Application of GIS for development and maintenance pipeline network with the aid of GPS

Hamid Adrees AL- khashab
Mosul University

Rami Dawood AL-Hindni
Ninavah Drug Industries Co. Mosul

Abstract:

Geographic information system (GIS) technology can be used for scientific investigations, resource management, and development planning, it is a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information; that is, data identified according to location.The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbits, GPS works in any weather conditions and anywhere, GIS is used in this research and is applied to waste and storm water(rainfall)pipelines network in large sector of Mosul university which is described as high population and construction density to be identical sample as urban's water and wastewater networks, To achieve this research ArcGis was used with aid of updated satellite pictures and Engineering drawing maps, also Gps was used to locate (Manholes) positions with high accuracy, The result was obtained a digital geographical map that can be spatial query about any part of network for monitoring and Maintenance and laying new expansion pipes

Introduction

geographical information system (GIS)

GIS captures, stores, analyzes, manages, and presents data that is linked to location. Technically, GIS is geographic information systems which includes mapping software and its application with remote sensing, land surveying, aerial photography, mathematics, photogrammetry, geography, and tools that can be implemented with GIS software. Still, many refer to "geographic information system" as GIS even though it doesn't cover all tools connected to topology.

In the strictest sense, the term describes any information system that integrates, stores edits, analyzes, shares, and displays geographic information. In a more generic sense, GIS applications are tools that allow users to create interactive queries (user created searches), analyze spatial information, edit data, maps, and present the results of all these operations [15].

GIS Applications include [13]:

- **Water, wastewater, and storm water operations**
- **Comprehensive planning**
- **Building inspections**
- **Zoning**
- **Parcel mapping**
- **Pavement management**
- **Tracking customer complaints**
- **Grant applications**
- **Routing**
- **Work management**
- **Facility model analysis/planning**
- **Operations and maintenance**
- **Document management**
- **Customer information systems**

- **Workforce automation**
- **Environmental testing**
- **Marketing**

Advantages of GIS application [13]

A. GIS Applications Save Time and Money

The foremost benefit of GIS technology is increased productivity and quicker turnaround. Increased efficiency saves time, which translates into saving money. GIS applications improve the quality of life because they make things easier to do. GIS allows us to perform routine work, such as keeping records of maintenance work or customer complaints, more efficiently.

GIS provides a spatial approach to organizing information about customers and the assets of a water or sewer utility, such as pipes, hydrants, pumps, and treatment equipment. GIS applications help a utility to analyze the spatial information about its customers and assets to improve planning, management, operation, and maintenance of its facilities.

B.GIS Applications are Critical to Sustaining GIS Departments

Continued development of new applications is critical to sustaining the growth of a new technology. GIS, being a new technology itself

C.GIS Applications Provide the Power of Integration

The typical local government office contains hundreds of maps displaying such information as municipal boundaries, property lines, streets, sewer pipes, watermains, voting district boundaries, zoning areas, flood plains, school bus routes, landuse, streams, watersheds, wetlands, topography, geology, and soil

types, to name afew. Paper maps, after all, have been the traditional method of storing and retrieving

geographically referenced information. The sheer number, range of types, and diversity of maps used by municipalities are evidence of the importance geographically referenced information plays in our day-to-day operations, The real strength of GIS is its ability to integrate information. This integration power makes the scope of GIS applications almost infinite. A GIS can be whatever we want it to be. GIS can organize the geographic information of a municipality or utility into one seamless environment. The unique integration capability of GIS allows disparate data sets to be brought together (integrated) to create a complete picture of a situation.

Piping system

Piping is defined as the pipeline network that have big diameters. Plumbing refers

to pipelines network with small diameters, each can be made from cooper ,stainless steel, plastic or reinforced concrete ……etc

Pipes are in general used in water, gas or vapor transportation also can used in oil industries or petrochemical productions and are called transportation pipelines and may have stretch for thousands kilometers over or under ground.

Pipes that collect water and gases from sewage collection emitting from basins across sewers and transport it to treatment plants are defined as the civilian pipes because of its function nature. These pipes are made of concrete or stainless steel.

Industrial installations can perform some operations that aimed at converting raw material to final productions by using air, water and vapor in many industries that deal with raw materials [4].

Conditions of pipes production and usage

Technical pipelines face a lot of neglect when they are used especially the effects of pressure (starting from vacuum pressure =250 mpa), temperature of the transported materials and average loads resulting from the soil weight.

Pipes' manufacturing conditions depend on:

Pipe type, diameter, thickness, type of the transported material, networks location, additives, strain, piping methods whether inside a channel-with or without conduits horizontally or vertically or hanging or within technical equipment, elevation, valves type, measurements tools and the type of supporting points of the pipes [4].

Global Positioning System (GPS)

The Global Positioning System (GPS) is a global navigation satellite system (GNSS) developed by the United States Department of Defense and managed by the United States Air Force 50th Space Wing. It is the only fully functional GNSS in the world, can be used freely by anyone, anywhere, and is often used by civilians for navigation purposes. It uses a constellation of between 24 and 32 medium Earth orbit satellites that transmit precise radio wave signals, which allow GPS receivers to determine their current location, the time, and their velocity. Its official name is NAVSTAR GPS. Although NAVSTAR is not an acronym, a few acronyms have been created for it,

fig (1) show satellite picture around earth.

