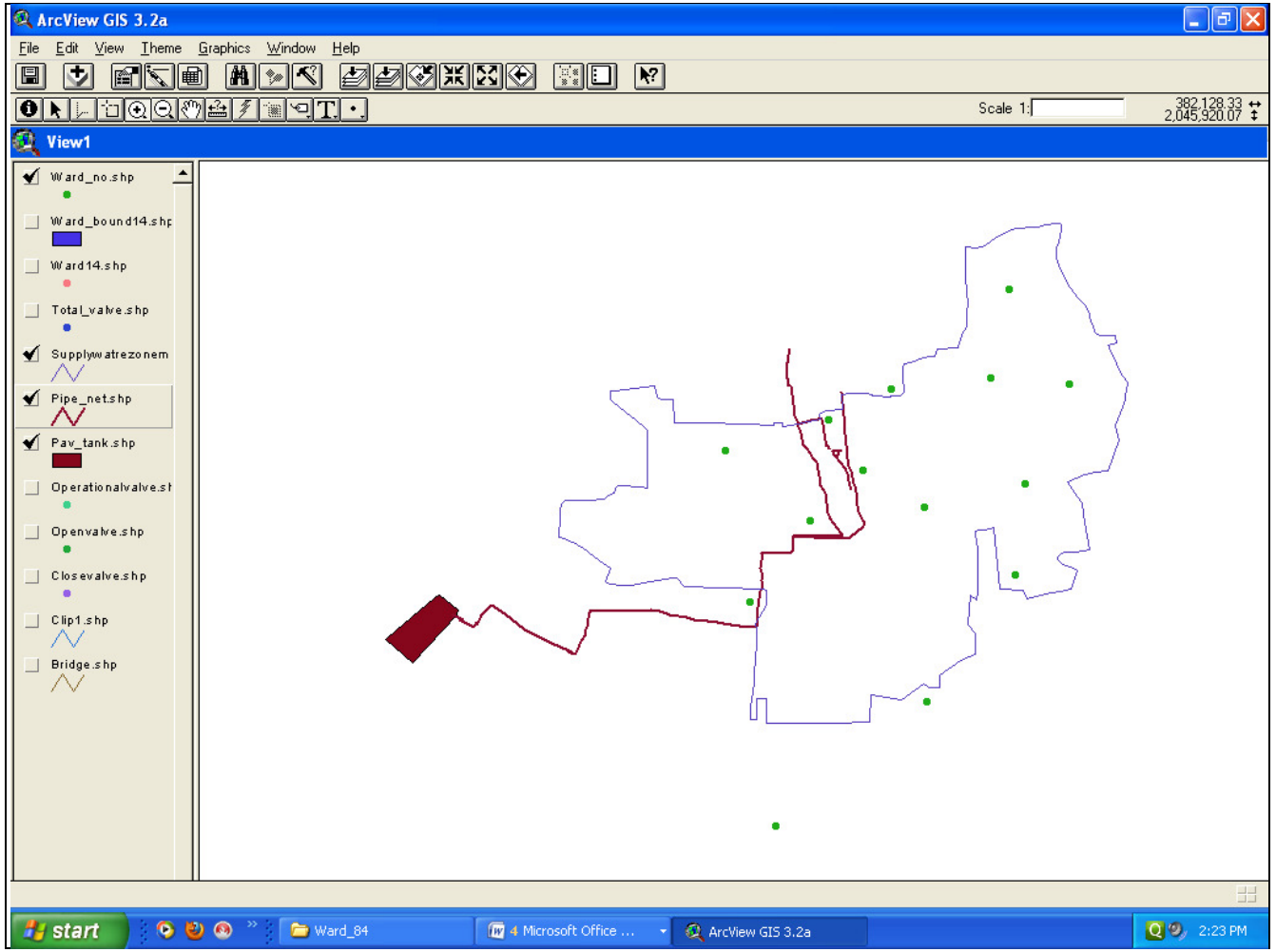


Fig.17: Pipeline Network for MLR zone of Ward No: 84 Ward Name: Mission Punchhaud developed using

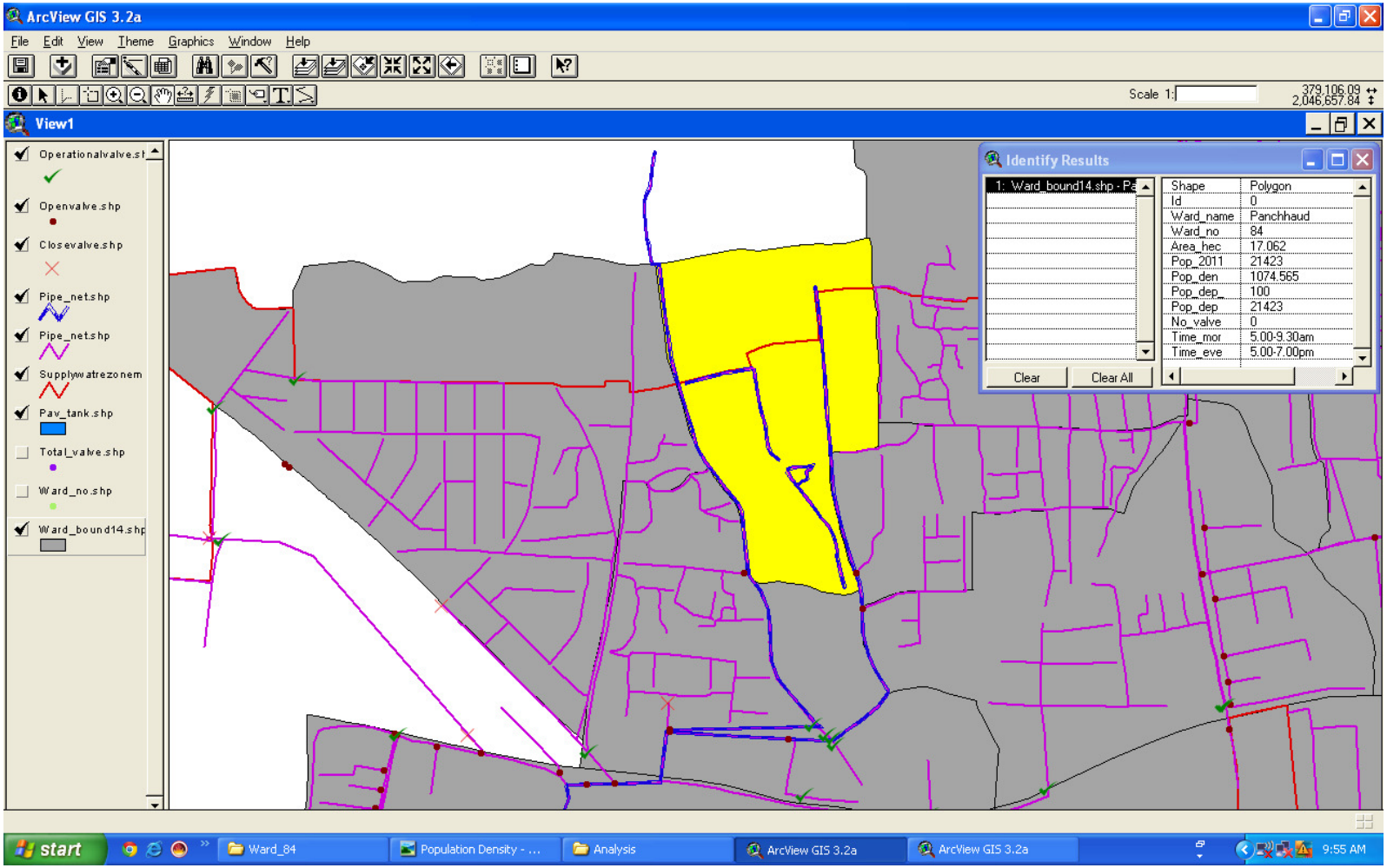


Fig.18. DMA design for MLR zone of Ward No: 84 Ward Name: Mission Punchhaud developed using ArcView GIS

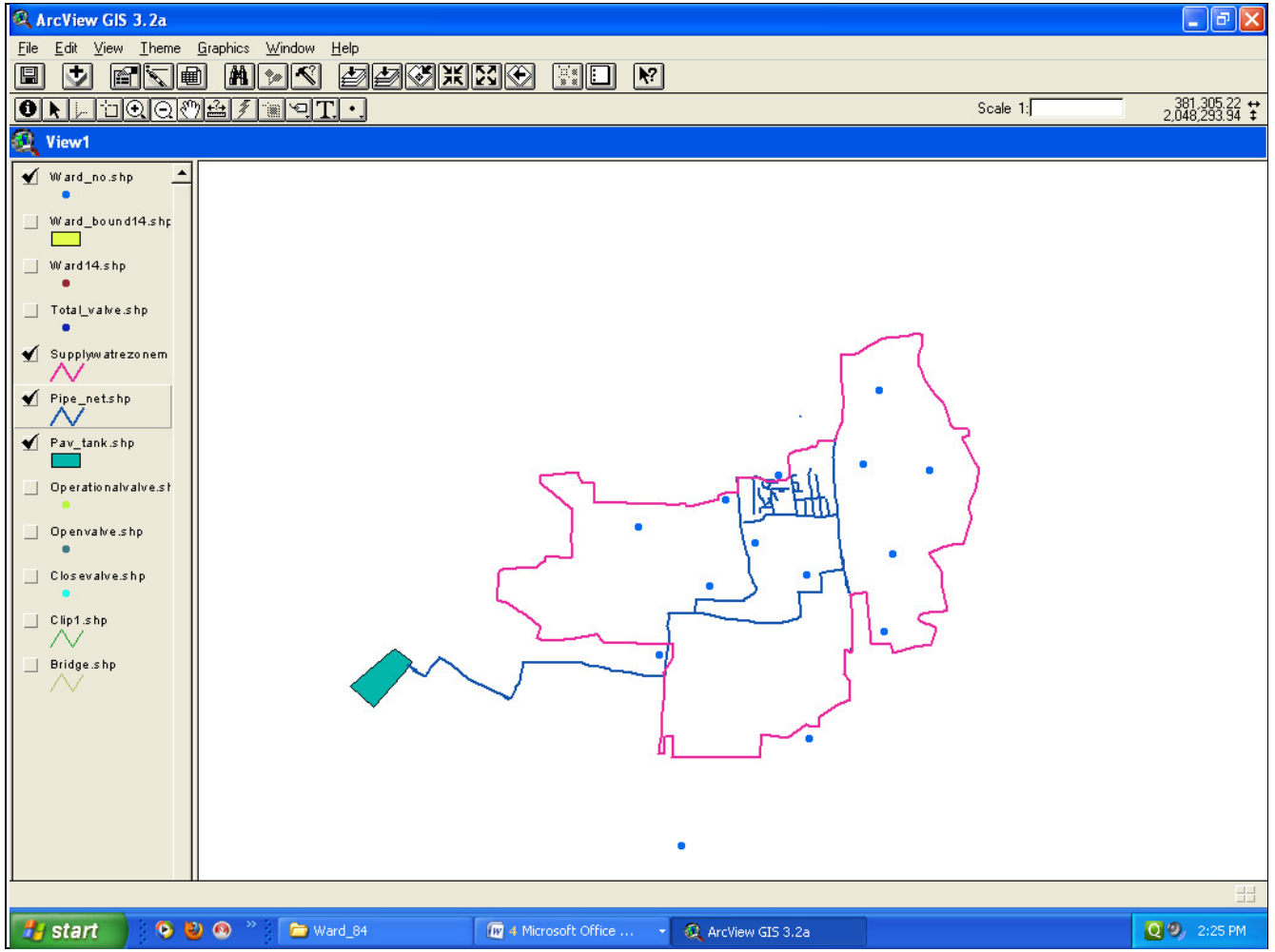


Fig.19: Pipeline Network for MLR zone of Ward No: 85 Ward Name: Mahatma Phule Udyan developed using ArcView GIS

