Cost of Optimum Design of Trunk Mains Network Using Geographical Information System and Support Programs

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ABSTRACT

Sewer network is one of the important utilities in modern cities which discharge the sewage from all facilities. The increase of population numbers consequently leads to the increase in water consumption; hence waste water generation. Sewer networks work is very expensive and need to be designed accurately. Thus construction effective sewer network system with minimum cost is very necessary to handle waste water generation.

In this study trunk mains networks design was applied which connect the pump stations together by underground pipes for too long distances. They usually have large diameters with varying depths which consequently need excavations and gathering from pump stations and transport the sewage to final waste water treatment plant. This situation urges to decrease the cost to minimum with efficient design of its performance. The aim of this research is minimizing the cost of all sewer components of trunk mains which are lengths, diameters, and volume of excavation with maintaining its performance.

In this research, the utilization of GIS (Geographical Information System) software and VBA (Visual Basic for Application) which is integrated with GIS was used to implement the MST (Minimum Spanning Tree) algorithm to create a visual basic computer program that was used to find the minimum total lengths of the trunk mains in a sewer network.

This method was applied on selected areas in Al-Mansour municipality where there is an existing sewer system containing trunk mains and pump stations. Total lengths of the existing trunk mains are calculated and later, the proposed method was implemented to find the minimum total lengths, with a difference in total lengths of (12601 m).

The new network used to design a proposed sewer system using the computer program SewerGemsV8i, which can be integrated with GIS. New pipes diameters and slopes were calculated by supplying the necessary information that is needed by the computer program.

New sewer system was designed which gave more reliable and economical aspects than the existing one. These results clearly show that when comparing the costs.

Key words: GIS, optimum design, trunk mains, pump stations, minimum cost.

كلفة التصميم الامثل لشبكة انابيب المجاري بإستخدام نظم المعلومات الجغرافية والبرامجيات الساندة

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الخلاصـــــــــــــــــــــة

تعد شبكات المجاري من اهم البنى التحتية للبلد والتي تقوم بخدمة عموم الناس بتصريف مياه المجاري من المنازل والمصانع وكافة الانشطة الحيوية، ونظر لزيادة عدد السكان وبالتالي زيادة استهلاك الماء مؤديا الى زيادة تصريف مياه المجاري.فان انشاء شبكات المجاري عمل مكلف جدا ويحتاج الى الدقة في التصميم، فأعداد تصاميم لشبكات المجاري وملحقاتها ذات كفاءة اعلى في العمل وذات كلف اقل في الانشاء ضروري لمعالجة تصريف مياه المجاري.

في هذه الدراسة تم اخذ تصميم شبكات الانابيب الناقلة التي تربط محطات الضخ مع بعضها بانابيب طويلة ممتدة تحت سطح الأرض وباقطار كبيرة عادة واعماق مختلفة وتقوم بجمع مياه المجاري من كافة المحطات ونقلها الى محطة المعالج الاخيرة، وبهذه الحالة كان من الاوجب تصميم تلك الانابيب بأقل كلفة مع ضمان كفاءة العمل.الهدف من هذه الدراسه هو حساب الكلفة الاقل لكل عناصر شبكة الانابيب الناقلة التي تتضمن الاطوال، الأقطار، أعماق الحفر، أعداد محطات الضخ، الموقع الأفضل للمحطات الذي يؤثر على كلفة هذه الانابيب واداؤها.

اعتمد في هذا البحث على استخدام برنامج نظام المعلومات الجغرافية وبرنامج الفيجوال بيسك المدمج مع نظام المعلومات الجغرافية بما يسمى (GIS-VBA) والذي استخدم لتنفيذ خوارزمية شبكة ذات اقل امتداد (Minimum Spanning Tree) وتكوين برنامج يقوم بايجاد اقل مجموع اطوال لشبكة الانابيب الناقلة.

تم اخذ بعض المناطق ضمن وحدة بلدية المنصور كمنطقة للدراسة ولتطبيق البرنامج وتم تحديد مواقع محطات الضخ التي تخدم تلك المنطقة ورسم شبكة تمثل كل الشوارع التي ممكن ان يقترح فيها انشاء انابيب ناقلة وتنفيذ البرنامج لحساب اقصر مجموع اطوال لتلك الشوارع التي تربط بين مواقع محطات الضخ ، حيث لوحظ الفرق بالاطوال بين الانابيب المنفذة والانابيب المقترحة باستخدام البرنامج هو (12601متر).

ثم اعتماد تلك الشبكة المقترحة واستخدامها في احدى برامج تصميم شبكات المجاري المدمج مع برنامج GIS وهو برنامج SewerGemsV8i لغرض حساب اقل اقطار ممكنة للانابيب الناقلة وحساب اقل ميل ممكن لهذه الانابيب وبالتالي الحصول على اقل كميات للحفريات ولوحظ ايضا الفرق بين اقطار الانابيب المقترحة والميول الخاصة بها.

واستنتج أن تنفيذ الطرق المقترحة اعطى مساهمة بإيجابية كبيرة في تصميم وتحليل أنظمة الصرف الصحي الموجودة أو الجديدة.

الكلمات الرئيسية : نظم المعلومات الجغرافية، التصميم الأمثل, الانابيب الناقلة،محطات الضخ، اقل كلفة.

1. INTRODUCTION

Sewerage pipeline networks is one of the essential infrastructures of the modern cities and it is very important in serving all people in their houses, factories, hospitals, schools and other vital utility activities by getting rid of unwanted waste water and water environment prevention.

In recent years, the population has increased significantly, commercial and industrial activities have also grown dramatically. This has led to an increase in water consumption and consequentially increases in quantity of wastewater, so there is need to construct a new sewer networks in areas that suffered from decrease of discharge of waste water.

