

## Visualization of Water Utility Network and tracing in a web GIS application based on Open Source Technology

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**Abstract:** The development and management of utility networks is one of the important aspects of a city planning. The water utility network is a very important factor for any developed city. Such utility networks are complex and difficult to manage due to ever-changing data, which can be difficult to store traditionally. Storing a water utility network data in the form of spatial data with the help of GIS technology is an easy way to manage, update, and analyze such complex datasets. This paper presents how Geographical Information System has been for a web-based water utility network system (WUNS) using open source technologies for making cost-effective implementation, operation, and management of spatial information through the web. The WUNS has been developed for the Navarangpura ward, Ahmedabad. This system enables users to visualize, analyze, querying, and downloading maps of water utility network for specific requirements. The WUNS provides interactive Graphical User Interface along with basic GIS functionalities over the web for users. With using WUNS users would be able to see the accurate location of water pipeline and the overall connected assets and infrastructure also. A unique tracing functionality has been developed, showing an impact analysis to display the number of properties and population affected due to damage in a water pipeline network at a particular point/stretch. The application provides a comprehensive view of spatial and nonspatial data and can act as a decision support system for organizations, decision-makers, and city planners.

**Keywords:** GIS, WebGIS, Open source technology, water utility network, OGC, FOSS4G

### I. INTRODUCTION

Utility is a service provided for the public such as electric, oil, gas, transportation, water supply and the other sectors. Water utility is an important and prominent societal role for distributing and supplying water in the respective communities. It is also helpful for improving the quality of life and enhances the productive efficiency of the people. The water supply is the process of transporting water from the transmission point to the end user's points. For management of water supply system in city, need to create water distribution network by using water supply related assets. Mainly there are two types of assets in water networking: 1.) Vertical assets - Present on the surface of the earth 2.) Horizontal assets - Below the surface of the earth Water distribution station (WDS), pumps, water treatment plants, overhead tanks etc. are vertical assets. Pipelines, valve, reducer, junction are horizontal assets. Due to this assets water supply system is getting complex. A geographic information system (GIS) is a computer system for capturing, storing, querying, analysing, and displaying geospatial data [1]. By using GIS, we can manage and improve the utility services. GIS offers combined power of geography and information systems an ideal solution for effective management of water utility infrastructure [2]. GIS support spatial analysis and locating geographical facilities in the water distribution

system. A GIS can locate the exact position of water utilities assets displaying them on a map. Location information is important for effective management as good decision can be made relative to the surrounding area and affected assets [3]. GIS is a grate tool for better way of analysing, monitoring, displaying and managing this water network data. Visualization and mapping features give us an overall, connected view of network in relation to surrounding infrastructure.

The Internet, in particular the World Wide Web, is fast becoming an integral part of our daily lives and an essential medium for satisfying everyday needs [4]. Significant growth of internet and increase in people's interest in accessing online geospatial information has led to the development of web mapping applications. Due to the benefits such as platform independence, the reduction of the web is considered very important in spatial application development. WebGIS is a distribute information system, which contains at least a server and a client. Here, the server is a GIS server and the client is a web browser, desktop application, or mobile application. webGIS can be defined as any GIS that uses web technology for connecting a server and a client [5]. WebGIS is gaining popularity and it is an important tool to share the spatial data on web. Today in the advancement of web technology, various management systems have been

developed for mapping, power distribution, Earth data and planetary data dissemination and archival. Web GIS is also important in decision making process such as urban planning, Public transportation management system, emergency response system, water utility, which have been developed using various tools and technologies [6].

This application developed using open source software's and libraries. Open source software is a type of free software to be accessed, used or modified by their user groups and developers. There are many similar terms for this type of software, such as free software, libre software, open software etc. One of the key features to differentiate open source software from other types is their free software license, which clearly defines the legal rights of users with liberty to run, study, modify, redistribute and licensed change software source code. All open source software licenses must be licensed. The process is to apply a free software licenses necessary to protect the legal rights of their users and to ensure the freedom of software [7]. A variety of free and open source software that can be found on desktop computers. In GIS domain, the widespread use of FOSS is also evident. Free and open source software for geospatial application (FOSS4G) is an annual recurring global event started by OSGO in 2006 that promotes open source software and its development [8]. The benefits of using FOSS can include decreasing software costs, increasing security and stability (especially in regard to malware), protecting privacy, and giving users more control over their own hardware [9].

