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A GIS-Based DSS For Management Of The Operation And Maintenance Of Water Distribution Networks For Rafah Area

أستخدام نظم المعلومات الجغرافية بجانب نظام دعم أتخاذ القرار لإدارة تشغيل وصيانة شبكات توزيع المياه لمنطقة رفح

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A thesis submitted in partial fulfillment of the requirement for the degree of Master of Science in Civil Engineering - Construction Management

The Islamic University – Gaza - Palestine
September, 2011

بسم الله الرحمن الرحيم

ن َ كَفَر ُوا أَنَّ السَّم َاو َات ِ و َالأ ْر َض َ كَانَتَا
و َج َع َلْنَا مِن َ الْم َاء ِ كُلَّ شَي ْء ٍ ح َي ٍّ أَفَلَا
ي ُؤ ْمِنُون َ ﴾

{ صدق الله العظيم}
(الأنبياء30)

DEDICATION

This thesis is dedicated to my husband,
who taught me aspire, dream and gain knowledge without limits, who didn't spare any time or effort to support me in all of my life, whom I'm here because of him.

Rola,

AKNOWLEDGEMENT

Sincere gratitude is hereby extended to the following who never ceased in helping until this research is structured:

- ***Dr. Ala Al Deen Al Gemase,*** *the thesis supervisor, for the unwavering guidance;*
- ***The members of construction management department*** *at the Islamic University –Gaza, for their support and encouragement;*
- ***All Rafah water department*** *for their participation in this research;*
- ***To my family*** *that did not skimp on provided unwavering moral, and emotional to support me;*
- ***For my young twin Meyer and Mohand*** *who have endured my preoccupation to complete this research;*
- *Above all, utmost appreciation to* ***Almighty Allah*** *who bestowed me the understanding and perseverance to achieve this academic endeavor.*

ABSTRACT

Rafah area is a part of Gaza strip which is considered one of the highest lands in population density in the world. This complicates the water problem where the consumed water is exceeding the renewable water. The water situation make it very important for mangers who are responsible for distribution, operation and maintenance water networks to make their best to build an effective and complete comprehensive management systems to manage the O&M of water networks systems.

The main aim of this research is to study and evaluate the existing O&M system which is applied in Rafah area. Rafah is selected as a pilot study area. This study proposes proper systems for O&M which can be used by Rafah municipality to manage water networks.

The proposed system deals with a huge quantity of data which is needed to propose an effective system that can save time, cost, and minimize the mistakes in managing O&M systems for water distribution networks, GIS is selected as one of the software program which deal with such quantity of data and can be linked with other softwares which can achieve the aim of this study.

To achieve the main aim for this study, interviews were conducted with relevant professionals in Rafah water networks department and site visit were done. The main goal of the interview and site visits is to collect data about the existing water distribution systems, and existing O&M system with all related data which can help to clarify and understand the existing situation about the management of Rafah water networks and the required steps to establish the needed O&M system for networks.

The research depended on the use of ArcView GIS datasets and Water CAD/WaterGEMS hydraulic modeling based on DSS for proposed water distribution plan systems, proposed O&M systems, and use pipe condition index to assist O&M manager to take the best decision.

The research provided several recommendations such as applying GIS in the O&M system for water networks in all Gaza areas due to its advantages of it for raising efficiency and improving the management of water networks and should also consider the needed training for the municipality staff who are responsible for the O&M of distribution water networks to be able to apply the proposed system which will be used to manage the O&M systems.

الخلاصة

تعتبرمدينة رفح جزء من قطاع غزة الذي يعتبر واحد من أكثر المناطق في العالم من حيث الكثافة السكانية والتي أدت إلي زيادة تعقيد المشكلة المائية في القطاع حيث أن كمية المياه المستهلكة تزيد عن كمية المياه الي تغذي الخزان الجوفي.
الوضع المائي الخطير جعل من المهم جداً بالنسبة للمسئولين عن إدارة توزيع وتشغيل وصيانة الشبكة بذل أفضل مالديهم من جهد لبناء نظام فعال يتعلق بإداره متكاملة لنظام تشغيل وصيانة شبكة المياه.

الهدف الرئيسي من البحث هو دراسة وتقيم نظام تشغيل وصيانة شبكة المياه الحالي في منطقة رفح والتي تم اختيارها كمنطقة للدراسة ،واقتراح نظام فعال ومناسب يتعلق بصيانة وتشغيل شبكة المياه يمكن استخدامه من قبل بلدية رفح لإدارة شبكة المياه.

وحيث أن النظام المقترح يتعامل مع عدد كبير من المعلومات والتي تلزم لاقتراح نظام فعال يعمل على توفير الوقت والتكلفة ويقلل الأخطاء المتعلقة بإدارة تشغيل وصيانة الشبكة لتوزيع المياه تم اختيار نظم المعلومات الجغرافية باعتباره واحد من البرامج المحوسبة التي تتعامل مع هذا الكم من البيانات و توفرإمكانية ربطه مع برامج أخرى تحقق الهدف من الدراسة.

لتحقيق الهدف الرئيسي من هذا الدراسة تم اجراء مقابلات مع الجهات المهنية ذات الصلة بإدارة وتوزيع شبكة المياه في قسم المياه ببلدية رفح وزيارة منطقة الدراسة لت كن من جمع البيانات المتعلقة بتوزيع شبكة المياه ونظام التشغيل والصيانة القائم لشبكة المياه وجمع كافة المعلومات التي لها علاقة بالشبكة ويمكنها المساعدة بتوضيح وفهم الوضع القائم حول إدارة شبكة المياه برفح والخطوات اللازمة لإنشاء نظام صيانة وتشغيل لتلبية احتياجات الشبكة.

البحث يعتمد على استخدام تكنولوجيا نظم المعلومات الجغرافية مع النمذجة الهيدروليكة بجانب نظام دعم اتخاذ القرار لأقتراح نظام توزيع وصيانة وتشغيل لشبكة المياه واستخدام نظام مؤشر حالة الأنابيب لمساعدة المدير المسئول عن ادارة شبكة المياه باتخاذ القرار الجيد المتعلق بصاينة وتشغيل الشبكة.