Fig (1) Satellite picture

GPS has become a widely used aid to navigation worldwide, and a useful tool for map-making, land surveying, commerce, scientific uses, tracking and surveillance [15]

Basic concept of GPS

A GPS receiver calculates its position by precisely timing the signals sent by the GPS satellites high above the Earth. Each satellite continually transmits messages containing the time the message was sent, precise orbital information (the ephemeris),

and the general system health and rough orbits of all GPS satellites (the almanac). The receiver measures the transit time of each message and computes the distance to each satellite. Geometric trilateration is used to combine these distances with the location of the satellites to determine the receiver's location as shown in Figures (2) and (3). The position is displayed, perhaps with a moving map display or latitude and longitude; elevation information may be included. Many GPS units also show derived information such as direction and speed, calculated from position changes.

It might seem three satellites are enough to solve for position, since space has three dimensions. However, even a very small clock error multiplied by the very large speed of light (the speed at which satellite signals propagate) results in a large positional error. Therefore receivers use four or more satellites to solve for *x*, *y*, *z*, and *t*, which is used to correct the receiver's clock. While most GPS applications use the computed location only and effectively hide the very accurately computed time (15)and [14].

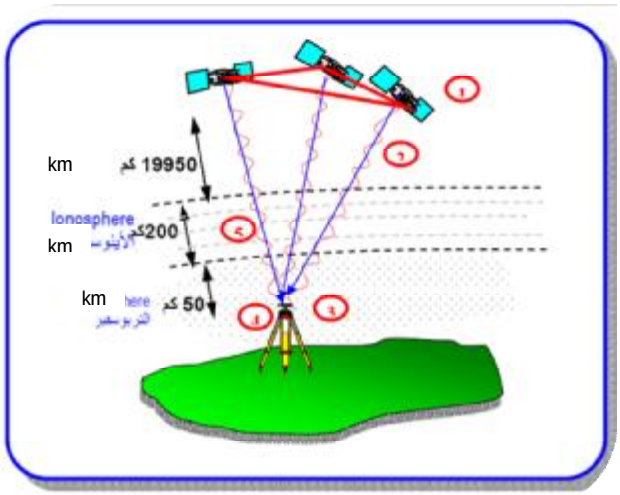


Fig (2)Principles of GPS work satellite

Fig (3) Orbital of satellite around earth

GPS APPLICATIONS IN GIS

GPS technology represents a space-age revolution in GIS data collection. It is providing an efficient and increasingly popular way for collecting both the location(coordinates) and the attributes data in the field.The new line of GPS receivers brings technology to water- and wastewater system operators and managers, who can populatetheir existing maps with precise location of features such as manhole covers, catchbasins, overflow points, hydrants, valves, pumps, flow meters, and rain gauges. The most basic application of GPS is collection of (x,y) coordinates for the GIS features. Initially, these coordinates were manually entered into the GIS database(14)and [15].

GPS Application in the water industry

At the present time, the GPS revolution is well under way. The GPS applications for the water, wastewater, and storm water(rain fall) systems, are revolutionizing the way these systems are designed, constructed, operated, and maintained. Representative GPS applications for the management of water, wastewater, and storm water systems are[13]:

1. GPS can be used to increase the accuracy of existing system maps by verifying and correcting locations of the system components. Frequent field changes often mean utility lines can be several feet off horizontally and/or vertically from where they appear on the plans. Thus, unless updated frequently, most utility plans, especially in growing cities, are outdated frequently. GPS data collection is no longer limited to collecting coordinates of point features. Now users can bikealong a channel to map line features, or walk around a detention pond to map polygon features.

2. New water system or sewer system maps can be created if they do not exist.

3. Water system or sewer system attributes can be collected for populating the GIS database.

Literature

(Seth et al, 2005) have used GIS in studying urban storm water, in view of the fact that storm water is considered one of most important surface water pollution resource, and that GIS is considered one of the most important tools in storing, treating, analysis and displaying results as geographical texts, and can affect storing, managing displaying data regarding water resource managing. Researchers have also made watershed model which can be defined as the studying of maps and documents for collecting information about land use, soil type, elevation, piping network as well as piping network for a water drainage for the under discussion areas.

(Du et al, 2006)from china and Netherlands studied managing and making 3D virtual model for pipelines network by using (DBMS) & (AEC) software. Managing and making virtual model for underground facilities (pipes, electrical and communication cables) are considered one of the most important things that are focused upon worldwide as inaccurate information about the location and the depth of these networks will cause a big economical problems and accidents when working nearby. The most important variables adopted by the researchers are (center line, diameter, depth, …) of pipes and finally the researchers were able to make a virtual model which can be used in the maintenance of networks in office and in field.

(samadder et al,2007)studied and analyzed health effects caused by drinking water Arsenic pollution in pipes by applying GIS in six Indian cities.

(Gamille et al, 2003) in the USA have applied GIS on water , waste water and oil pipelines and cables system in the north of Louisiana. the main reason for choosing this state is the high population density which resulted in complicated networks laying underground as well as pipelines of exporting oil that is pulled out from this area led to high damages and accidents for unawareness of the locations of these facilities. The researchers were able to set a map for these networks by applying GIS by data analysis and drawing after getting field coordinates by Gps.