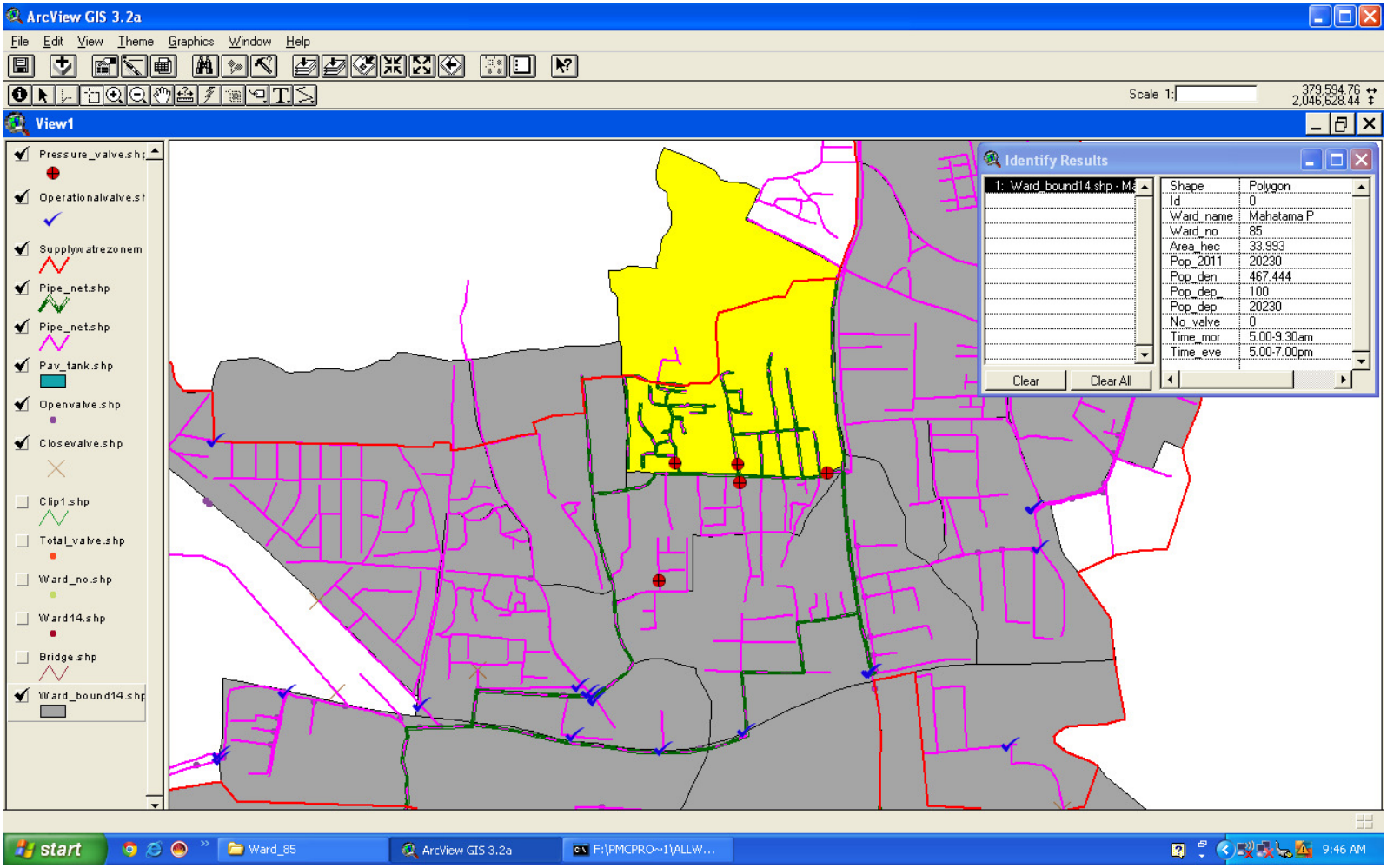


Fig.20. DMA design for MLR zone of Ward No: 85 Ward Name: Mahatma Phule Udyan developed using ArcView GIS

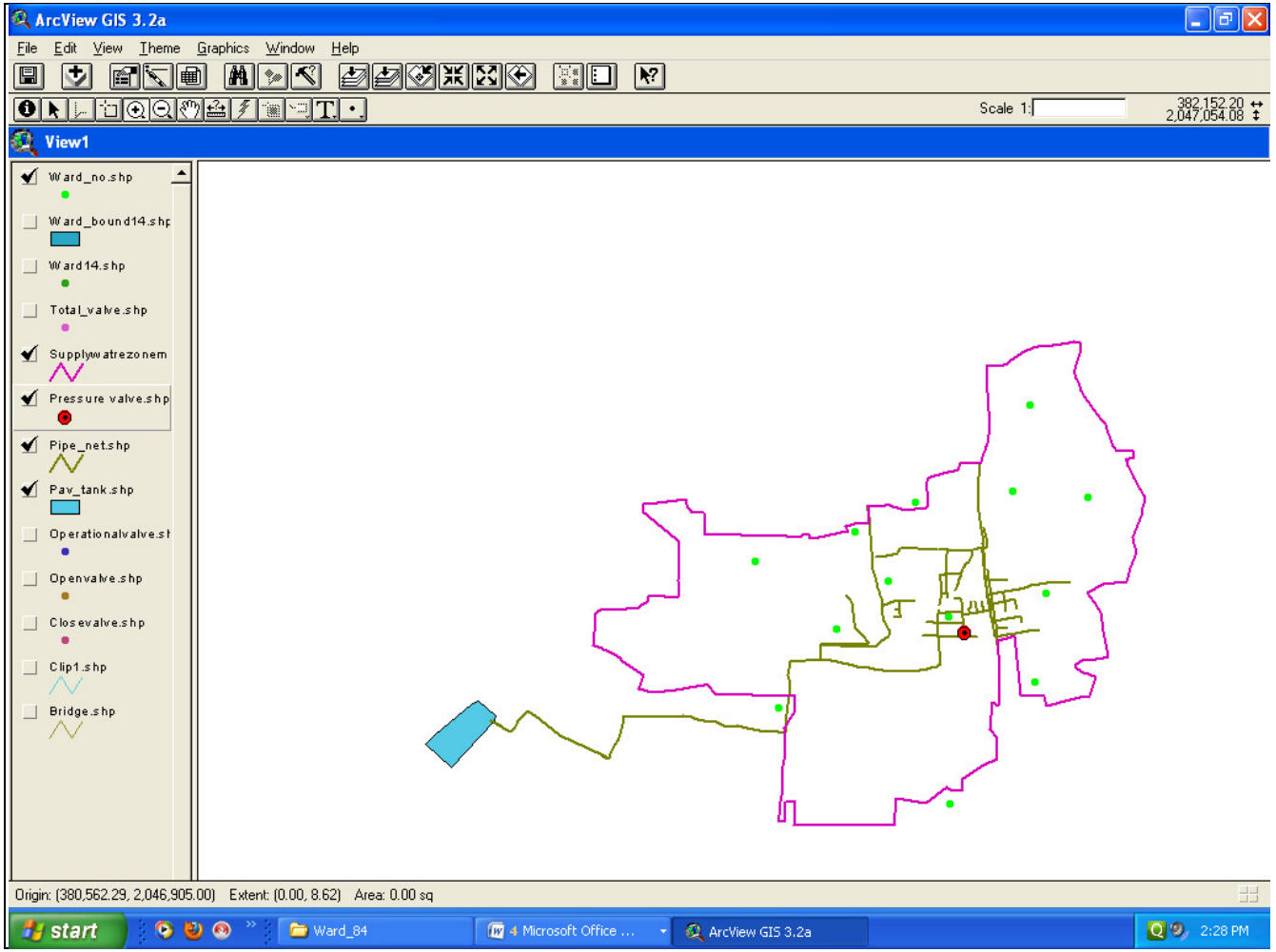


Fig.21: Pipeline Network for MLR zone of Ward No: 87 Ward Name: Ekbote Colony developed using ArcView GIS

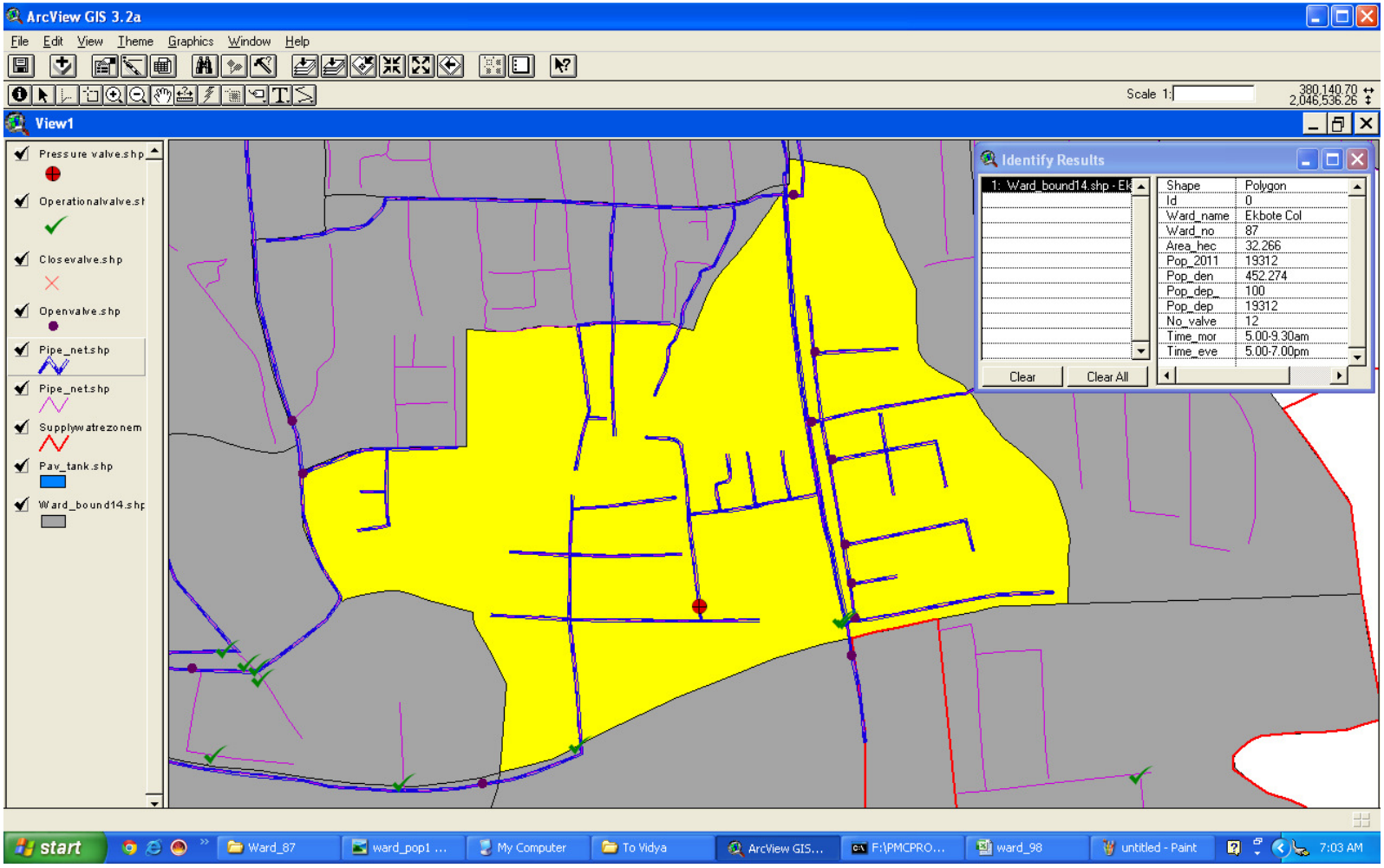


Fig.22. DMA design for MLR zone of Ward No: 87 Ward Name: Ekbote Colony developed using ArcView GIS