لقد قدم البحث بعض التوصيات المتعلقة بموضوع الدراسة مثل استخدام نظم المعلومات الجغرافية لتشغيل وصيانة شبكة المياه في جميع مناطق قطاع غزة. وذلك لما له من مزايا في رفع وتحسين إدارة شبكات المياه. اضافة إلي اهمية النظر في موضوع تدريب موظفي البلدية الذين يتحملون مسئولية توزيع و تشغيل وصيانة شبكة المياه ليكونوا قادرين على تطبيق النظام المقترح لصيانة وتشغيل الشبكة.

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LIST OF ABBRIVIATIONS

GIS: Geographic Information System.

WSS: Water Supply System.

AM: Automated Mapping.

FM: Facilities Management.

O&M: Operation and maintenance.

WDS: Water Distribution System.

DSS: Decision support System.

LS: Language System.

KS: Knowledge System.

CBIS: Computer-Based Information System.

REDSS: Requirements Engineering Decision Support System.

GDSS: Group Decision support System.

ADDSS: Activity Duration Decision Support System.

FMBD: Fuzzy Module Ponens Deduction.

SQL: Structured Query Language.

DMS: Database Management System.

SDSS: spatial Decision support System.

WSTWS: Water Science & Technology Water Supply.

CMWU: Coastal Municipality Water Utility.

PSBC: Palestinian Central Bureau of Statistics.

UPVC: Un-plasticized poly vinyl chloride.

PE: Medium Density Polyethylene.

DSW: Direct Supply from Wells.

WTS: Water Tank Supply.

E.C: Electric Conductivity.

TDS: Total Dissolved Salts.

NO3: Nitrate.

CL: Chloride.

PPM: parts per million.

MCM: Million Cubic Meter.

UFW: Unaccounted For Water.

MoR: Municipality of Rafah.

PWA: Palestinian Water Authority.

L/C/D: Liter per Capita per Day.

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CHAPTER 1
INTRODUCTION

This chapter introduces the background of the research, the significance of the research, the aim and objectives and thesis content.

1.1 Back ground for Rafah Area

Rafah Governorate is located at the southern part of the Gaza Strip and its area is about64 Km2 with a population density of 6 persons per 1 m2 in the built up area. The population of Rafah Governorate reached 174,498 inhabitants according to the latest figure of the Palestinian Central Bureau of Statistics (PCBS 2006). Rafah area is considered as part of the desert since the rainfall intensity hardly reaches 200 mm/year (MoA 2006). Rafah Governorate has 28 wells to serve the domestic water demands in the area. Eight of them are belongs to Rafah Municipality, one belongs to the UNRWA, and the rest two wells are belong to the eastern village Shoka and Al Nasser Municipalities. The agricultural land area in Rafah is about 33 km2 (MoA 2006), which represents more than 50% of the Rafah Governorate area. Table 4.1 illustrates the name of the governorate wells, while Figure 1.1 shows their location within Rafah Governorate area.

Table 1.1: Name of Rafah municipal wells.

No.	Well_Name	Well_No_
1	Ex-Settlement Well_no.23	J23
2	Al Baher Well	P/139
3	Ex-Settlement Well_no.25	J25
4	Ex-Settlement Well_no.26	J26
5	W1	W1
6	W2	W2
7	El Saudi Project-UNRWA	P/164
8	El Eskan	P/153
9	Canda Well	P/144
10	PWA Well Tall Al Sultan	P/148
11	Abu Zuhri	P/138
12	Al Hashash	P/145
13	Naser 02	NASER 02
14	Naser 01	P/163
15	Abu Hashem	P/124
16	Hejazi	P/15
17	ZOHIRATE	ZOHIRATE
18	Hiba	HIBA
19	SEKA	SEKA
20	SAFA	SAFA
21	W3	W3
22	Islamic jamea well	Islamic jamea well
23	Shuka Well	SHUKA WELL
24	El Fakhari well	El Fukhari
25	TRC1	TRC1
26	TRC2	TRC2

