THE BENEFITS AND POTENTIAL IMPLEMENTATION PROBLEMS OF GIS IN THE WATER DISTRIBUTION SERVICES OF MUNICIPALITIES

CASE STUDY: THE KIRKUK WATER DIRECTORATE

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Title of the Thesis: **The Benefits and Potential Implementation Problems of GIS in the Water Distribution Services of Municipalities**
Case Study: The KIRKUK Water Directorate

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by rules and conduct, I have fully cited and referenced all material results that are not original to this work.

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ABSTRACT

The Benefits and Potential Implementation Problems of GIS

in The Water Distribution Services of Municipalities

Case Study: The KIRKUK Water Directorate

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A potential implementation of geographic information systems (GIS) in Kirkuk Water Directorate is evaluated at a preliminary level. Selected literature has been surveyed and it is perceived that there are municipalities of smaller, bigger and same sizes which have successfully setup GIS in their water distribution departments for asset management, real time monitoring and hydraulic modeling in there services . Such works report success stories in managing their network as well as pinpointing malfunctioning segments due to problems such as leak, blowout or broken pumps.

This research targeted to reveal potential problems that Kirkuk Water Directorate can face while transforming paper based records into digital environment for a prospective GIS. While the literature survey has provided reports of successful applications, any potential problem that Kirkuk Water Directorate can face could be only inferred from them. Hence, to experience GIS software and data preparation, a GIS course has been followed by the researcher. The researcher has also contacted key informants who have actively worked in Ankara's water distribution department during the rehabilitation of its GIS. By this way, potential problems could be identified.

Investigations have been done over sample files of map sheets shared by the Kirkuk Water Directorate and it is seen that potential problems can be solved by a data operator who has attended a basic GIS course.

Both the literature and investigation results show that preparing spatial and non-spatial databases of assets is the start of a productive GIS. Before increasing data quality, building a hydraulic model is almost impossible and setting up a real time monitoring system is quite difficult.

It is also found that organizational changes such as in business rules could be necessary as frequent field trips will be needed with the GIS staff to check assets in use.

It is expected that this research will be beneficial for the municipality of Kirkuk to manage resources in implementing GIS for it is anticipated to start financial feasibility works under this topic.

Keywords: GIS, water distribution network, Kirkuk Water Directorate, potential problems, asset management, real time monitoring, hydraulic model.

ÖZ

CBS'nin Belediyelerin Su Dağıtım Hizmetlerinde Yararları ve Hayata Geçirilmelerinde Karşılasılması Olası Sorunlar

Örnek Konu: Kerkük Su Müdüriyesi

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Kerkük Su Müdüriyesi'nde muhtemel bir coğrafi bilgi sistemlerinin (CBS) kurulması, giriş seviyesinde incelendi. Literatürdeki seçme kaynaklar incelendi ve Kerkük'ten daha küçük, daha büyük ve Kerkük'le aynı büyüklükte belediyelerin, su dağıtım bölümlerinde başarılı CBS kurulumları öğrenildi. Bu sistemler, su şebekelerinin varlıklarının yönetiminde, ağı gerçek zamanlı izlemede ve hidrolik modellemelerde kullanılmaktadır. İşlenen çalışmalar, su dağıtım ağının yönetimi dışında, sızdırma, patlama ve bozuk pompa gibi sıkıntılardan kaynaklanan sorunlu parçaların tesbiti hakkında başarı raporları vermiştir.

Bu araştırma, Kerkük Su Müdüriyesi'nin, CBS için, kağıt tabanlı kayıtların sayısal ortama aktarılmasındaki olası sorunları ortaya çıkartmayı hedeflemiştir. Literatür taraması başarılı uygulamaları raporlasa da bunlardan Kerkük Su Müdüriyesi'nin olası sorunları ancak dolaylı yoldan ortaya çıkartılmıştır. Araştırmacı, CBS yazılımı ve veri hazırlanması deneyimi için bir CBS kursuna katılmıştır. Aynı zamanda, Ankara'nın su dağıtım bölümünde, CBS iyileştirilmesinde etkin görev almış deneyimli personelden bilgi alınmıştır. Bu sayede, olası sorunlar belirlenmiştir.

Kerkük Su Müdüriyesi tarafından paylaşılan paftalar üzerinde yapılan incelemeler göstermiştir ki temel bir CBS kursu alan bir veri çalışanı, olası sorunları çözebilir.

Literatür ve incelemelerin sonuçları gösteriyor ki şebeke varlıklarının mekansal ve mekansal olmayan özniteliklerinin veritabanlarının olusturulması, üretken bir CBS için olması gereken bir başlangıçtır. Veri kalitesini yükseltmeden, bir hidrolik model yapılması neredeyse olanaksız, aynı şekilde, gerçek zamanlı izleme sistemlerini kurmak da oldukça zordur.

Bir başka bulgu da belirtmiştir ki kurumsal, örneğin iş kurallarında gibi, değişikliklerin yer alması olasıdır çünkü, CBS çalışanlarının yerinde gözlem için sık sık arazi çalışması gerekecektir.

Bu çalışmanın, Kerkük Belediyesi'ne, CBS kurulması için kaynak yönetiminde faydalı olması umulmaktadır çünkü bu konu altında mali fizibilite çalışmaları başlatılması beklenmektedir.

Anahtar sözcükler: CBS, su dağıtım ağı, Kerkük Su Müdüriyesi, olası sorunlar, varlık işletmesi, gerçek zamanlı takip, hidrolik model.

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CHAPTER 1

INTRODUCTION

1.1. Introduction

Geographic information systems (GIS) are employed in many disciplines, related to city planning, including water resources engineering, environmental science, and water distribution network planning section 1.2.1.

Such systems are helpful while engineering planning, design, management of water resources are conducted in municipalities.

GIS analysis functions and linked mathematical models provide extensive capabilities to examine alternative plans and designs; and GIS is a comprehensive tool that provides a medium for integrating all phases of water resources engineering planning and design; those phases may include not only planning from scratch but also rehabilitating an already established network as in Kirkuk, Iraq.

Transforming a paper based management system into a digital environment requires systematic project management in the organizations including organizational, people and technological dimensions [1]; hence, such a transformation may have problems in those dimensions. This thesis addresses potential technical problems that a municipality can face in GIS setup.

The following section gives a quick background on GIS and Kirkuk. The scope and the purpose of the study are in sections 1.3 and 1.4, respectively. The research target hence questions are given in section 1.5; and this chapter concludes with the thesis structure outlined in section 1.6.

1.2. Background

By using GIS, the users can present information in the form of maps and feature symbols. As we mention in section 2.1, GIS integrates databases containing attribute data on the features. Just by looking at a map or by performing few analyses, a trained user can obtain information about where geographic features are, what they are, and how they are related to each other. A GIS can also provide tabular reports on the map features e.g. create lists of all features connected in a water distribution network and support simulations of water flows in the network, travel time and dispersal of pollutants section 2.8.4.3.

GIS provides a means to collect and archive data on the environment. Measurements in a location, distance, and flow by various devices are typically handled in digital formats and quickly integrated into a spatial database. Data processing, synthesis, and modeling activities can be performed based on these data sets by using the GIS, and analysis results can be archived. Hence, GIS spatial and attribute databases can be used to generate reports and maps, often interactively, to support decision making on which design alternatives are more suitable. As a natural consequence, such information can be shared in public forums on the web when the data relate to the public concerns; by this way, citizens concerned with planning and design choices can understand better the activities of the municipalities and they can participate in decisions i.e. they can be more involved as a sense of governance.

1.2.1. GIS in water distribution networks

Planning and design in water resources engineering typically involve the use of maps at various scales and the development of documents in map formats. A GIS can be utilized to manage these data sets. It provides a comprehensive means for handling the data that could be harder to accomplish, manually. Data sets of larger sizes require computerized systems; in case spatial data is a component then a GIS may manage geographic features having a location, associated attributes, and relationships among them. Additionally, a typical GIS can provide a means of capturing, browsing and archiving such data, and producing thematic maps in color-coded formats. This data-review capability supports quality control, as errors or ambiguities can be easier to identify. Additionally, through visualization, the user can gain a better understanding of patterns and trends in the data; such pattern recognition may be hard or impossible if the data is only in tabular format without any integrated physical drawing with coordinates i.e. non-spatial format. One can argue that a CAD software may handle geographic features as drawings and a non-spatial database can store attribute data; however, a combination of such software may be insufficient to reveal patterns because a CAD software only keeps the geographic locations and shapes; and a text database only keeps attribute data; the user needs a means in which both capabilities present and are running together. This distinction is discussed in sections 2.5 and 2.6.

A typical GIS is expected to provide analysis capability, as well. Its database can feed a separate database and provide input to various modeling procedures to generate derived products.

In this thesis, we are interested in studying GIS applications in water distribution networks in the municipalities with the motivation of perceiving important and increasing use of GIS in the management and operation of water distribution networks to the fact that such systems deal with spatial data, as well as ease of integration with data from other sources such as CAD (AutoCAD), hydraulic models and SCADA.

As Kirkuk is within the scope of the study, following is to inform the audience about the city and its municipality.

1.2.2. Kirkuk

The city of Kirkuk is located at north of Iraq in the Kirkuk State Figure 1.1.
Kirkuk city centre coordinates are 35.46 (35 degree, 27 minutes) North and 44.38 (44 degree, 33 minutes) East. The city extends 14km North-South and 11 km East-West directions. It is surrounded from the north and north-east and north-western mountain of Mount Por.
The city is at 300m above the sea level and has a surface area of 103 km^2. Apart from the city center, the districts of Dubiz, Hawijah and Daquq are populated centers.
The estimated population of Kirkuk is 1,395,614 as of 2011 [2].

Figure 1.1 Middle-East Region, Iraq and Kirkuk

The Kirkuk Water Directorate (Su Müdüriyesi) of Kirkuk Municipality is responsible of the water distribution service in the city.

This department is assigned to prepare the annual plans for the implementation of projects of water such as planned new central processing establishments, installation of water pipes, valves and so on and to rehabilitate the network within the investment and operational budgets.

There are 250,000 registered water consumers as clients, however, it is estimated that around 10,000 additional water consumers exist without any registration.

The main source of water to the city of Kirkuk is the Dubiz dam Figure 1.4, built on the Zap River. Water gathered at the dam is channeled Figure 1.3 to the Kirkuk water treatment plant Figure 1.2b after which it is brought to the four main sedimentation basin, underground reservoirs; an example to these reservoirs is shown on Figure 1.5. Basically, the populated areas are fed with this water for drinking and household usage.

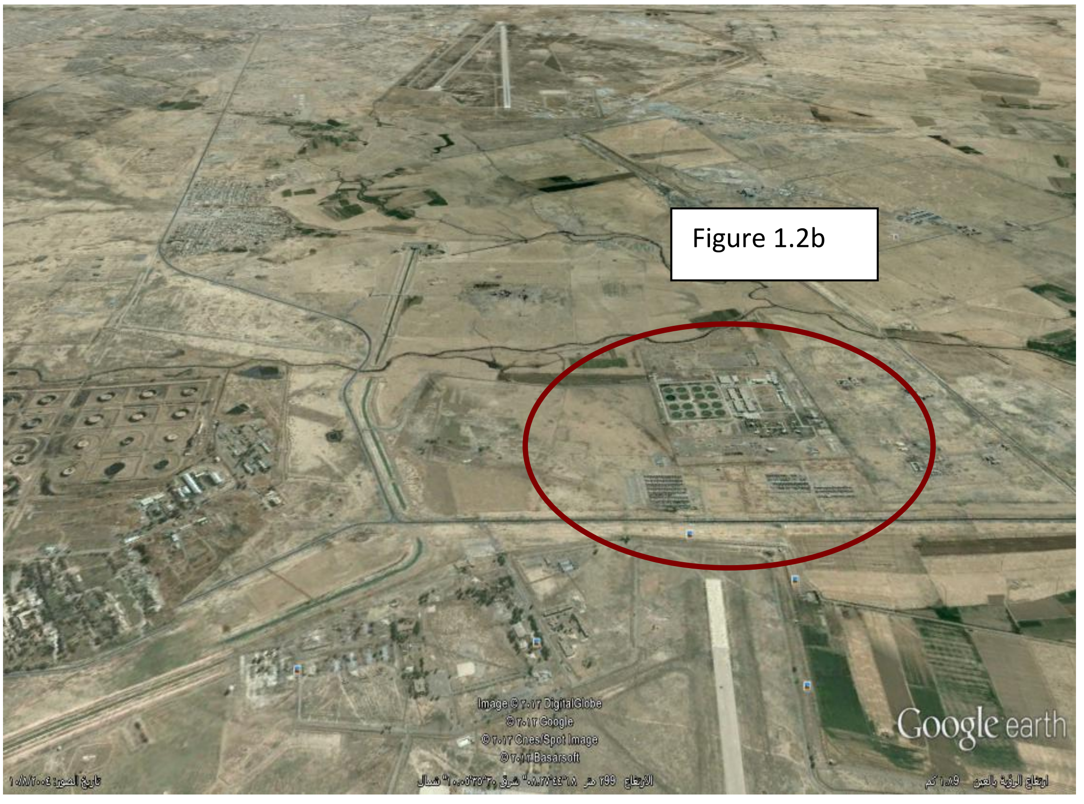


Figure1.2 .a Kirkuk water treatment plant

Figure 1.2. b Kirkuk water treatment plant closer view

Figure 1.3 Kirkuk water channel

Figure 1.4 Dubiz Dam on the Zap River

Figure 1.5 An underground Reservoir

1.3. Scope

As a case study we have chosen the Kirkuk Water Directorate in a municipality which aims to implement GIS at the time of writing this thesis; our motivation is further explained in section 3.1. Similar in exemplar cities, the Kirkuk Water Directorate goal is to switch its current paper based activities to a more digitized medium.

The scope of the study includes potential problems that Kirkuk may face during the implementation of GIS in water distribution network applications in asset management, predicting risky pipe segments, valves, tanks and pumps vulnerable to mal-functionalities and real time monitoring of the network; and how to overcome such problems.

1.4. Purpose

The author aims to prove that successful GISs can be installed in the Kirkuk Water Directorate, Kirkuk municipality.

This will hopefully facilitate and untangle water distribution activities such as tracking the history of pipes, archiving paths, managing client data and obtaining regular reports in the city. However, this implementation will face problems; hence itemizing such problems have become a natural and a consecutive purpose of this study. Apparently, highlighting those problems as a list and proving that all of them can be solvable is a part of the purpose of this thesis.

1.5 Research questions

In the light of sections 1.3 and 1.4, following research questions are addressed in this thesis.

(1) Can Kirkuk set up a successful GIS for its water distribution system?

(2) What problems will the municipalities face during the transformation from its current paper based system to a digital environment?

(3) Is it possible to solve those problems, practically?

1.6 Thesis outline

The thesis is organized as follows:

This chapter introduces the thesis both in purpose and scope of the audience. The reader is aimed to understand the research targets of the study after completing this chapter.

Second chapter provides a body of knowledge of GIS, its application in the municipalities mainly focusing on applications for water distribution.

Third chapter explains the research method by describing research procedures in each phase of the study.

The fourth chapter presents itemized problems that can be encountered potentially while passing to GIS environment and how to overcome them.

Fifth chapter gives the limitations, further research avenues and conclusion of this study. This chapter is the last chapter of this thesis.

CHAPTER 2

LITRERATURE REVIEW

This chapter aims to present selected works on GIS applications already reported in the literature.

For the reader can follow the content it is necessary to give definitions of GIS, CAD, vector, raster, spatial and non-spatial data; hence, the following section provides information on fundamental terms.

2.1. Basic definitions

A typical GIS usually requires following key components to work together: network, hardware, software, data, people, and procedures.

A successful GIS is expected to integrate these components for an effective use of geographic information, and develop [3].

A computer network is an infrastructure that interconnects two or more computers or other devices for resource sharing and parallel computation. It refers to the terms, local-area networks (LANs), wide-area networks (WANs), and the Internet [8]. These networks are fundamental components of GIS, with their ability to enhance the accessibility and reusability of geo-referenced data and analysis tools [8].

Hardware are devices that the user interacts with directly/indirectly in carrying out the operations in GIS. A hardware component is a technical equipment needed to run GIS; for example, to input data, scanner, digitizer board and GPS, and to have output, printer and plotter are used.

Software provide tools for the input, manipulate and output as geographic data. The software also provides functions to store, query and display data. There is a remarkable market in the industry to provide GIS software; popular examples are MapInfo of Pitney Bowes and ARCGIS of ESRI.

To manage the attribute data the user can use separate database software such as MS Access or Oracle, and match these non-spatial data sets in the tables with the geographic features kept in GIS software by the help of geographical location identifiers.

The GIS technology has limited value if no individuals manages the system and creates plans to apply to the problems of reality. Hence, a variety of users ranging from data operators to technical specialists, who design and develop the system are among the performers.

The most important component of GIS is data as spatial data and text data i.e. non-spatial data. GIS may integrate spatial data with other data resource using DBMS for further organization and data management through, such as, normalization and query optimization.

Finally, application component includes how data is to be retrieved, input into system, stored, managed, transformed, analyzed, and finally presented as output.