System Design

his step recommends a GIS to support the applications identified in the previous

steps. It should evaluate the as-is state of the organization relative to key business functions and identify the required elements needed to create the desired improvements [13].

System design includes determining specifications for the following components:

- **Data conversion (mapping)**
- **Database**
- **Software**
- **Hardware**
- **User interface**

Data Conversion (Mapping)

Approximately 75% of typical GIS costs are related to data conversion and creation.

This component includes data conversion methods (scanning, digitization, etc [13]

Database

A GIS database stores descriptive information about map features as attributes. For

example, a water system database includes attributes for pipes, valves, meters, hydrants, and so on; and a sewer system database contains attributes for pipes, manholes, catch ,basins, outfalls [13].

Software Selection

It is a computer programs that can connect descriptive geographical databases with spatial data and could doing treatment operations and complete analysis about the nature of the relationship among variables in different places within topology for those geographical phenomena, which means a description for world sites and its geometrical properties and its inter-communicative limits such as ArcGIS-global mapper-raster to vectors-map information [13].

Hardware Selection

The selection of appropriate GIS hardware depends on the scope of the GIS application project and the available resources [13]

- **Computer with fast processor, large memory, and extensive disk space**
- **GPS receiver**
- **Computer server (for networked configurations).**

Mapping

GIS provides powerful and cost-effective tools for creating intelligent maps for water, wastewater systems

MAPPING BASICS

The basic concepts essential for understanding GIS mapping are summarized in the following subsections.

Map Types

There are two major types of GIS maps: vector and raster. In *vector* format, objects are represented as points, lines, and polygons. Examples of the vector format are maps of water mains, hydrants, and valves. Scanned maps, images, or aerial photographs are examples of *raster* format. Raster data are also referred to as grid, cell, or grid–cell data. In raster format, objects are represented as an image consisting of a regular grid of uniform size cells called *pixels*, each with an associated data value. Many complex spatial analyses, such as automatic land-use change detection, require raster maps. Raster maps are also commonly used as base maps. Existing paper maps that are used to create GIS maps are called source maps.

Map Projections and Coordinate Systems

Because the Earth is round and maps are flat, transferring locations from a curved surface to a flat surface requires some coordinate conversion. A map projection is a mathematical model that transforms (or projects) locations from the curved surface of the Earth onto a flat sheet or 2D surface in accordance with certain rules. Mercator, Robinson, and Azimuthally are some commonly used projection systems. Small-scale(1:24,000 to 1:250,000) GIS data intended for use at the state or national level are projected using a projection system appropriate for large areas, such as the Universal Transverse Mercator (UTM) projection. The UTM system divides the globe into 60zones, each spanning 6˚ of longitude. The origin of each zone is the equator and its central meridian. X and Y coordinates are stored in meters [13].

Methodology of work

In this paper the study area will be recognized and which include a large sector of Mosul university and has been selected for many reasons ,such as it is easy to take benchmarks (practical reading), it is easy to obtain topographic and satellite maps and CAD maps ,in addition to the nature of the region that is characterized by high population density. the work steps are as given below

1. After recognizing the work area; locations that to be geographically surveyed were identified.

2. Many points were taken along the path of water and waste water pipeline system and fixing the coordinates were fixed for each manhole. Global position system(GPS) technology was utilized in taking these points. This device has been manufactured by a company specialist in this field called (Garmins) and the model is (eTrex H) as shown in Fig (4).

Fig (4) GPS Model e-trex H

It has many specifications, the most important of which are: high accuracy with a small error percentage doesn't exceed 3-5 meter ,it has the ability to trace the

path for many points so it will be easy to follow any path, this device can save many points and paths that would be taken by it.

It is known that data which can be obtained from GPS is the location of longitude ,latitude and elevation from the sea level.The table(1) below shows the points that were taken in GPS for manhole coordinate ,these points will be projected on the map later

Manhole No.	X (degree)	Y (degree)
1	36º 22.649´	43 º 08.743
2	36 º 22.617	43 º 08.791
3	36 º 22.602	43 º 08.792
4	36 º 22.586	43 º 08.794
5	36 º 22.538	43 º 08.816
6	36 º 22.538	43 º 08.783
7	36 º 22.537	43 º 08.766
8	36 º 22.538	43 º 08.752
9	36 º 22.536	43 º 08.729
10	36 º 22.536	43 º 08.699
11	36 º 22.536	43 º 08.683
12	36 º 22.535	43 º 08.666
13	36 º 22.536	43 º 08.648
14	36 º 22.534	43 º 08.631
15	36 º 22.534	43 º 08.611
16	36 º 22.530	43 º 08.603
17	36 º 22.515	43 º 08.604
18	36 º 22.501	43 º 08.604
19	36 º 22.487	43 º 08.604
20	36 º 22.471	43 º 08.604
21	36 º 22.459	43 º 08.605
22	36 º 22.446	43 º 08.605
23	36 º 22.423	43 º 08.592
24	36 º 22.588	43 º 08.909
25	36 º 22.571	43 º 08.885
26	36 º 22.543	43 º 08.866
27	36 º 22.540	43 º 08.868
28	36 º 22.531	43 º 08.855
29	36 º 22.530	43 º 08.850
30	36 º 22.537	43 º 08.973
31	36 º 22.531	43 º 08.950