No.	Well_Name	Well_No_
27	TRC3	TRC3
28	El Matar Well	

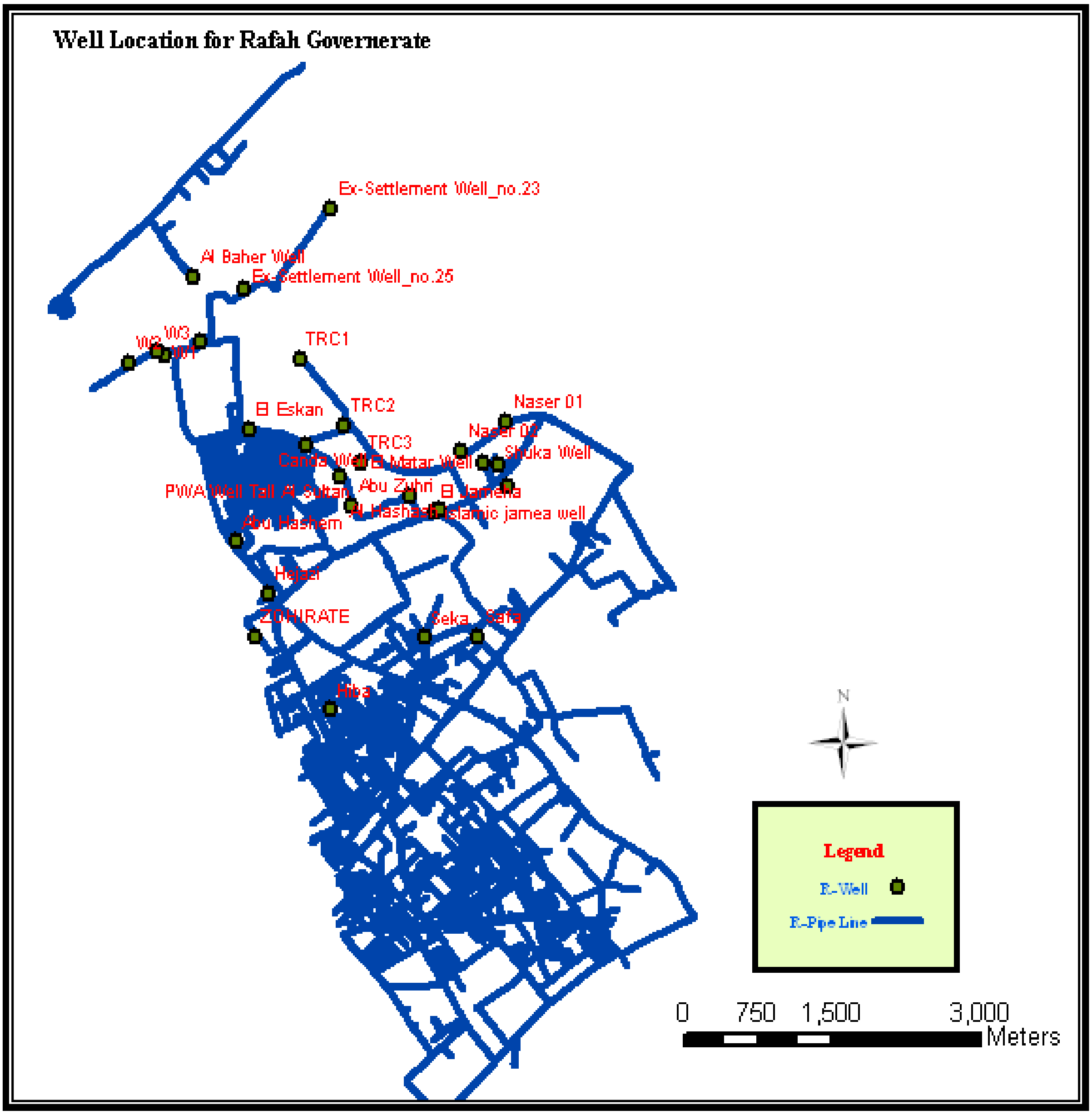

Figure 1.1: Well Location for Rafah Governerate.

This research, will concern Rafah municipality water problem. The production of rafah wells is 8.2 Million Cubic Meter in a Year (MCM) and the consumption is 3.7 MCM which means that the percentage of efficiency is 45%.This low efficiency is reflecting three things in this area; the first thing is referring to the efficiency of the water pipe network system itself within the domestic area, and the other reason referring to the Unaccounted For Water (UFW) which seen in the illegal connections from the municipal wells towards the agricultural area of Rafah without any monitoring or control, while the third reason is reflecting the un-stable situation in Rafah.

1.2 Existing Water Distribution System (WDS) for Rafah Municipality

To clarify the existing water distribution system in Rafah municipality area, interview is made with head, manger, and water networks operators to clarify WDS and describe O&M system which the municipality depend on for management water networks.

All the data in the following paragraphs which is clarified the existing WDS & the existing O&M is related to interview with head, manger, and water networks operators.

The water wells abstraction is increasing while the network efficiency is decreasing in the past 4 years. The reason behind that can be referred to;

- The old pipe network system.
- The illegal connections without any monitoring or control.

The water facilities in Rafah is composed of main transmission pipes, distribution pipelines, ground water storage tanks, wells, booster pump stations and control valves. All these components comprise the water distribution system in Rafah.

The supply scheme in Rafah Governorate is an intermittent water distribution system and complicated which is prevalent in Gaza Strip. This is due to the insufficient water infrastructure and water sources. Intermittent water distribution systems are water networks that operate at specific time intervals i.e. not continuous. This system is controlled by manual operated valves located at the main feeders in the water network as will describe later in this thesis.

As discussed before that the groundwater is the only water resources in the area. Table 1.2 shows the GIS analysis for the existing water pipes network in Rafah, it shows that the Asbestos pipes are still exists in the area with a total length of about 838 m length, while the major type in the area is the UPVC, PE and Steel pipes which forms 60%, 15% and 24% respectively of the whole lengths of the water pipe in Rafah.

Table 1.2: Breakdown of the Water Pipe Network Types in Rafah.

Water Pipe Type	Size (in)	Length (m)	Percentage(%)
Asbestos	4 & 6	838	0.3
Unplasticised poly vinyl chloride (UPVC)	4,6,8,10,&12	169396	60.5
STEEL	2,3,4,6,8,10,12,&14	67435	24.1
Medium Density Polyethylene(PE)	2 & 8	42361	15.1
Total		**280,030**	**100**

Water supply in Rafah is an intermittent water supply and that due to insufficient water quantity in the area. The operation system is controlled manually by opening/closing valves in the major trunk lines. The water distribution cycle is completed every 48 hour. Rafah area has been divided into 13 zones as shown in Figure 4.2 according to the existing water distribution facility and scheme that municipality of Rafah is following so far, these zones are described as:

1. Zone 1: Tal Elsultan Area.
2. Zone 2: Western Rafah Area.
3. Zone 3: Al Salam Mosque Area.
4. Zone 4: El Shouat Area.
5. Zone 5: Yebna Area.
6. Zone 6: El Shabora Area.
7. Zone 7: El Brazil Area.
8. Zone 8: El Salam Area.
9. Zone 9: El Gunina 1 –Upper.
10. Zone 10: El Gunina 2 –Lower.
11. Zone 11: El Mosabeh Area.
12. Zone 12A: Kherbet El Adas.
13. Zone 12B: Kherbet El Adas.