CAD (Computer aided design or drafting): it is using software and hardware to design and create virtual models of products [6]. Basically, a CAD is employed by engineers to design their models and prototypes. CAD was originally developed to assist people with technical drawing and drafting, however, it has been expanded to include geographical mapping and associated activities such as rendering 3D topographic views and cross-section illustrations.

Spatial data: any data that has a geographic location. This type of data describes location of geographic features so that they can be mapped on the view. Spatial data is stored and presented in the form of maps; basically, there are of two types as raster and vector.

Raster data: Basically, raster data sets are cellular based data structures composed of rows and columns for storing image unites called cells or pixels. The most common examples are satellite images and scanned images. This type of data consists of a matrix of pixels organized into rows and columns, a grid structure [4]. Each pixel is assigned a value, usually an integer between 0-255, to represent cell-based data such as aerial and satellite imagery. Because the usage include terrain analysis GIS may be confused system that manipulate raster data. A GIS may use raster data however, remote sensing software is specialized to handle and manipulate raster images.

Vector data bear a coordinate based data structure commonly used to represent geographic features as points, lines, polylines and polygons which correspond to map features such as landmarks, roads and parcels [4].

Non-spatial data: additional information about each spatial feature. They are usually presented in tabular format. Such data can be of Boolean, text, date or numeric type.

Layer: In order to better organize geographical data in a region, data that describe similar themes are stored separately. The descriptions for each would be stored in different files, and these are referred as layers. A typical GIS stores information such as road network, as thematic layers linked to each other by geography, for example, a standard topographic map sheet shows contours, road networks, stream networks, power lines, forested areas, buildings, and landmarks [9]

GIS databases can be described as series of map layers that are geographically referenced and registered into a common map projection system. Most GIS organize data by layers, each of which contains a theme of map information that is logically related by its location.

Each of these separate thematic maps is referred to as a layer, coverage, or level and each layer is precisely overlaid on the others so that every location is matched to its corresponding locations on all the other maps. For this precision, all the geographic features should be registered to represent their locations on the Earth.

Obviously, there are more than one map projection and coordinate systems. The data operator/analyst may have different data layers, for example, road network, water drainage system and topography of an area all in the correct coordinate registration but in different map projection/coordinate systems. Once those features are imported, a typical GIS is expected to bring all of them and overlay them as data layers; this feature is called automatic coordinate conversion and on the fly map projection.

A GIS provides advanced process to manage information with a geographic component primarily stored in vector form with associated attributes.

Another important aspect of a GIS as given in [5] is the capability of dealing with spatial data. With the increasing expectation from the information system, integration of images with vector data becomes a necessity for a full-featured GIS system. To make map making easy, a GIS should include a variety of standard map components that can be readily added to a layout. In addition to is the association of attributes with elements and the ability to select elements and view their attributes and to use attributes to select elements.

Information in a GIS describes entities that have a physical location referring to spatial region, while queries involve identifying these entities based on their spatial and temporal attributes and relationships between these entities where the authors refer geographic features as entities [4].

Additionally, manipulating and analyzing data referenced to a specific geographic location are among the key capabilities of a GIS.

GIS are defined in a numbers of ways, for example, in [10] GIS is defined as a computer system to capture, storage, manipulate, analyze geographically referenced information and displaying of maps, tables and charts. In the other words GIS is a powerful system tool in mapping and analysis of spatial data, hence it can defined as database management system technology integrated common database operation such as query, statistical analysis and visualization.

2.2. GIS tasks

Before you can use geographical data in a GIS, you should convert the data into digital format. This conversion process is called digitizing.

Digitizing includes registration of aerial photograph or scanning a paper based drawings such as cadastral drawing or elevation contours and creating vector data from them on the screen or on the digitizing board.

A modern GIS can handle some scanning jobs automatically for large projects; however, small businesses may require manual conversion in all the phases. In modern times, most types of data can be obtained as digital format from its source; in such cases, GIS can easily import them.

Similar to other information systems, data imported to GIS must be cleaned i.e. it should be accurate, precise and coordinates should be registered. For this reason, scanning a topographical map does not mean that your GIS is ready for a topographic analysis. Basically, the scanned document will be used as a guiding picture so that the data operator can generate vector data by using it. While generating vector data, spatial relationships between connecting or adjacent vector features, points, polylines and polygons, are constructed i.e. the topology [7]. Apparently, the map should be registered before the generation of the vector data. This registration task is actually pinpointing and marking real world coordinates to adjust the map Figure 2.1.

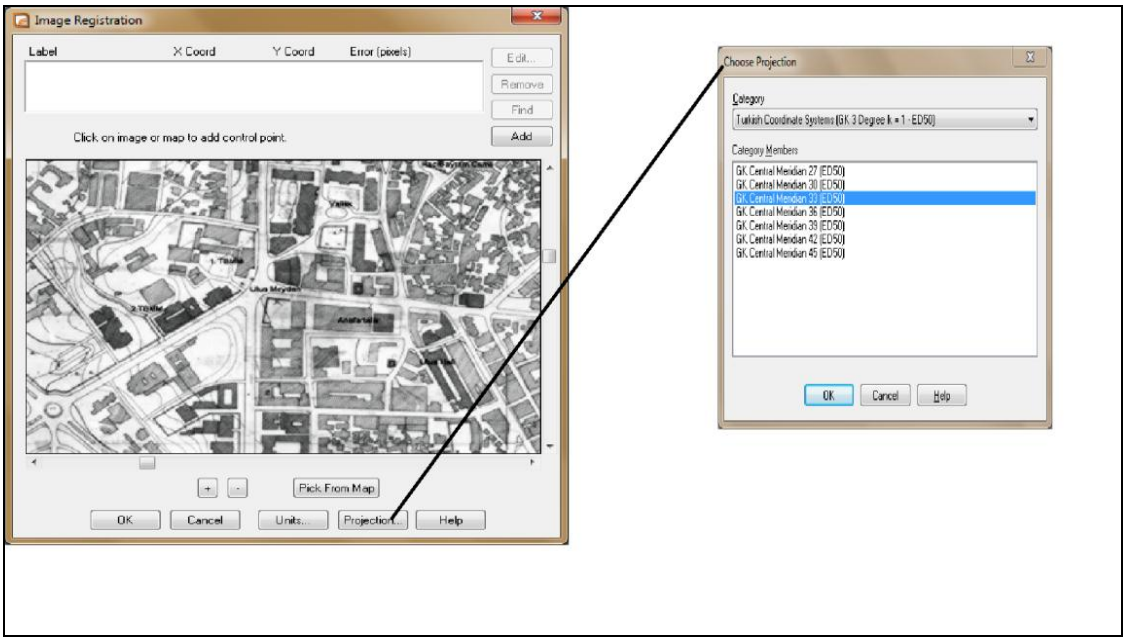


Figure 2.1.a Importing the image and choosing map projection system

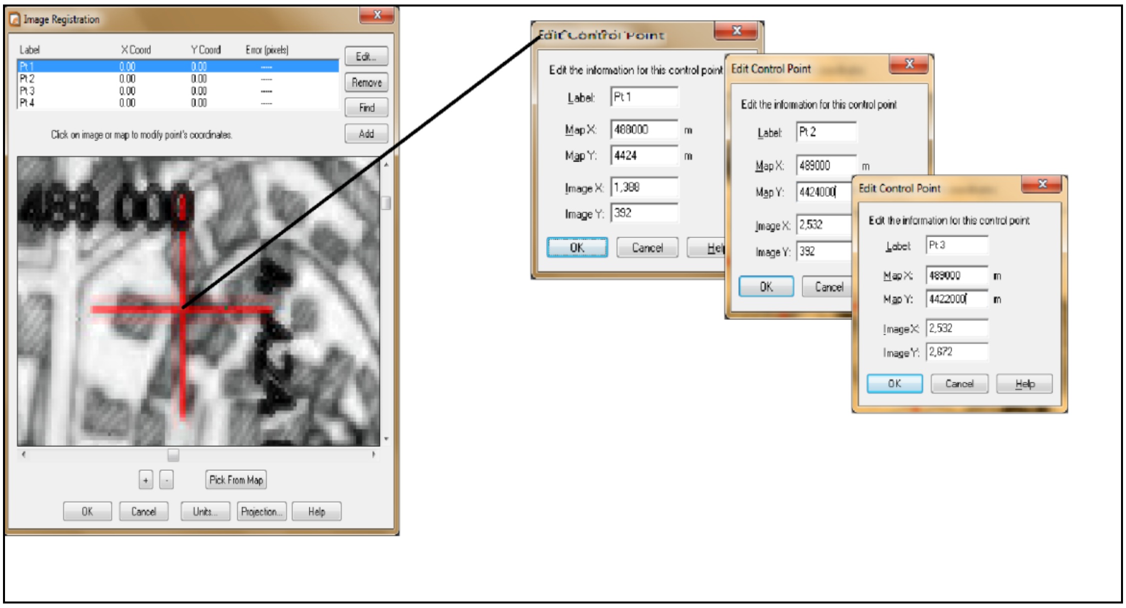


Figure 2.1.b Indicating control points

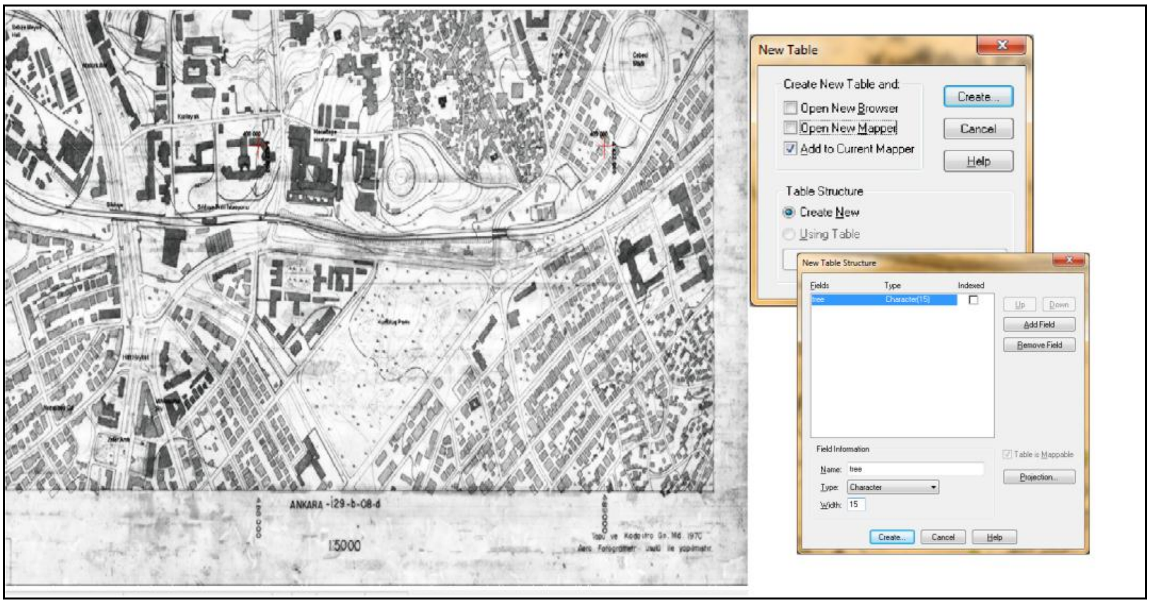


Figure 2.1.c Adding the image as a new layer to the map and creating a new layer for geographic data entry

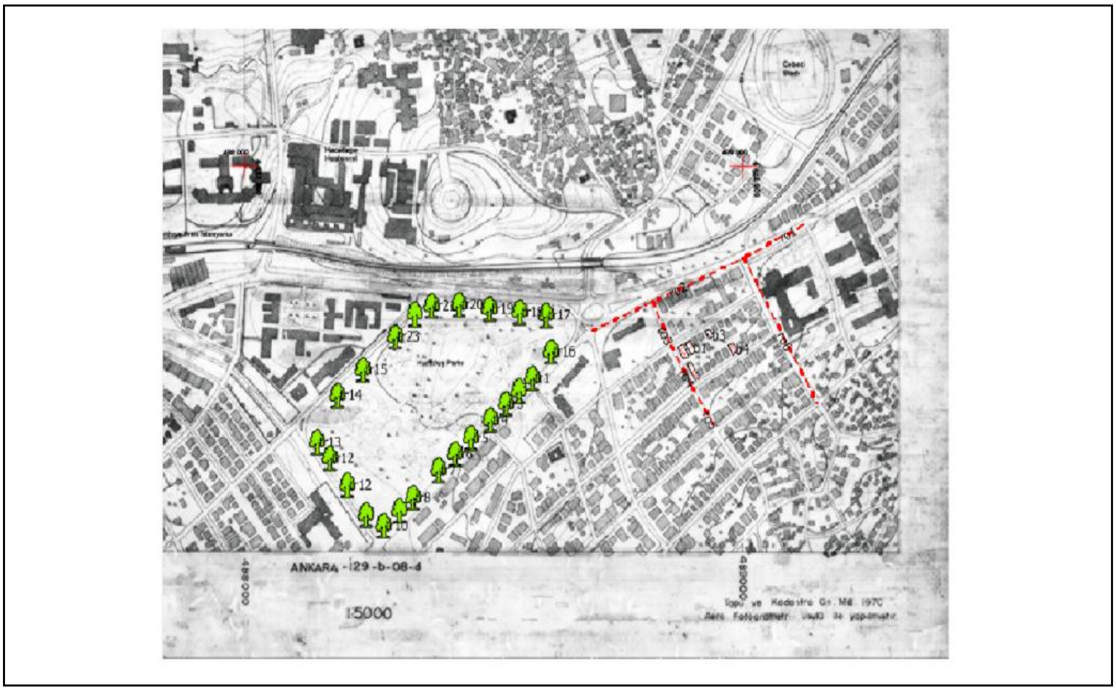


Figure 2.1.d Overlay view

Figure 2.1 Image registration

2.3 Database Management

As we have already mentioned, the user may keep non-spatial dataset in a separate database and connect it to GIS software. In small systems it can be sufficient to store such data only in GIS software as well; however, the systems designers may prefer to employ a DBMS to store, organize and manage data when there is large volume of data, and large number of users.

A GIS must provide tools for finding specific features based on their location or attributes. Queries, which are often created as logical statements or expressions such as SQL, are used to select features on the map and their records in the database.

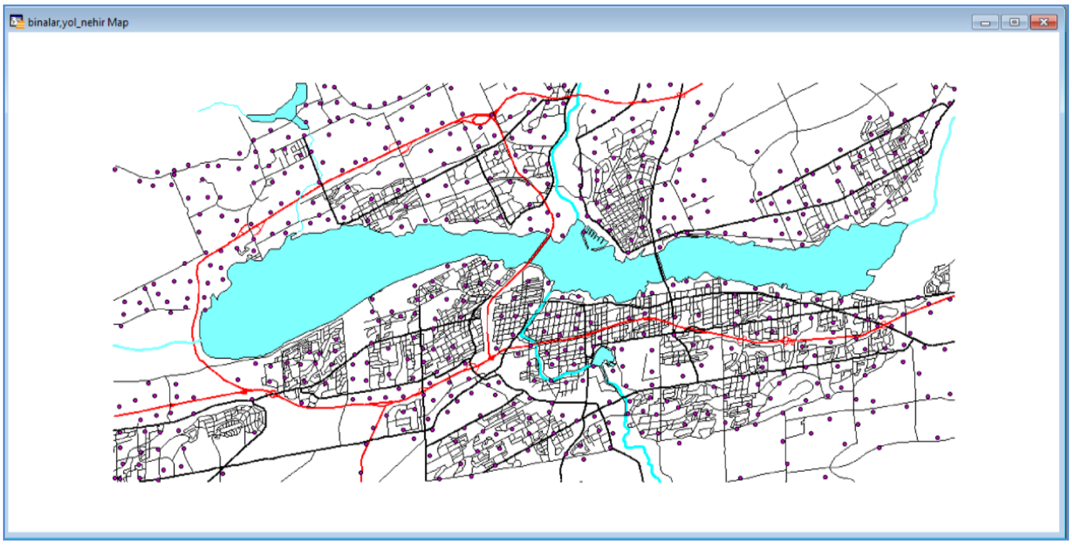
Typical questions are as the following examples. Measurements (distances, and angles - trends, and spaces), location (where is the city X), and the condition (which cities have population bigger than 100,000) and change (what change in population has happened in the city X since 1980), and the distribution pattern (what the relationship between population distribution and the areas where water exist), and the most appropriate way (what the most appropriate route between the cities X and Y), and scenarios (what happens if the number of residents of the city X migrate to neighboring cities).

Geographic analyses usually involve more than one geographic datasets and require working through a series of steps i.e. they do not appear in a single click. For this reason, a GIS must be able to analyze the spatial relationships among multiple datasets to answer above questions hence help to solve problems.

There are many types of geographic analyses, however, two common types are proximity and overlay analyses.

Proximity analysis is about using the distance between features to answer questions such as how far hospital A from nursing home B.

GIS technology often uses a process called buffering to determine proximity relationships between features; for example which buildings and roads are within a one kilometer proximity of the lake? A buffer of a kilometer is created on the perimeter of the lake to find those features Figure 2.2.



a) Before buffering

b) After buffering

Figure 2.2 Buffer analysis

Overlay analysis (spatial join) is used to integrate different data layers. This may be done to show different data layers on a single map view and/or to perform analyses in which data from different map layers are required concurrently. Usually, analytical operations require one or more data layers to be joined, physically. Overlay analysis could be used to integrate various data on such as soil, slope, vegetation, land ownership or tax assessment.