In this study, FOSS technology has been used to develop a WUNS application for sharing map, spatial data and non-spatial data efficiently in web environment. This paper is organized as follows. Section 2 describe the objectives of the paper. Section 3 describe study area and their water supply information. Section 4 discusses in detail regarding the various tools which are used to develop WUNS. Section 5 describe application architecture. The methodology is described in Section 6. In section 7 result and discussion about WUNS functionalities. The final conclusion in Section 8.

#### A. Objective

The paper aims to design and develop a water utility network system where information can be analyzed and it can help to take decisions on the basis of available information. The study indented to develop a WUNS system with interactive graphical user interface along with GIS functionality for water utility management. It also intends to develop network tracing and impact analysis tool.

#### B. Study area

Ahmedabad city is located on the River Sabarmati, in north central Gujarat and the Western part of India. It spans an area of 205 km<sup>2</sup>. Ahmedabad is the 7th largest metropolis in India [10] and 2nd biggest trade centre of Western India. Ahmedabad city has a many historical places and It is also industrial city of Gujarat. The

Ahmedabad Municipal Corporation, established in July 1950 under the Bombay Provincial Corporation Act, 1949. The Central Government declared this city as 'Mega city' in 2005. For Administration purpose, the city divided into 6 zones-central, east, west, north and south and new west zone. Each zone is further split into wards. There area at present total 48 wards. For the development of WUNS application, this study has selected Navarangpura ward. The study area map shown in Figure-1. Navarangpura ward consist in the west zone of the Ahmedabad and lies between longitude 72° 33'39.84" East and latitude 23° 2'11.06" North. According to census 2011 Navarangpura ward had 55,647 population and 12,839 households. As per the AMC, Navarangpura area extent is 7.16 sq.km. Navarangpura have six water distribution station for distribution of water in related areas. Kotarpur Water treatment plant supply water in this six water distribution stations. The Kotarpur water treatment planet constructed during 1983 to 1987. The treatment plant capacity is 650 MLD. The Narmada canal alignment was planned by GoG of Kotarpur water works and escape in Sabarmati was constructed and commissioned. So that Narmada canal water was available in the river to pick up this water, AMC has planned Intake well work in phases. 165MLD intake well-1 at kotarpur works was constructed in year 2003 and 330 MLD intake well-2 constructed in year 2006 under JnNURM project. The 2500mm diameter gravity line from Narmada main Canal to Kotarpur Water 15 Works was laid in December 2006 and started in January 2007. By this gravity line AMC 330 MLD water to kotarpur water works [11].

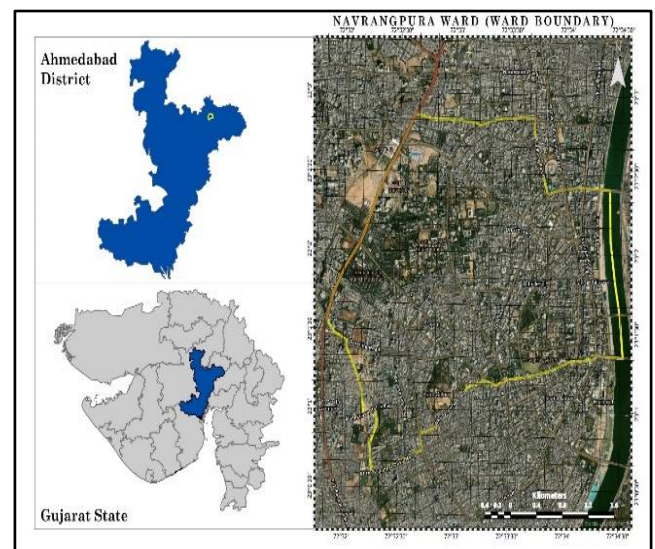


Figure-1: Map of Study area

## II. RELATED WORK

### 1. Developing a Web-Based Water Distribution Geospatial Information system for Nairobi Northern Region, Lucy Mulongo Mamai, Moses Gachari and Godfrey Makokha.