Design of sewer system includes layout of sewer network, finding lengths, diameters, depths of all pipes, in addition to finding the best locations of other sewer system components such as outfall, manholes, pump stations, etc.

Efficiency and good performance are required in the design of sewer network hence it is not an easy work, in addition it is expensive work; hence need to minimizing and decreasing of construction and operation costs to the minimum.

1.2 GIS Applications in Sewer Networks

GIS are powerful and cost effective tools for deigning intelligent maps for water, wastewater, and storm water systems. Effective waste and storm water management requires linking of specialized computer models to the GIS. Also, integration of engineering, environmental, and socioeconomic objectives into waste and storm water management could be included.Most of the physical, social and economic problems associated with waste and storm water are attributable to unwise land use, insufficient attention to land drainage in urban planning, and ineffective updating of existing waste and storm water control systems, **Rusko et al., 2010**.

Typical applications of GIS for waste and storm water systems include: (1) Watershed storm water management, (2) Floodplain mapping and flood hazard management, (3) Hydrologic and hydraulic modeling of combined and storm sewer systems, including estimating surface elevation and slope from digital elevation model data (DEM), (4) Documenting field work, (5) Planning, assessment of the feasibility and impact of system expansion, (6) Estimating storm water runoff from the physical characteristics of the watershed, e.g. land use, soil, surface imperviousness and slope **Shamsi, 2002 and Paul Longley, 1999**.

Various spatial data layers can be combined and manipulated in a GIS to address planning, operation, and management issues. For example, water and sewer line information can be combined with population statistics and ground elevation data to assess the adequacy of water and sewer utilities, **Shamsi, 2005**.

2. THE OBJECTIVE OF THE RESEARCH

Trunk mains extents for long distances under the ground, these trunk mains usually have large pipe diameters, and since they connect many pump stations, they are embedded deeply under the ground surface for their protection. The design of these trunk mains will be very expensive and need to be reduced with maintaining accuracy and efficiency in its performance. So the aim of this research is to find the optimum design of trunk mains network which implement the highest efficiency and minimum cost. This aim achieved by minimizing the cost of the sewer system components that includes:

i. Length of trunk mains, ii. Trunk mains diameter, and iii. Volume of excavation.

3. METHODOLOGY OF THE WORK

This research developed a methodology in the trunk mains design method that depend on graph theory algorithm to find the minimum total lengths of trunk mains which is Minimum Spanning Tree (MST); it was programmed in Visual Basic for Applications (VBA**)** which is integrated with GIS, this algorithm was implemented on some selected areas in Baghdad city to give minimum total pipe lengths.

Bentley SewerGEMs V8i program is one of computer program that could be integrated with GIS to compute the appropriate pipe diameters and slopes that affect the trunk mains pipes depths.

4. MINIMUM SPANNING TREE ALGORITHM

Using graph algorithm MST is very powerful in providing the tree that connects all nodes of a Graph (which are represented by pump stations in this research) with minimum length of edges (which are represented by the pipe lines connecting the pump stations), the root of the tree is the disposal location of the waste water. It is necessary to use this algorithm and obtain a tree shaped network because there will be only one root for this tree which is the location of waste water disposal and the other branches of the tree represent the links between pump stations. A minimum spanning tree is so named because it is constructed from the minimum of number of edges (lines) necessary to cover every node and it is in tree form because the resulting graph is acyclic (i.e. with no cycles). The minimum spanning tree depends entirely on the starting node. **Michael Mcmillan, 2005**.

From the researchers have studied the MST algorithm and its applications is **Jason Eisner, 1997** who explained that the classic "easy" optimization problem is to find the minimum spanning tree (MST) of a connected, undirected graph. Good polynomial-time algorithms have been known since 1930. This work reviews those methods, building up strategies step by step so as to expose the insights behind the algorithms. Implementation details are clarified, and some generalizations are given. And **Paola Flocchini et al., 2007** deduced that in many network applications the computation takes place on the minimum-cost spanning tree (MST) of the network G; unfortunately, a single link or node failure disconnects the tree.

5. SEWER SYSTEM DESIGN AND ANALYSIS USING GIS

5.1 Case Study

A sample districts in the west of Baghdad/Iraq city located in the municipality of Al-Mansour was taken as a case study for implementation the MST to obtain the minimum cost of trunk mains pipes construction and using SewerGEMs to complete the sanitary design. **Fig. 1** shows the satellite image that shows the sample districts was taken as a case study in municipality of Al-Mansour with the number of districts.

5.2 The Data Sources

In this research, the required data were gathered from different source, such as shapefile forms, satellite images, maps, and numerical tables from various resources, which are:

- ✓ Shape file includes all main streets in municipality of Al-Mansour from department of GIS in Mayoralty of Baghdad (MOB) projected by Universal Transfer Mercator (UTM) and the spheroid is world geodetic system 84 (WGS84), Zone 38 N.
- ✓ Shape file includes the locations of all pump stations in municipality of Al-Mansour from department of GIS in Baghdad Sewage Directorate (BSD) in (MOB) projected by Universal Transfer Mercator (UTM) and the spheroid is WGS84, Zone 38 N.
- ✓ Information about diameters and path of existing trunk mains which connect pump stations together in municipality of Al-Mansour was obtained from BSD.
- ✓ Information about each pump station, such as discharge, depths of wet-well was also obtained from BSD.
- ✓ Satellite image of Bagdad city with resolution of 60 cm was obtained from Quick Bird satellite.