Example In Figure 2.3, shows that a successful overlay analysis can help to view water pipes with land parcels on a single map which is a relatively harder task to perform by looking those datasets, separately.

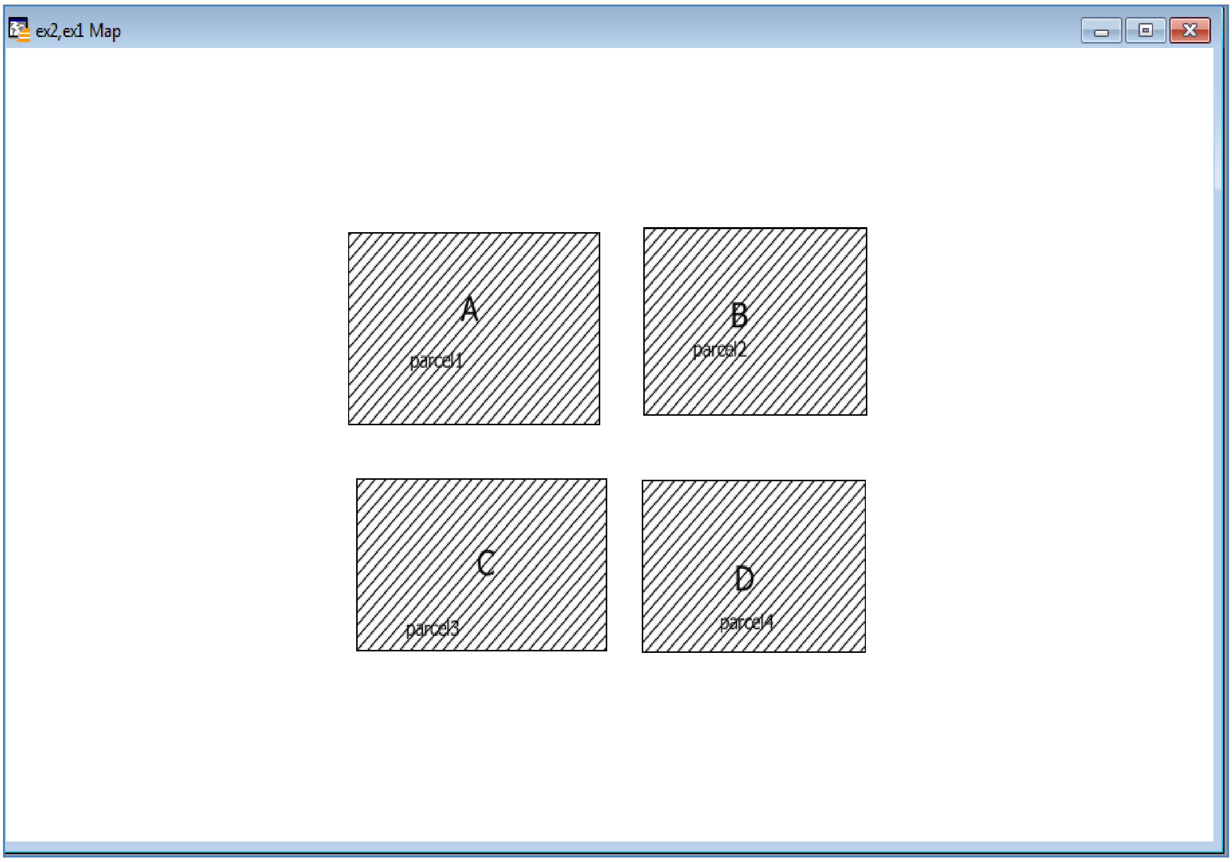


Figure 2.3.a Land parcel map

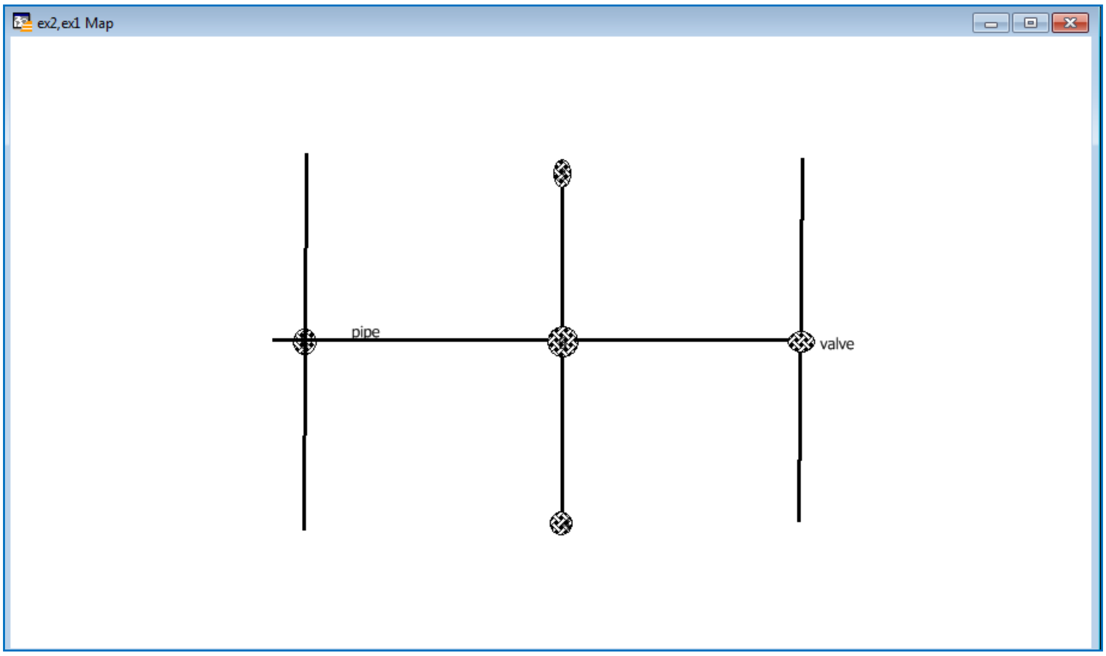


Figure 2.3.b water pipes and valves

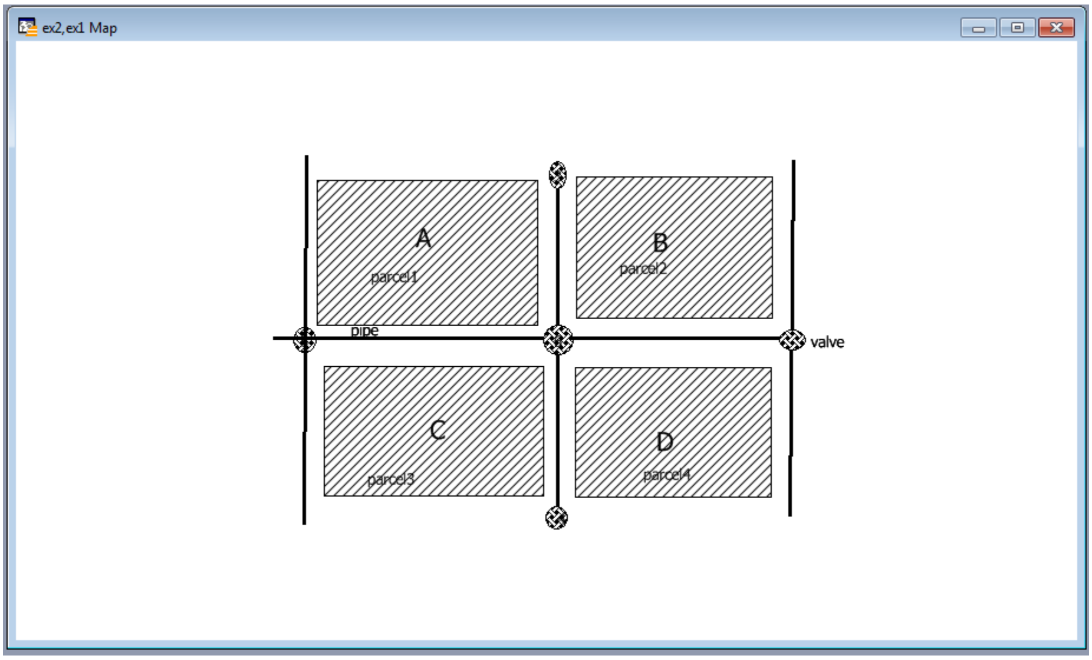


Figure 2.3.c Overlay

Figure 2.3 Overlaid view of two maps

With GIS analysis, enhanced visualization may and usually reduce complexity and help to focus on the selected key features.

2.4 GIS Data

As the name implies, geographic data are data about geographic features, including their location, shapes, and descriptions, as we have already defined spatial and non-spatial data in section 2.1.

It is a requirement that the user should grasp the vital link between those two types of data which makes the strength of such systems [5], [9], hence basic difference between GIS_CAD and GIS_DBMS sections 2.5, 2.6. For example, water-wells may be represented as points on map; these points with coordinates are the spatial data component of those wells. Linked to each point, attributes such as the owner's name and license number and depth of the well compose non-spatial data component. A successful GIS should associate those different types of data so that when the user chooses any of the wells, he should be able to see the attached attributes; similarly, he may choose to highlight the wells with a certain depth of he chooses and create a color coded map.

As instructed in [4] and [5], attributes do not have to be visible properties of the geographical features; for example, they can be data of, construction year of building, which is mapped for a cadastral purpose. Attribute data can be useful in carrying out spatial analysis which requires combined usage of the spatial information stored in the geometry of features with their attribute information. This property allows the user to study features and how they relate to each other. As seen in this example, attribute data sets keep track of information associated with coordinated data elements, such as a polygon's soil class, the road type of a line, or the identity of a point.

2.5 GIS and CAD

As a result of the nature of geographic data, representation and manipulation of such data requires computer aided drawing. For this reason, GIS may easily be confused with CAD software. However, with the support of what we have discussed in sections 2.3 and 2.4, GIS is expected to link attribute data with the spatial data components of geographic features. This property lacks in CAD programs as they focus of high ability of drawing of objects. GIS usually provides limited means of drawing map objects as well; however, digital outputs of popular CAD programs such as AutoCAD are strongly expected to be imported into GIS software.

As informed in [8] CAD software to draw features in the real world where drawing is the only information of the geographic objects which do not necessarily know about each other i.e. CAD may lack topological information. Hence, topology can be another difference between CAD and GIS.

2.6 GIS and DBMS

The abilities of GIS are different from other traditional information systems in that it integrates database operations and statistical analysis with the unique visualization on a map. A DBMS is a specialized system that handles not only the database activities but also functional requirements such as GUI designs, constraint definitions and physical design of the database as well as user restrictions. As a part of its capabilities it handles text based attributes in, for example, relational data model [40]. A DBMS is not expected to handle geographic relations among map objects. Recently ORACLE, IBM and Microsoft have deployed DBMS solution with models that can hold vector data, however, it is too early to say that such products have comprehensive GIS tools. GIS can benefit a separate DBMS to retrieve non-spatial data of the geographic features.

As we have already discussed in section 2.2, GIS can store topological properties through objects which are connected to each other into logical groups to model real world features e.g. a town along with the topography where it is situated.

2.7 A Supervisory Control and Data Acquisition (SCADA)

SCADA system is a distributed computerized system employed to remotely control and monitor the state of field-based assets such as pump stations, valves, treatment plants and reservoir tanks.

As we focus on the water distribution network more in this thesis, following list is limited to selected common objectives of SCADA systems used in water distribution and control [42]:

- Monitor the system to control its performance.
- Provide automation from a central location hence reduce operational staff by minimizing routine visits to remote sites.
- Record data of system hence and generate reports to regulatory agencies.
- Inform on the performance of the system consecutively to build asset management procedures.
- Provide a control system that will enable operating objectives to be set and achieved. Such system can easily provide alarm systems that pinpoint malfuntionalities/ overloading's to be diagnosed from a central point.

The SCADA communication network is dispersed throughout the water distribution system to monitor parameters such as tank levels and system pressure which are graphically shown on the monitors. The related data is collected through the sensors attached to the equipment such as water level in a tank, and the collected data is sent to a centre by radio signals. In this way, operators can view tracked processes. Real-time station flow, pump run times, pump starts/status such as running, failed, off, forced on/off, power status and generator status among are the tracked activities.

2.8 GIS applications in municipalities

The growing popularity of GIS applications is largely a response to the usefulness of the spatial and non-spatial data integration technology. For this reason, GIS has become one of the choices for solving geospatial-related problems. Outlined below is a description of selected GIS applications in municipalities.

2.8.1 Road traffic accidents (RTA)

GIS is useful technology while generating thematic maps and further analysis of RTA data; it can alleviate the problem of RTA through the employment of spatial and non-spatial data hence thematic mapping. An example is reported [11] from Kenya where GIS is employed to mark "black spots" and “accident spots”. In this way, appropriate geometrical highway design principles are suggested to reduce RTA occurrences. Safety measures for highways hence contemporary engineering design of new highways and improvement of existing ones are recommended with the integration of the digital terrain model data along with the already registered road network. Digital terrain models are created in CAD for they can be registered later in GIS for further analyses section 2.5. The GIS software is used to create data layers and spatial distributions at identified accident spots along with the types i.e. fatal, serious and slight injuries and time of the accidents.

Usage of GIS in RTA is a popular activity including analyzing urban traffic accidents [12], highlighting high risk geographical areas for road safety [15], suggesting candidate locations for pedestrian crossing [14], [16].

There are also local examples from turkey in which GIS has been employed to analyze RTA such as black spot [17], hazardous location [32] determination and Bursa traffic accident evaluation project [31] managing database in road maintenance engineering [20].

A working GIS in municipalities can help data sharing among different agencies such as ambulance services [18].

GIS vendors such as ESRI provide RTA specific solutions such as GIS-based traffic and incident management systems[19].

The capabilities to integrate data feeds and share dashboard views make GIS ideal for viewing a comprehensive picture of current traffic conditions. For example, traffic managers can visually monitor bottlenecks and related information to quickly respond to vehicle incidents. In addition, these views can be shared with the public over the web, giving drivers the latest information on road closures and current travel conditions.

2.8.2 Cadastre

Much of cadastral work is time consuming with repetitive similar routines for different jobs while procedure documents are created to provide a geometrical description of property formation. European countries are developing strategies to improve their land management with the help of cadastral management applications. Software vendor, such as ESRI, provides GIS technologies e.g. ArcCadastre [22] to quickly access and produce maps and for leveraging database information, and automating enterprise work processes. An exemplar case study from Sweden [41] reports success of a GIS automated work flow which has been modeled and carried out in GIS to improve accuracy and quality and to save labor, time, and money hence improving efficiency in the cadastre procedures.

In another example [22] a local government in Lithuania is reported to employ GIS for cadastre management to compute land appraisal. This comprehensive project includes multi-layer data including administrative boundaries, buildings' center points, address points, real property value zones, topographic objects, land use, standard map sheets, and aerial photos integrated with the text based data sets to calculate, for example, tax, so that the system became dynamic with the changing market valuation and tax legislation.

2.8.3 Waste planning and management

Choosing suitable disposal waste sites bearing environmental and public safety remains as a hot topic with continuous contribution to the literature such as by [25] at which the authors argue that GIS can provide a base to integrate field parameters with population and related data, in selection of suitable disposal sites. Determining waste disposal sites and their management are still challenging matters of the municipalities. As spatial data is required along with the money and human resources, GIS has been recognized as one of the approaches to automate the process of waste planning and management hence such systems can be used as a decision support tool for planning waste management.

A case study [23] informs about waste collection via GIS routing optimization in Nikea, Greece.

Basically, the application has minimized collection time of the bins, distance travelled and man-effort, hence financial and environmental costs. The applicators were able to integrate various spatial analysis methods, such as geostatistics, analytical hierarchy process, fuzzy logic modeling based on a GIS-based modeling approach.

Additional examples include [24] where a model is designed for a city for the purpose of planning waste management. The benefits of such a model are but not limited to reduce the waste management workload. As the analysts can overlay residential areas, roads and waste bins, the management can conduct proximity and optimal route analyses to supervise waste collector vehicles [22]. With the analyses of attributes such as recyclable waste bins, restriction of the roads, e.g. one way restriction, the management can consider to solve problems such as proper allocation and relocation of waste bins, check for unsuitability and proximity convenience due to waste bin to the users, proposal of recyclable waste bins for the required areas. Such activities can be achieved by applying the functions such as overlaying, applying buffer for proximity analysis or by applying SQL queries. Demographic maps can be overlaid to generate reports of statistics on waste generating areas; furthermore, more focused studies of waste can be performed e.g. domestic, industrial and commercial waste generating areas in the cities.

2.8.4 GIS application in water distribution networks

The role of GIS as a means for understanding and dealing with water and related resources management has been acknowledged as reported in the literature more than 30 years. With its technology of collecting and organizing the water related data and providing means to expose their spatial relationships it helps us to perform analysis to model and compile information and it provides a means for visualizing resource characteristics in decision support on resource management from small, such as in Niue [39] to highly urbanized areas in Seoul [27]. Among the uses of GIS in water management, leakage spotting and control, pressure and velocity of water and infrastructure mapping contribute to the municipalities. However, there are a lot of data sets to be completed and compiled before any hydraulic model and simulations section 2.8.4.3 can be done such as establishing spatial and non-spatial databases; such examples commonly report that establishing overlay between network spatial information and background cartography must be done as basic activities.