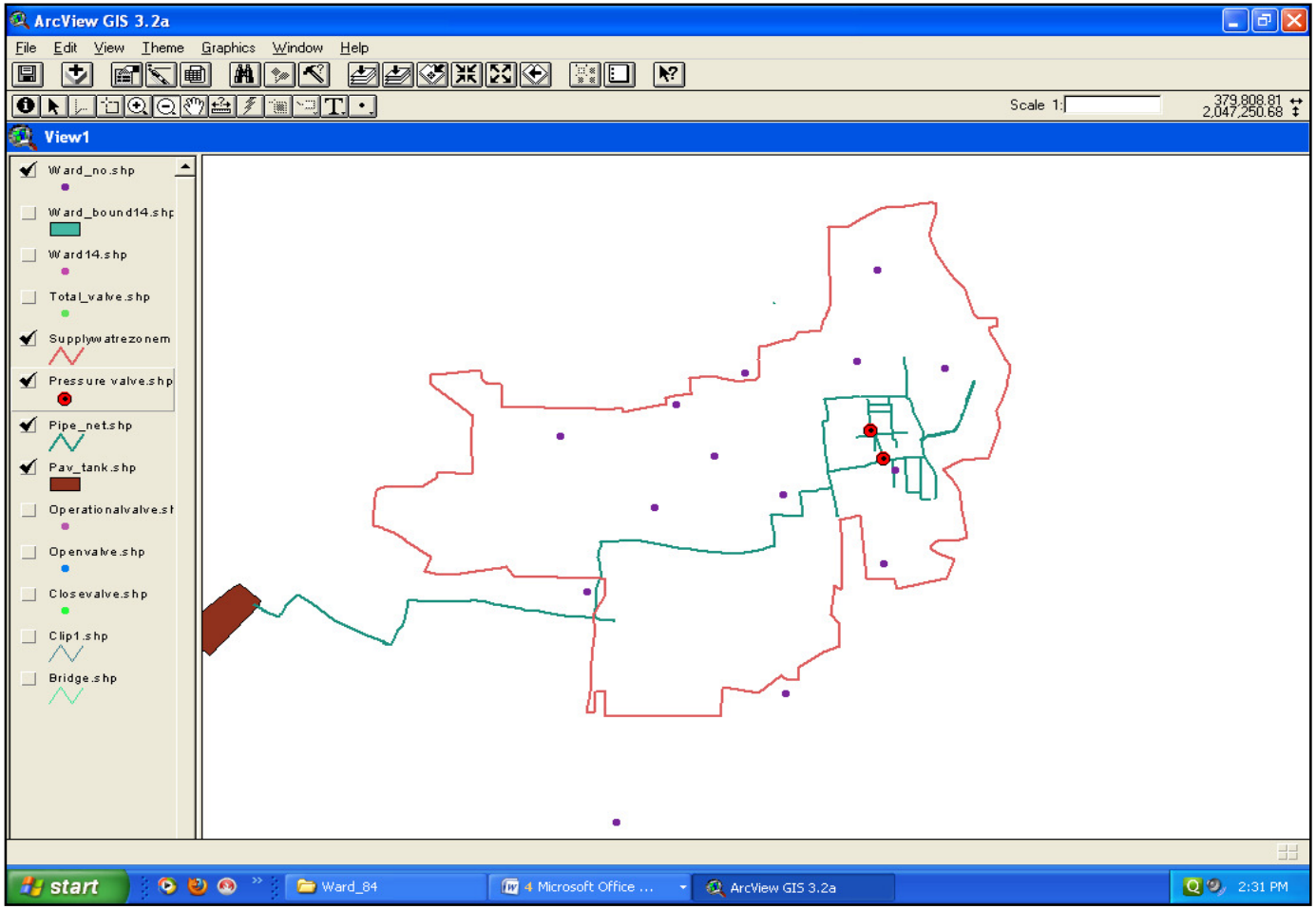


Fig.23: Pipeline Network for MLR zone of Ward No: 88 Ward Name: Gurunanak Nagar developed using ArcView GIS

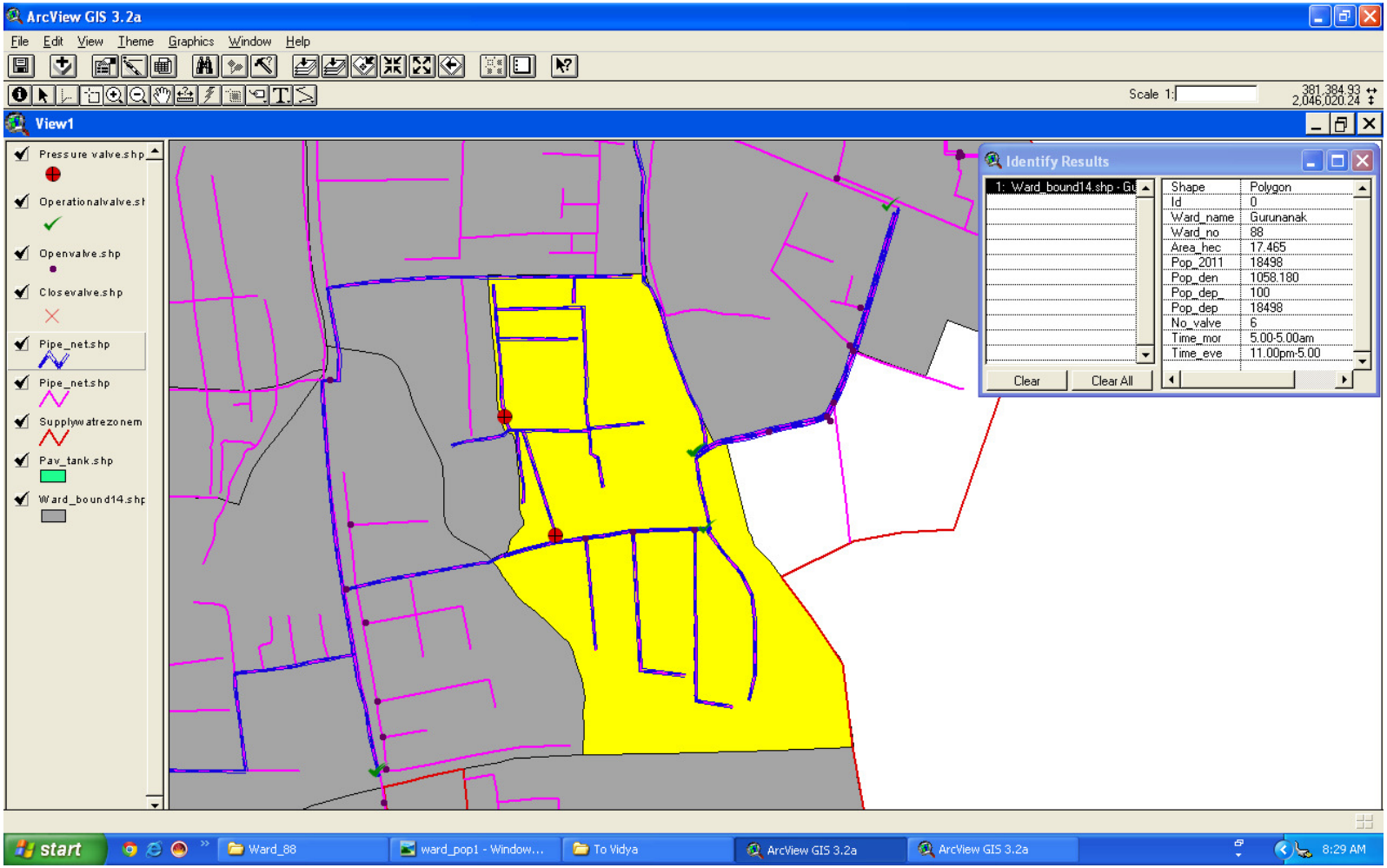


Fig.24:DMA design for MLR zone of Ward No: 88 Ward Name: Gurunanak Nagar developed using ArcView GIS