Fig. 2 shows a satellite image of the study area in Al-Mansour municipality, and also shows the locations of pump stations (yellow rectangles) and the main streets (red lines), where each pump station is shown with a label of its name. **Fig. 3** shows the satellite image that shows existing sewer network of trunk mains in the municipality of Al-Mansour.

5.3 Existing Sewer Network

For the analysis of already existing network, collecting some necessary data needed to this study such as:

1. Ground elevation of Pump stations.
2. Waste water inflow to each pump station.
3. Path of the existing trunk mains, and
4. Trunk mains diameters.

5.4 Obtaining Ground Elevations

Source of the elevations that is depended in this research is from Baghdad Sewage Directorate (BSD). These elevations were produced by the Japanese Nippon Koie company, and were obtained in a shape file form. **Fig. 4** shows the satellite image that show point's network of the case study. Any point in these data has ground elevation in addition to Cartesian coordinates (X and Y).These points can be converted to terrain surface using ArcMap10 by interpolation these points by IDW method to product Digital Elevation Model (DEM). **Fig. 5** shows the satellite image that shows Digital Elevation Model (DEM) of the districts in municipality of Al-Mansour.

5.5 Waste Water Flow

Waste water flow information was obtained from Baghdad Sewage Directorates (BSD). Each pump station inflow is shown in **Table 1** in cubic meter per day (m3/day). This table also shows elevations of the pump stations.

5.6 Lengths of the Existing Trunk Mains

Fig. 3 showed the existing trunk mains that are in service, where the total lengths of the trunk mains have a sum of (44895.95 m) which was calculated using ArcGIS computer program. The depth of these trunk mains ranged generally from 3 m at the start of the pump station and ends at 8 m reaching the next pump station where the waste water level is raised using pumps to 3 m again. Trunk mains pipes lengths, diameters, and start depths and end depths are shown in **table 2**;additionally **table 2** shows the calculations of the soil excavations in cubic meters (m3) and the cost of the excavations. These calculations are necessary to obtain the approximate costs that will be used later for comparison with the new proposed method.

5.7 Pipes Diameters

Pipes diameters are an important factor that affects the cost of the sewer system. The pipes diameters contribute in the cost in two ways; first, the cost increases with the increase of the pipe diameter, and second, the pipe diameter affects the width of the excavations, consequently affecting the excavations cost.

5.8 Pipes Material

The cost also depends on the type of the material used for the pipes in trunk mains. There are five types of materials usually used for sewer trunk mains, and these types are as following:

- Ductile Iron Cement Lined (DICL),
- Unplasticised, Modified and Oriented Polyvinyl Chloride (PVC),
- Glass Reinforced Plastic (GRP),
- Steel Cement lined (SCL) (special applications only),and
- Polyethylene (PE) (Less than 100 mm internal diameter only).

The material of these pipes material are used in the districts under study is assumed the UPVC, the cost per unit length and the approximate total cost of the UPVC pipes for each used diameter is shown in **table 3**.The calculations which are shown in **table 2** give the approximate value of the total volume of the excavations in addition to an approximate cost for the excavations.Adding the cost of the pump stations to this cost gives us the total sewer system cost for the districts under the case study. This cost can be easily obtained approximately by multiplying the cost of one pump station by the total number of pump stations as follows:

Total cost of pump stations = No. of pump stations × Cost average of a pump station

Total cost = 23 × 3,000,000,000 = 69, 000,000,000 I.D.

The total cost of a sewer network is calculated and shown in **table 4.**

5.9 Design of the Proposed Network

Minimizing the total cost can be obtained by minimizing the three items which are: Length of trunk mains, Trunk mains diameter, and Volume of excavation. The design procedure can be implemented via the following steps.

5.9.1Obtaining the minimum pipe lengths

Obtaining the minimum trunk mains length can be achieved by implementing Minimum Spanning Tree (MST) algorithm. To implement the new proposed algorithm for network design, it is required to draw a complete streets network graph that connect almost every point which represents a pump stations to all other neighboring points (or other pump stations) in the districts as shown in **Fig. 6**.

These complete streets network represent all main streets in the districts which are connected to pump stations and represents a candidate path for trunk mains. The total length of the complete streets network was (94091.48 m).

Based on Visual Basic for Application (VBA) which integrated in GIS program a new scripting was designed to find the minimum total lengths of the streets by implementing the MST algorithm. This code execution can be done by pressing the command button added to the toolbar of the ArcGIS program as shown in **Fig. 7**, denoted by the small red circle.

When pressing the command button, a series of commands will be executed that asks for the required data to implement the algorithm and obtain the required solution, which are the streets with minimum total lengths.

As soon as the file is stored, the minimum streets network will be shown in the ArcGIS display area. **Fig. 8** shows the minimum spanning streets lengths that connect all pump stations together and provide the minimum required path for the waste water disposal. The total length of the streets network is (32294.10 m). **Table 5** shows the new total length of streets network.

A simple comparison between the two networks in **Fig. 3**and **Fig. 8** shows the difference in total lengths of (44895.95 – 32294.10 = 12601.51 m) which saves more than twelve kilometers of pipe lengths and excavation efforts which has a great economical effect on the total cost of the sewer system.

5.9.2 Design of sewer system

In the previous sections, the design and layout of the sewer pipes was obtained. The inflow of the waste water was already obtained as shown in **table 1**.The sanitary design will be carried out including the design of the pipe diameters, slopes, and required depths.

The computer program SewerGEMs V8i was used for this purpose as it can integrate with ArcGIS program and provide the sewer design environment in the ArcGIS environment, which means it can read the shape file of the new proposed street network and use it for the sewer system design.