2.8.4.1 Asset management

A case study [39] from a small and remote area reports that creating a detailed digital plan of assets and storing them in database has been a good start for a simple outline of a pipe network. Utility assets data include pipe material, tank dimensions, pump power requirements, equipment costs, maintenance schedules, pressure and flow information, and water-quality.

One of the major problems is reported in collecting pipe data. Collection of spatial data can be done with GPS, digital cameras and scanners. As the pipes have been buried without reliable records, pipe-detection surveys have to be carried out. Later, these data are put into GIS using MapInfo software along with valves, boreholes, tanks, pumps, water meters and fire hydrants so that dwelling spots can be overlaid as separate GIS layers in digital environment.

Another example of design and asset management in water network [37] is on intermittent water distribution systems i.e. water networks that operate at intervals. Such networks are within our concerns as Kirkuk water distribution network is an intermittent water distribution system that supply water just in the evenings section1.2.2. Due to this broken pumping, severe supply pressure problems and inequities in the distribution of water occur.

As reported in [37], GIS can be used as an integrated tool in processing of spatial data and effective tool to help the engineers in the design and asset management of intermittent water distribution systems. However, network assets should be collected and organized for such an application as we have already mentioned. Later, the analysts can draw intelligent maps to answer everyday queries, such as display only pipes of greater than 100mm diameter or view those greater than 400mm diameter in blue, and those greater than 200mm diameter in red.

As seen in this example, GIS contains database structure that can be used to have selective views. However, this is considered as only the tip of the iceberg as statistical analysis, modeling and design on demand, integration with hydraulic model to obtain, for example, potential blowouts, low pressure zones, maintenance schedules, choice of the optimal layout of the new pipes with geographical locations in parallel to the city growth estimation of future demands are possible. By this way, engineers can improve logical decision making processes with the planned land uses of the local and central governments. In such implementations, further problems such as finding the shortest distance that can link the new users' locations and the existing network, hence drawing the shortest route in a network topology naturally appear.

The data type and source variety can naturally exist in municipalities. In such an environment, creating data sets of water mains can be from diverse digital information as in the example of a case study reported in [38].

The author informs that the data sets should be organized not only based on their origins but also for later usages. Such data sets may emerge from infrastructure, customer, spatial, network elements work plots or small inventory databases. The implementation becomes more sophisticated with the real time connections to the AM/FM systems.

2.8.4.2 Managing network through system integration

Managing pipeline network includes locating objects rapidly, querying information about physical and historical properties of the pipes, valves, pumps, reservoir tanks and running simulations to forecast material needed in accordance to the city planning. The municipalities should have the related data along with distribution of water pipe segments, distribution of valves so that the operators can take proactive measures against possible failures and prepare plans for the maintenance and further development of the network.

Before we resume visiting our literature review on the water network, we shall give brief information on EPANET, which is a computerized hydraulic model, commonly used with GIS in municipalities.

2.8.4.3 EPANET

EPANET is a computerized simulation model to predict dynamic hydraulic and water quality behavior within pressurized drinking water distribution system. It is an open source software of which the code is public from the Environmental Protection Agency of USA (EPA)'s website, http://www.epa.gov/nrmrl/wswrd/dw/epanet.html. EPANET runs under Windows O/S, and it is mainly used to obtain an integrated environment for editing network input data, run hydraulic and water quality simulations, and to have the results in a variety of formats which can be used as input to GIS.

According to its manual [43], operators can register pipes, nodes, pumps, valves and storage tanks to build models. The software can simulate flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of chemical materials. Additionally, water age and source tracing can be simulated. Results can be seen as outputs of color-coded maps, data tables, time series graphs, and contour plots. By this way, alternative management strategies for improving water quality and emergency procedures in case of a blowout, chemical injection can be simulated. Such simulations can include:

- Changing water sources within multiple source systems
- Altering schedules of pumping and tank filling/emptying
- Treatment activities, such as re-chlorination at storage tanks
- Targeted pipe cleaning and replacement

The hydraulic and water quality modeling features include:

- Computing head-loss due to friction, bends and fittings and calculating wall reaction rate coefficients to be correlated to pipe roughness
- Modeling constant or variable speed pumps hence energy and cost calculations
- Modeling various types of valves including shutoff, check, pressure regulating, and flow control valves
- Registering tanks of various shapes
- Modeling pressure-dependent flows for sprinkler heads
- Running for both simple tank level and timer controls
- Modeling movement of reactive and nonreactive material through the network over time e.g. a disinfection by-product or chlorine residual, and the age of water throughout the network
- Keeping track of the percent of flow from a given node reaching all other nodes
- Modeling reactions both in the bulk flow and at the pipe wall
- Simulating growth or decay reactions to proceed up to a limiting concentration
- Simulating concentration or mass inputs at any location in the network

2.8.4.4 Management of water loss

In the management of the water loss and leakage problems in the distribution networks, works such as [26] report successful methods for real-time leakage detection with the use of GIS along with SCADA systems section 2.7. Basically, the network is monitored at different points for real time and also flow rates and pressure at those points are recorded periodically. These data sets are input to GIS so that spatial distribution of the problems could be seen and, for example, value of pressure in the distribution system can be mapped thematically.

Common problems encountered in the municipal water networks include blowouts, uncontrolled pressure, leakage, off the record consumption and uncontrolled maintenance activities. For these reasons, many local governments are trying to establish digitized and real time models to monitor their water infrastructure. Following examples are reported to the literature as selected works. Additionally, case studies visited in this section show that GIS is useful in the pipeline network management which introduce integration of GIS of water supply pipeline network and hydraulic model which can help to simulate the whole system and analyze the condition of pipeline network.

A study on detecting and/or predicting water main burst in Seoul [27] informs that analyses of old pipes have been done along with installation year, type of the material, length and diameter of the pipes. The study finds that the major reason of such blowout was due to the inefficiency in design and management of the network. The municipality decided to develop a GIS-based management system to monitor old pipes and design alternative network so that the operators can keep the track of pipe type/material or installation year to estimate replacement time.

In another example [30], the author reports how a pipe blowout model can help the operators to control pressure and highlight potential pipe segments bearing risk of blowout.

For such a model, huge amount of pipe blowout data of the past several years and hydraulic model have been used in conjunction; additionally, pipe length, material and pipe diameter of every segment of water pipe, water direction of conjoint valves are input. By this way, the condition of pressure dynamic has been integrated with the historical data in GIS environment. As a result, the system controls the pressure to ease water pipe loads to prevent the dangerous pipe segment to blowout. Additionally, the analysts can forecast the pipe blowout accidents to increase security of water pipes. After the input of these data sets, the operators create thematic maps to classify pipeline network into safety grades as low dangerous grade, dangerous grade, high dangerous grade and extreme dangerous grade.

This example shows how a hydraulic model can be integrated into GIS to simulate the whole system and analyze the condition of pipeline network.

After the system setup, operators can perform spatial position analyses, mathematical models, optimal path analyses, and correlating relation of topology and pipeline network accidents. By this way, dangerous pipe segment in the network can be pinpointed and extra attention can be given for pressure.

2.8.4.5 Modeling and monitoring

Running simple queries such as choosing a segment of water pipe on the digital map, and let the system to calculate the data of user, such as water consumption and pressure and view them thematically on the screen are possible.

As seen on this previous example, employing GIS along with hydraulic models are among the applications in the water infrastructure management of local governments. A popular example in hydraulic modeling is EPANET section 2.8.4.3.

Being public and open source, EPANET is an extensively used software in hydraulic modeling; for example, a water supply pipe network model in Fangcun District of Guangzhou is developed based on GIS technology and EPANET pipe network model [28]. In this work, the authors report that the water distribution network is simplified by the help of ArcGIS of ESRI. Basically, small pipes have been omitted in the calculations in order to establish the network calculation diagram that can reflect actual hydraulic state while assuring calculation speed of network hydraulic model. To achieve this simplification, physical properties of the pipes including length, pipe diameter and roughness coefficients are introduced to the system similar to [27].

Statistics in water consumption data and water supply data are performed by the help the data supplied by SCADA from the monitoring nodes [28]. With this platform, it became easier to overlay client data kept as spreadsheet as geographic location and link these spatial data sets to postal code information.

Software such as Water Utilities [35] can be synchronized with SCADA to monitor transactions throughout the system and perform analysis and control procedures. Such integrations are used in real-time leakage detection through the pressure and flow rate analyses. These data sets can be sent to other systems for further hydraulic analyses and determination of the size and location of the leakage in the network such as in [26].

Another use of such systems is the determination of water consumption through statistical analyses of the water supply data e.g. [28].

System integrations e.g. GIS+SCADA+EPANET provide the analysts to draw emergency scenarios as well. For instance, an attack, targeting critical infrastructure of water distribution that aims to inject poisonous material to the network can create panic and cause public wide harm. In case such an event occurs, the management should know the spreading pattern as well as the speed of the water in the network and determine the risk areas of the pollution. An exemplar work [36] presents an integration of EPANET and ArcView to create Pipeline Net system in the Salt Lake City, UT. The Pipeline Net model permits the user to model the flow and concentration of biological or chemical agents within municipal water system. With the help of the model, the analysts can simulate the propagation of the pollution and estimate the population at risk due of contaminants. The system graphically maps, calculates and locates the population at risk.

Basically, the hydraulic model, EPANET, routes the pollution through the system under extended period simulation, results of the simulation are viewed within ArcView. Additionally, US Census Population database provides population data as another layer to provide a combined view. By this way, area of interest, feature and population at risk can be selected and displayed. Consequently, the integrated model provides a powerful tool for routine planning and emergency response while giving emergency managers real time information for estimating the risks to public water supplies and population at risk.

2.8.4.6 Maintenance

Similar to many products, water network assets are getting worn-out due to material deterioration. For this reason, it is essential to find pipe segments, valves and pumps bearing high risk of mal-functionality or breaking down before any damage occurs. Usually, the maintenance activities carried out if, for example, there is a blowout or a pump running queerly.

Taking precautions and generating proactive solutions along with cost analysis is an essential part of the management in the water distribution. In [33], the authors investigate replacement versus maintenance of water supply assets through a case study based on asset performance.

As we have discussed in section 2.8.4.1, preparing an accurate inventory of the network should be one of the starting items of the management. For this, creating a geodatabase to determine costs of asset replacement is necessary as to know the locations of the assets is vital to an effective management. Otherwise, much man power and money can easily be wasted because, for example, location, exact route and depth of the pipes are unknown.

After building the geodatabase, the study [33] informs that an analysis of the pipeline network shows more than half of the network is over-aged.

Keeping a healthy inventory is beneficial not only to pinpoint risky segments of the network but also to isolate repairing part e.g. closing valves to redirect water flow to optimize water pressure and keeping service down time to its minimum as possible by quickly determining minimum number of valves to shut off to isolate break.

GIS software vendors such as ESRI, are developing GIS solutions [35] as utilities for water distribution; with such software products, the operators are able to store both attributes and images of pipes, valves, meters, manholes, and so forth, as objects with location coordinates and a single database of assets to eliminate redundant data collection and maintenance activities. These products help the management to schedule maintenance work as well.

2.9 Conclusion

As reported in the literature, there is a variety of benefits of GIS in the water distribution network management of the urbanized areas; the examples include small size municipalities and larger local managements.

The case studies we have visited in this chapter show that GIS is employed not only in data entry and compilation but also in monitoring, pinpointing malfuntionalities and allocating resources in the different aspects of the water distribution networks. A basic example is reported at [33] where installing a GIS provides a suitable base for geodatabase techniques for studying water distribution networks so that it can support long term growing and maintenance plans of the city.

In another example [30], GIS is utilized in pipeline network standardization so that the case study provides a template for the municipalities to use GIS in the management of water distribution network. In a further example [27], the researchers report that GIS has been proved to be successful in the water pipe management thanks to models based on GIS data that have been used to simulate possible failures in the water network due to physical properties of the pipes and topography of the city.

Case studies show that such system they are using has also been beneficial for it has provided a tool in selecting alternative routes for the pipes to be added to the network.

In many similar works, the researchers inform successful applications on detecting leakage in water networks.

We have covered selected literature that report utilizing GIS with other systems such as SCADA and/or EPANET to collect and manipulate real time data as well as to perform simulations in hydraulic models.

On those examples, we have seen that GIS based database bearing pipe properties and AutoCAD drawings can feed EPANET as an integrated system to run hydraulic simulations e.g. [28], also integration of GIS with a toolkit, computer aided rehabilitation of water networks e.g. [34] to visualize and handle hydraulic service reliability of the network.

As the literature reports such stories of successes, the expectation to integrate GIS with an already installed system increases hence software vendors continue to provide larger solution packages with multiple modules; for instance ESRI [35] offers modules to manage sewer collection and storm water drainage networks as well as integration with SCADA.

As a conclusion, implementation of GIS promises considerable benefits to the municipalities especially in the management of water distribution. While there is a chronic money problem in local governments, successful GIS implementations can stop redundancies of work, provide real time monitoring, proactive solutions for potential malfunctionalities hence help the management to save money for further projects. The applicability of such systems increases with the scalability of the systems as we have given related examples in this chapter.

In conclusion, this chapter has served not only to build body of knowledge but also to address research question(1), section 1.5. We have seen that there is an extensive literature on GIS applications in various sizes of municipalities both in rehabilitation and development purposes.

Chapter 3

Research methodology

This work has a basis of research techniques with philosophical assumptions. The audience may find this chapter to inform on how the researcher drew a method to pinpoint the research questions and identified the steps to support her thesis to seek a rational answer.

3.1 Motivation

The researcher is employed by The Kirkuk Water Directorate (Su Müdüriyesi) of Kirkuk, Iraq. The organization has newly opened a section that will handle GIS transformation in the water network. The researcher is appointed to this new section and is to handle/manage following jobs, regularly.

- Transformation of maps from paper to digital environment
- Creating database to keep assets both in use and in stocks
- Increasing quality of the data by removing variety of entries and avoiding further mistakes

As mentioned in section 1.2.2 Kirkuk municipality considers installing GIS, seriously.

Basically, this background has made the research topic to emerge and initiated our exploratory research section 3.2.1. Being a member of the municipality, the researcher questions the pros and cons in implementing such a system and if decided to implement, what will be potential problems that the municipality may face section 1.3.

3.2 Research methods

Basically, the researcher has covered the following steps.

Phase 1: Surveying the literature on GIS applications in the municipalities, focusing on water distribution network

Phase 2: Visiting Ankara's water distribution department of ASKİ

Phase 3: Collecting guiding information from key informants

Phase 4: Reporting

A written consent has not been necessary as neither audio nor written recording took place. For more detailed further works, we refer to sections 5.2 and 5.3 for limitations and how to overcome them.

3.2.1 Literature survey

The literature on GIS applications in municipalities is remarkably large and rich both as theoretical and practical reports. Hence, we have chosen a set of selected works (Chapter 2) which is just a fraction of the whole knowledge. These works generally inform that there is a common inclination in local governments to transform their works to digital platforms where possible.

However, we could only infer the difficulties they have faced as the literature reports only successful stories most generally. For this reason, reviewing the related literature can only build a body of knowledge to support that municipalities with similar size of Kirkuk can build GIS which addresses to just one part of our studies.

Nevertheless, this phase of the study has formatted our suppositions and increased our body of knowledge on the GIS applications in the municipalities. With such characteristics, this phase of the research matches with the exploratory research [44].

Another outcome of this phase is to draw the boundaries of the thesis scope and set the consecutive research questions.

To generate a list of difficulties/problems in GIS implementation, we found support from the industry sections 3.2.1 and 3.2.2.

3.2.2 ASKi Water distribution department of Ankara

The Kirkuk water Directorate in Kirkuk municipality has already installed some infrastructure and provides services. Unfortunately, the records are not complete and not well maintained. Although Ankara's population is quiet big when compared to Kirkuk, the water distribution department had the same problems with today's Kirkuk about 20 years ago.

At present, ASKİ has several successful GIS projects both in asset management and monitoring.

We have visited ASKİ several times and observed briefly data and SCADA centers. We also found opportunities to speak to data analysts and operators who have been working there more than 15 years.

3.2.3 System developers

A local IT company, Başarsoft, has been operating in Ankara more than 15 years. Being a GIS company, they have been developing, installing and rehabilitating GIS in many municipalities as well as in Ankara.

Towards the end of reviewing the literature (phase 1), the researcher has registered to a GIS course offered by Başarsoft, through which technical basics in generating, manipulating spatial and non-spatial data are thought. During the course, the researcher found opportunities to speak to the system developers of ASKi's current GIS. Compiled with the course material, many examples from ASKi projects are shared hence their experience in problems while setting up GIS in water distribution departments is discussed.

This technique is basically defined as a part of participant observation [45].

3.3 Validation

As it is not easy to forecast what difficulties that Kirkuk will face, we have approached the problem by visiting related literature and consulting system developers who set up working GIS in similar municipalities.

As we have mentioned in section 3.2.1, we could only infer the problems since success is more reported in the literature.

A draft list of potential problems and how to overcome them derived from the literature survey has been validated by those professional a working GIS and system developers.