Manhole No.	X (degree)	Y (degree)
32	36 º 22.528	43 º 08.930
33	36 º 22.519	43 º 08.893
34	36 º 22.491	43 º 08.858
35	36 º 22.511	43 º 08.857
36	36 º 22.516	43 º 08.856
37	36 º 22.652	43 º 08.713
38	36 º 22.652	43 º 08.696
39	36 º 22.652	43 º 08.664
40	36 º 22.652	43 º 08.643
41	36 º 22.650	43 º 08.622
42	36 º 22.651	43 º 08.608
43	36 º 22.633	43 º 08.605
44	36 º 22.616	43 º 08.604
45	36 º 22.543	43 º 08.608
46	36 º 22.830	43 º 08.717
47	36 º 22.816	43 º 08.689
48	36 º 22.801	43 º 08.660
49	36 º 22.753	43 º 08.601
50	36 º 22.735	43 º 08.603
51	36 º 22.717	43 º 08.575
52	36 º 22.716	43 º 08.532
53	36 º 22.716	43 º 08.490
54	36 º 22.712	43 º08.385
55	36 º 22.706	43 º.08.359
56	36 º 22.651	43 º 08.596
57	36 º 22.650	43 º 08.584
58	36 º 22.650	43 º 08.561
59	36 º 22.649	43 º 08.544
60	36 º 22651	43 º 08.517
61	36 º 22.649	43 º 08.489
62	36 º 22.650	43 º 08.468

Table (1) Manholes coordinates

3. With the aid of remote sensing center which provides us with a satellite picture for Mosul university as shown in fig(5)

Fig (5) Satellite Picture of Mosul University

We have also an engineering draw map type (CAD file) from the projects and construction office in Mosul university as shown in fig (6).

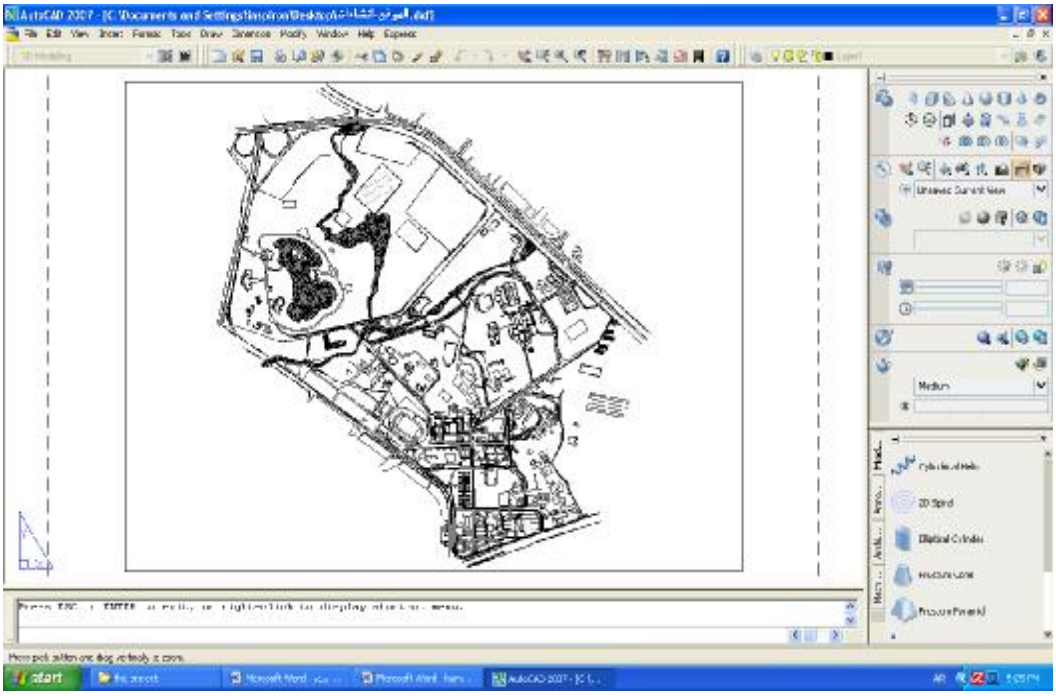


Fig (6) Mosul university as an AutoCAD map

4. after obtaining all the data that may be useful for the project, one must program's environments (Arc GIS).

Arc GIS software

ArcGIS provides a scalable framework for implementing GIS for a single user or many users on desktops, on servers for use in the enterprise and across the Web, and in the field. ArcGIS is an integrated family of GIS software products for building a complete GIS. It consists of four primary frameworks for deploying GIS:

ArcGIS Desktop, Server GIS, Developer GIS, Mobile GIS.

in this paper ArcGIS Desktop is applied (3). ArcGIS Desktop is an official version for GIS, described as a complete group of GIS applications.