Annexure 13

Results of EPANET Hydraulic Water Model -I



Fig 1: EPANET Pipe Water network for Ward No.82 and 83

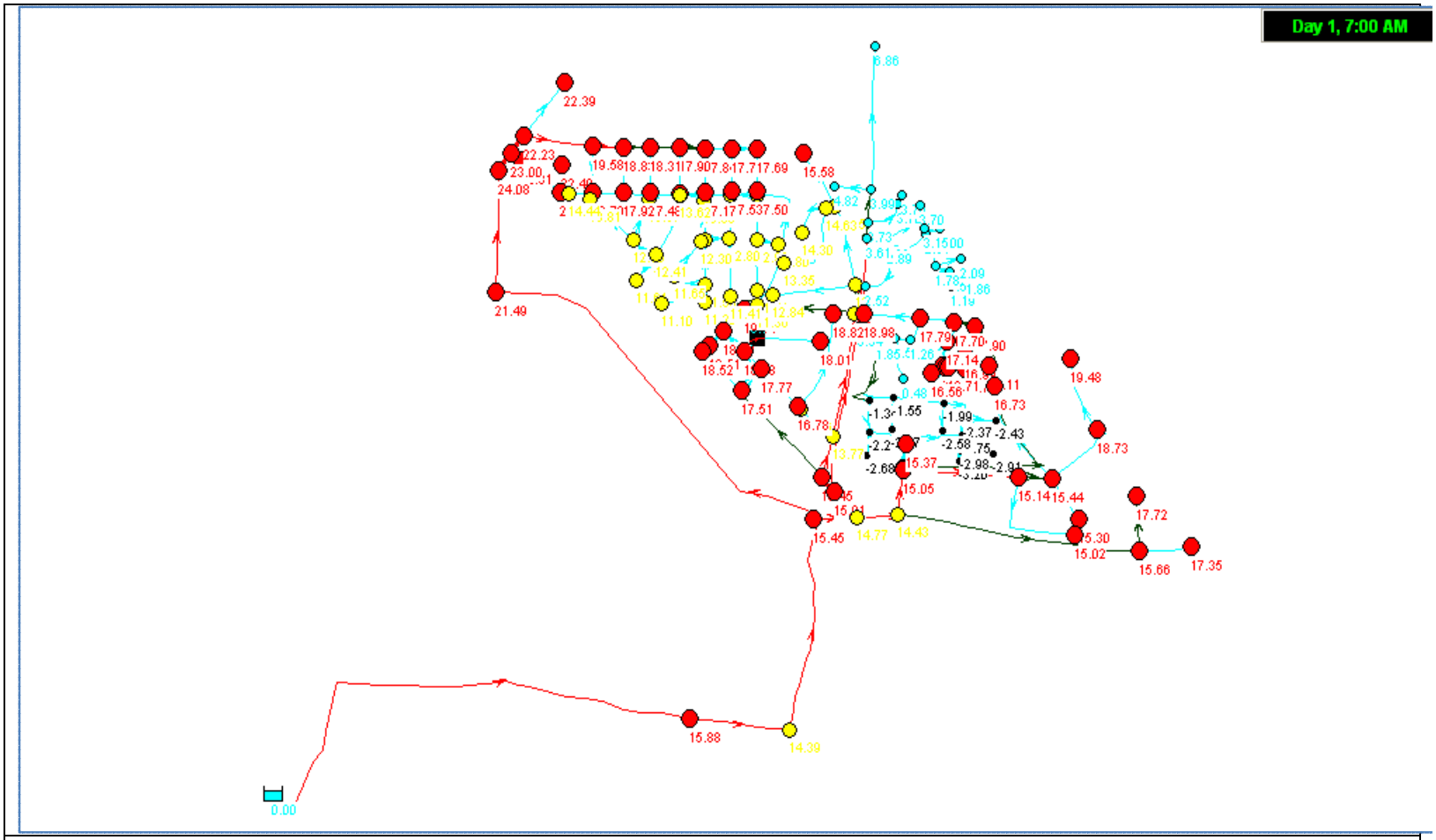


Fig 2: EPANET Water network along with pressure data for Ward No.82 and 83

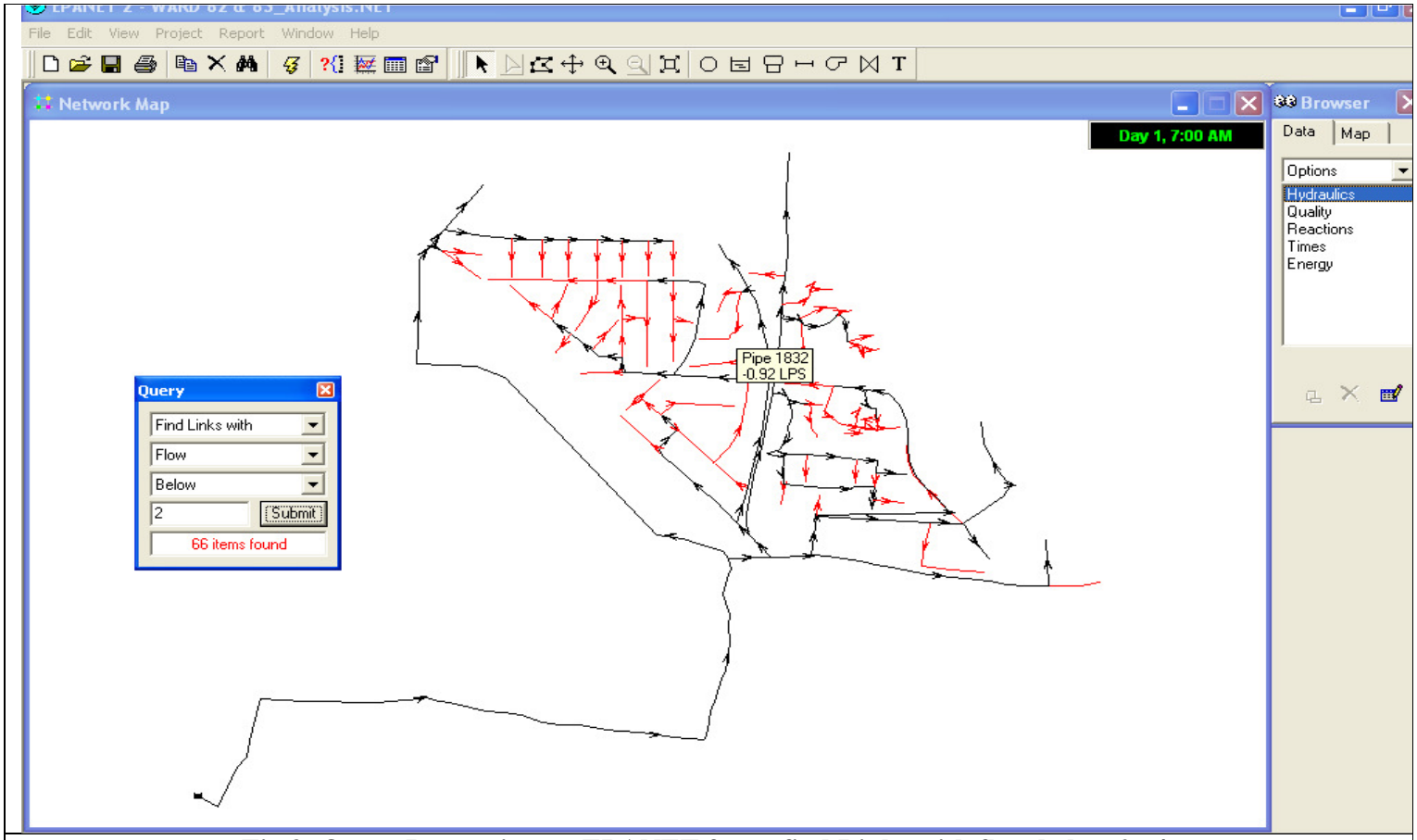


Fig.3: Query Processing on EPANET for to find Links with flow below 2m/s

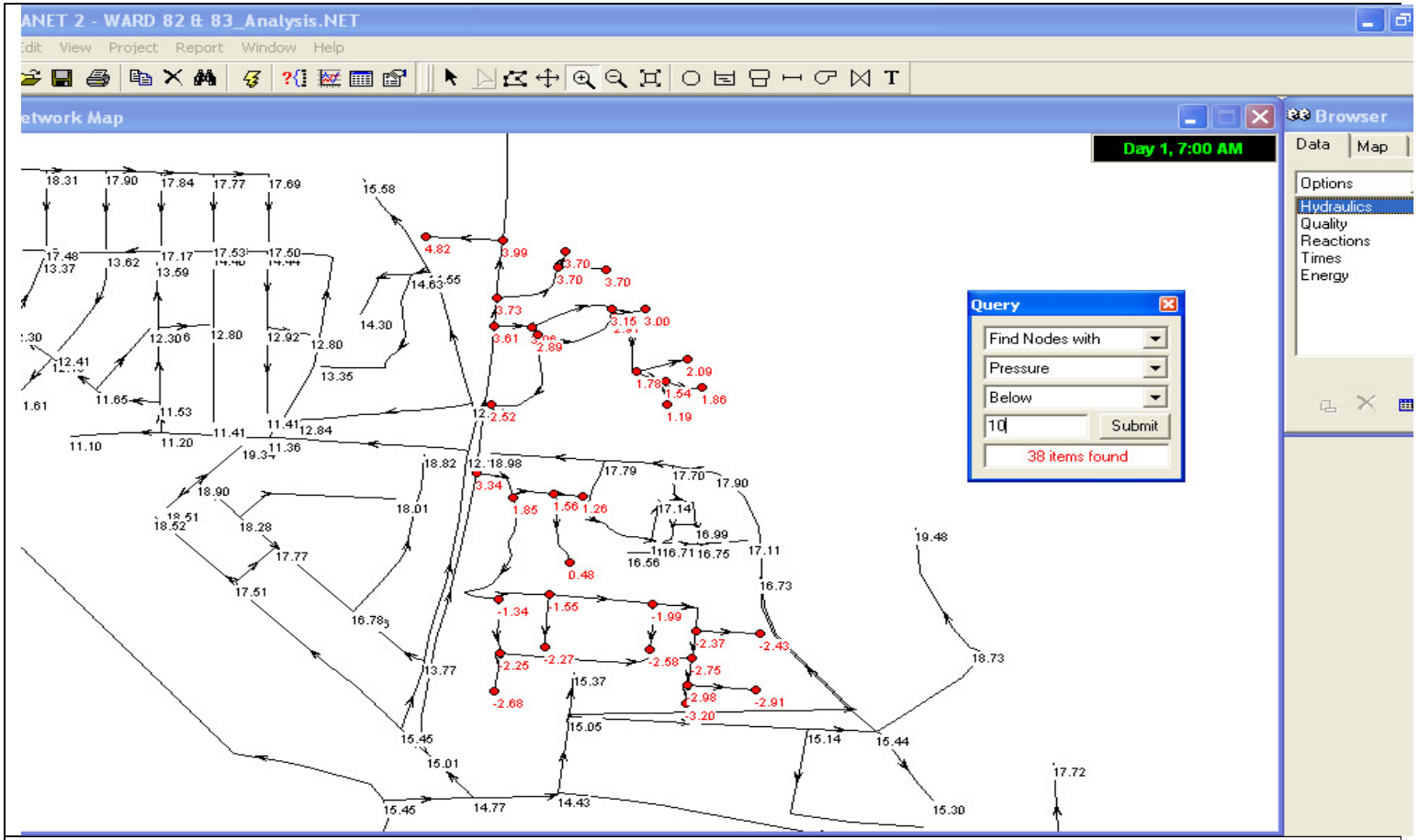