3.4 Reporting

During the conduct of this study a variety of materials have been covered (Chapter 2). The sources reported in the References section provide materials in paraphrasing and/or direct quoting by the researcher. However, there are also many parts in which the researcher's own thoughts are expressed, naturally. Because it is not possible to cover all the literature there may be unintentional similarities out of our knowledge. Apparently, such similarities may be evaluated as plagiarism regardless the intension of the researcher. Such illegal use of copyrighted material is seriously emphasized in academic writing guides [46].

To avoid any possible plagiarism, the thesis is passed through Urkund software before the final print. By this way, a further check has been done before the reviewers.

The findings, their borders hence the limitations and further research avenues are reported in this dissertation along with the conclusion; any extra material is not attached. Apparently, we suppose/hope to report further studies emerged from this thesis e.g. as conference proceeding or journal paper; however, this thesis is the whole report of this study by the researcher so far.

CHAPTER 4

POTENTIAL PROBLEMS AND POSSIBLE SOLUTIONS

This Chapter is dedicated to report problems during the transformation of data from paper based and old information systems to GIS. Basically, those problems are already faced in ASKİ at Ankara and they show strong correlation with the problems that Kirkuk Water Directorate is now struggling as discussed in section 3.2.1. Ankara water distribution system of ASKİ has MapInfo based GIS systems to track current infrastructure activities, on-going projects, SCADA, 3D engineering applications, and automated map production applications. The system has been developed by ASKI technical staff with Başarsoft's technical support, consultancy and trainings.

The examples shown on the figures of this chapter are from Kirkuk Water Directorate. They are prepared mainly by the contractors as drawn in AutoCAD based on the map sheets on paper.

4.1 Introduction

As we have detailed our research methodology in Chapter 3, we have discussed current problems of Kirkuk, with key informants in ASKi and Başarsoft. Section 4.2 explains why the current data cannot be put directly to a GIS. Selected problems are reported in 4.3 and the chapter concludes with section 4.4.
We make it clear that the term "manhole" is not used only in sewerage in Kirkuk. The municipality of Kirkuk uses "manhole" term for any hole in the ground which a maintenance person can get in and operate such as shutting off a valve.

4.2 Major problems with the data

As we have surveyed the literature (Chapter 2), the data accuracy and precision is vital in the information systems. The quality is not limited to the text based attributes but also to the spatial data due to drawings in computer environment.

To perform an automated file transformation, map projections and coordinate systems as well as file types should be specified; however, while transforming present drawings to GIS, we have seen that the quality of spatial data is not good enough for an unsupervised export of the files to a GIS in Kirkuk.

In water distribution network, the spatial data was stored as different AutoCAD files and/or stored on different paper sheets. Conversion of such files requires additional resources both in human and time as an automated translation cannot be trusted.

Following section provides potential problems that Kirkuk can face.

4.3 Technical problems

Information systems have basically three legs, organization, people and technology as discussed in section1.1; in this section we have focused on the technical problems that can be avoided by a series of systematic working projects following simple training courses.

Following selected problems are frequent in Kirkuk municipality.

4.3.1 Missing or misleading coordinates

The digitization jobs of the old map sheet are handled by the contractors. As the coordinates are either missing or nonstandard the same problem continues in the computerized environment. Figure 4.1 presents such an example that AutoCAD drawings are imported to MapInfo; however, the drawings are not correctly coordinated.

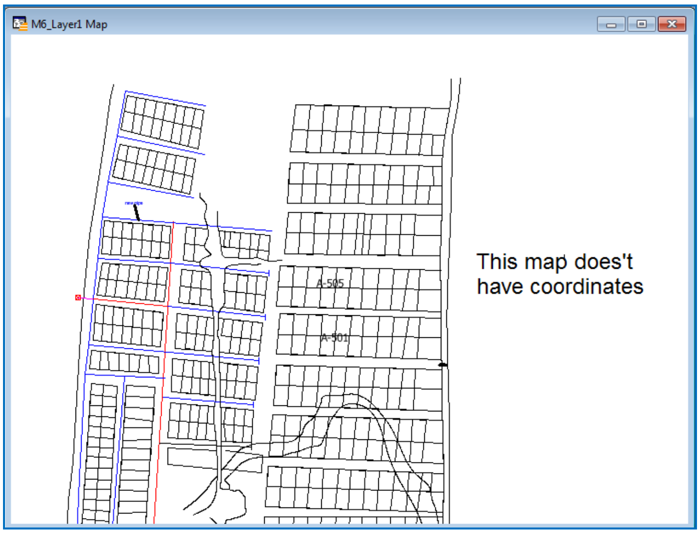


Figure 4.1 Digitized map sheets without coordinates

Such problems can be fixed if the drawn features are scaled. Land features can be given coordinates by field works and simple program codes or scripts can be written to systematically correct coordinates.

Figure 4.2 Confusing features

However, if there is an ambiguity in the scales then shifts that cannot be corrected through programs can occur Figure 4.2.

4.3.2 Confusing pipe intersections and end points

Water lines were not broken at the intersection. Thus, when the line is selected all attached pipes are selected as a single polyline

.

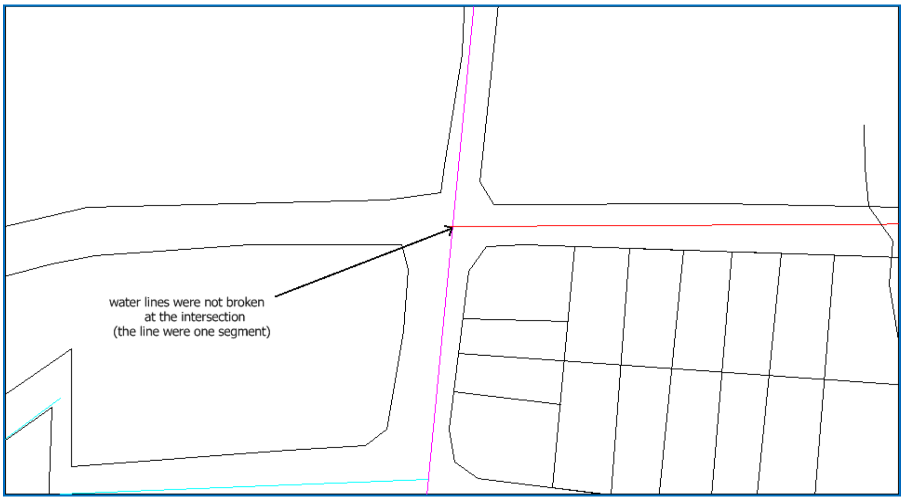


Figure 4.3.a Unbroken waterlines

To solve such problems, water lines must be broken in separate pipes and junctions must be put between them. However, this action should be done after a ground unit checks the intersection points because identifying a junction point is important for network analysis and pressure control for a hydraulic models.

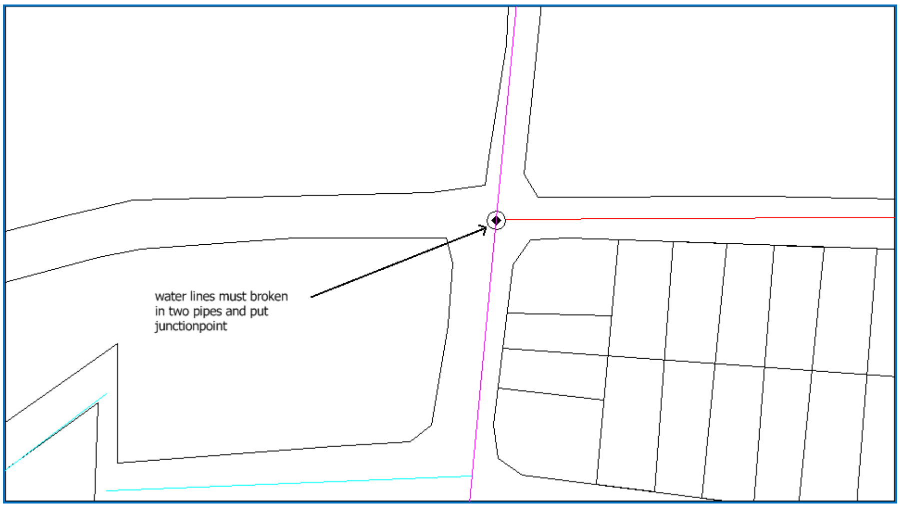


Figure 4.3.b Junction point

Such ambiguities with the intersections occur with missing manholes as well (Figure 4.4).

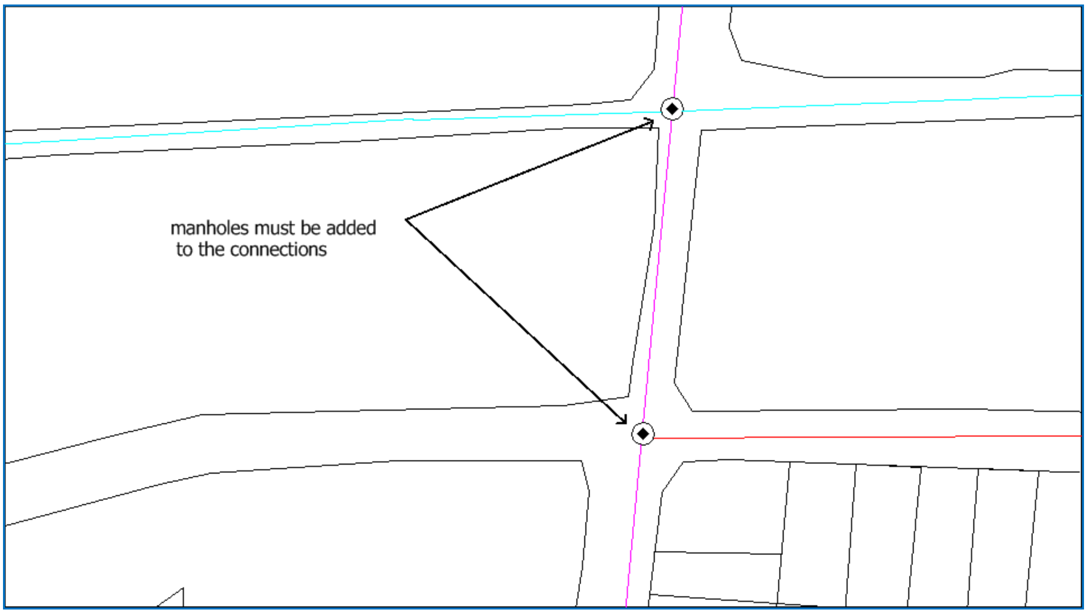


Figure 4.4 Missing manhole

Related to pipe connections, some pipes have no proper ending Figure 4.5.a

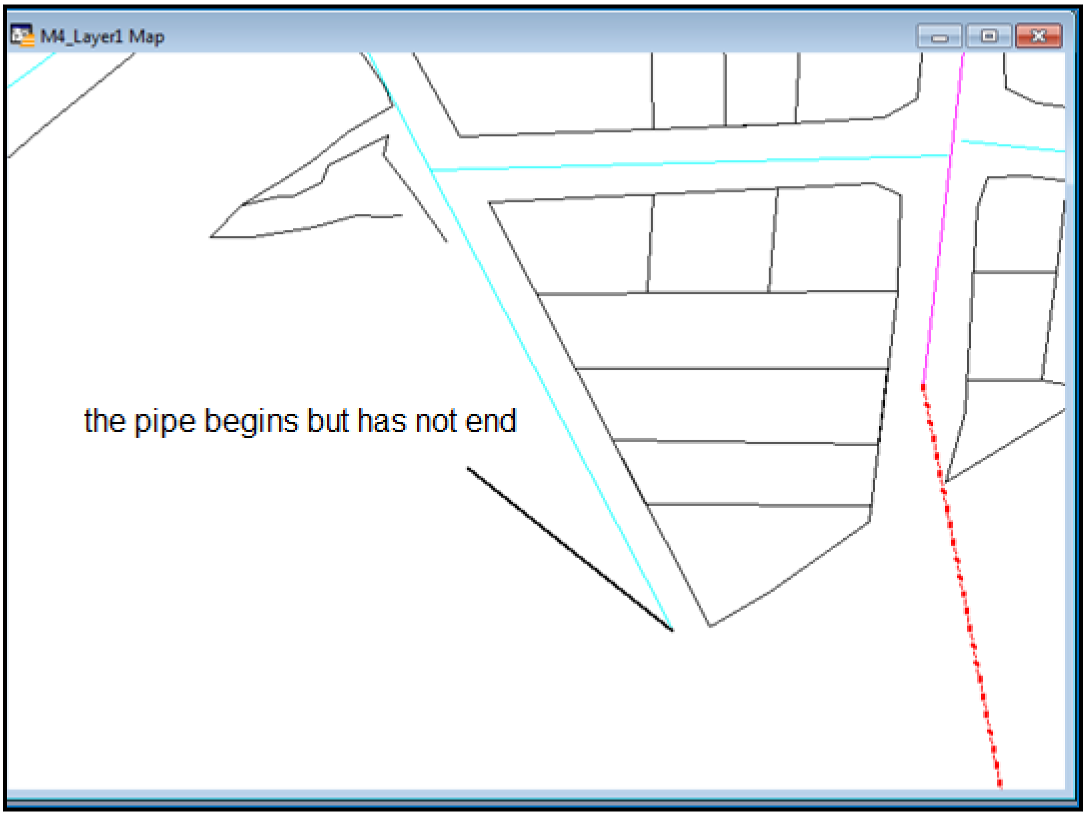


Figure 4.5.a Pipe without any proper ending

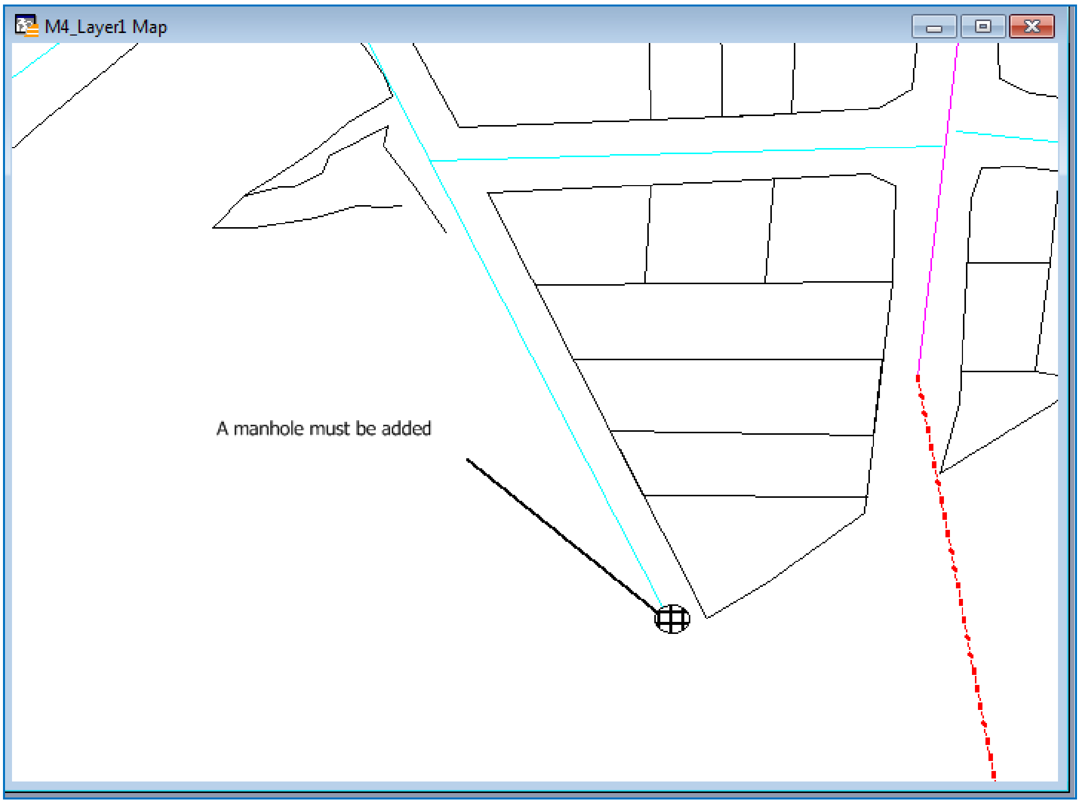


Figure 4.5.b A manhole is added

Such problems should be solved by checking the original map sheets. If accurate information is absent on the original drawing then a field trip should be done. Without checking the pipe at its place it is not right to make any modifications on the drawings because a pipe could be connected to another pipe or it could have a manhole at the end or even completely removed. In the example presented at Figure 4.5b, a manhole has been found at the place.

4.3.3 Misplaced attributes

Attribute texts are spread in different layers. The data written in text entered to lines as attribute such as diameter and type of the water pipe; e.g. house connection pipe diameter is in wrong layer.

Figure 4.6.a shows such a problem in which the pipes are tagged by the parcel names instead of their own names.