This research work aimed to develop a web system that will allow effective dissemination, extraction and analysis

of spatial information over the internet. It has customized and integrated an open source WebGIS system based on QGIS for spatial data creation, Map server as WebGIS server and PostGIS/PostgreSQL as a database server. It supports concurrent multi-user access. Through this system Spatial data related to water network is available on digital format. The web take time to downloads content from server to the client computer, therefore in developed system, the speed of downloading and displaying depending on the content and bandwidth. Different screen size will also affect the clarity of displayed content and also effect the resolution. It has various GIS tools for spatial data visualizations, analysis, querying and printing of map and it can be used by any non-GIS person who know nothing about GIS.

## 2. Geographic Information System in Water Distribution Networks, A.R. Ayad, Haytham Award, Alaa Yassin.

In this Study, design and analysis water distribution network with the help of GIS. GIS is used to provide graphical display of result obtained from both hydraulic simulation and optimization models linking with the Geographic location and graphical drawing. In ArcGIS, perform some steps like Creation of vector maps and Geodatabase, Build Geographic network and accurate network drawing, and applied to external model's data with GIS database. This study presents the water pipeline complex network to save the time required for hydraulic analysis, as single network connected to households and also handle their assets. ArcGIS uses Sql to define a subset of data on which to perform some operations and output are highlighted both, at the map and in database table. Then after, create a thematic map which is used to visualize and represent a data with colours, labels and symbols associated with each feature. The created application is identified isolation valves in case of pipeline break, adjusting GIS layers to equivalent hydraulic analysis layers, Service area allocator for water distribution plants and demand aggregation for junction in skeletonized network. It's also managed the shortest distance based on network weight assign by geographic network and travelling distance to the site. Present study also provides upstream network based on the flow direction. Using GIS has enabled prompt action to identify problems in the water network, maintain work and provide a frame work for continuous improvement.

### III. METHOLOGY

#### A. Tools and Technology

The web-based application was developed using various open source software and libraries, which are directly involved in web application. Desktop GIS software QGIS were used in developing spatial features and spatial analysis. PostgreSQL is free and open source object-relational database system [13]. PostGIS extension for PostgreSQL database with to store spatial data. PostGIS spatially enables the Postgres database and support for geographical objects, coordinate systems,

projections. PostGIS support importing / exporting ESRI shapefile vector data via command-line and GUI packaged tools and support standard textual formats such as KML, GML, GeoJSON and many more using SQL. Also supports importing raster data from many standard formats such as– GeoTiff, PNG and more. It is highly useful tool that is frequently used in WebGIS applications and projects. PostgreSQL and PostGIS are both OGC compliant [14]. GeoServer is an open source web map Server and it is primarily based on the Java language. GeoServer can access spatially enabled databased such as ArcSDE, PostGIS, etc. GeoServer publish data from many sources like – PostGIS, shapefile, GeoTIFF, Image Mosaic and other. GeoServer provides basic functionality for creating and editing geospatial data and also making maps in a service-oriented architecture. GeoServer is the reference implementation of the OGC, WFS, WCS standards as well as a high performance certified compliant WMS. Some other formats and publication options are available as extension including web processing service (WPS) and web map tile service (WMTS) [15]. OpenLayers is an open source client-side JavaScript library that can be customized in a HTML document for making and displaying interactive web maps, viewable in any web browser [4], but requiring a programming skill for to use or customize its interface. It supports a different type of layer sources and backends. With OpenLayers render vector data from GeoJSON, TopoJSON, KML, and other formats and also render tiles from OSM, Bing, MapBox and any other source you can find [16]. QGIS is Free and Open Source (FOSS) desktop GIS software. QGIS is an official project of the Open Source Geospatial Foundation (OSGeo) [17]. QGIS application that support viewing, editing and analysis of geospatial data. QGIS access vector data stored in a wide variety of formats (e.g. ESRI Shape Files, GML, KML), Geodatabases (e.g. PostgreSQL/ PostGIS) and raster data over 40 formats supported by the GDAL raster library. QGIS access OGC services 20 such as WMS, WFS and WCS. The software provides useful GIS tools in spatial analysis, geoprocessing, geometry, and data management tasks [18].