The layout of the conduits is shown in **Fig. 9** which also shows that the pump stations, the pump station usually contain a) Wet-well, b) Pump or pumps battery, and c) Ductile iron pipes to uplift the waste water under pressure to a higher level and let it flow again under gravity till it reach the next pump station or the treatment plant. A larger scale of some sample pump stations is shown in **Fig. 10**, where the wet-well, the pump, and the pressure pipes combinations are drawn. A detailed schematic drawing of one pump station is shown in **Fig. 11**.

5.9.3 Computer program components

The next step is to prepare the appropriate data required for modifying the properties of the components of the sewer system, which includes:

1) Pump stations data: Elevations of pump and inflow quantities are already mentioned in **Table 4**. Depth of its will be initially 2 m. These values will be considered in the design of the new sewer network.
2) Conduits data: Conduits data can be represents the gravity pipes are represented as follows:
    a. Lengths: already found from minimum streets network.
    b. Type: UPVC pipes will be considered as it is typically used for the construction of trunk mains.
    c. Diameters: The initial pipe diameters used is 200 mm which is the smallest diameter; this diameter size will change automatically by the computer program as needed in the design procedure.
    d. Inlet and outlet elevations: the inlet elevation is taken from the manhole attached to the starting side of the pipe while the outlet elevation is taken from the wet-well that is at the end of the pipe.
3) Outfall data: (End point of sewer system e.g. treatment plant). The last point that was considered as the outfall is the al-Kadisiya pump station, because of the limitation of the area under study (actually, the Al-Kadisiya pump station convey waste water to other station).
4) Outfall data The last point that was considered as the outfall is the al-Kadisiya pump station, because of the limitation of the area under study (actually, the Al-Kadisiya pump station convey waste water to other station
5) Pressure Pipe: Pressure pipes are the link between the wet-well and the pump from one side and the link between the pump and the manhole from the other side, as the waste water flows from the wet-well through the pump to the next manhole. All pressure pipes were given a length of 300 mm (as recommended by the instructions of the sewer GEMs program manual), ductile iron material, and a diameter of 150 mm was taken as an initial value

5.9.4 Sewer GEMs program run

The computer program has two calculation alternatives, the first, is the design alternative, and the second is the analysis alternative.

The design alternative is the first choice where the computer program performs the design procedure regarding all constrains that were already supplied to the calculation options including the slope constrains (0.001 – 0.1), cover constrains (0.7m – 10m), and velocity constrains (0.61 m/sec – 4 m/sec) (as recommended by the instructions of the computer program manual).

The design was done for steady state condition neglecting the variation of the amount of waste water during the day (24 hrs.), only peak values were taken into consideration in the design procedure.

The results obtained from the design procedure affect the pipes diameters, slopes of pipes, and cover constrains. Minor adjustments were made at the analysis phase of the program including pipe invert level to maintain slopes within constrains.

Results of computer program run is shown in **table 6** which also includes the necessary calculations for the amount of excavations and its cost, while **table 7** shows the calculations of pipe costs considering the reduced lengths of pipes and its diameter which reflects the reduced cost. After the result was taken it can be compute the total cost of proposed sewer network as shown in **table 8** and the **table 9** that shows the comparison between the costs and the reduction obtained using the proposed network.

6. DISCUSSION& CONCLUSION

A. MST provides a successful solution for obtaining the minimum total lengths of trunk mains pipes, those pipes usually are large in diameters, they run for long distances and may go deep into the ground, consequently, they may cost a lot according to these factors, so any reduction in these costs may reduce the overall cost of the system.

B. MST algorithm can be very useful in estimating the paths for trunk mains (or any large pipes may be used in sewer systems) as any reduction may be obtained is reflected directly on the total cost of the sewer system.

C. After obtaining the MST, the integrated computer program (SewerGems) with the GIS program, can facilitate the sewer system design or analysis. This computer program takes the required information directly from the ArcGIS map. The trunk mains pipes lengths and pump stations locations are obtained through "Model Builder" command in the SewerGEMs menu.

D. Other hydraulic design operations are carried out by the computer program after all the complimentary information is supplied (e.g. hydraulic constrains, velocities, minimum and maximum cover, slopes, etc.).

E. The computer program (SewerGEMs) can work either in design mode or analysis mode. It depends on the required operation by the user. Usually a design process is carried out first then any required adjustments may be carried out then an analysis process is then worked out to see the effect of these adjustments. This operation may be repeated till the required design (or analysis) constrains are fulfilled.

F. For estimating the locations of new pump stations, the AHP process can be very handy. Any factors that may be considered as effective factors can be calculated among other factors to find the most candidate locations.

G. The resulting map from the AHP calculations can be very helpful for human judgment especially that these results are obtained in a map form for the area under consideration which facilitate recognition any environmental factors that many affect the human judgment in choosing the required locations for pump stations.

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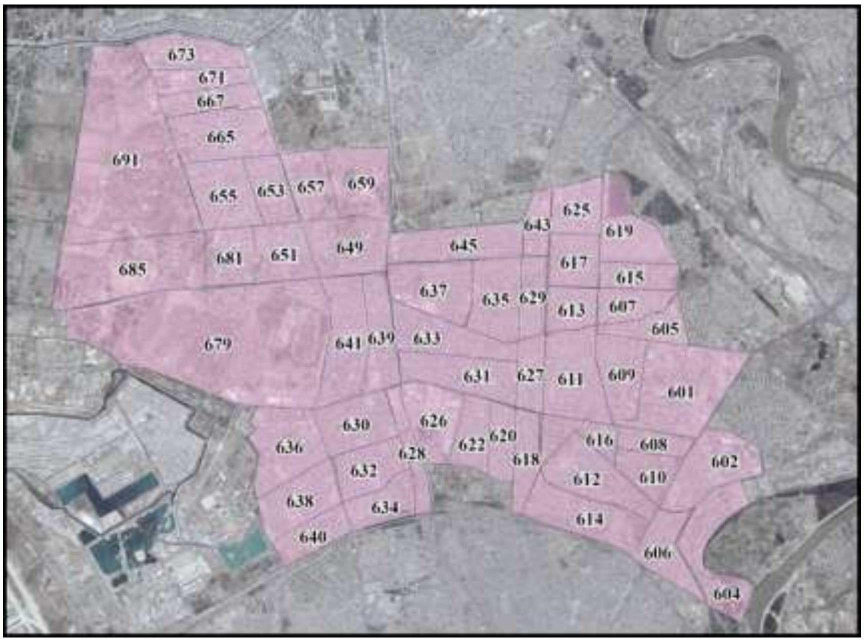