Fig.4:Query Processing on EPANET for to find nodes with Pressure below 10 m

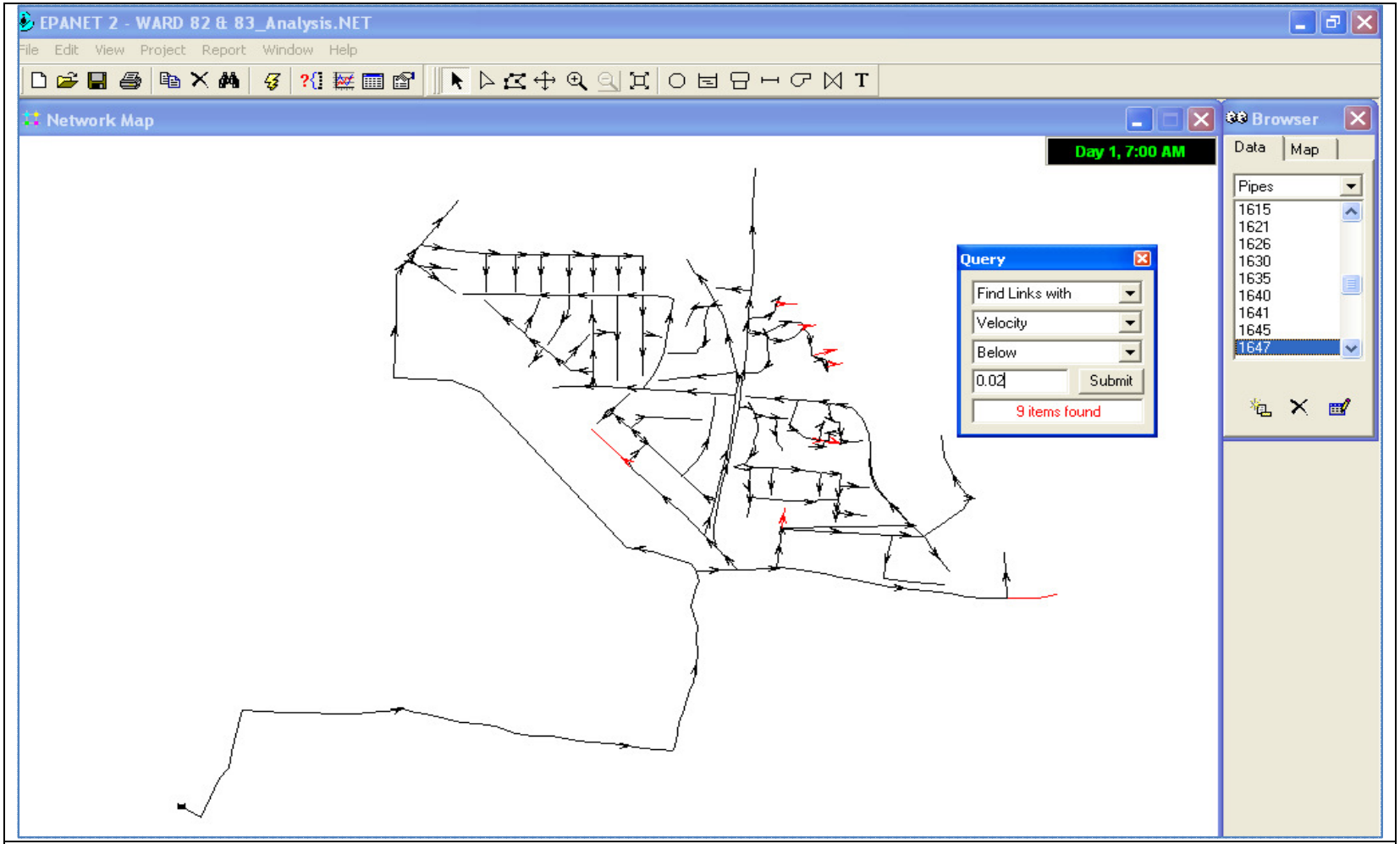


Fig.5:Query Processing on EPANET for to find links with Velocity below 0.02



Fig.6: Contour map developed by using EPANET

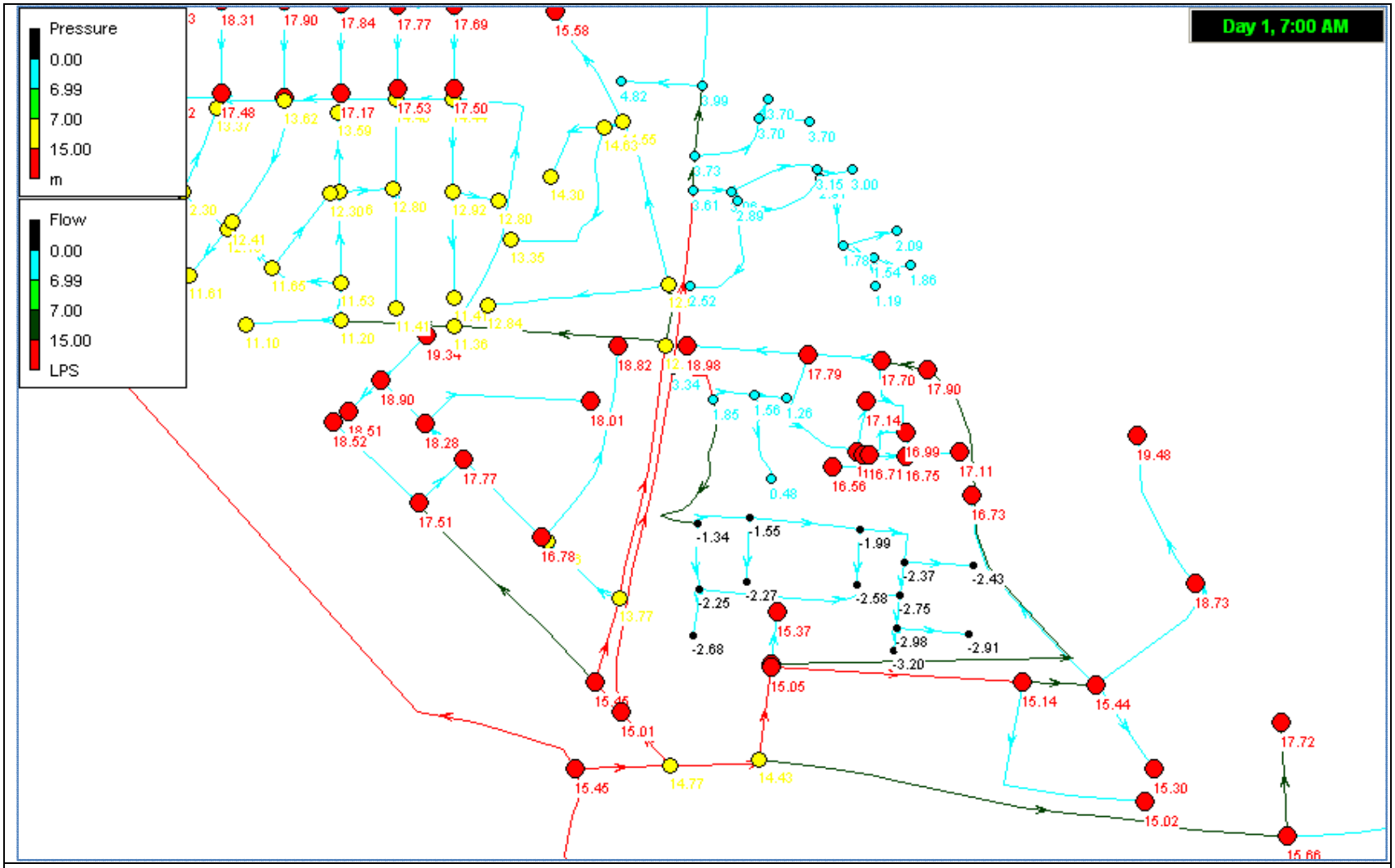


Fig.7: Pressure and Water flow data along with network

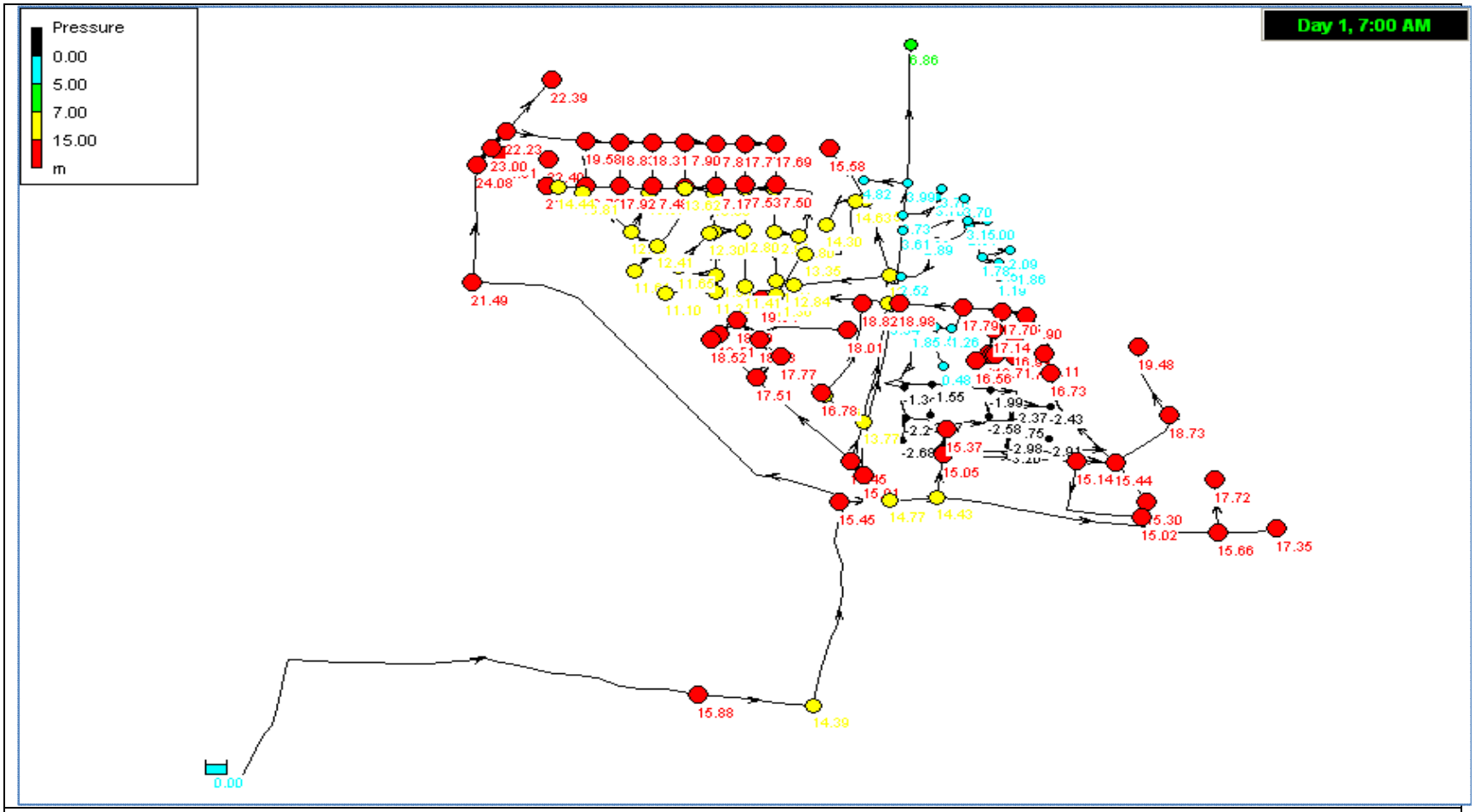
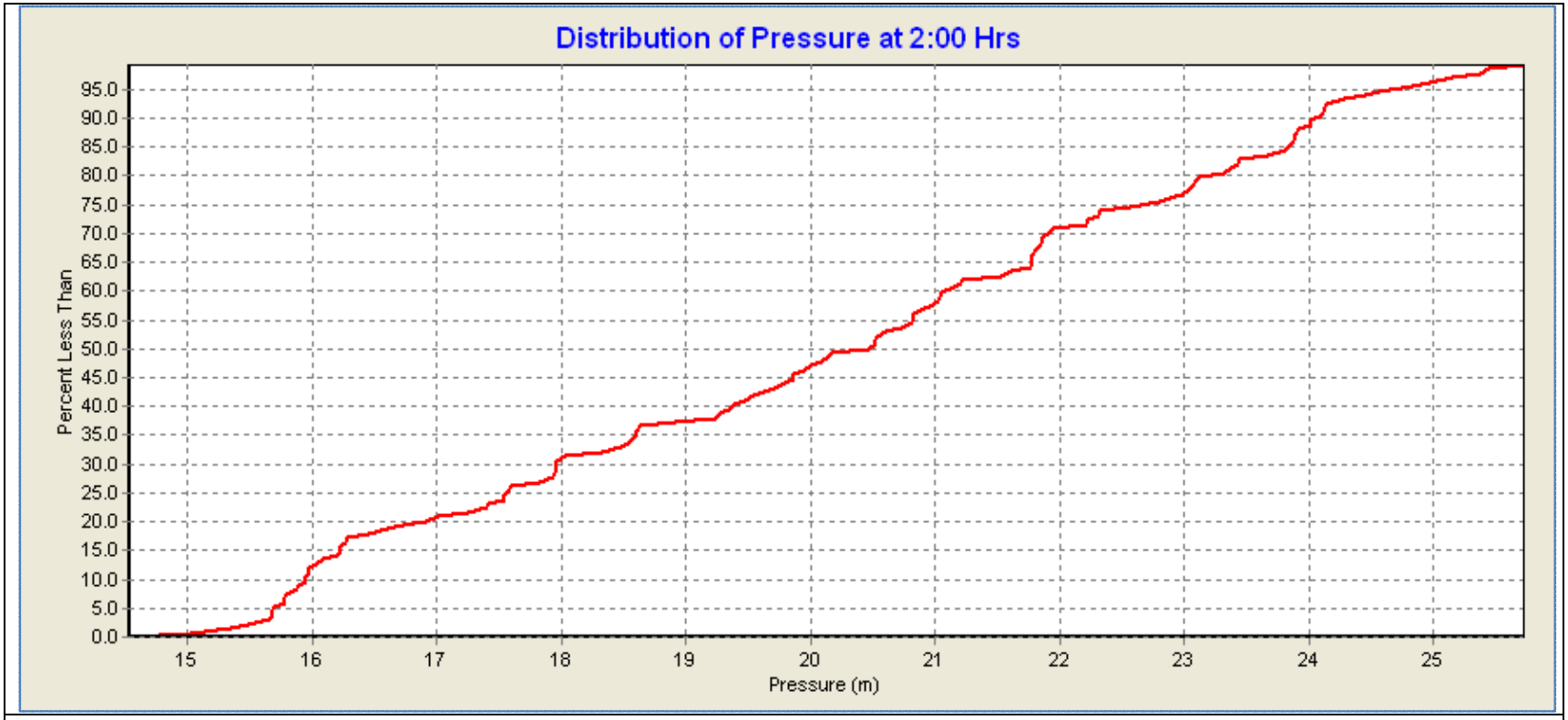
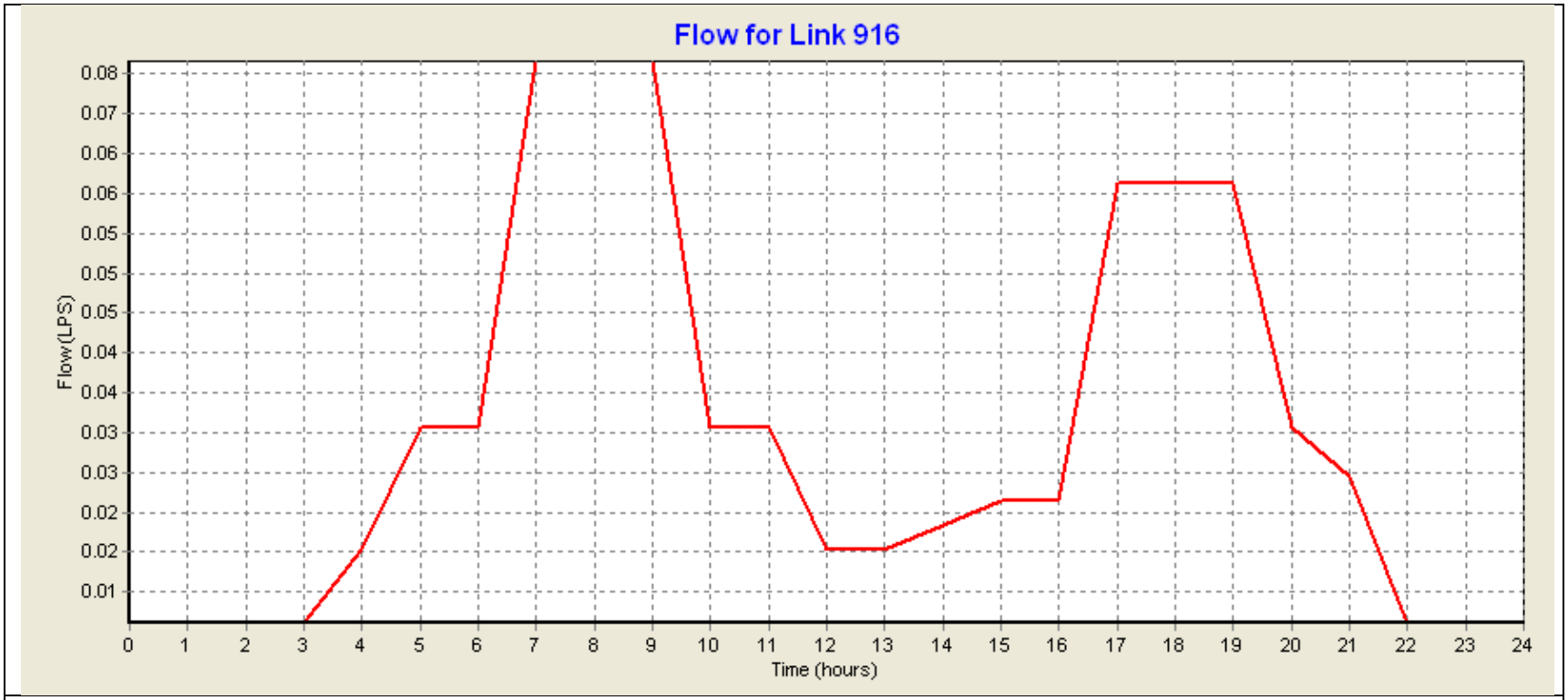