#### B. Application Architecture

The WUNS web application has three tier architecture: Client, Server and Database. Client tier is allowing the interaction of user with the developed application and provide spatial and non-spatial data display in the application. The user send request using web browser, client service sent request to the application server. The application server analyses the request and send the query either/both to geospatial data server or/and database server. Then the geospatial data server or/and database server completes the query operation according to the application server request and returns the response to the application server. The application server sends the response on web browser and application.

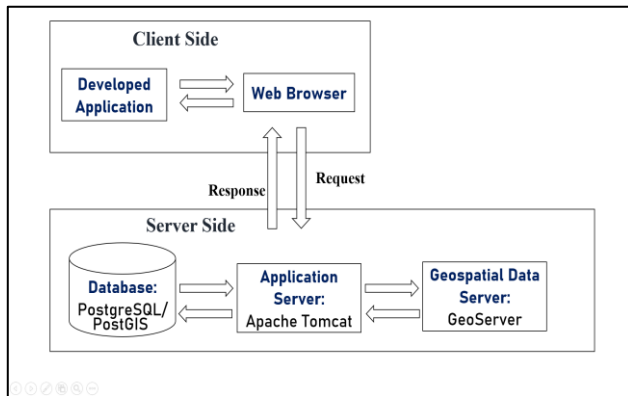


Figure 2: Application Architecture

### C. Data Collection

Spatial data used for the study was collected from Nascent Infotechnologies Pvt. Ltd. Table-1 shows list of collected various vector layers with their data type, geometry type and their attribute data. The all data are in ESRI shape file format and well maintain their attribute information. The shapefiles were projected to the EPSG:32643 - WGS 84 coordinate system, and the data frames were set to the same projected coordinate system.

Table 1: List of spatial layers, geometry of the layers and their attributes

Layer Name	Data and Geometry type	Attribution
Ward Boundary	Vector (Polygon)	Id, Ward name, Zone, Area, Ward Id, Zone etc.
Building Footprint	Vector (Polygon)	Id, Object Id, Grid no., Remarks, Area, Ward, Zone etc.
Water Pipeline	Vector (Line)	Id, Object Id, Material, Diameter, length, Ward Id, Zone Id etc.
Water Trunk Main Line (WTML)	Vector (Line)	Id, Diameter, Material, Length etc.
Road Centreline	Vector (Line)	Id, Length, Material, Road Category, Road Name etc.
Water Distribution Station (WDS)	Vector (Point)	Id, Tank Code, Source, Capacity, No. of Pumps etc.
Junction	Vector (Point)	Id, Material, Zone, Ward, Road Name etc.
Valve	Vector (Point)	Id, Valve Type, Zone, Ward, Road Name, Enabled/Disabled, Diameter etc.
Reducer	Vector (Point)	Id, Zone, Ward etc.
Endcap	Vector (Point)	Id, Zone, Ward, Diameter etc.
Landmarks	Vector (Point)	Id, Name, Zone, Ward, Category etc.
Society	Vector (Point)	Id, Name, Zone, Ward, category etc.

### D. Pre-processing and Spatial Database Creation

A new database was created in PostgreSQL database using user friendly interface PgAdmin4 and the created database

enabled with PostGIS extension for storing spatial data in database. After creating database, a new shapefile was imported into newly created database. All shapefiles were converted to their corresponding table in database. Each PostgreSQL database table is a geometry column as well as its corresponding spatial description. In this way the tables become spatial tables. This process was repeated for each vector layer created for the scope of the study.