Figure1. Satellite image shows the sample districts as a case study in municipality of Al-Mansour, (source: MOB).

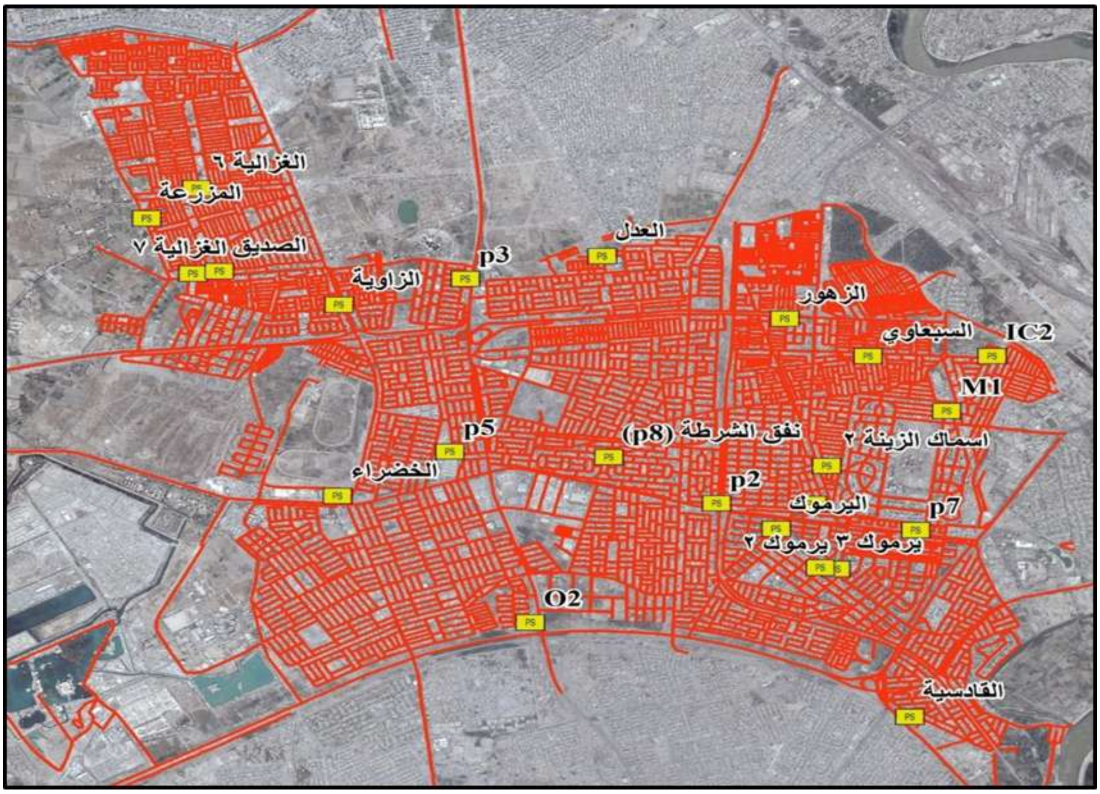


Figure 2. Satellite image shows pump stations and main streets in municipality of Al-Mansour, (source: MOB&BSD).

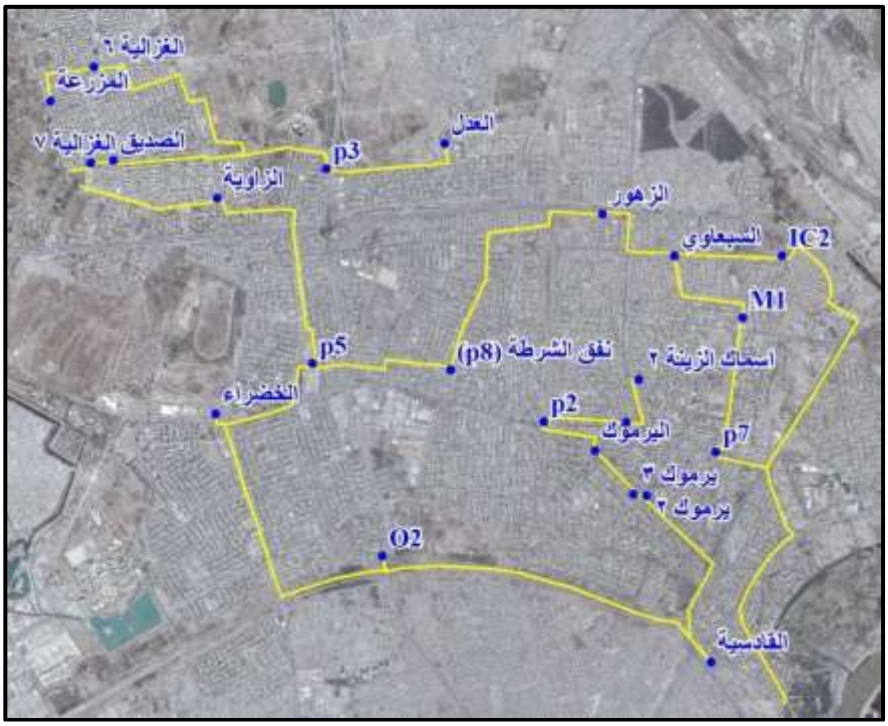


Figure3. Satellite image shows the existing sewer network of trunk mains in municipality of Al-Mansour, (source: DSD).