Methods for distributions water networks depend on two ways as the following:

1. Direct Supply from Wells (DSW).
2. Water Tank Supply (WTS).

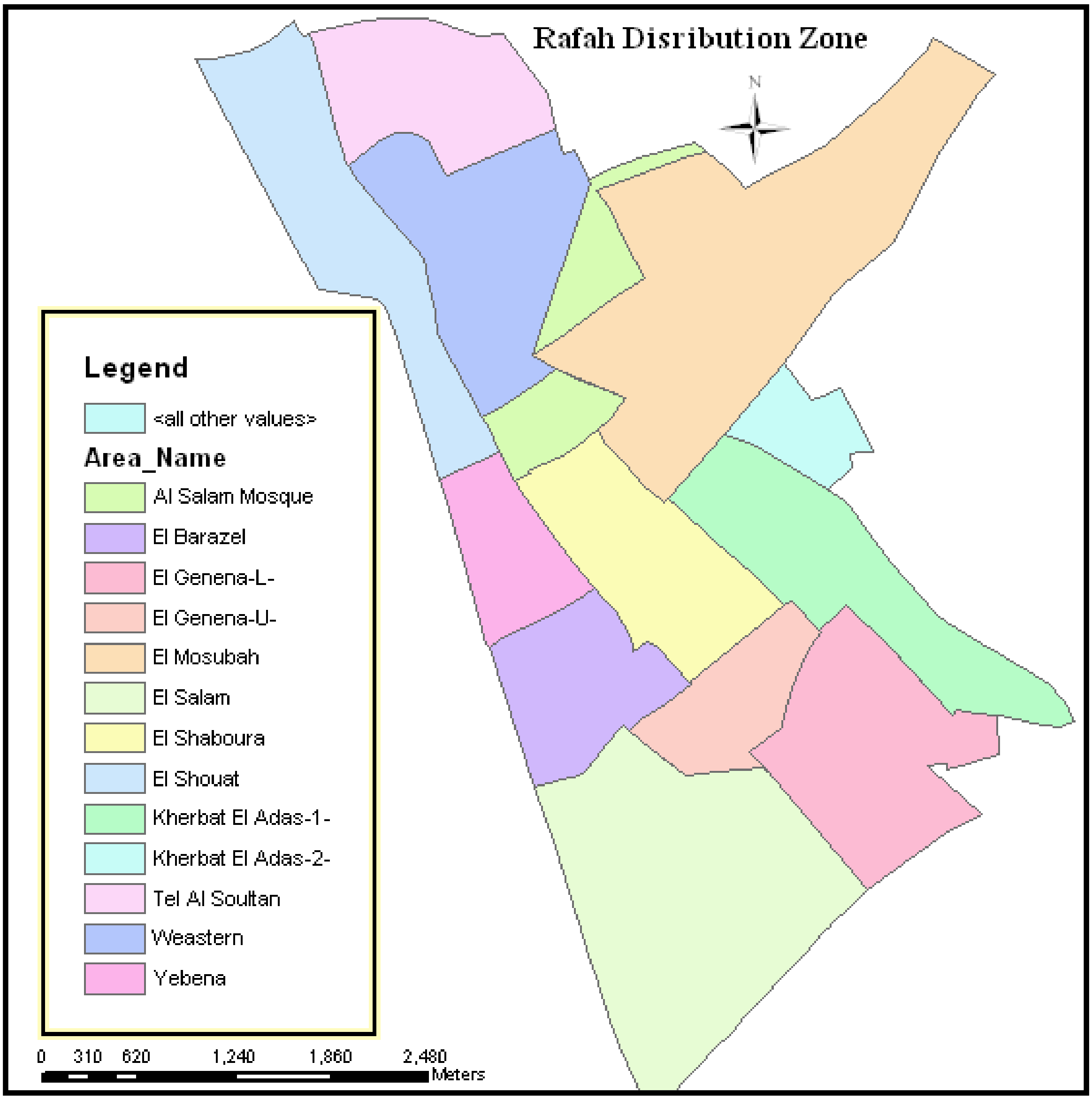

Figure 1.2: Rafah Distribution Zone.

1.2.1 Rafah Water Wells Quantity, Location, & Quality

Rafah municipality is depending on 26 water wells to serve the domestic water needs. Rafah Municipality abstracted about 8.2 MCM from the existing wells.
Table 1.3. Illustrates the name & quality of the Rafah municipality water wells.

Table 1.3: Name &Quality for Rafah municipality wells (Rafah Municipality record, 2010).

No.	Area	Code_No	Well_name	Electric Conductivity (E.C) Micromho/cm	Total Dissolved Salts (TDS) ppm	Nitrate (No3) ppm	Chloride (CL) ppm	Production m3/month
1	Rafah	TRC1	New well 1	438	272	21	57	7430
2	Rafah	TRC2	New well 2	1013	628	27	199	8910
3	Rafah	TRC3	New well 3	389	241	14	53	8820
4	Rafah	W2	Well W2	760	471	63	112	879
5	Rafah	P/153	El Eskan well	780	484	94	128	59270
6	Rafah	P/145	El Hashash well	2470	1531	166	546	58883
7	Rafah	SEKA	El Seka well	3910	2424	275	922	38330
8	Rafah	HEBA	Heba well	4100	2542	281	886	10725
9	Rafah	SHUKA WELL	Shuka well	2060	1277	153	425	35990
10	Rafah	SHOUKA JAMEA	Shuka Jamea well	635	394	38	85	5900
11	Rafah	P/159	El Fekary El Gharbea well	2520	1562	243	511	32085
12	Rafah	P/163	Al Nasser 1 well	710	440	53	112	10720
13	Rafah	NASER2	Al Nasser 2 well	2160	1339	214	518	14580
14	Rafah	P/10	UNRWA well	4680	2920	254	956	32470
15	Rafah	P/164	UNRWA well	2670	1655	30	719	32470
16	Rafah	P/138	Abuo Zhoure well	2890	1792	25	426	37390
17	Rafah	P/124	Abuo Hasheam well	2250	1395	108	502	109500
18	Rafah	P/148	Rafah Municipality well	1180	732	148	213	58720
19	Rafah	P/15	Hejaze well	3410	2114	191	733	37860
20	Rafah	ZOHIRATE	Zohirate well	3930	2437	136	872	29520
21	Rafah	SAFA	Safa well	4220	2610	142	986	28800
22	Rafah	P/144	Kanda well	1797	1114	57	454	111023
23	Rafah	P/139	Baher well	2110	1308	35	238	42000