After the database was configured and designed in PostgreSQL as it was required to connect to Quantum GIS desktop software. Topology describes the relationships between points, lines and polygons that represent the features of a geographic region. QGIS software was used to validate the topology errors with various topology rules set for polyline listed below:

- End points must be covered by
- Must not have dangles
- Must not have invalid geometries
- Must not have multi-part geometries,
- Must not have pseudos

### E. Implementation

GeoServer is a map and feature server for sharing, analysing and editing geospatial data. In GeoServer a new workspace was created and added a new store which is connected to the PostgreSQL database. Spatial data were published as map layers such as ward boundary, water pipelines, road centreline, building footprints, water distribution stations, water trunk main lines, underground assets (valves, junctions, endcaps and reducers), etc. A grid were made to set for rendering map layers, features and feature related labels at different zoom levels. Geospatial data has no internal visual component. To see and understand any data, it must be symbolic, this means mentioning colour, thickness and other visible attributes. The styles write in GeoServer with YSLD format for each layer and zoom levels were set in the grid set.

OpenLayers render map layers on web through the WMS and WMTS open geospatial consortium (OGC) standards services. OpenLayers is an open source client-side JavaScript library which can be modified in HTML document. The Water Utility Network System web base application user interface that has been programmed using HTML, CSS and JavaScript. A connecting of GeoServer and OpenLayers allowed getting data from the underlying database. Some basic functionality was later added in WUNS application, for example, zoom in, zoom out, and panning.

Attribute information for map layers were retrieved through PHP script on application. The network tracing functionality was developed in application using Open Source Routing Library: PgRouting. PgRouting is an extension of PostGIS and PostgreSQL geospatial database which enables routing and network analysis. PgRouting is part of OSGeo Community Projects from the OSGeo Foundation and included on OSGeo Live [19]. The tracing function was therefore developed in PostgreSQL database



and this function was used to configure sqlview. In addition, layer filtration functionality was also developed to filter map layers and show attribute information of each feature on map through the i-tool functionality. Figure-3 presents an implementation chart of the described method.

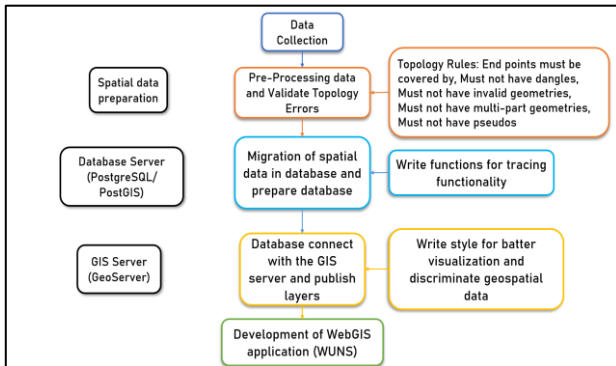


Figure-3: Implementation Chart

IV. RESULT AND DISCUSSION

The developed application enables the delivery of spatial data, non-spatial data, and maps over the internet. An effective geospatial database management system that allows effective storage, management, and retrieval of spatial data for water networks and other accompanying infrastructure was successfully developed. This can be used for the management of water utilities assets and infrastructure. The connection of the database with QGIS ensures automatic updating of spatial data in the database hence saving on time while maintaining data integrity. The adopted approach and its implementation using open source software and libraries such as, PostgreSQL, PostGIS, OpenLayers, GeoServer, PHP to develop a web-based GIS application. The developed application consists of various useful GIS tools for visualization, analysis, querying, and downloading maps for water networks and various water network-related assets. The basics GIS functionalities are provided in the application to render map layers within the map are zoom-in, zoom-out, pan layers. The WUNS application gives the accurate location information of underground water pipeline and their related assets, also performs network analysis and impact analysis if the water pipeline is the rupture or their asset is damage how much population and households are affected.

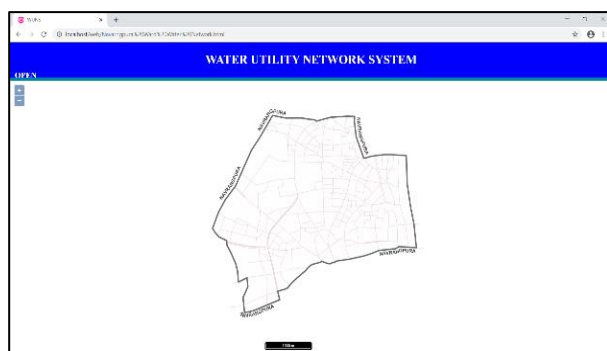


Figure-4: Initial user Interface of application

Figure-4 shows an initial user interface of application. The base map formed by overlays of Navarangpura ward boundary, road centrelines, landmarks and building footprints. At initial zoom level user visualize only ward boundary and road centrelines. Below the base map scale is also available, with this scale user can know how much height they are looking at the map. User can render map layers with different zoom levels and also show feature and feature related labels. User add map layers with layers switcher panel.