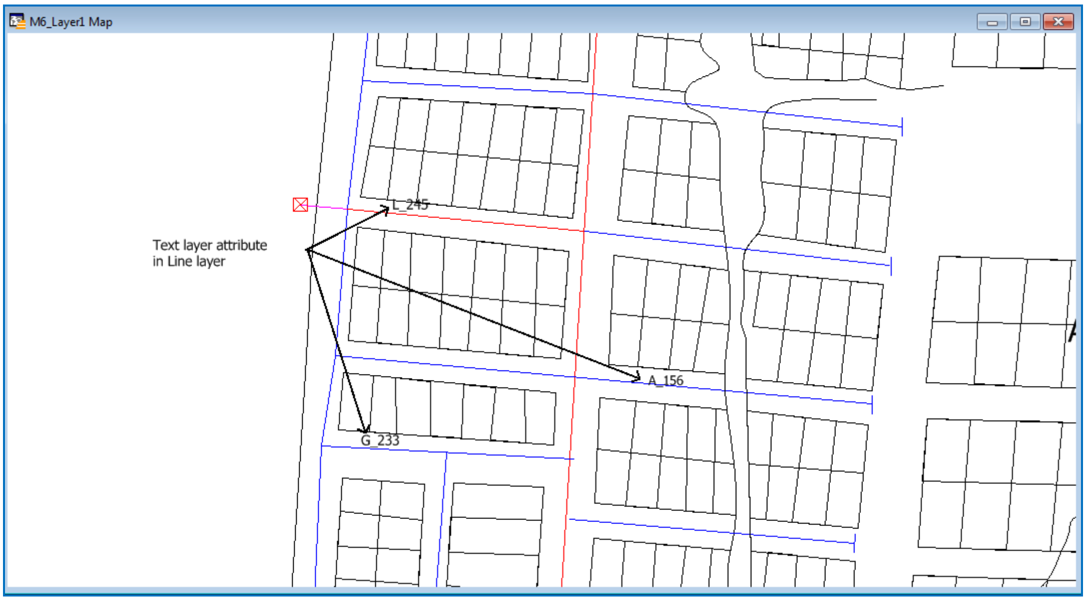


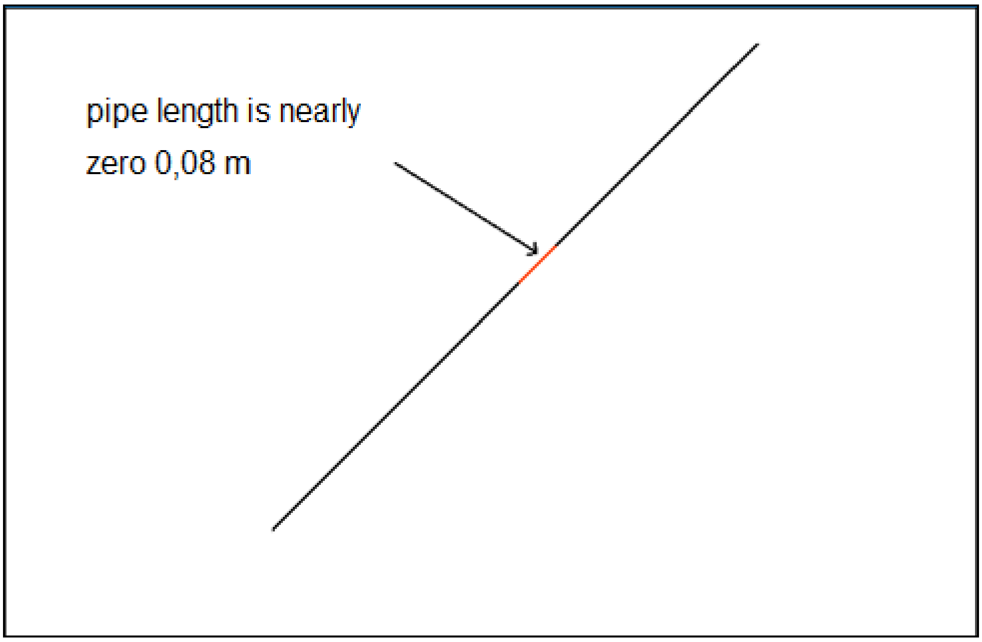
Figure 4.6.a Misleading tags

This problem is due to bad design of the CAD drawing. The attributes are not registered under their own entity types. Gathering attributes under the related entities can solve this problem. Before taking print outs the layouts should be checked so that misleading tagging does not occur.

Figure 4.6.b Corrected

4.3.4 Pipes with zero lengths

There are pipes with nearly zero or zero lengths. Such problems occur when the operator fails to snap two polylines as a single water pipe or there are actually two pipes connected by a junction node. Nevertheless, such small lines have no meaning moreover they can and will produce problems in the basic calculations and hydraulic models as discussed in section 2.8.4.5.



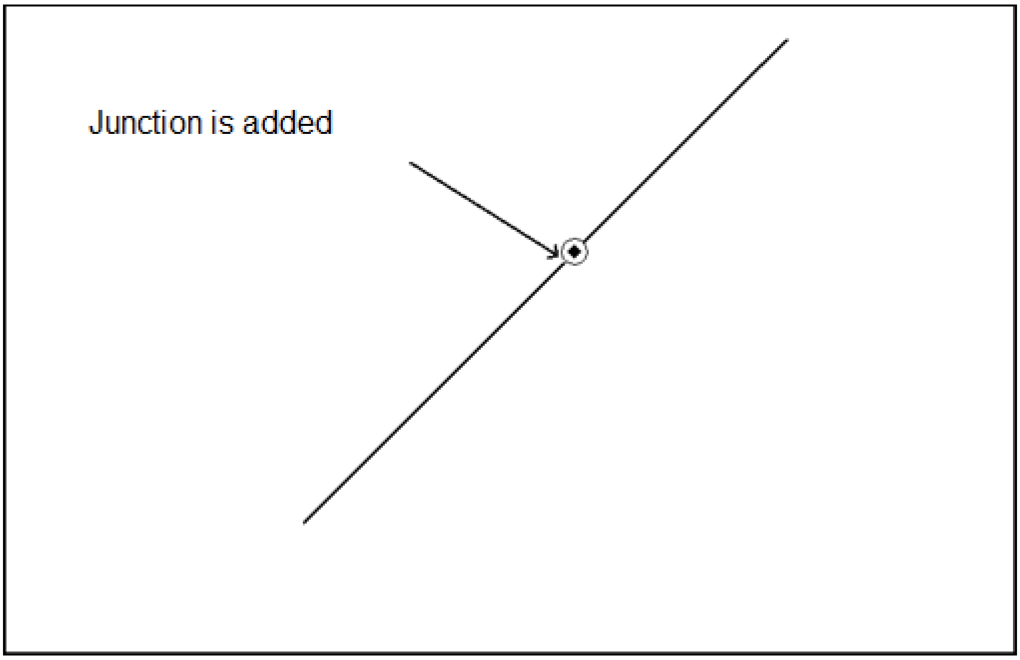


Figure 4.7 Pipe segment with nearly zero length

The operator should be certain whether there is a junction or not; this can be checked from the original map sheet; if not, a field check is necessary. In this example, a junction point is put.

4.3.5 Varieties in attribute at the sheet edges

When the adjacent map sheets are attached to each other, the operator can see that there are shifts in the pipes. This problem can be due to wrong registration of the map sheets and/or due to wrong drawing of the pipes. In Figures 4.8 and 4.9. the problem is due to wrong drawing of the pipes because of coordinate approximation.

Additionally, there may be varietites not only spatially by also in the attributes as seen on the same figures; e.g. different names and/or diameters of the same pipe in adjacent map sheets.

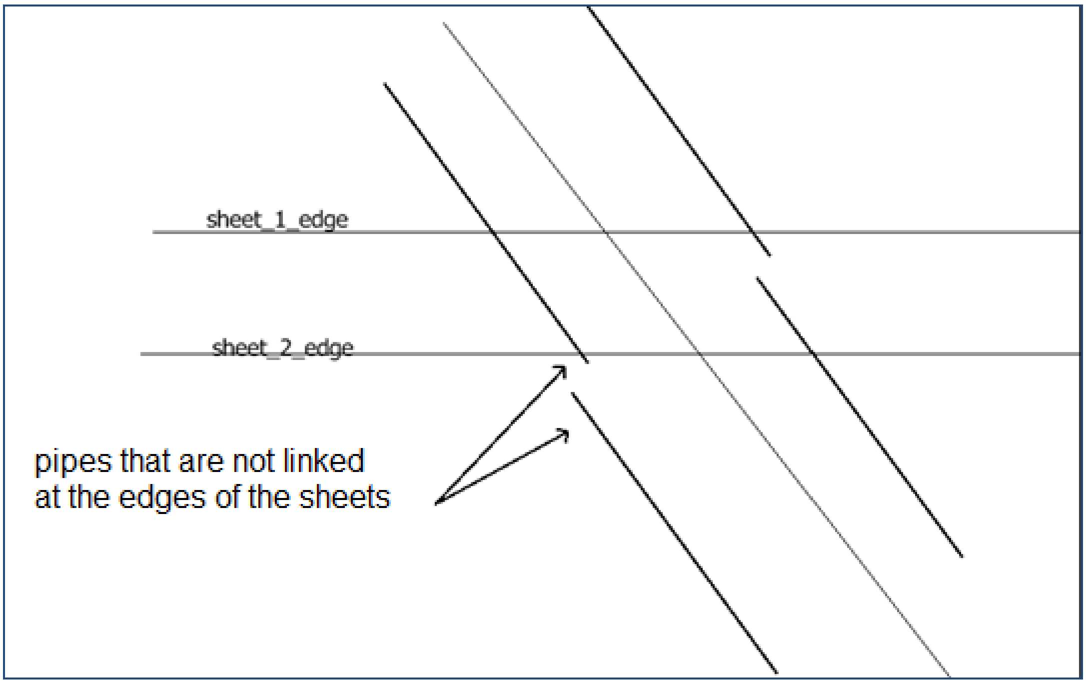


Figure 4.8 Shifted pipes at the edges of map sheets

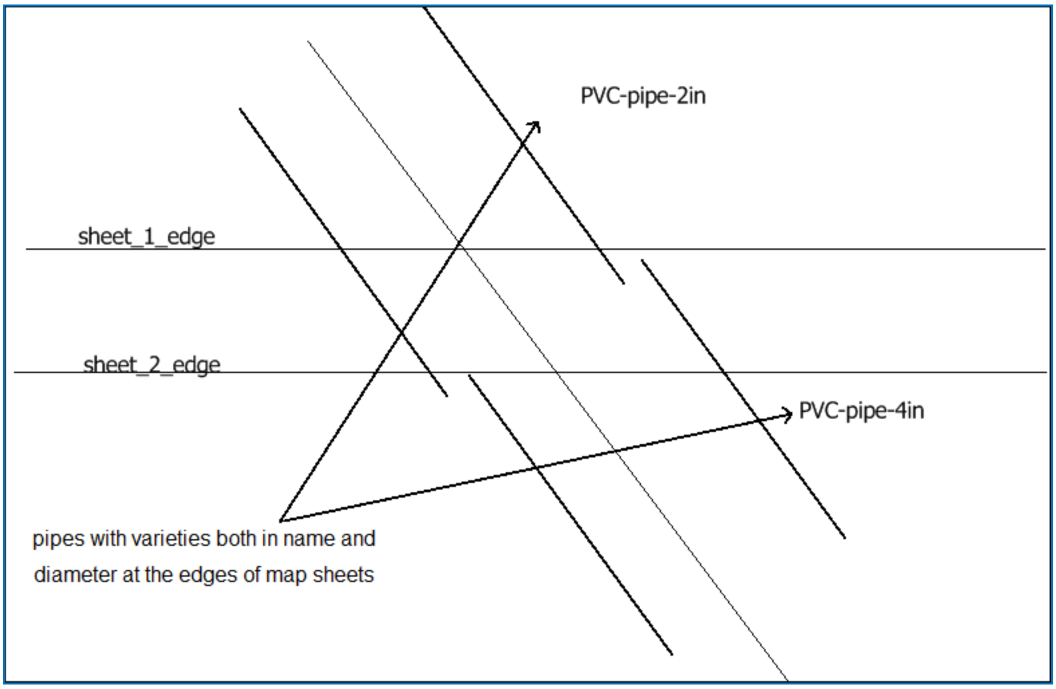
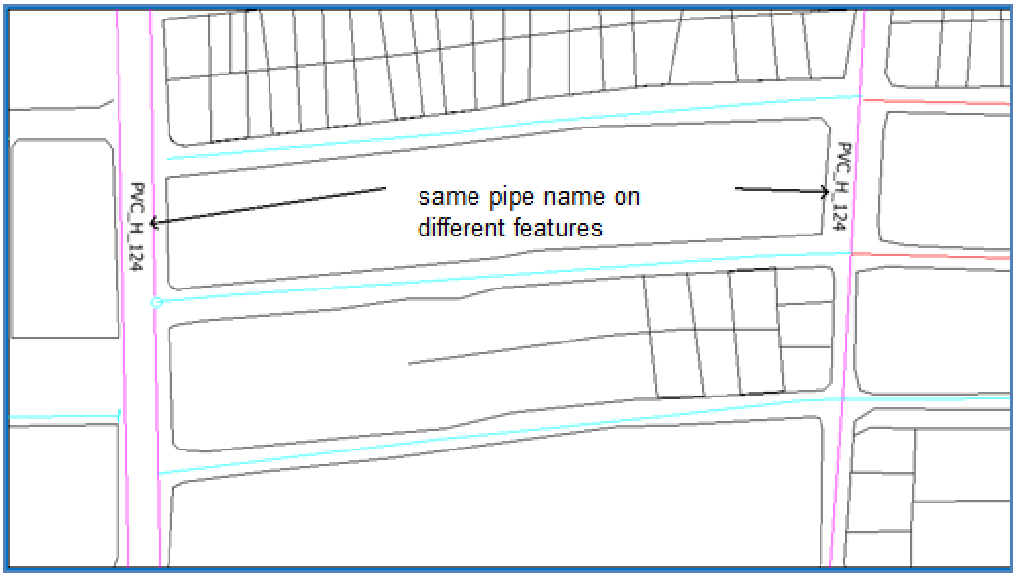


Figure 4.9 Shifted pipes with varieties both in name and diameter at the edges of map sheets

4.3.6 Faulty values

This problem is hard to solve unless it is obvious. Values such as pipe diameter or pipe names can be entered due to several reasons including operator mistakes. In Figure 4.10, same name appears on different pipes .



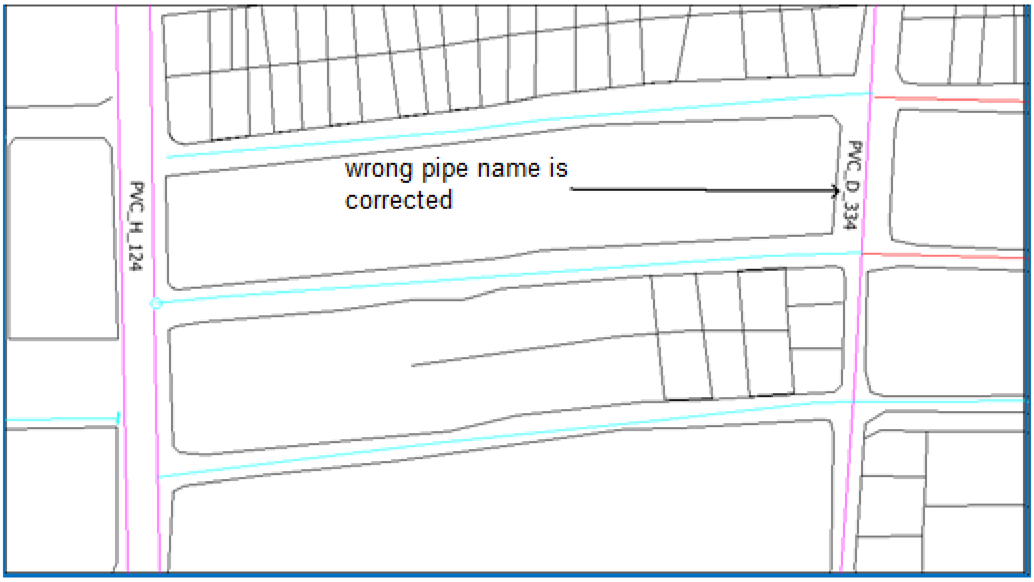


Figure 4.10 Wrong pipe names

The municipality does not have any database, either paper based or digital; hence, it is not possible to know all the values by matching. For this reason, only obvious mistakes can be caught.

Another example is presented on Figure 4.11 where two names are given to a single pipe.