ArcGIS Desktop is applied in this paper which includes three parts which can be with any task related to GIS

a. Application of Arc map: it is considered the basic application for Arc GIS Desktop and it performs many purposes including mapping ,editing, analysis, displaying digital data ,handling layers and adding certain elements to maps like drawing scale map key and the figures below shows the application window Fig (6) and Fig (7)

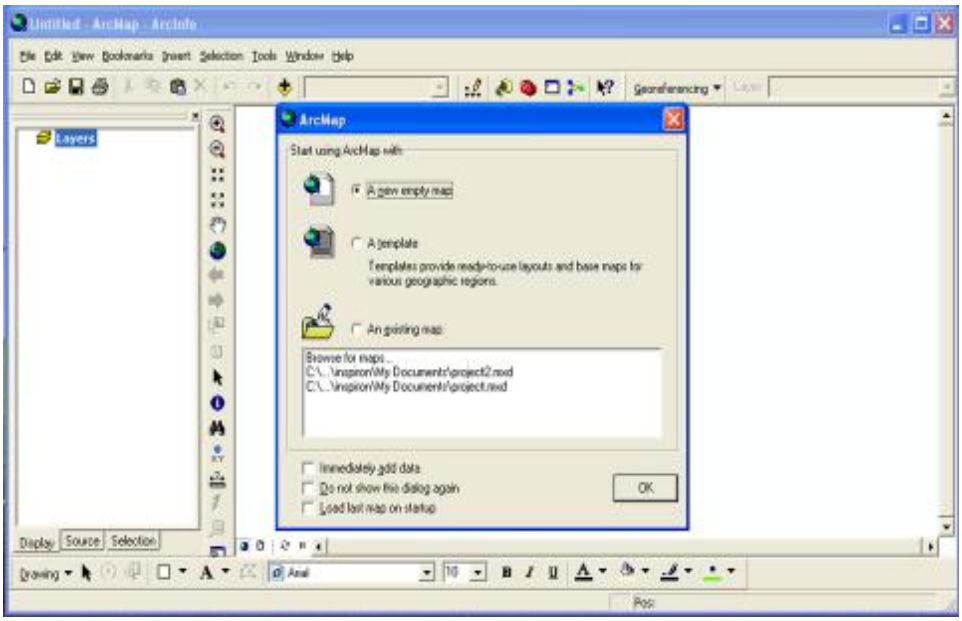
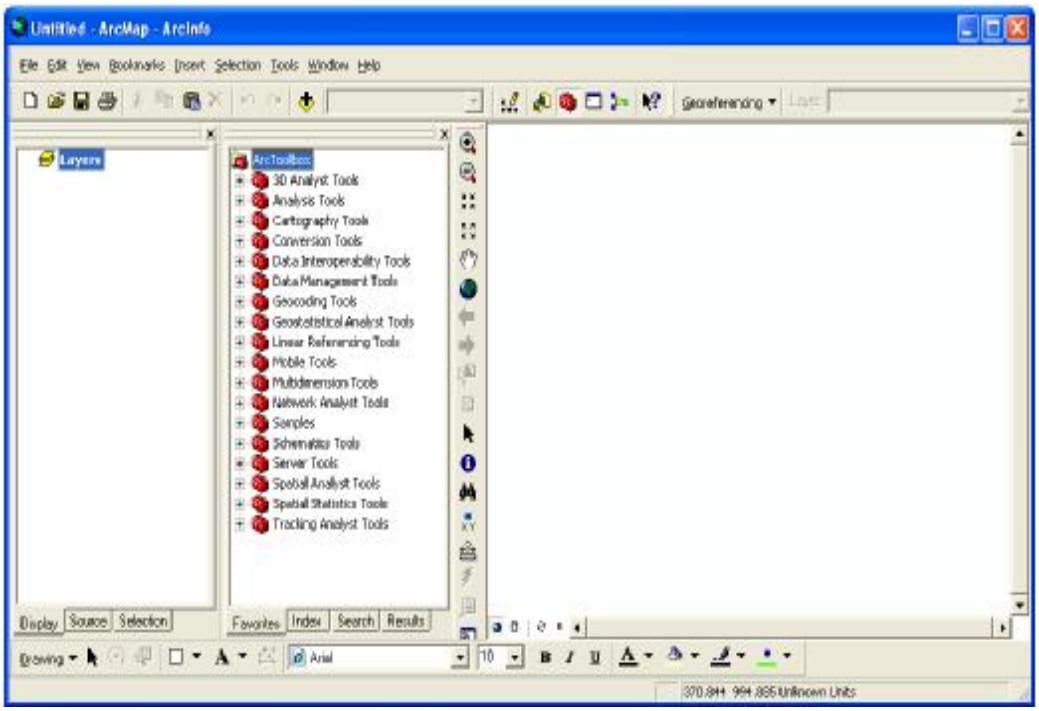
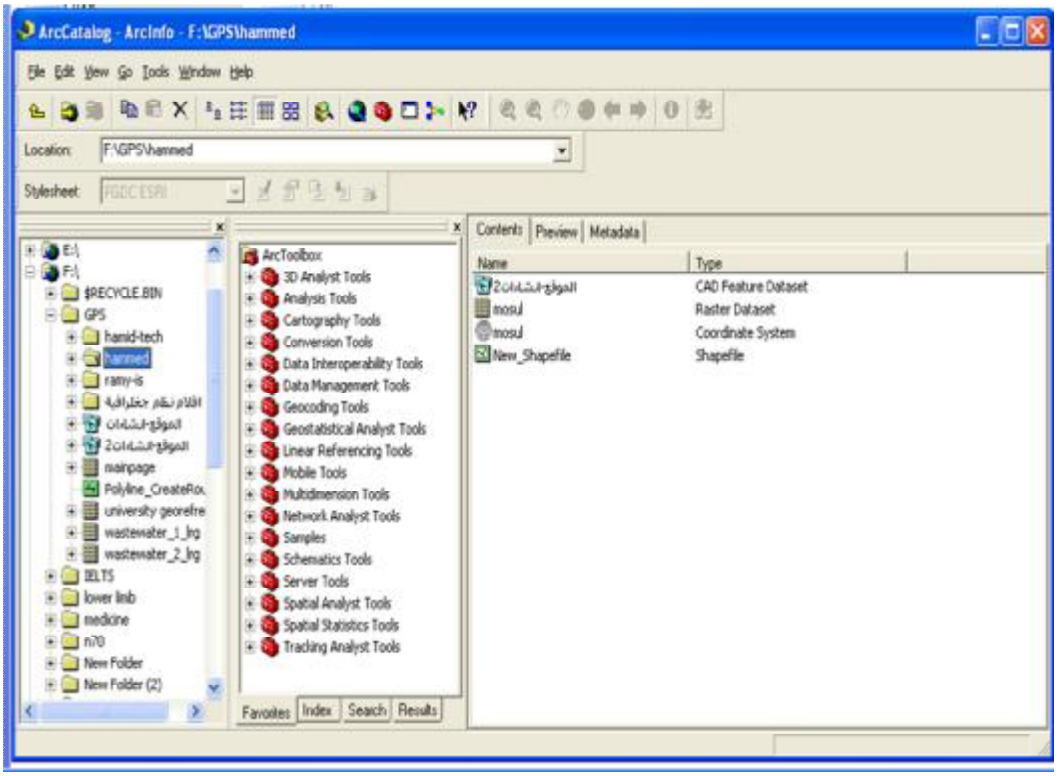