User has to click on any feature of a particular layer to get the attribute information of that feature with I-tool functionality (Figure-5).

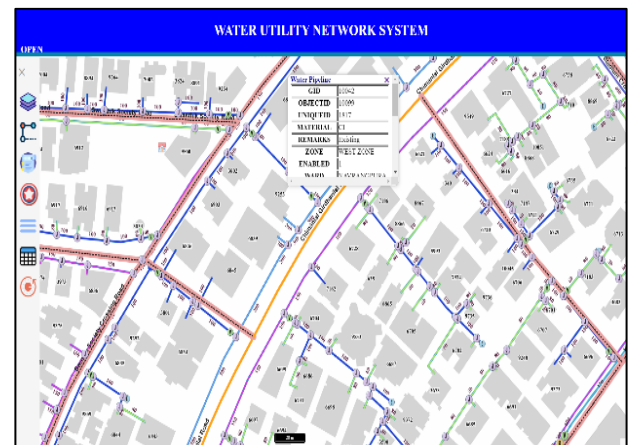


Figure-5: I-tool functionality

The measurement tool is available in the application for measure length of roads, water pipelines, calculate distance from one place to another place and measure the area also (Figure-8). User can perform attribute query on any layer and get the result on map for analysis and decision-making purpose. Figure-9 shows an example of a filtered water pipeline with a water pipeline diameter greater than 400 meters. The application display legends of all layers displayed on the map. The Legends is represented by the different symbols and colours for each layer and show the name of the layers in the panel (Figure-10).