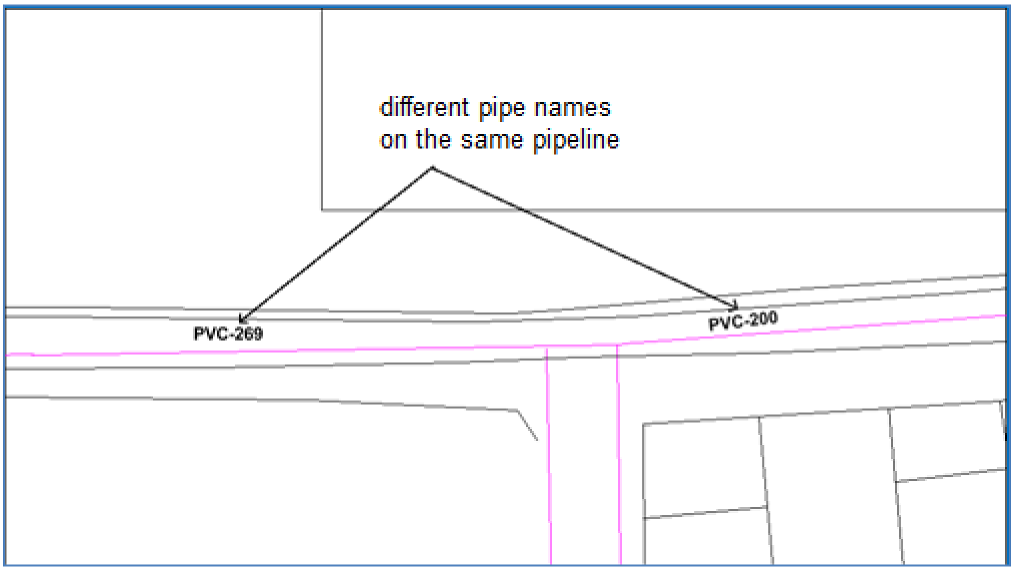


Figure 4.11 Single pipe with two names

Although is it not easy to capture such faulty entries, automated queries may reveal some of them; for instance, the elevation of a manhole cannot be largely different than the endings of connected pipes Figure 4.12.

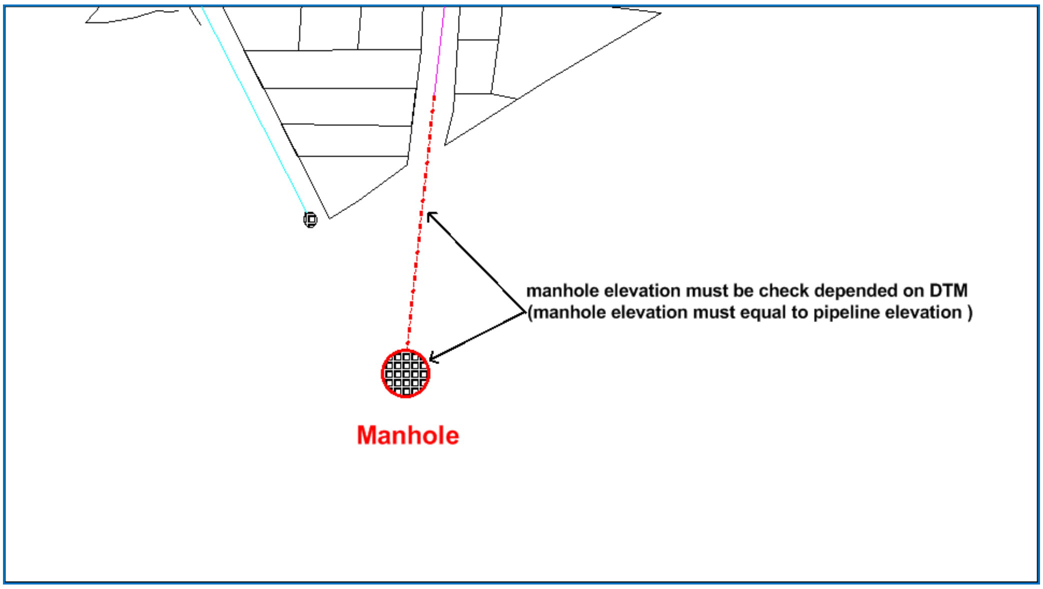


Figure 4.12 Unmatched elevation of manhole

In this case, the operator can check the elevation by overlaying digital elevation model; if it is not possible then a ground survey should be done.

4.3.7 Missing features

On the digital drawings, there are some texts which are assumed to be written diameter or type of pipes; however, but there is no such a pipe on the drawing.

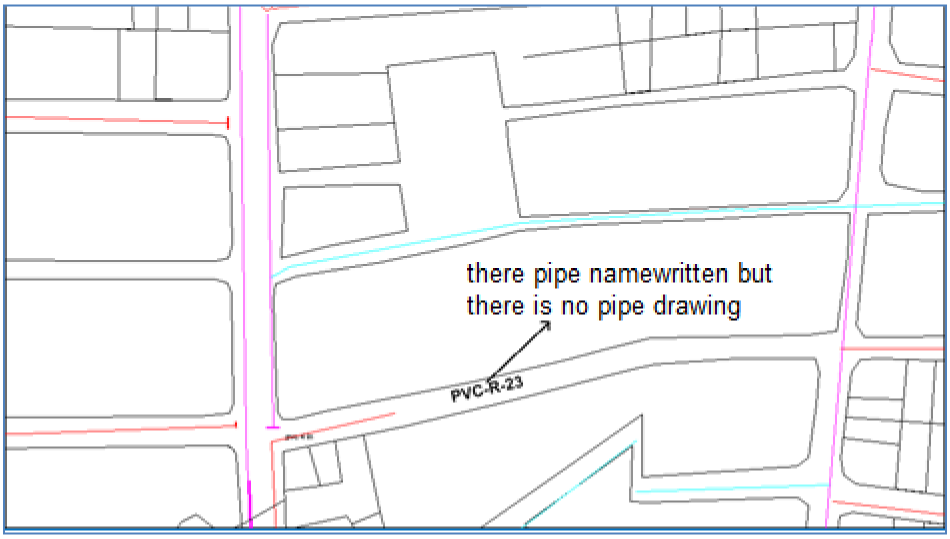


Figure 4.13 a A tag exists without its pipe

Still the original map sheet should be checked if not a ground survey should be done to be certain that there is such a pipe laid or it is absent.

In this example, the original map sheet shows that the pipe exists, so it is added to the drawing and snapped to the network Figure 4.13b.

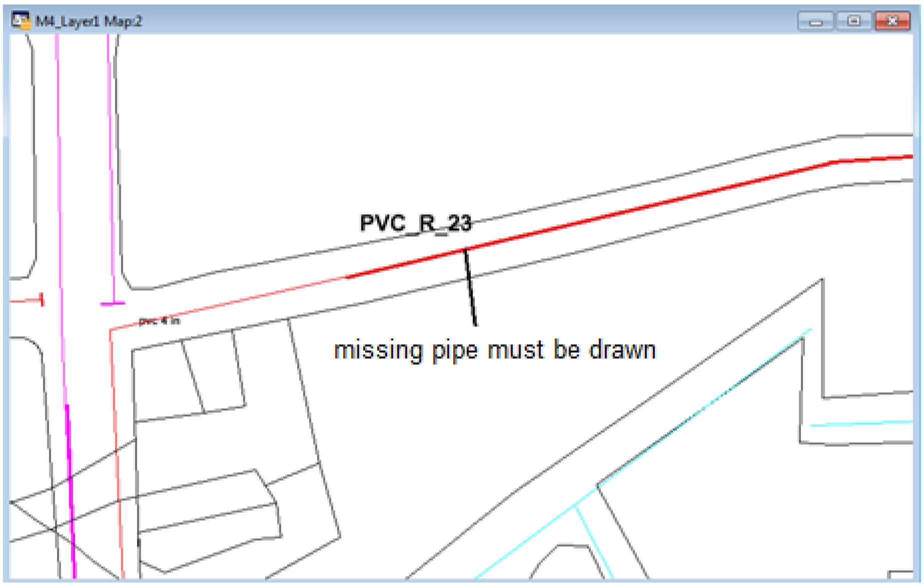


Figure 4.13 b The missing pipe is added

4.3.8 Confusing manholes

Each connection and ending of pipes must have manholes and there should be a minimum distance between the manholes.

There are cases in which two manholes are too close to each other Figure 4.14. In such cases, the operator should be certain that both of them exist or only one of them is true.

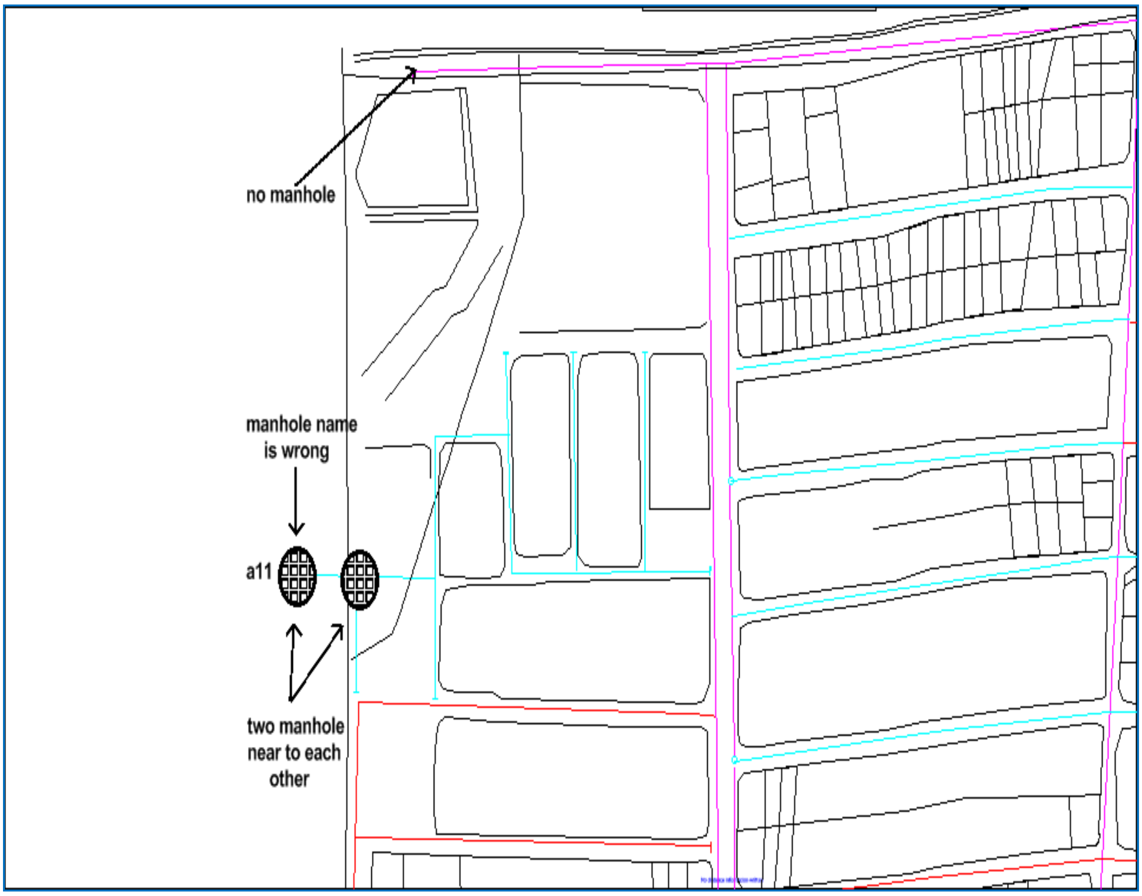


Figure 4.14 Two manholes are too close to each other.

4.3.9 Incompatible pipelines

As the diameters should be the same at the same pipe, varieties in the attributes such as in capacity, type or direction are ambiguous. In Figure 4.15a, more than one diameter is entered along the same pipeline with breaks. After the map sheet check, the drawing is corrected Figure 4.15b.

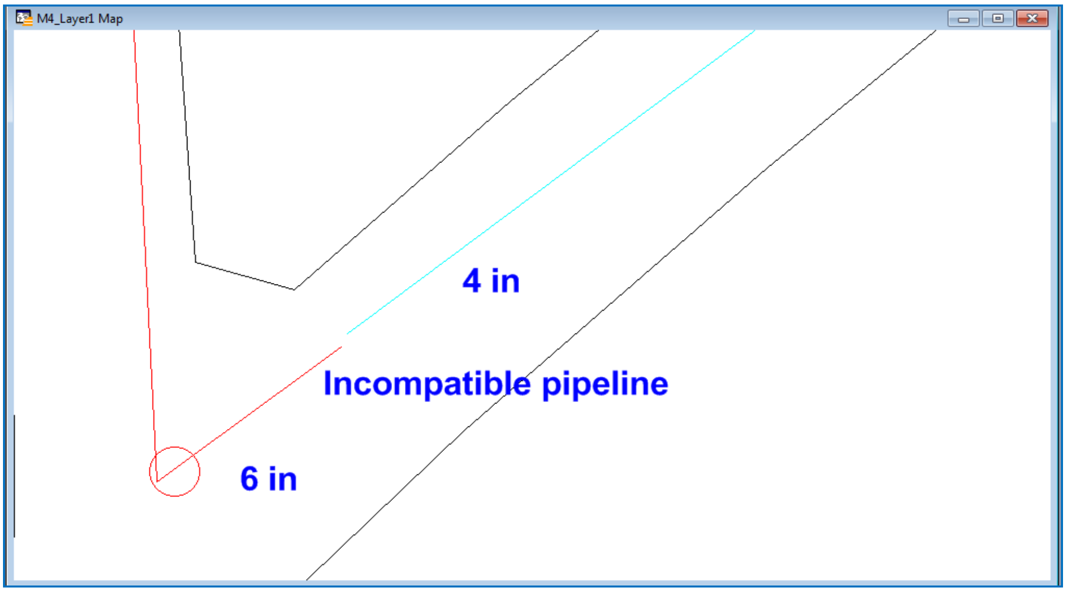


Figure 4.15a incompatible pipelines with a variety in diameter

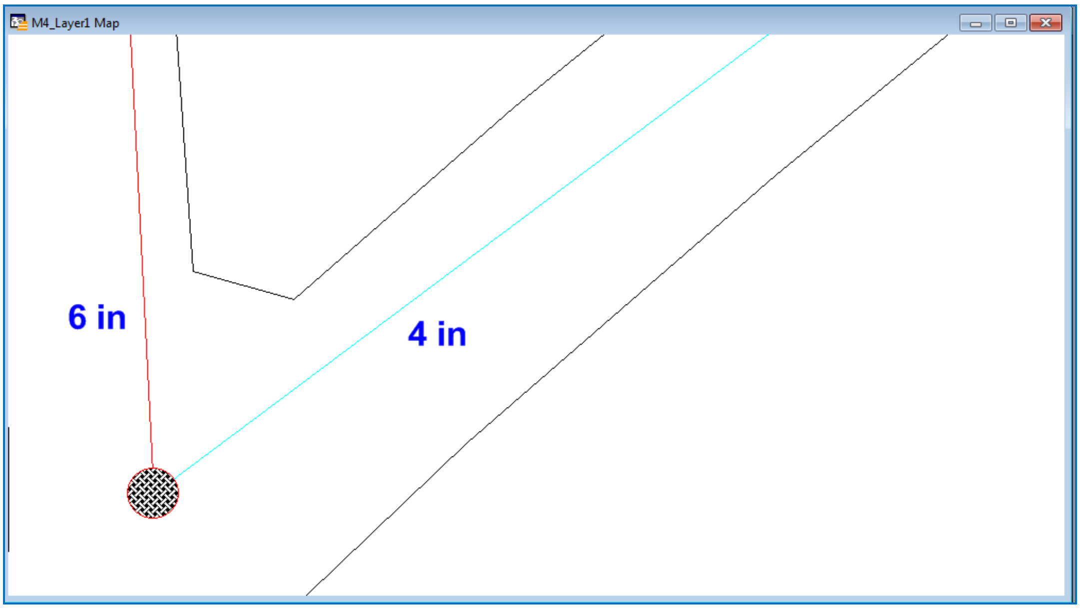


Figure 4.15b Corrected

4.3.10 Messy drawings

There are some features at which the operator cannot be certain. For example, the polylines in Figure 4.16 are not clarified.

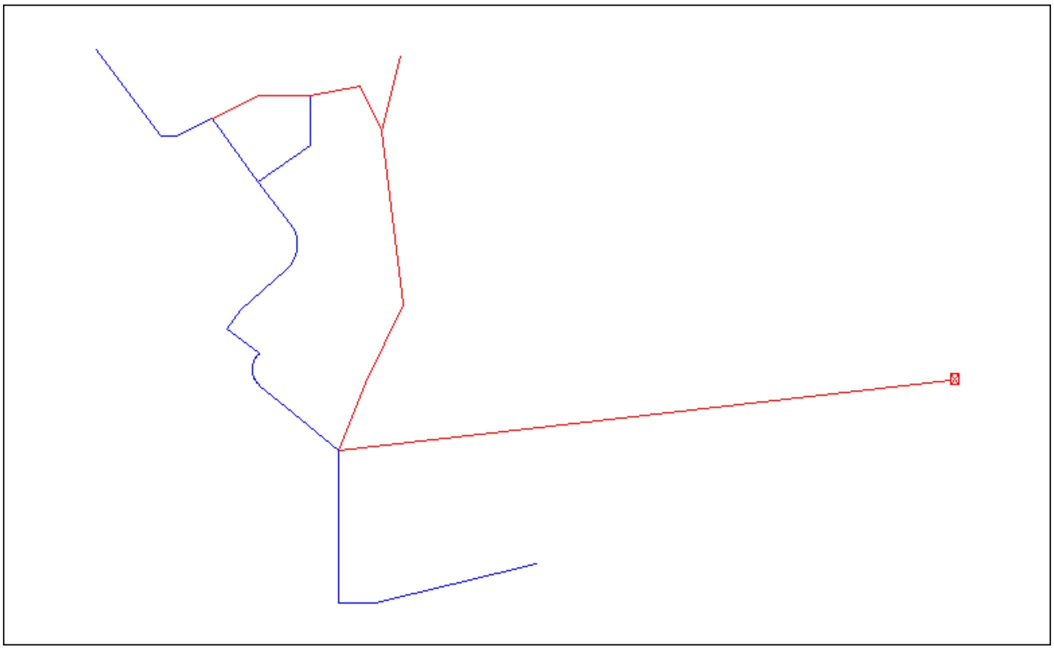


Figure 4.16 Polylines without attributes

Another example is seen on Figure 4.17 where there are unmarked and unknown geographic features.