Fig (6) Arc map window-1



Fig(7) Arc map main window

b. Application of Arc catalog: It is an application that helps to arrange and managing GIS data, it also contains tools for searching and paging geographic information as shown below.



Fig(8) Arc catalog main window

As well as it records and displays documentary information related to GIS files. This application is extremely similar to windows explorer, but it is more specialized in geographical database and map design.

<u>C. Arc tool box application</u>: It is a simple application which is integrated with arc catalog (ninthversion) anditincludes GIStools This application converts between different formats of GIS files and it can export the files that work in arc GIS environment into different kinds of file and the previous Fig (7) and Fig (8) show arc tool box on the left of application screen in the program.

.5 Its known that maps drawn in programs other than GIS program or satellite pictures, visual picture, pictures of maps taken by scanner were not Geo-referenced map , and To be able to deal with these maps and making use of them; digital maps should be revived and make them Geo-referenced.

Geo-referencing

which is defined as improving pictures efficiency and constructing coordinates for it and connect it together or with geographical maps that have coordinates resulting from air spatial photography or surveying works.

Therefore; it is a correction of the digital maps pictures or paper maps that could not be depended on or making use of it because they have no accuracy or efficiency to be a surveying map that can be depended on. So old porous maps or paper maps could be revived in general whether digital map or paper to be connected with Arc GIS system (3).

6. A digital Georeferencing map for Mosul university has been obtained as shown in Fig (9) The satellite picture map may opened in Arc Map and it illustrates that the work area was buffered.