Fig. 8:Pressure variation in the entire network

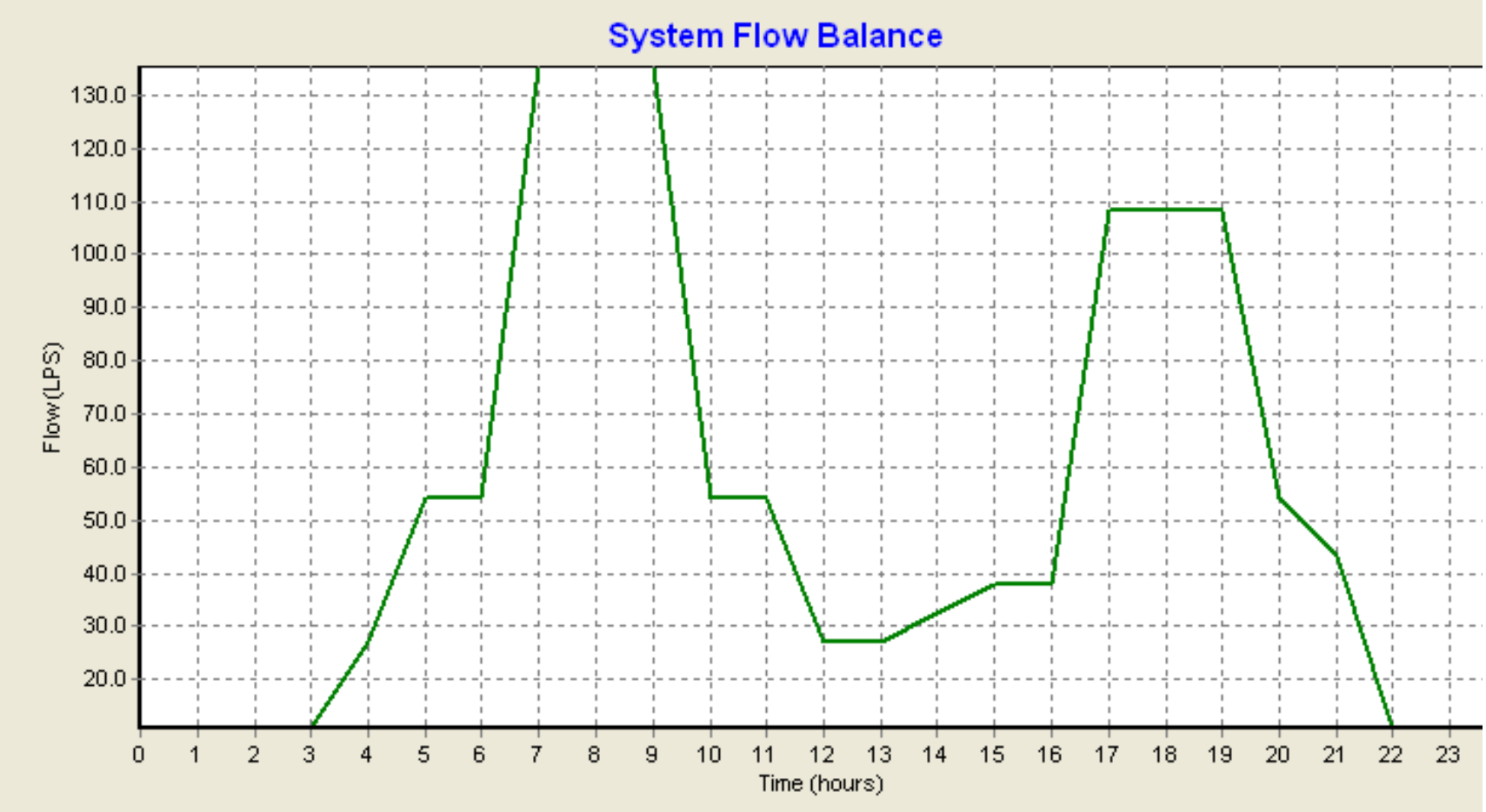
Viewing Results with a Graph



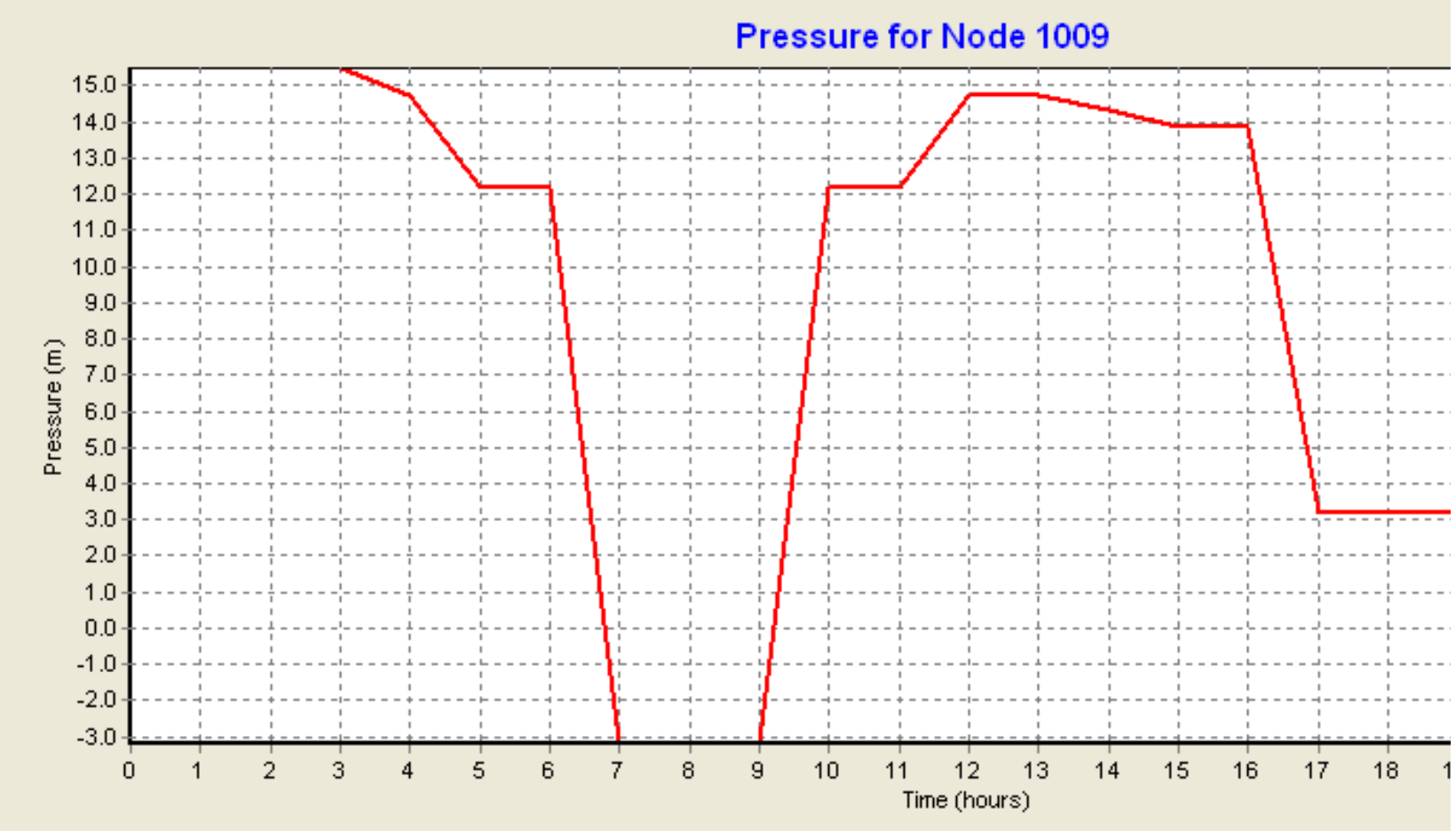
Graph 1 :Frequency Plot



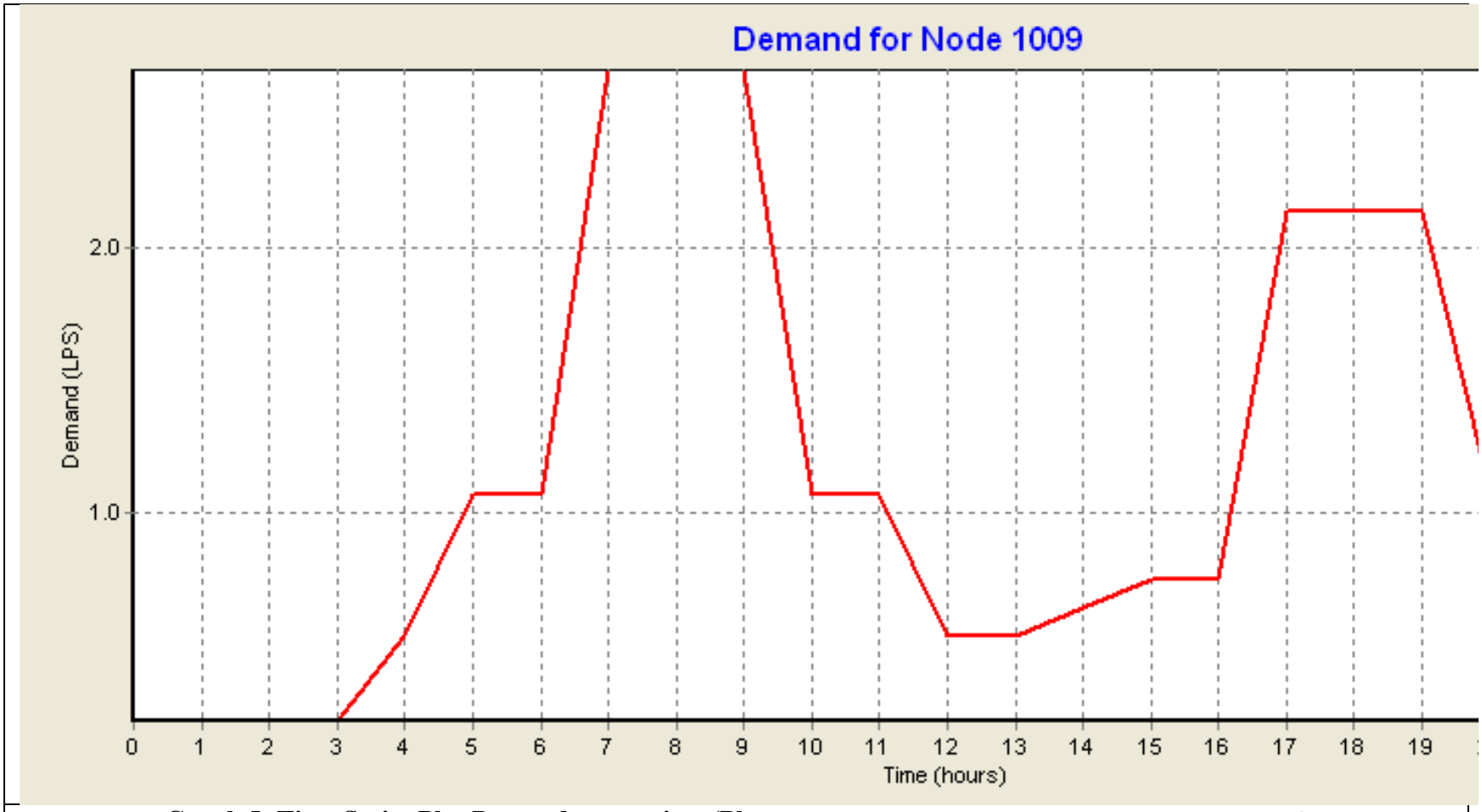
Graph 2: Water Flow within pipe (Link 916) in between 24 Hrs