No.	Area	Code_No	Well_name	Electric Conductivity (E.C) Micromho/cm	Total Dissolved Salts (TDS) ppm	Nitrate (No3) ppm	Chloride (CL) ppm	Production m3/month
24	Rafah	W1	Well W1	760	471	63	112	879
25	Rafah	W3	Well W3	760	471	63	112	879
26	Rafah	ALMATER	Al Mater well	1988	1233	111.4	420	6000
Total Production (m3)						**820033**		

***ppm means: parts per million.**

Table 1.4 & Figures 1.3 & 1.4 illustrate the increasing of water wells numbers& chloride and Nitrate concentration.

Table 1.4: Water wells numbers& chloride and Nitrate concentrations (Rafah Municipality record, 2010).

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Total Number of wells	6	5	6	7	8	9	13	13	17	20	26
Total Flow Rate For Water Wells m3/h	520	610	710	770	890	960	1285	1265	1505	1532.67	1532.67
Cl (ppm)	356.01	362.96	340.5	387.65	208.22	315.89	399.34	367.4	428.59	482..34	514.15478
% increasing in Cl		***1.95***	***-4.36***	***8.89***	***-41.51***	***-11.27***	***12.17***	***3.20***	***20.39***	***35.48***	***35.48***
No3 (ppm)	87.01	92.59	102.52	109.34	93.21	96.77		101.81	113.62	127.56	128.56211
increasing in No3		***6.41***	***17.83***	***25.66***	***7.13***	***11.22***		***17.01***	***30.58***	***46.60***	***47.76***

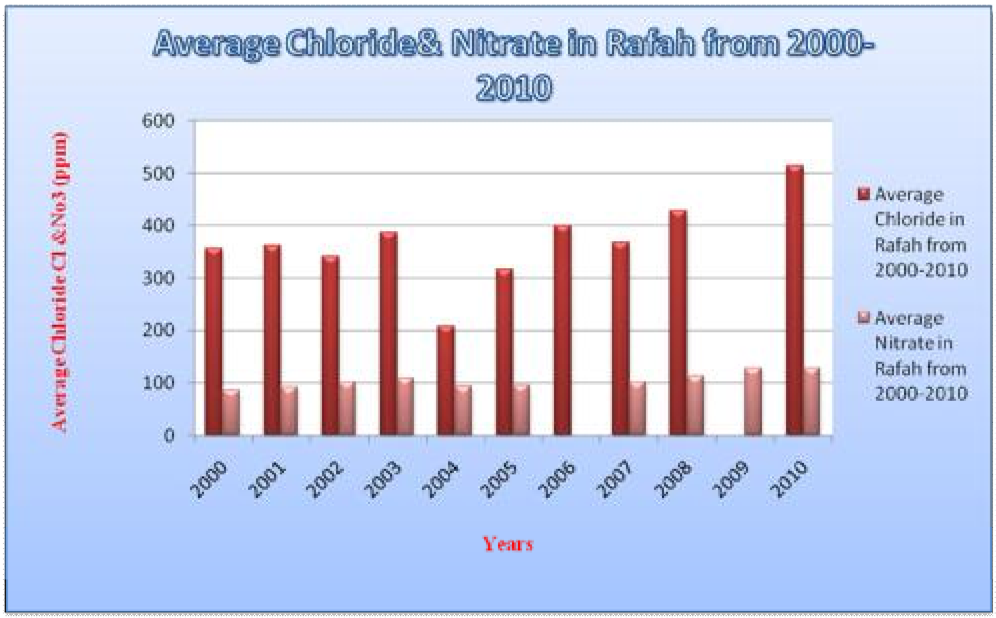

Figure 1.3: Average Chloride& Nitrate in Rafah from 2000-2010(Rafah Municipality record, 2010).

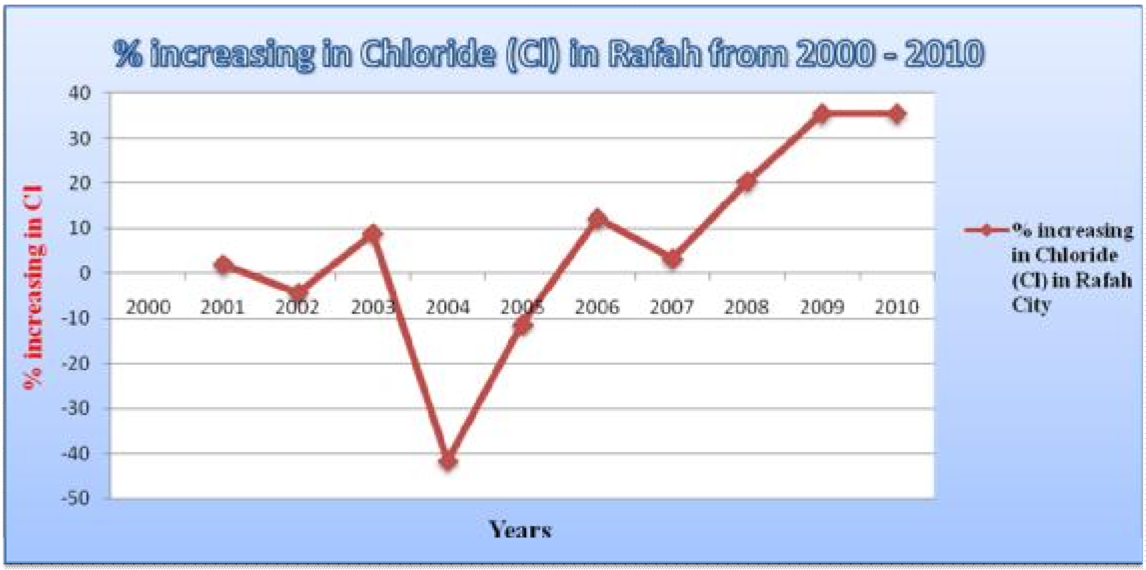

Figure 1.4: % increasing in Chloride (Cl) in Rafah from 2000 – 2010(Rafah Municipality record, 2010).