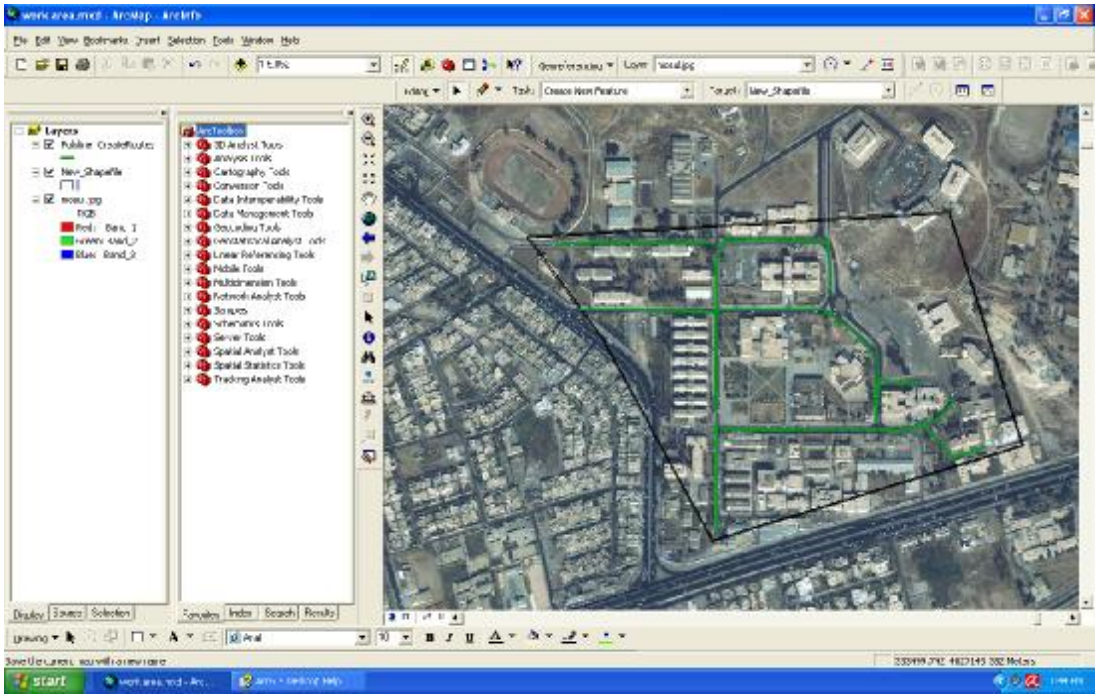
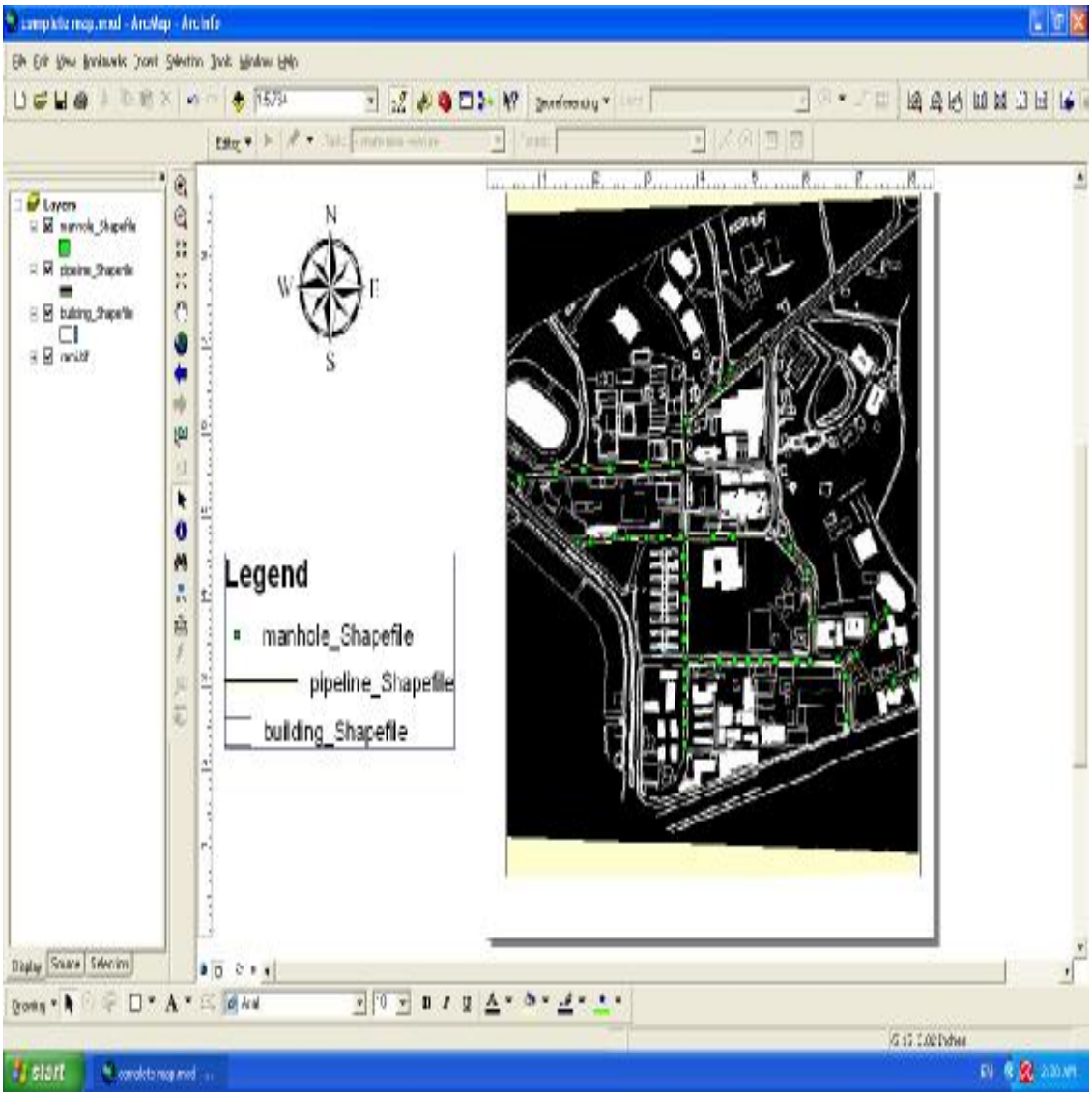


Fig (9) Buffer area and pipeline drawing for Mosul university in Arcmap

7.The Arc map enable us to open the map with extension (DWG) that was pre drawn in AutoCAD, so we consider this map as a base map(main layer) where other layers are added on. Then they were added as a layer for pipeline (shape file . line) ,manhole(shape file.point) andbuildings (shape file.polygon)

8.after completed drawing pipeline system and manhole then GPS points were projected on the map and merely indicating anywhere we want to query about; the location (longitude and latitude)of the point will immediately appear and the Fig (10) show the final result of the water and wastewater piping system.