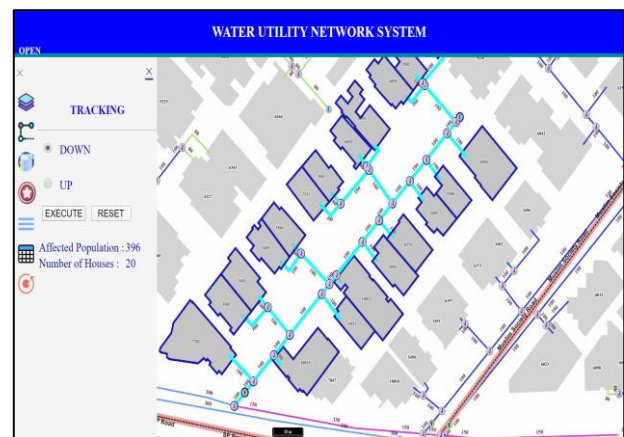


Figure-6: Downstream Tracing and Impact analysis

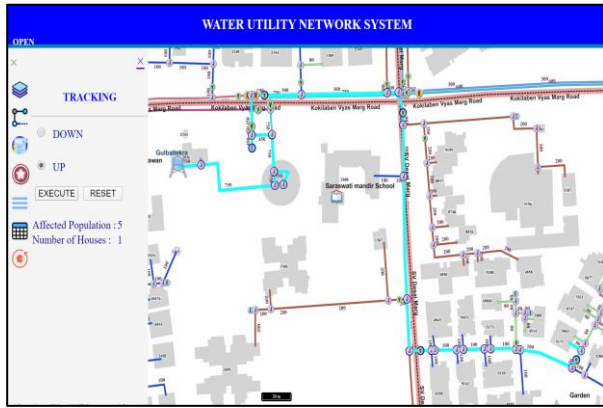


Figure-7: Upstream Tracing and Impact analysis

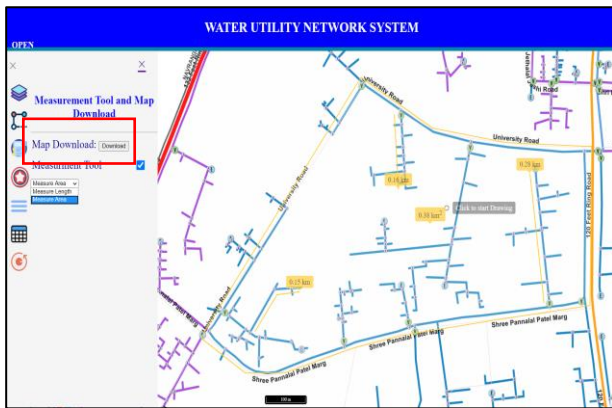


Figure-8: Measurement Tool

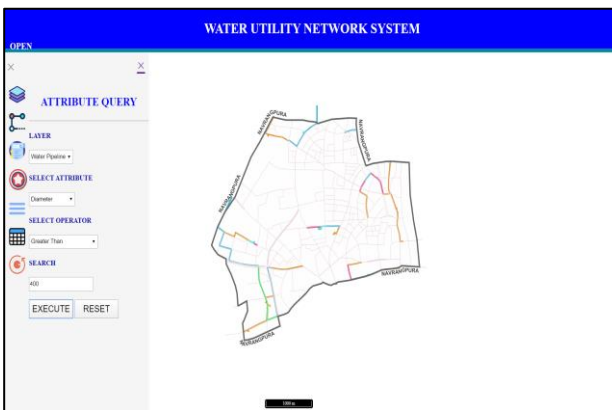


Figure-9: Attribute Query

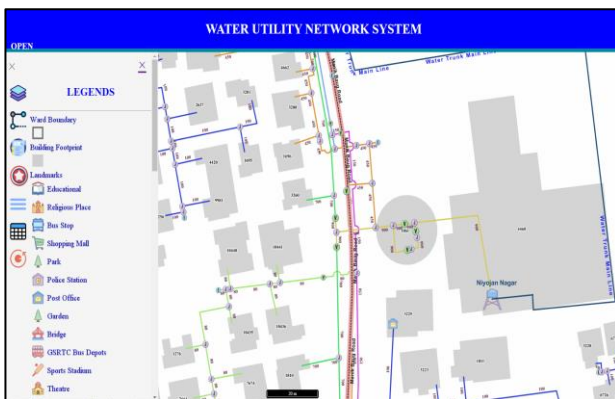


Figure-10: Legends

## V. CONCLUSION AND FUTURE SCOPE

Developed WebGIS application has been designed for visualization, analysis, querying and downloading map for water utility network of Navarangpura ward, Ahmedabad. The use of an adequate database management system allows for effective storage, management and retrieval of spatial data. User can query any layer on map with attribute data and can see results on map. With i-tool user can get non-spatial information about the selected layer feature. User can also get the information about how many properties and population affected when performing upstream and downstream tracing. User can measure length/area with helping of measurement tool. From this current study, it can be concluded that with use of GIS technology organization know their underground water pipeline and their assets accurate location and endless amount of information, it will help to reduce maintenance and operation cost at some extent and also it can save time and they can reduce the risk of injury and provides confidence the user especially when dealing with underground utility. With this information city planners could easily plan other underground utilities and develop infrastructure with information about current utility. The study has also show-cased the combination of free and open source technology and WebGIS for water utility of city. With use of web-based GIS system could be used by any user without installing any traditional desktop GIS software. Through the WebGIS-based application, one can access the spatial data on web and carry-out analysis work, even if the user does not have any prior GIS knowledge. GIS and various internet technology can effectively combine spatial information as a method of sharing freely, openly and easily.

The developed application is visualised and analyse for a water utility network and display nonspatial information of all layers. The network tracing functionality is also developed, but there is chance to enhance the capability of the system like, showing water usage information about area with the graphs. If any pipeline can rupture, the message will send to the property owner and the concerned organization. Organization also get the accurate location of the ruptured pipeline. It will also provide the shortest path with related water distribution station area to rupture pipeline location so that operation process takes less time to find the location of ruptured pipeline and also save time, save water and reduce cost of operation. With the location information, we can also get the depth information so that operation process is also become easy. The pressure information coming from the sensors can be placed on the pipelines. When the pressure gets down, the message will be sent to the concerned organizations to take actions accordingly.

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