Table1.4 shows that the bulk average of total dissolved solids (TDS) for Gaza Strip is 1302.19 mg/l and the average nitrate (NO3) value is 128.56 mg/l and the average chloride (Cl) (Salinity) content is 514.15 mg/l bearing in mind that the Palestinian standard for nitrate (NO3) should not exceed 70 mg/l and that for chloride should not exceed 600 mg/l and the World Health Organization (WHO) standard for nitrate(NO3) should not exceed 50 mg/l and that for chloride(Cl) should not exceed 250 mg/l.

1.2.2 Direct Supply from Wells (DSW)

This distribution scheme is used in 6 zones of the above mentioned zones (1, 2, 3, 11, 12A and 12B). Table 1.5 shows the water supply resource for each zone with the time interval scheme within the 48 hour completed water distribution cycle.

Table 1.5: Water Distribution Time Interval and Quantities for DSW(Rafah Municipality record, 2010).

Zone#	Zone Name	Water Resource Supply (well #)	Day#	Time Period	Supply Water Quantity (m3/48hr)
Z1	Tal Elsultan Area	P/153,P/144A,P/148, P/15,P/124,TRC1,TRC2 .TRC3,W1,W2,&W3	1	6AM – 2PM (8hr)	4360
Z2	Western Rafah Area	P/138	1&2	6PM – 6AM (12hr)	1440
Z3	Al Salam Mosque Area	P/138&P/145	1&2	6AM – 6PM (12hr)	2664
Z11	El Mosabeh Area	P/145	1&2	6AM – 6PM (12hr)	1224
Z12A	Kherbet El Adas	P/145	1&2	6PM – 12AM (6hr)	1212
Z12B	Kherbet El Adas	P/145	1&2	6PM – 12AM (6hr)	1212
Total Water Supplied from different sources (m^3/48hr)					**12112**

1.2.3 Water Tanks Supply (WTS)

In this scheme the water is being abstracted from 5 different wells in different times as shown in Table 1.6, taking into consideration that the delivered waters to the storage tanks will lose 5 % of its quantity as natural losses because the water pumped into the 18" welded steel trunk line pieces towards the major water tanks area. The water tanks area is composed of two water tanks, one is 4000 m3 capacity and the other is 2000 m3 capacity. Two pump stations are connected to these water tanks, each pump station is composed of three booster pumps. The booster pump capacity varies from 100 to 250 m3/hr capacity with a pressure of 5 bar maximum. Usually two pumps operating at the same time, and the third one is kept for emergency purposes.

Table 1.6: Water Storage Tanks Feeder Sources and Filling Time within 48 hours(Rafah Municipality record, 2010).

Feeder Source	Feeder Time Interval (within48hr)	Water Quantity Feeder Sources	Water in the Storage Tank (5%Losses)
P/144A	2PM – 5PM (1st Day) 24hr (2nd Day)	6280	5966
P/153	2PM – 5PM (1st Day) 24hr (2nd Day)	3200	3040
P/148	2PM – 5PM (1st Day) 24hr (2nd Day)	3080	2926
P/15	2PM – 5PM (1st Day) 24hr (2nd Day)	2160	2052
P/124	2PM – 5PM (1st Day) 24hr (2nd Day)	7080	6726
Total Q Delivered to the Tank within 48 hour			**20,710**

There are seven distribution zones in the Municipality of Rafah (MoR) that feeder from the storage tank (zone 4, 5, 6, 7,8, 9, and 10). El Shouat area (zone 4) is being supplied from the reverse 6" UPVC pipeline without pumping, this pipe line is start supplying this zone when the water tanks is almost full and can't handle the coming waters into it, the duration in supplying this zone is about 3 hours day after day with a total water quantity of about 1,554 m^3 every 48 hour. The other six zones are being supplied by boosting the water from the water tank towards their district with a pressure reaches 5 bars to reach the elevated areas. Table 1.7 shows the quantity and duration time for those zones.

Table 1.7: Water Quantity and Duration for Supplied Zones from Water Tanks(Rafah Municipality record, 2010).

Zone#	Zone Name	Supplied Duration	Means of Supply	$Q_{\text{at feeder point}}$ (m^3/48hrs)	Q_{Demand} (m^3/48hrs)
5	Yebna Area	6AM-11AM(5hrs)	Booster Pumps	2200	1540
7	El Brazil Area	2PM – 6PM(4hrs)	Booster Pumps	1440	1008
9	El Gunina 1 -Upper	6PM – 6AM(12hrs)	Booster Pumps	5280	3696
10	El Gunina 2 -Lower	6AM – 11AM(5hrs)	Booster Pumps	2200	1540
6	ElShabora Area	11AM – 6PM(7hrs)	Booster Pumps	3080	2156
8	El Salam Area	6PM – 6AM(12hrs)	Booster Pumps	5280	3696
4	El Shouat Area	11AM – 2PM(3hrs)	Without pumping	1230	861
Total				**20,710**	**14,497**

Table 1.8. Shows the calculated water quantity per person according to the water supply district versus population in Rafah municipal and Mawasi areas. Because of the difficulties in obtaining the population for each water supply district from the BCPS, I had used the projected population for those areas from Rafah Master Plan for year 2005. The table declares that there is unequal water quantity in the different district areas, for instance the supplied water volume in some district areas reach about 180 L/C/D and others does not reach 40 L/C/D.

Table 1.8. Calculated Water Quantity per Person in MoR(Rafah Municipality record, 2010).