Fig(10) Piping system with manholes location for work area Mosul university by Arcmap



Monitoring and maintenance Monitoring

GIS is ideally suited to install, maintain, and query monitoring equipment such as, rain gauges, flow meters, and water quality samplers for system physical and hydraulic characterization. GIS allows display and analysis of monitoring data simply by clicking on a map of monitoring site

Monitoring Basics

Monitoring of various types of data is essential to the effective management of water, wastewater, and stormwater systems. Generally, two types of data are required:
(1) physical characterization data and (2) hydraulic characterization data. Physical characterization data describe the physical condition of the infrastructure, such as pipe and manhole conditions. Examples of physical characterization data sources include closed-circuit television (CCTV) inspection of pipes, manhole inspections, of buildings.

Wastewater and storm water systems typically require data on flow quantity(depth, velocity, flow rate, and volume), quality (e.g., suspended solids and bacteria), and rainfall. The Figure shows a flow meter and weir installation in a combined sewer system overflow manhole. The flow meter shown on the left records incoming combined sewage depth, velocity, and flow data [13].

Fig (11) Flow meter and weir installation in a manhole for monitoring incoming and outgoing flows.

Maintenance

GIS can be used to prepare inspection or maintenance work orders simply by clicking on a sewer pipe or manhole. This approach simply takes just a few minutes compared to the conventional method of locating and copying maps and typing the work order forms, which usually takes several hours.

To fully appreciate the benefits of GIS-based inspections, the Metropolitan Sewerage District (MSD) developed and implemented a new GIS-based rehabilitation method called "piperating.", The piperating method has five main elements: (1) CCTV information, (2) adefect scoring system, (3) GIS database software, (4) sanitary sewer overflow (SSO)history, and (5) engineering analysis. These components are combined to generate specific projects for problem lines. Each structural defect noted in the video inspection is given a defect score, in accordance with MSD's standardized scoring system[13]

Fig (12) Sample mini movie in AVI format showing collapsed sewer pipe

Finally, Arc GIS is considered one of the large geographic programs that needs a work of institutions or governments to get maximum benefit from it ,but we were able in no time to achieve good results and give an obvious idea about this program , to pave the way for collective work in this type of information technique program that saves time , effort and costs to get the best results.

Conclusions

1. The possibility of performing field survey for pipelines and facilities (water supplying, sewer systems, oil pipelines and electrical cables) and setting representation maps for them, such that damages and cuttings of these pipes and wires can be avoided when maintenance or laying new projects that depend on digging nearby are needed.

2. This study was achieved by applying Arcmap software and is considered the first of this kind for storm water pipelines in Mosul university.

3. The possibility of generalizing this study upon Mosul pipelines and facilities in order to achieve low costs of maintenance and laying new networks via the avoidance of causing damages and cracks for the old pipes.

4. This map will be easier for developing when it needs to be revised while paving new routes and new networks via surveying the new area ,adding or removing new coordinates for the achieved project and consequently getting correct and new map with low costs .

5. It is an attempt to generalize the project idea upon the directories of municipalities, electricity and communications.

6. Achieving Low costs of survey by applying GPS compared to traditional methods.

7. Survey process of pipes and wires currently used in Iraq needs a long time to be achieved; therefore it should be proceeded and finished on several stages.

8. Population density is considered one of the most effective factors on the quantity of pipes and wires, as the more the quantity increases, the more complicated the survey process will be.

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استخدام نظم المعلومات الجغرافية في صيانة وتطوير شبكة انابيب مياه الامطار في جامعة الموصل

م.م. حامد ادريس الخشاب
جامعة الموصل / كلية الهندسة

م. رامي داؤد الهندي
شركة نينوى لصناعات الادوية

المستخلص:

نظم المعلومات الجغرافيةGIS وهي تقنية تستخدم للأبحاث العلمية وإدارة الموارد وتطوير الخطط وهو قابلية أجهزة الحواسيب للالتقاط وخزن وتحليل وعرض المعلومات الجغرافية حيث أن البيانات تعرف طبقا لمواقعها، وان نظام تحديد الموقع العالمي(GPS) هو نظام ملاحة فضائي مكون من شبكة من الأقمار الاصطناعية وعددها 24 قمر موضوعة في مداراتها، يعمل هذا النظام في أي ظروف مناخية وفي أي مكان في العالم وعلى مدار الساعة, وكما يمتاز الـGPS بكونه مجاني ولا يحتاج إلى دفع اشتراك أو جور تنصيب لاستخدامه، وقمنا في هذا البحث باستخدام نظم المعلومات الجغرافية وتطبيقه على شبكة أنابيب جمع مياه الأمطار والفضلات في جزء واسع من جامعة الموصل يمتاز بالكثافة السكانية والإنشائية العالية لتكون نموذج مطابق لما موجود من شبكات المياه والمجاري في الأحياء السكنية,ولغرض انجاز البحث تم استخدام برنامج الـ (Arc Gis) والاستعانة بالصور الفضائية وخرائط الرسم الهندسي الحديثة كما تم الاستفادة من جهاز GPS لتحديد مواقع الـ(Manholes) بدقة عالية, فكانت النتيجة الحصول على خريطة رقمية جغرافية يمكن من خلالها الاستعلام المكاني عن أي جزء من الشبكة لغرض الصيانة والمراقبة ومد الخطوط الجديدة المستقبلية.