Figure 4. Satellite image shows the point's network of the districts in municipality of Al-Mansour, (source: DSD).

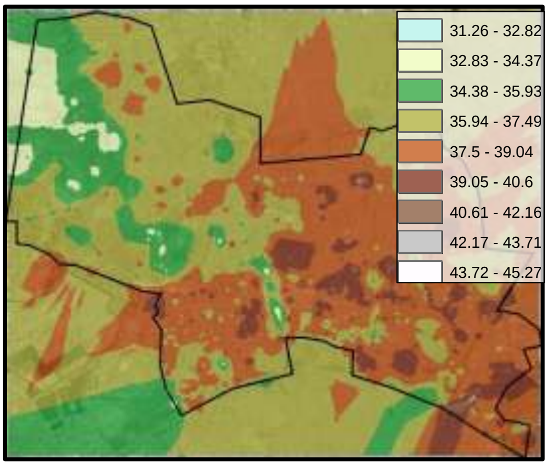


Figure 5. Satellite image shows Digital Elevation Model (DEM) for case study.

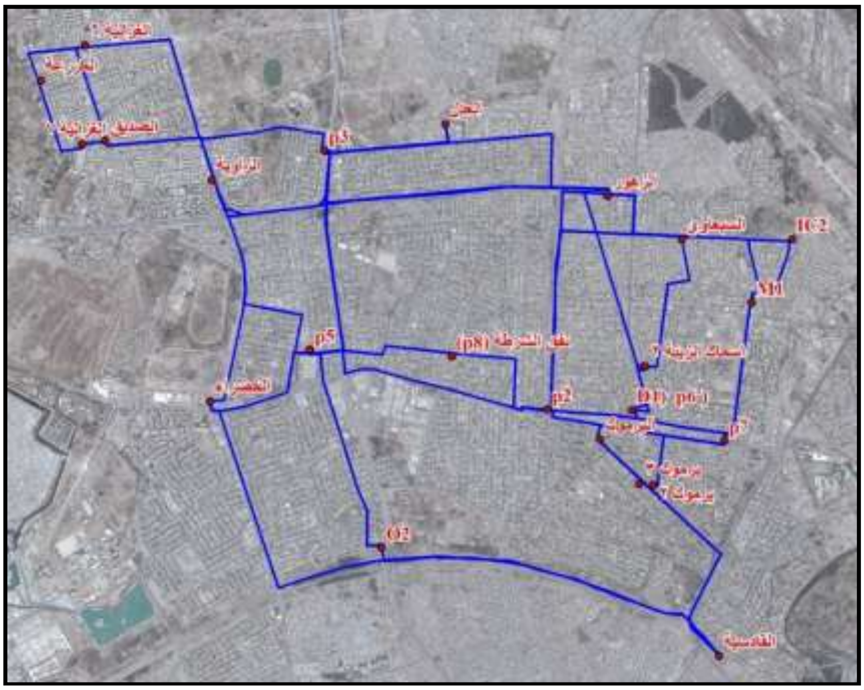


Figure 6. Complete streets network.

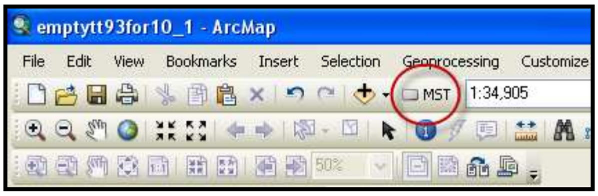
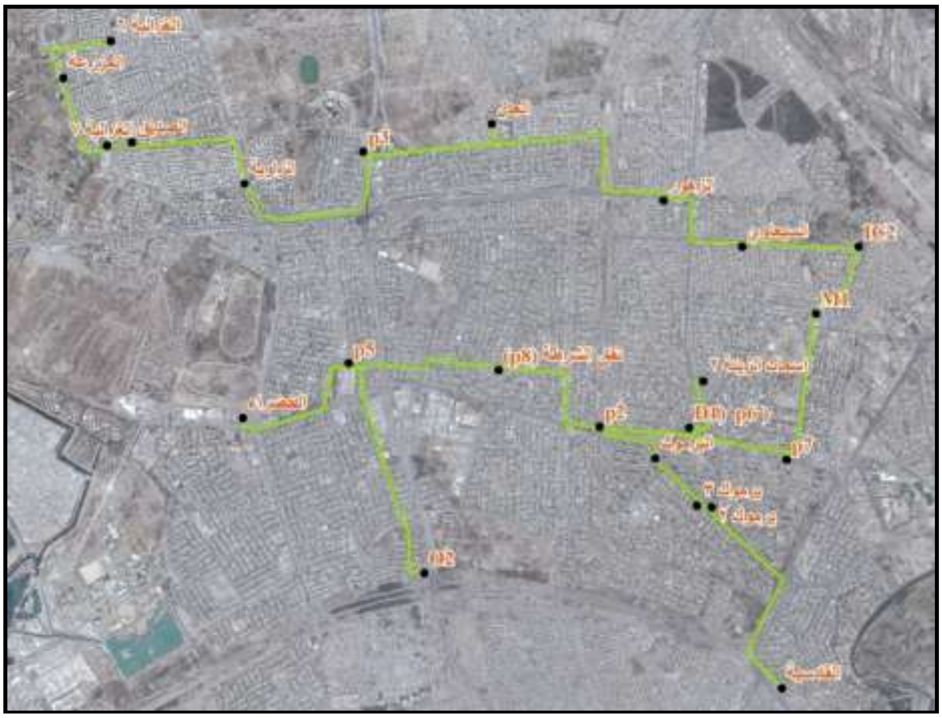


Figure 7. Command botton in the tool bar.