Zone #	Area	Population Density	Water Supply Source	Supply period (hours)	Supply Water Quantity (m^3/48hr)	L/C/D
Z1	Tal Elsultan Area	31,500	Direct Well	8 hrs	4,360	69
Z2 & Z3	Western Rafah Area & Al Salam Mosque Area	17,915		12 hrs 12 hrs	4,104	115
Z4	El Shouat Area	15,500	Storage Tank	3 hrs	1,230	40
Z5 & Z6	Yebna Area & El Shabora Area	30,500		5 hrs 7hrs	5,280	87
Z7	El Brazil Area	19,283		4 hrs	1,440	37
Z8	El Salam Area	15,500		12 hrs	5,280	170
Z9 & Z10	El Gunina 1 –Upper & El Gunina 2 -Lower	20,810		12 hrs 5 hrs	7,480	180
Z11	El Mosabeh Area	8,976	Direct Well	12 hrs	1,224	68
Z12A & Z12B	Kherbet El Adas & Kherbet El Adas	8,815		12 hrs	2,424	137
P/139	Mawasi Area	3,500		3 – 5 hrs	550	79

1.3 Existing Rafah water distribution system O&M performance

As a result of high shortage of water department staff and the other problems of the municipality organization structure there is a clear weakness in the O&M performance of the water distribution system. To evaluate the existing O&M system in Rafah municipality it is worth to discuss the following points:

1. Existing Planning method for O&M in Rafah Municipality

The unplanned random extension of the network and the spontaneous response to breakdown and emergency pressure, with nonexistence of a master plan and O&M plan all leads to serious O&M problems.

Rafah municipality carry out the micro plans only, while the macro plans are carried out by Palestinian Water Authority (PWA) &CMWU for the whole of Gaza Strip municipalities and village councils. The technical department with cooperation with finical department prepares the annual budget related to the O&M running cost of Rafah water distribution systems. The needed spare parts, fuel, disinfecting materials,..etc. this cost is normally covered from municipality different incomes.

To improve the water distribution system the technical department in Rafah municipality prepares the needed plans related to the extension of the system, the replacement of the existing old or defected pipelines and plants, and increasing of the water productivity. Because of the high cost of implementation these plans, Rafah municipality depends on the donors to fund the execution of such plans. The non-certainty of the fund availability makes it impossible for the technical department to conduct a land term plans. The Rafah municipality technical department prepares short term plans, prioritize the needed projects, prepare the cost estimation of the needed projects, and prepare the projects' proposal to be submitted to the donors.

2. Existing controlling method for O&M in Rafah Municipality.

To understand how the O&M is controlled in Rafah municipality it will be worth to study the data recording systems, reporting and information flow, and the O&M procedure.

a- Data recording system

There is no effective recording system in rafah municipality related to the O&M of the water distribution system. There are no records for many of the necessary information such as pressure, number of repairs, type of repairs, data of pipe replacement, repairing time…etc.

However there are in the other hand many useful records in the municipality As built drawings, updated cad maps, purchased materials, meters readings, electrical meters records, pressure at well outlets…etc.

The problem in the available records is that there is no clear system to keep the available records. It is difficult to achieve to the required information at the needed time.

b- Reporting and information flow

The following reports are prepared and kept in manual files without numbering:

- Weekly report is prepared by manager of technical department includes summary about the executed works during the report period, the planned works for the next week; the problems faced the staff and the proposed solution for these problems. This report is prepared for the three sections in the technical department.
- Purchasing request form to be approved by the top management and the financial manager.
- Water consumption monthly report is prepared by the head of water section.
- Illegal connection report is prepared by the head of the water section to be followed up by the legal advisor.

- Wells routine job dally report includes records for all gauges and meters in the well facilities in addition to the operator notes about engines and pumps (temperature and noise, and other notes).
- In addition to the mentioned reports the following reports related to water system operation prepared by collection section and feed to the collection department software.
- Customers' meters readings.
- Customers' bills.
- Customer's payments.
- New connection form to be approved by water department and municipality manger.

The following reports are prepared by the water section to be submitted to the water service improvement project contractor's office:

- Monthly report: give the water and wastewater improvement project contractor" the contractor" summary information about the number of new connection, the status of the under execution project, the number of illegal connections…etc.
- Meters reading report give the contractor information about the resources meters readings.
- Network efficiency report (the produced and billed quantities of water and loses percentage).
- New customers monthly report (names, numbers, location, and meter type and size for each new customer.
- Chlorine request report to order a determined quantity of chlorine to be provided by the contractor to the municipality's wells.
- Chlorine receiving form to inform the contractor that the municipality had received the ordered quantity of chlorine.
- Spare parts request report.
- Network maintenance report give information about the repaired pipes (location of the repaired pipe, time of repairing, diameter and material of the repaired pipe, the tools and materials used for repairing and persons who repair the pipe).

c- Existing O&M procedure in Rafah municipality

It is clear from the previous paragraph that there is no clear O&M system for the water distribution system in Rafah. The procedure of the O&M of the distribution system can be described by answering the following questions:

Who operates and maintenance the water distribution system of Rafah? And how the system is operated and maintained?

- The municipality's well is operated and the routine job for the well plants is done by the well operator. (Repairs for well plants is done by either "the contractor" maintenance staff or by the private sector).
- The networks supervisor operator wells.
- Four water samples for biological tests are collected by the plumper's and the water is tested in the ministry of health laboratories.
- The plumbers collect 6 water samples weekly to test the residual chlorine using an electronic instrument was provided to the municipality by "the contractor".
- Ministry of health staff collects samples from all the water resources and performs the chemical test quarterly.
- Meters readers in collection section read the customer's meters monthly and the data clerk feed the reading to the collection department software.
- Cashier collects water bills and feed the payment to the collection software.
- New connections to connect a new connection the customer has fill down a special form to be checked by:
    1- The water department (is the networks allow connecting? Is the house network ready to be connected).
    2- The planning and building control system (is house permitted?).
    3- The legal advisor (are the ownership documents correct is the customer has the right and qualified to sign a contracts with the municipality?).
    4- The mayor (final approval).