Graph 3: System Flow Plot -Plots total system production and consumption versus time(Water demand for all nodes over all time periods



Graph 4: Time Series Plot-Node versus time (Plot Specific nodes or links over all time periods)



Graph 5: Time Series Plot-Demand versus time (Plot Specific nodes –water demand for all time periods)

Annexure 14

Referred Images from News Paper

1. Wastages of Water



The Mutha Right Bank Canal has breaches in its boundaries, through which thousands of liters of water seep out every day... (Source:The Indian Express,Thursday, May 26, 2011)



Water collects outside the canal, resulting in major wastage
(Source: The Indian Express, Thursday, May 26, 2011)



Workers at this construction site near the canal have to pump out water every day...
(Source: The Indian Express, Thursday, May 26, 2011)



Wastages of Water
(Source: The Indian Express, Thursday, May 26, 2011)



A valve in PMC's pipeline at Vitthalwadi spurts a fountain of water into the air
(Source: The Indian Express, Thursday, May 26, 2011)

2. Misuse of Water





Mis use of water at Serving Centers(Washing Centers)
(Source: Times of AP 24X7 Online News Portal)



Huge wastage of water on Range Hills road, where as Pune is suffering shortage of it.

3. Water Shortage



Water Shortage at Slum Area (Source: DNA,5th March,2012)



Mohammedwadi residents line up for water from a tanker supplied
(Source:Times of India,April,2012)

4. Water Pollution



Water Pollution - Polluted river Mutha

(Source: Indian Express,7th Dec, 2012)



Garbage, scrap flowing in a canal - polluted water- Pune

(Source: Times of India ,19-10-2012)



Water Pollution, garbage thrown in canal



Water pollution - People Bathing on dam back water in Pune city



Polluted Nulla in Pune city
(Source: Indian Express 13-04-2010)



Garbage thrown in the river causing water pollution, Pune

5. Gray Water



Wastes generated in Pune city

6. Water Scarcity



The severe water shortage Pune city faced in the last two summers
(Source: Express News Service : Pune, Wed Apr 27 2011, 03:12 hrs)



With Pune city facing continued water shortage for the last years
(Source:Express News Service : Pune, Fri Sep 18 2009, 02:13 hrs)

7. Water Leakages



The leakage, detected in the Amar Society premises in the main supply link between Parvati and SNDT water works

(Source: Pune Mirror ,Saturday, April 21, 2012 at 03:30:05 AM)



The pipeline, which is to leak several liters of water for almost a decade

(Source: Pune Mirror ,Saturday, April 21, 2012 at 03:30:05 AM)



Water Pipeline Leakages



Severe water leakage near the Bishops School in Pune Camp

(Source: SakalTimes,Wednesday, February 22, 2012 AT 12:47 PM (IST))

8. News Articles on Water Shortages

DNA PUNE SPEAK UP

Pune, Monday, July 27, 2009 www.dnaindia.com epaper.dnaindia.com 4

CITIZENS FEEL CHEATED OVER THE 'WATER AFFIDAVITS'

Since 2001, a large number of new housing societies have come up in the fringe areas of Pune and many of them have been chronically dependent on water tankers. Year after year, residents of these societies have naively provided a flourishing business to the water tanker mafia in the city as the Pune Municipal Corporation (PMC) did not develop the water supply infrastructure, but indiscriminately gave building permission to builders.

Although the PMC and land developers benefited by way of development charges, taxes and profits from the new constructions, housing societies have been forced to fend for themselves on the water supply front.

While granting building permissions, the PMC secured 'water affidavits' from the builders stating that the PMC and the builders are aware of the acute water scarcity in the area and that

SPEAK UP

Would you like to react to the 'water affidavits' issue in Pune? Write to us at

providing water to these housing societies will not be the responsibility of the PMC.

The affidavits specify that it is the builder who will provide water "by tankers or water tankers" and will under no circumstances complain to the PMC about water scarcity.

Although builders have sworn in their affidavits that they will provide a copy of the document to flat buyers, not all have honoured this commitment.

Flat owners feel cheated as the PMC never informed the public about these water affidavits and many flat purchasers also did not get a copy of the document as promised by their builders to the PMC.

The water affidavits can also be challenged in the courts, and the PMC's claim to water and other taxes from the affected areas can be challenged as the PMC has admitted it was unable to supply water to the fringe areas and passed on this responsibility to the builders.

Pune's Watergate

PMC, builders must come clean

The common man in the fringe areas of Pune has suffered at the hands of the Pune Municipal Corporation (PMC), which indiscriminately gave building permissions without making a provision for water supply. The PMC's 'water affidavits' were dishonoured by many builders who did not provide a copy of these affidavits to flat-buyers.



Krishna Mohan, Resident, Viramnagar

"The entire area of Viramnagar is suffering. The builder promised us facilities, including water, but has not provided them. Recently, we got a huge water bill, which is just unacceptable. I am ready to extend all help to make a change and find a resolution to this problem."

The PMC has neglected its duty towards citizens



The PMC has shirked its responsibility of giving water to citizens. It is the statutory responsibility of the PMC to provide water to citizens.

The civil body cannot allow buildings to flourish without ensuring adequate water supply, electricity and basic amenities like roads, for consumers. The civil authorities have been grossly negligent in their duty and have sought to indemnify themselves by taking this affidavits. Citizens must take them to task for this gross neglect of duty.

Will the PMC specify what action it will take against errant builders? Will they ensure that the builder will foot the water tanker bill? Or will the civic body ensure that until all building conservation permissions including rainwater harvesting, rainwater, sewage treatment plants and water needs are met, the builder will not be given any new sanctions? They must give some concrete statement. The authorities have supported the builders' lobby and breached the principles of the Bombay Provincial Municipal Corporation (BPMC) Act, 1949."

—Sudhakar Vaisakar, town activist

Citizens must oppose this policy of the PMC



I'm surprised to know how the citizens kept quiet over the issue while the civic body has nearly built itself as private bonchers. I want to ask them whether they are going to file public interest litigation (PIL) after knowing the facts of the water affidavits.

"Water, electricity, drainage and roads are four basic amenities which a civic body must provide to its citizens. I am shocked at the apathy of the affected citizens in not raising a hue and cry over the issue all these years. The PMC is clearly at fault and it is questionable as to how the civic commissioner agreed to circumvent the law.

There is no provision either in the BPMC Act, 1949 or the Maharashtra Regional Town Planning (MRTP) Act, 1966 for the affidavits and it is questionable on what basis they were signed. I wonder how the PMC gave sanctions to builders who have signed such affidavits, shattering even the basic amenity of the citizens.

The PMC was fully aware of the impending water shortage owing to the swelling population of Pune, design flaws in the existing pipeline and haphazard construction in the city. I believe the builders might have pressurised politicians and civic officials to sanction their construction plans.

Corporators cannot be expected to oppose the water affidavits as many of them own water tankers/ tankers and would be opposed to any hindrance to their flourishing business."

—Maj Gen (retd) SCN Jatar, president, Kalyani Nagar Citizens Forum

PMC will take action against builders who didn't deliver



Action will be taken against any builder who has signed the affidavit, but failed to make fair, arrangements for water. Although it is the civic body's primary duty to provide drinking water, the affidavits were undertaken from builders in the fringe areas of Pune as the pipelines had not been laid, particularly in the western parts of the city. The builders were expected to provide water by boremells or tankers.

The developers have clearly promised in the affidavits that they will not complain to the PMC about water scarcity and will not blame the PMC for not providing water. The developers have also promised that they will inform flat owners about such affidavits. The civic body has not received any complaints about developers violating their undertaking. If genuine complaints, the PMC will definitely initiate action against the developer.

—Prashant Waghmare, PMC corporator

team speak up
Abhay Khairnar, Kiran Dahibure & Ritu Goyal Harish

Water tax should be refunded to all residents



A fair should be released to the press and all members of such housing societies be invited to visit the PMC on Monday during the first weekly flight information day of the PMC.

If housing societies have not been receiving any or even adequate water, the water tax collected by PMC should be refunded to all the residents. This amount, along with a fine, should be recovered from the builders and promoters. Most residents of such housing societies are cheated."

—Satish Khot, president, National Society for Clean Cities

Water dept did not consider capacity of water distribution



The civic body has failed to check water availability before issuing building permissions in the fringe areas. The water department is issuing no-objection certificates to builders, but it is not considering the capacity of water distribution. Henceforth, the civic body will take note of the infrastructure before issuing the building permissions.

—Mahesh Zagade, municipal commissioner

It's unbelievable that Zagade was unaware of the problem



Viramnagar's water problem must be addressed by the PMC. An official from the Hadapsar Garden water works division said the private water supply tankers from the Hadapsar pumping station were due to power failure. The PMC should take this up with the Maharashtra State Electricity Board (MSEB). Can municipal commissioner Zagade really expect us to believe that he wasn't aware this was happening?

—BK Anand, resident, Viramnagar

It's imperative that builders show the affidavits to buyers



I completely agree with what Sudhakar Vaisakar has said. Both the stakeholders, the PMC and Promoters & Builders Association of Pune (PBAP), now renamed as Confederation Of Real Estate Developers Association Of India (Credai), Pune chapter, should come together to make a list of societies that have made these affidavits. The list should be kept in the public domain, like on the PMC website. If this is done, people will at least know which societies come under this list.

The Credai should enforce members to give advertisements saying they have made water affidavits. It's imperative that builders show the affidavits to the buyers before selling flats to them.

If the PMC rules make it mandatory for builders to provide water to residents, they should also mention who has to foot the water bills. The builders do not inform the PMC or the residents. They provide water for 24 hours and charge the residents for it. Residents are unaware of the rules. If they come under the 'water affidavit' list, they should not be liable to pay water tax.

Now, I think the affected people should consult a legal authority to clear the issue and sort out what is written in the affidavits and what steps should be taken further.

—Col (retd) SD Dalvi

It is the PMC's duty to provide water in residential areas



The PMC has adopted a wrong policy of issuing affidavits. Even developers arrange for water supply for reality, it is not possible. If the PMC is charging the tax to citizens and taking these charges from developers, it is the civic body's duty to provide water. Developers need permission, so instead of fighting with the PMC, they just file these affidavits. In addition, if the PMC declares a particular area as residential zone, naturally builders will try to develop it. It is the civic body's duty to provide water in residential areas. If it cannot do so, those areas should be declared as agriculture zones.