Figures 8. The minimum spanning streets network.

Figure 9. Project components after modification.

Figure 10. Larger scale of sample section showing wet-well, pump, and pressure pipes.

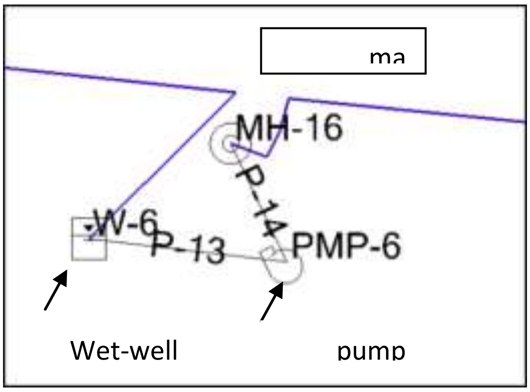


Figure 11. Schematic drawing showing wet-well, pump, and pressure pipes.

Table 1. Pump Stations names, Elevations, and Flow.

No	Name	Elevation (m)	Flow (m^3/day)
1	الغزالية 6	39.0	2000
2	المزرعة	36.0	800
3	الغزالية 7	37.5	1200
4	الصديق	37.0	800
5	الزاوية	36.0	1800
6	p3	38.0	1800
7	العدل	38.5	1000
8	الزهور	37.0	1400
9	السبعاوي	37.8	500
10	M1	38.8	400
11	IC2	37.0	1100
12	اسماك الزينة 2	36.0	600
13	p7	38.5	600
14	اليرموك 2	36.4	600
15	اليرموك 3	37.0	600
16	اليرموك	38.0	600
17	p2	38.0	800
18	نفق الشرطة (p8)	38.5	2100
19	p5	35.0	1600
20	الخضراء	40.0	600
21	O2	38.5	4400
22	D1 (p6)	37.7	2200
23	القادسية	37.0	Outlet

Table 2. Existing Trunk mains connecting Pump Stations.

No	From sta.	To sta.	Length (m)	Start depth (m)	end depth (m)	Area (m^2)	D. (m)	Vol. m^3
1	المزرعة	الغزالية6	924.95	1.5	5.0	3006.09	0.50	1503.04
2	الغزالية 6	P3	3953.76	2.0	6.0	15815.00	1.00	15815.04
3	الغزالية 7	الصديق	272.58	1.5	4.0	749.59	0.50	374.80
4	الصديق	Intersect	1598.66	1.5	6.0	5994.98	0.50	2997.49
5	الزاوية	P5	2958.93	2.0	6.5	12575.50	1.00	12575.45
6	O2	القادسية	4383.84	2.0	7.0	19727.30	1.00	19727.28
7	العدل	P3	1680.82	1.5	7.0	7143.49	1.00	7143.49
8	يرموك3	يرموك2	222.96	1.0	4.0	557.40	1.00	557.40
9	M1	P7	1715.00	1.5	6.5	6860.00	1.00	6860.00
10	اسماك الزينة	P6	839.44	1.5	4.5	2518.32	0.50	1259.16
11	P6	P2	1049.94	2.0	6.5	4462.25	1.00	4462.25
12	السبعاوي	IC2	1344.82	1.5	5.5	4706.87	1.00	4706.87
13	الزهور	السبعاوي	1405.76	1.5	6.0	5271.60	0.50	2635.80
14	P2	يرموك	889.00	1.5	5.0	2889.25	1.00	2889.25
15	يرموك	يرموك3	735.28	2.0	6.5	3124.94	0.75	2343.71
16	الزهور	P8	3265.19	2.0	7.0	14693.40	1.00	14693.35
17	الخضراء	P5	1727.79	2.0	7	7775.06	1.00	7775.06
18	السبعاوي	M1	1808.23	1.5	6	6780.86	1.30	8815.12
19	P7	Intersect	3906.17	2.0	7	17577.80	1.00	17577.77
20	يرموك2	القادسية	2511.46	2.0	6	10045.80	1.00	10045.84
21	IC2	Intersect	3622.53	2.0	7	16301.40	1.00	16301.39
22	P3	Intersect	1014.43	2.0	7	4564.94	1.00	4564.94
23	P5	P2	3173.72	1.5	6	11901.50	1.00	11901.45
24	P8	Intersect	306.18	2.0	7	1377.81	1.00	1377.81
Sum			44895.90			186421.00		178903.73

Unit cost (I.D.)	**500,000**
Total cost of excavation (I.D.)	**89,451,866,250**

Table 3. UPVC Pipes Cost.

No.	Dia. (m)	Total Length (m)	Price per unit length (I.D.)	Cost (I.D.)
1	0.50	5041	80,000	403,280,000
2	0.75	735	230,000	169,050,000
3	1.00	37726	400,000	15,090,000,000
4	1.30	1808	600,000	1,084,800,000
			Total Cost	**16,747,530,000**

Table 4. Total Cost of existing sewer network.

Item	Cost in I.D.
Excavations Cost	89,451,866,250
Pipes Cost	16,747,530,000
Pump Stations Cost	69,000,000,000
Total Cost	**175,199,396,250**

Table 5. Minimum Streets lengths.