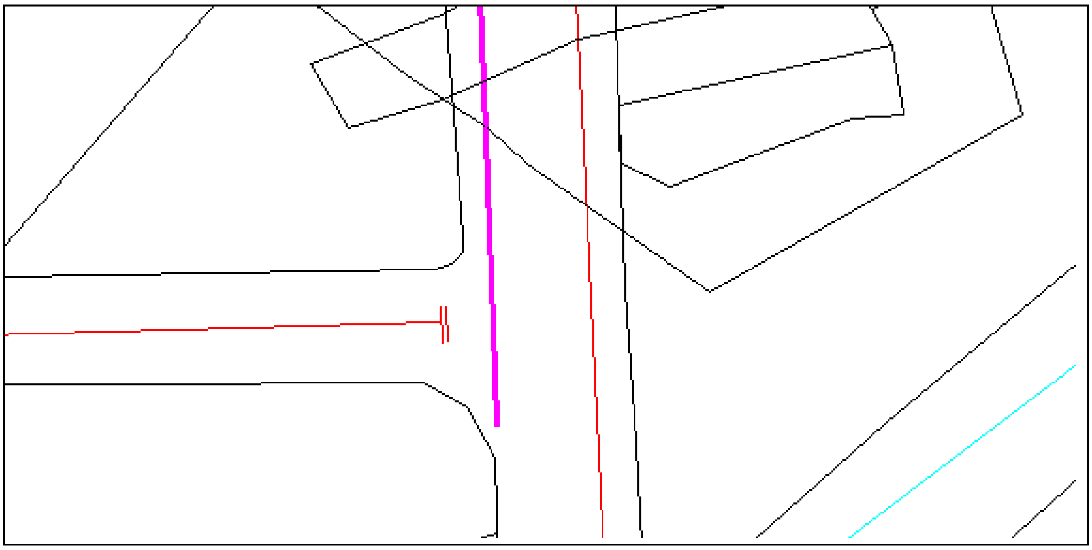


Figure 4.17 Unknown features

A suggested attribute data of pipe can be as follows:

Non- spatial data for pipe

id	material	diameter	date	engineer	Provider	roughness coefficient	length
101	**steel**	**4 in**	**1/ July/ 2012**	**Suha ALI**	**Company A**	**0,6**	**10 cm**

4.3.11 Variety in the address format

In order to make successful and fast queries, the addresses should be registered in a standard format i.e. without any variation.

A proper way to do this is to be consistent with the entries such as in the abbreviations.

Following examples are from ASKİ, Ankara:

"1.Açelya"➔"1. Açelya"

"Şehit Osman Avcı➔"Şht. Osman Avcı"

New and changed street names must be updated. All addresses must be filled with proper address structure, rather than a description of the address for each client. Invalid or missing address information must be collected with the help of meter reading staff.

4.4 Conclusion

As seen in this chapter, the majority of the potential problems are due to poor quality of the data. Before cleaning the ambiguities it would be quite unrealistic to start a full scale GIS because the poor quality data both in spatial and non-spatial nature will produce insignificant output hence benefits.

We have seen that most of the problems need field check for an accurate asset database. Thereafter, it would be relatively easier to correct problems in the digital environment.

In conclusion, a basic GIS training of the IT staff can easily provide solutions to the potential problems highlighted in this chapter once the data is cleaned.

CHAPTER 5

CONCLUSION

As we have presented at our literature review and examples from the Kirkuk Water Directorate we have aimed to underline potential problems and feasible solutions to seek answer to the research questions.

This chapter presents our findings we have discovered throughout the preparation of this thesis and the limitations hence further research avenues for follow-up studies.

We underline again that this study has limitations. The audience is encouraged to comment on the findings for we can work on the limitations for further studies.

The chapter concludes with the benefits of this research study in the light of seeking answer to the research questions.

5.1 Findings

The findings emerged from this study are not limited to the research questions defined in Chapter 1. There are additional findings that open further research topics.

The findings partially answer our research questions; however, we should remind that this study is subject to limitations section 5.2.

Following is the list of our findings:

(1) The literature review shows that municipalities at various sizes can implement GIS in their water distribution service departments

Chapter 2 provides many examples reported to the literature in which successful GIS applications are implemented at municipalities in small, medium and large in population. Because this technology can be scaled, Kirkuk can setup GIS for its water distribution system.

(2) There will be difficulties in achieving target in finding (1).

Chapter 4 lists the potential problems. Those problems are supported with the real world data shared by the Kirkuk Water Directorate.

(3) It is possible to solve problems emerged in finding (2).

Still the 4th chapter shows that the problems can be solved by a team of staff who attends a GIS course of one or two weeks.

(4) Kirkuk can implement GIS in its other services than water distribution.

The 2nd chapter has a quick visit on GIS applications of municipal services on road maintenance, cadastre, waste collection and disposal.

5.2 Limitations

As we have mentioned several times, this study has limitations hence the findings should be read accordingly. These limitations include the followings.

(1) Sizes of the municipalities reviewed

The literature review targets the similarities of Kirkuk to other municipalities only in size of population. Budget, working habits, public governance and responsibilities and rights of local government of Kirkuk are excluded in this study. This limitation relates to findings (1), (2) and (4).

(2) Technical problems

The researcher has attended a MapInfo course to learn GIS applications and how they can be utilized to build an asset database, manage spatial and non-spatial data and have reports. Problems due to business rules, organizational behaviors and staff education are not studied in detail. This limitation relates mostly to findings (2), (3) and (4).

(3) Possible solutions to potential problems

The problems itemized in Chapter 4 are given solutions only in practical and technical sense. Allocating human and monetary resources by the authorities are not discussed. This scope limits the findings (3) and (4).

(4) EPANET and SCADA

Only EPANET and SCADA examples which are hydraulic modeling and real-time monitoring, respectively, are considered in this study.

5.3 Future studies

As the limitations show there are further research topics that can emerge from this study. Following is a quick list for such a set.

(1) More comprehensive studies on the municipalities

This item is emerged from the limitation (1). Apart from the population similarities, further public management and technology acceptance studies may provide additional support in the GIS acceptance by the local governments both in organizational and human factors.

(2) Business rules

Emerged from the limitations (2) and (4), additional studies on organizational restrictions in providing resources both human and financial as well as business rules of Kirkuk municipality would make this study more complete.

Furthermore, other GIS software than MapInfo, for example ArcGIS or Smallworld GIS, can be studied to seek technical solutions given in Chapter 4.

(3) Hydraulic model and monitoring

EPANET and SCADA are among the most popular choices in hydraulic modeling and real-time monitoring in water distribution systems in referring to the limitation (1). Further studies on bespoke modeling software and telemetry – automatic meter readings and their applicability in Kirkuk may be integrated to this study.

5.4 Conclusion

By the light of our findings section 5.1 within the limitations section 5.2 presented, we conclude that Kirkuk can start to transform its water distribution system from paper based to GIS; hence, the following research questions targeted in the thesis are approached and encouraging positive answers are found.

(1) Can Kirkuk set up successful GIS for its water distribution system?

(2) What problems will the municipality face during the transformation from its current paper based system to digital environment?

(3) Is it possible to solve those problems, practically?

Keeping in mind that most of the potential problems are due to poor quality of the data, the water directorate is discouraged and not urged to implement hydraulic model and SCADA. Those systems/software will give further development tools to the department; however, it is too early to start for such a work as the pipes, valves, pumps and water tanks are not completely registered into a digital environment, yet.

Regular backups of any GIS and critical information should be kept in another city. In parallel to this suggestion, Iraq has a policy that digital backup is kept in Bagdad. We recommend that trained personal should be available in Bagdad so that Kirkuk GIS data can be managed in case of a catastrophe in Kirkuk e.g. an earthquake.

We recommend that the starting point should be cleaning spatial and non-spatial data including locations and properties of water distribution assets, and starting an integrated work with other governmental departments to share address information of Kirkuk to avoid variety in the client data sets.

REFERENCES

[1] **LAUDON, LAUDON** (2011) “ Essentials of management information systems”, 9th edition, Pearson 457 pages .

[2] **CENTRALl ORGANIZATION FOR STATISTICS** (2011) “Estimated Population By Governorates, Social Origin For The Year 2011” available at http://cosit.gov.iq/AAS2012/section_2/8B.htm, visited June 2012

[3] **BOLSTAD, P.**V (2008)"GIS Fundamentals: A First Textbook on Geographic Information Systems", Eider Press, 3rd Edition ISBN: 9780971764736, 688 pages

[4] **SUTTON, T. , DASSAU, O. , SUTTON, M.** (2009),"A Gentle Introduction to GIS", Chief Directorate: Spatial Planning & Information, Department of Land Affairs, Eastern Cape, South Africa, 113 pages

[5] **SKRDLA, M.P.** (2005) "Introduction to GIS with TNTmips", MicroImages, 20 pages.

[6] **COWEN, D.J.** (1988) "GIS versus CAD versus DBMS: What Are the Differences?", Photogrammetric Engineering and Remote Sensing 54(11), pp 1551-1555.

[7] **ESRI** (2005) "GIS Topology", White Paper, July 2005, 14 pages.

[8] **KARIM, H.A. , AKINCI, B. (Editors)** (2010) "CAD and GIS Integration", Auerbach, ISBN: 9781420068054, 250 pages

[9] **REYNOLDS, H.** (1997) "An Introduction to Geographic Information Systems (GIS)", unpublished, available at http://www.badpets.net/IntroGIS/GIS_Intro.pdf, 22 pages

[10] **WRIGHT, T.** (1997) ,"Geographic Information Systems", Office of the Information and Privacy Commissioner, Ontario, 55 pages

[11] **MWATELAH , J.K.Z**.(2001) "Application of Geographical Information Systems (GIS) to Analyze Causes of Road Traffic Accidents (RTAs) Case Study of Kenya", International Conference on Spatial Information for Sustainable Development, 2-5.October.2001, Nairobi

[12] **SUN, Z., YANG,. Z.** (2003)" A GIS System for Managing and Analyzing Urban Road Traffic Accident", Eastern Asia Society for Transportation Studies, vol. 4, October 2003, Pp 1442-1449

[13] **RAZZAK, A.J., KHAN, U.R. , JALAL, S.** (2011) "Application of Geographical Information System (GIS) for mapping road traffic injuries using existing source of data in Karachi, Pakistan - A Pilot Study, Journal Pakistan Medical Association, 61(7) Pp 640-643

[14] **LIGHTSTONE, A.S., DHILLON, P.K., PEEK-ASA, C., KRAUS, J.F.**.(2001) "A geographic analysis of motor vehicle collisions with child pedestrians in Long Beach, California: comparing intersection and midblock incident locations", Injury Prevention, 7(2), Pp 155-160

[15] **MORENCY, P., CLOUTIER, MS.** (2006) "From targeted "black spots" to area-wide pedestrian safety", Injury Prevention, vol. 12, pp 360-364

[16] **SCHUUMAN, N., CINNAMON, J., CROOKS, V.A., HAMEED, S.M.** (2009) "Pedestrian injury and the built environment: an environmental scan of hotspots", BMC Public Health, 9(233). Pp

[17] **ERDOGAN, S., YIMAZ, I., BAYBURA, T.,GULLU, M.** (2008) "Geographical information systems aided traffic accident analysis system case study: city of Afyonkarahisar", Accident Analysis & Prevention, 40(1), pp 174-181

[18] **MOORE, D.** (2004) "GIS in Emergency Planning: A Spatial Analysis of Ambulance Services" Spatial Planning Solutions Report, unpublished, available at http://www.spatial.ie/downloads/GIS%20in%20Emergency%20Planning.pdf, 8 pages

[19] **ESRI** (2011) "GIS Solutions for Highway and Roadway Management"

[20] **YUNUS, M.Z.B.M., HASSAN, Bt.H.** (2010) "Managing Road Maintenance Using Geographic Information System Application", Journal of Geographic Information System vol. 2, Pp 215-219

[21] **TIMMONS GROUP** (2006),"City of Fredericksburg, Virginia GIS Needs Assessment" 110 pages

[22] **ESRI** (2005),"GIS for Cadastral Management"

[23] **CHALKIAS, C., LASARIDI, K.** (2011) "Benefits from GIS Based Modeling for Municipal Solid Waste Management", Integrated Waste Management, vol.1, Pp 417-436

[24] **AHMED, S.M.** (2006) "Using GIS in Solid Waste Management Planning: A case study for Aurangabad, India" Master's Thesis, Linkoping's University

[25] **RAHMAN, Md. M., SULTANA, K.R., HOQUE, Md. A.** (2008) " Suitable Sites For Urban Solid Waste Disposal Using GIS Approach in Khulna City, Bangladesh", Proceedings of Pakistan Academy of Sciences, 45(1), pp 11-21

[26] **ABURAWE, S.M, MAHMUD, A.R** (2011) , "Water Loss Control and Real-Time Leakage Detection Using GIS Technology", Geomatics Technologies in The City (GTC), 10-13.May.2011, Jeddah.

[27] **JUN, C., KOO, J., KOH, J.** (2004)," Developing a Water Pipe Management System in Seoul Using The GIS", International Archives of Photogrammetry Remote Sensing and Spatial Information Sciences, 35 (2), pp 290-293.

[28] **YU, T., LIYA, M, XIAOHUI, L., YUNZHONG, J.** (2010) "Construction of Water Supply Pipe Network Based on GIS and EPANET Model in Fangcun District of Guangzhou", Second IITA International Conference on Geoscience and Remote Sensing, pp 268-271

[29] **CARTER, B., DUPONT, D.** () "Using GIS to Assist in Understanding Residential Water Conservation" .

[30] **WANG, ZS., WEI, ZK., YIN, Q.** (2008) "The Design of Water Supply Network Based on GIS", Cybernetics and Intelligent Systems, 21-24.September.2008, Chengdu, pp 209-213

[31] **ISIK, M.**, **KOSAK, M.** (2002) "Bursa traffic accidents inspection and evaluation project (BUTKID Project)", International Symposium on GIS, 23-26.September.2002, Istanbul

[32] **KARASAHIN, M.,TERZI, S.** (2002) "Determination of Hazardous Locations on Highways Through GIS: A Case Study-Rural Road of Isparta-Antalya", International Symposium on GIS, 23-26.September.2002, Istanbul

[33] **ADUAH,M.S.,MANTEY,S.,TAGOE, N.D.** (2011) "GIS in Water Supply Network Maintenance in Tarkwa, South Western Ghana", Research Journal of Environmental and Earth Sciences, 3(6), pp 737-744

[34] **ZHANG, T.** (2006) "Application of GIS and CARE-W Systems on Water Distribution Networks, Skärholmen, Stockholm, Sweden", MSc Thesis, Royal Institute of Technology, Sweden

[35] **ESRI** (2007) "GIS Technology for Water, Wastewater, and Storm Water Utilities"

[36] **BAHADUR, R.,PICKUS, J.,AMSTUTZ, D.,SAMUELS, W.** (2001) "Water Distribution Model for Salt Lake City , UT", ESRI Users Conference, 8-13 July 2001, San Diego

[37] **ANAND, S.** (2002). “GIS in Design and Asset Management of Intermittent Water Distribution Systems .”

[38] **JAVIER, F.** (2002). Water Mains Creation Using GIS, 1-7.

[39] **DAWE, P.** (2000). Pipe Detection Surveys and Creation of a Water Utility GIS , NIUE, (September)

[40] **A.SILBERSCHATZ, H.F., KORTH, S., SUDARSHAN** (2005) "Database System Concepts" McGrawHill

[41] **ANDREASSON, K.** (2008) "Lantmäteriet The Swedish Mapping, Cadastre and Land Registration Authority", Cadastral Information System, a resource for land management policies workshop, Permanent Committee on Cadastre in the European Union (PCC) meeting December 10-11, Rome

[42] **BENTLY SYSTEMS INC.** (2004) “The Fundamentals of SCADA”, White paper, 18 pages

[43] **ROSSMAN, L. A.** (2000) "EPANET 2 user's manual", NATIONAL RISK MANAGEMENT RESEARCH LABORATORY OFFICE OF RESEARCH AND DEVELOPMENT, 200 pages

[44] **KUMAR, R** (2005) “Research Methodology: a step by step guide for beginners” 2nd edition, Pearson Longman, 332 pages

[45] **HAYLLAR, B. and VEAL T.** (2000) “Pathways to research”, Heinemann, 102 pages

[46] **BELL, J** (2010) “Doing your research project” 5th edition, McGraw Hill, 290 pages

APPENDIX A

CURRICULUM VITAE

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BS	Mousl Univ. Computer seince	1999
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WORK EXPERIENCE

Year	Place	Enrollment
2003-Present	The Kirkuk water directorate	programmer
2002-2003	AL-FAW Enginerring Compony	programmer
2000-2002	Kirkuk Internet Center	programmer

FOREIGN LANGUAGES

Arabic, English, Turkish