—SB Kulkarni, president, Pune Maratha Builders Association

The issue is not affecting us as we take care of this aspect



We sign many affidavits before we get the completion report for our projects. Every builder has to sign them. As far as I and my company are concerned, we are not facing any problems because of the water affidavit issue since we are taking care of this aspect as far as our customers are concerned.

—Rohit Oora, builder & developer

केशवनगरमध्ये पाण्यासाठी वणवण; आंदोलनाचा इशारा

पुणे : केशवनगरमधील सिंह पार्क, लोकमत पार्क, आनंद नगर, इसमदार पार्क, पोई पार्क, पार्थेश्वरनगर, हुतात्मा नगर, पवार कॉलनी, शंकर पौळाकडील जलवाहिनीच्या शिरवळ पाण्यासाठी भयानक परिस्थिती आहे. सोसायटीच्या आवारात विंधन पाण्याचे खोदकाम करण्यात आले आहे. परंतु त्यातून अत्यंत कमी प्रमाणात पाणी येत आहे. त्यामुळे या भागातील नागरिक अक्षरशः वैतागले आहेत.

केशवनगरमधील नागरिकांना पुरेसा पाणीपुरवठा, ड्रेनेज, आणि रस्त्यांचे डांबरीकरण या मूलभूत सुविधा, या नागरिकांचे कर्तव्य आहे. त्यासाठी त्यांनी अनेक वेळा प्रशासनाला मागण्यांचे लेखन केले होते. पण या मूलभूत प्रशासनाकडे आजपर्यंत पूर्ण केलेल्या नाहीत. या नागरिकांच्या अनेक समस्यांपैकी पाण्याची समस्या सर्वात गंभीर आहे. त्यासाठी या भागातील नागरिक अक्षरशः वैतागले आहेत.

पुणे महानगरपालिका पाणीपुरवठा, ड्रेनेज व केशवनगरमध्ये पाण्याचे खोदकाम करण्यात आले आहे. काही पाण्याचे नागरिकांना पाणी विकत घेण्याची वेळ आली आहे. परंतु तेथील नागरिकांना परवडेल अशा दरात टँकर मागणाचा नसल्या आहे. प्रशासनाचा या भेदभावपूर्ण नागरिकांत मूलभूत पुरवू शकत नाही.

पुणे महानगरपालिका पाणीपुरवठा केला जातो, पण प्रशासनाच्या दिरंगाईमुळे, या भौगोलिक नागरिकांना एक दिवसआड पाणी पुरविले जाते. काही भागांत तर काही भागात अनियमित पाणी पाणी, पाऊस सुरू पाणी पोटाले जाते. त्यात एक बोअर पाण्यासाठी सुमारे २५ हिंदिये लागतात.

या काही नागरिकांच्या मागील भाग पाणीपुरवठा केला जाते. प्रशासनाकडे वर्ष पाण्याचे पाणीपुरवठा करावा, अन्यथा तिव्रतेच्याच्या नागरिकांनी रास्ता आंदोलन करण्यात येईल, असे विधान ठेकेदार पाणी नागरिकांनी.

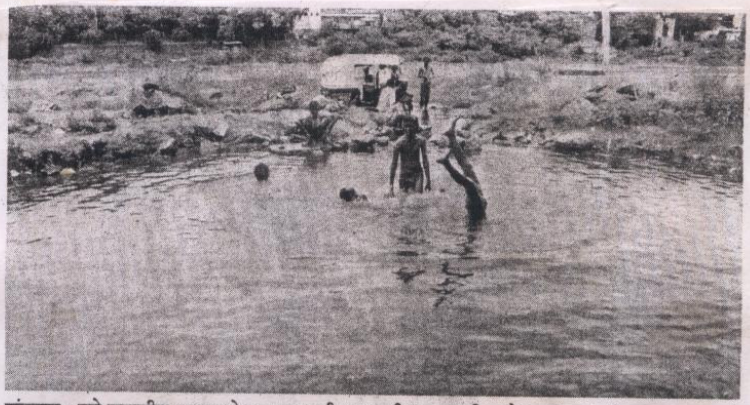
Insufficient Power Supply



रोज हजारो लिटर पाण्याची गळती;
विजेचीही सोय नाही !

टाकीला
वीजपुरवठा शेजारच्या
झोपडीतून!

Lake Created from Water leaking from Pipelines



एरंडवणा : पुणे शहरातील धरणामध्ये उपयुक्त पाणीसाठा कमी असला तरी म्हात्रे पुलाजवळ नदीपात्रालगत पाण्याचे 'जिवंत झरे' वाहत आहेत. या ठिकाणी असलेल्या जुन्या जलवाहिनीतून दररोज हजारो लिटर पाणी वाया जात आहे. या पाण्याचे प्रमाण एवढे मोठे आहे की, या पाण्याचे लोंढे ओढ्याच्या स्वरूपात नदीपात्रात जात आहेत.

(विनायक बेदरकर : सकाळ छायाचित्रसेवा)

(Source: Daily Sakal 19th May,2011)

Shortages of Water



Insufficient and Low Pressure Water Supply



(Source: Daily Sakal 19th May,2011)

Losses of Water



Underground Water storage tank with No Lid invites all sorts of Pollutions



(Source: Daily Sakal 19th May,2011)

Wastage of Water



People Carrying Water from long Distances

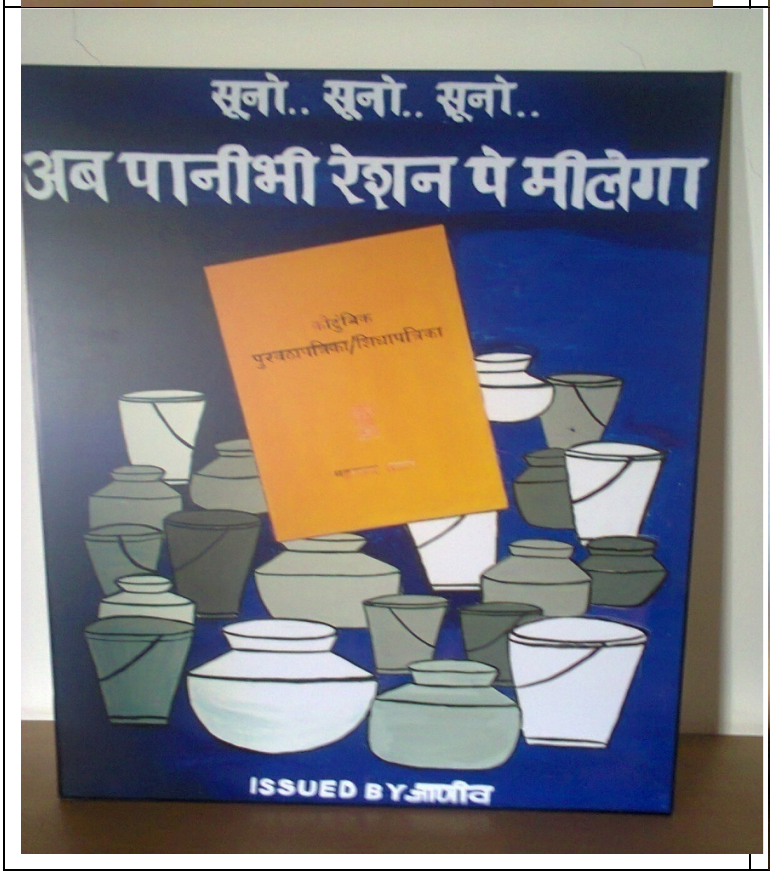


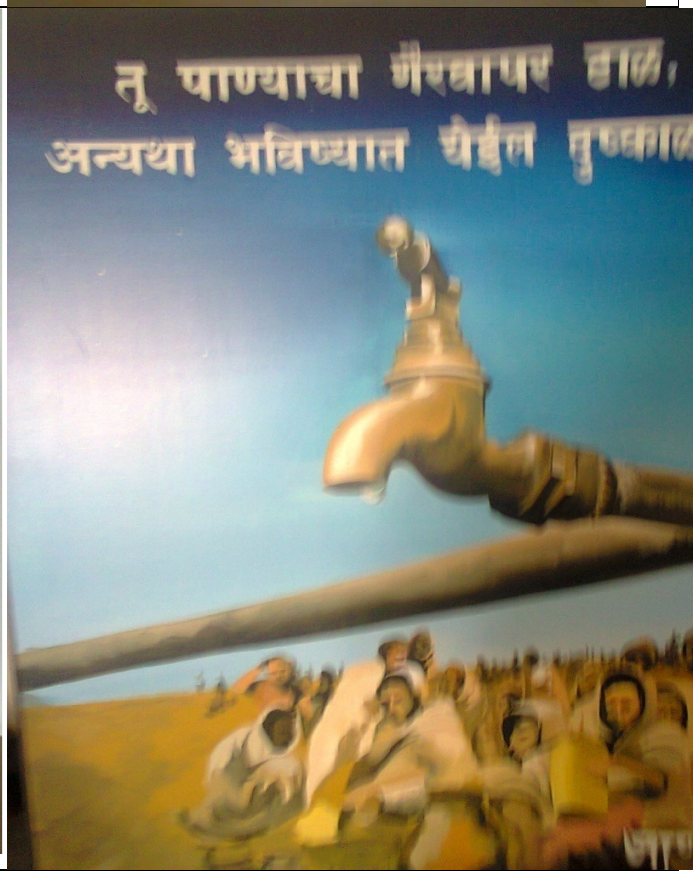
(Source: Daily Sakal 19th May,2011)

Annexure-15 Water Pictorial Quotes



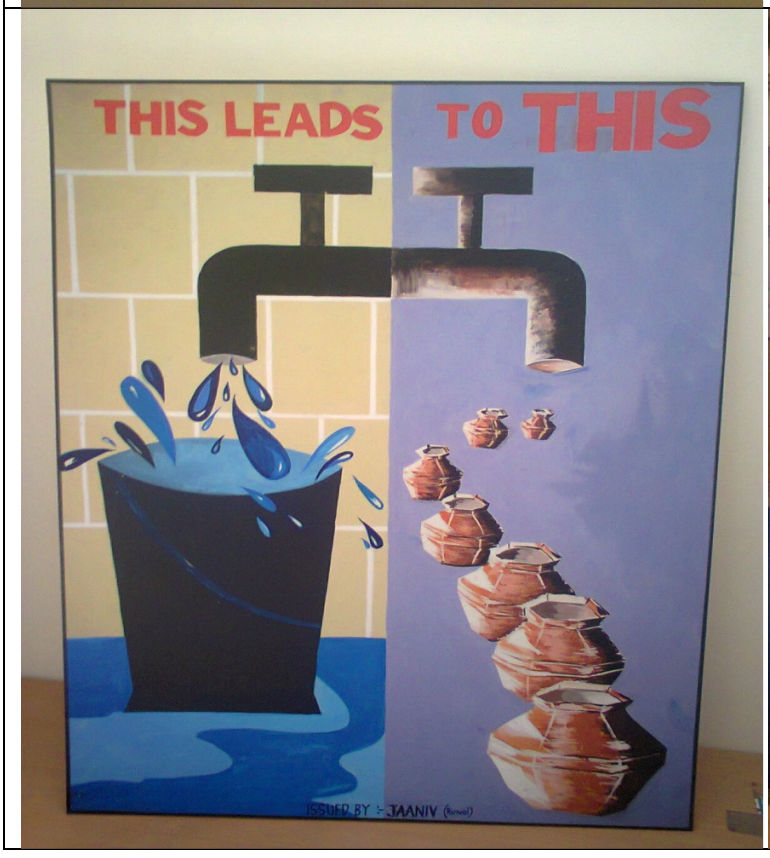







जल नाही तर
जीवन नाही
पाणी हेच जीवन


Save water.
The world
is in your hands.


THIS LEADS TO THIS
ISSUED BY :- JAANIV


हे पाहुन हसू नका
अशी पाळी येऊ देऊ नका
पाणी वाचवा