No	From sta.	To sta.	Length (m)	No	From sta.	To sta.	Length (m)
1	19	20	272.58	12	8	12	2715.78
2	20	10	1685.27	13	22	21	1344.70
3	11	23	1063.62	14	23	19	1173.03
4	17	10	2223.12	15	1	17	1711.96
5	6	5	1793.10	16	16	14	1731.50
6	5	4	1193.12	17	15	4	832.86
7	8	9	216.19	18	1	18	2790.74
8	2	8	745.501	19	7	3	1701.25
9	4	14	1302.44	20	22	16	1016.30
10	5	2	900.05	21	7	13	2678.52
11	7	6	1812.05	22	18	21	1390.45
				Total length			**32294.10**

Table 6. Result of Program Run.

No	Pipe Label	From sta.	To sta.	Length (m)	Invert Elv. start (m)	Invert Elv. stop (m)	Start depth (m)	end depth (m)	Slope	Area (m^2)	Dia. (mm)	Vol. m^3
1	swr-7	MH-2	MH-1	216.20	35.45	34.74	0.95	2.26	0.0033	347.00	254.00	88.14
2	swr-1	MH-3	W-16	272.60	36.34	35.84	1.16	1.16	0.0018	316.22	457.20	144.57
3	swr-17	MH-5	W-7	832.90	35.05	32.31	0.95	5.39	0.0033	2640.29	254.00	670.64
4	swr-3	MH-7	W-1	1063.60	37.92	34.92	1.08	1.08	0.0028	1148.69	304.80	350.12
5	swr-8	MH-9	MH-1	745.50	36.23	34.74	1.77	2.26	0.0020	1502.19	914.40	1373.60
6	swr-10	MH-10	W-19	900.00	36.23	35.33	1.77	2.67	0.0010	1998.00	914.40	1826.97
7	swr-20	MH-11	W-9	1016.30	35.39	34.37	1.61	4.43	0.0010	3069.23	762.00	2338.75
8	swr-14	MH-8	W-17	1173.00	34.84	33.49	1.16	4.01	0.0012	3032.21	457.20	1386.32
9	swr-6	MH-6	W-4	1193.10	36.09	34.89	1.61	3.11	0.0010	2815.72	914.40	2574.69
10	swr-22	MH-13	W-11	1390.40	35.54	34.15	1.46	3.65	0.0010	3552.47	762.00	2706.99
11	swr-9	MH-15	W-7	1302.40	36.89	32.31	1.61	5.39	0.0035	4558.40	762.00	3473.50
12	swr-5	MH-16	W-4	1793.10	37.04	34.89	1.46	3.11	0.0012	4097.23	609.60	2497.67
13	swr-13	MH-14	W-10	1344.70	36.34	34.99	1.46	2.01	0.0010	2333.05	762.00	1777.79
14	swr-19	MH-18	MH-17	1701.20	39.10	33.61	0.90	1.39	0.0032	1947.87	203.20	395.81
15	swr-2	MH-4	W-15	1685.30	35.69	34.01	1.31	1.99	0.0010	2780.75	533.40	1483.25
16	swr-4	MH-19	W-14	2223.10	34.69	32.47	1.31	5.53	0.0010	7603.00	609.60	4634.79
17	swr-15	MH-20	W-13	1712.00	36.54	34.83	1.46	3.67	0.0010	4391.28	609.60	2676.93
18	swr-16	MH-12	W-8	1731.50	37.19	35.45	1.61	3.05	0.0010	4034.40	762.00	3074.21
19	swr-11	MH-17	W-6	1812.00	33.61	31.80	1.39	6.70	0.0010	7329.54	609.60	4468.09
20	swr-18	MH-21	W-12	2790.70	37.04	34.25	1.46	2.75	0.0010	5874.42	762.00	4476.31
21	swr-12	MH-1	O-1	2715.80	34.74	32.02	2.26	4.98	0.0010	9831.20	1,066.80	10487.92
22	swr-21	MH-23	W-5	2678.50	37.27	33.77	1.23	1.23	0.0013	3294.56	457.20	1506.27
sum				**32293.90**								**54413.32**
											Unit Cost	**500,000**
											Total Cost	**27,206,656,801**

Table 7. UPVC pipes cost.

No	Dia. (mm)	Total Length	unit price	Cost
1	203.20	1,701.20	50,000	85,060,000
2	254.00	1,049.00	60,000	62,940,000
3	304.80	1,063.60	70,000	74,452,000
4	457.20	4,124.10	80,000	329,928,000
5	533.40	1,685.30	120,000	202,236,000
6	609.60	7,540.20	180,000	1,357,236,000
7	762.00	9,576.10	230,000	2,202,480,000
8	914.40	2,838.70	400,000	1,135,480,000
9	1066.80	2,715.80	500,000	1,357,900,000
	Total Length	**32,294.00**	**Total Cost**	**6,807,735,000**

Table 8. Overall Total cost of proposed sewer network.

Item	Cost
Excavations Cost	19,510,900,000
Pipes Cost	6,807,735,000
Pump Stations Cost	69,000,000,000
Total Cost	**95,318,635,000**

Table 9. Cost comparison between existing network costs and proposed network costs.

Item	Existing Network	Proposed Network	Reduction in Cost
Excavations Cost	89,451,866,250	19,510,900,000	**69,941,366,250**
Pipes Cost	16,747,530,000	6,807,735,000	**9,939,795,000**
Pump Stations Cost	69,000,000,000	69,000,000,000	**0**
Total Cost	**175,199,396,250**	**95,318,235,000**	**79,880,761,250**