Some of the above mentioned activities results are recorded in manual files which cannot help in decision making because of the difficulty of achieving the needed data at the needed time.

The repairing of networks pipelines is done usually after a telephone communication from some customer. It is rarely to discover a leakage by the water section crew.

This procedure illustrates how much the O&M performance is low in Rafah municipality and how much it is urgent to start the building of effective O&M system in Rafah and whole of the Gaza strip municipalities.

1.4 Significance of research

The significance of this research comes from its topic and results. The topic of this research is totaly new in Gaza Strip, and discusses the subject about the natural resource (Water) which is important to continue human life. The research related to study the O&M system for WDS by applying GIS with hydraulic modeling in creating O&M system for water distribution system in Gaza Strip. The study discusses one of the most existing important technology (GIS & DSS) for managing O&M which occupy the first level in database technology around the world.

1.5 Research Aim

The main aim of this study is to improve the efficiency and performance for water pipes networks to improve the services for the population in the Gaza strip.All that done by establishing a methods for the management of O& M system for water distribution systems using GIS & hydraulic modeling based on DSS. This will help the manger to select the best decision to managing water networks. The proposed systems for O&M which established in this thesis can be used by Rafah Municipality which carries the responsibility for managing water networks services in Rafah area.

1.6 Research Objectives

The objective of this research can be clarified by the following points:

1. Study the previous research and experience related to my thesis topic about use of GIS based DSS for management of operation and maintenance of distribution networks.
2. Select the area which will be used as pilot area.
3. Study the existing water distribution networks for Rafah area, and existing O&M systems which is used by the municipality of Rafah to manage water pipe networks.
4. Prepare database for water networks parts and facilities to be used as a guide for mange O&M systems for Rafah area depend on GIS & hydraulic modeling software.
5. Propose distribution plane for operation water networks pipes in Rafah area.
6. Proposed procedure for O&M using GIS & DSS and illustrate the methods for using data in decision making.

1.7 Thesis Content

This thesis consists of five chapters as the follows:

Chapter One: Introduction

This chapter has a general introduction to the subject of the thesis (background of the study area, significant of research, research aim, objective, and thesis content).

Chapter Two: Literature Review

This chapter includes the definition of decision support system (DSS), characteristic, types of DSS, decision making in construction management, research on development of DSS, DSS Components, Benefits and limitations of DSS. Also this chapter discus Geographic Information System(GIS) and the relation between GIS and DSS, building a DSS using a GIS as a generator, available DSS, operation and maintenance of water networks and finally take about data for water supply network management.

Chapter Three: Research Methodology

This chapter clarifies the process and methods which are used during the preparation of the thesis that will be applied through the collection of data, interview, site visit, and techniques which used to establish the proposed O&M system for the study area by clarifying all of that in flow chart methodology.

Chapter Four: Use GIS & hydraulic modeling based on DSS for proposed O&M systems for Rafah area

This chapter include proposed plan for distribution water networks, GIS with hydraulic modeling, Proposed procedure for O&M using GIS & DSS, pipe condition index, and clarify the methods for using data in decision making.

Chapter Five: Conclusion & Recommendation

This chapter states the conclusions and recommendations for this research.

CHAPTER 2
LITERATURE REVIEW

This chapter discusses the definition of decision support system (DSS), characteristic, types of DSS, decision making in construction management, research on development of DSS, DSS Components, Benefits and limitations of DSS. Also this chapter discus Geographic Information System(GIS) and the relation between GIS and DSS, building a DSS using a GIS as a generator, available DSS, operation and maintenance of water networks and finally talked about data for water supply network management.

2.1 Introduction

The use of information technology to support decision making and problem solving continues to advance. Decision Support System (DSS) have evolved significantly since their early development in the 1970. During the 70s and 80s, the concept of DSS grew and evolved into full field of research, development and practice. DSS was both an evolution and a departure from previous types of computer support for decision for decision making.

2.2 Definitions of Decision Support Systems

The DSS initially defines the nature of computer-based systems to assist decision makers with ill-structured problems (Watson et al, 1997).

There is no consensus concerning what a DSS is and how it should be defined. Some definitions focus on what a DSS does, and others focus on how to accomplish the DSS's objectives. Definitions that are categorized as having a "what focus" consist mostly of concepts such as: the purpose of DSS, the people using them, and the type of problem that can be supported. An example of a definition that has a "what focus" is Keen and Scott Morton's (1978, p 1): "Decision support implies the use of computers to: (1) Assist managers in their decision processes in semi structured tasks. (2) Support, rather than replace, managerial judgment. (3) Improve the effectiveness of decision making rather than its efficiency."

The definitions categorized as having a "how focus" consist of concepts such as system components and development process. Bonczek et al. (1981, p 69), for example, have a distinct "how focused" definition. They define DSS as having "… three principal components: a language system (LS), a knowledge system (KS), and a problem-processing system (PPS)".

There are definitions that include both "what concepts" and how concepts". One example is Turban's (1990, p 109) definition: "A DSS is an interactive, flexible, and adaptable CBIS [Computer-Based Information System] that utilizes decision rules, models, and model bases coupled with a comprehensive database and the decision maker's own insights, leading to specific, implementable decisions in solving problems that would *not* be amenable to management science optimization models per se. Thus, a DSS supports complex decision making and increases its effectiveness."

It is surprising that many DSS definitions contain system components (see e.g. Holsapple & Whinston, 1996; Sprague & Watson, 1979; Power, 2002), because components may differ between systems. In our view, the most important parts of a DSS definition are system objectives and problem type. These parts indicate what we are aiming at, i.e. to support decision-makers so they can make more effective decisions when dealing with semi-structured and unstructured problems. The others can differ over time and between systems, hence definitions containing such parts may be out of date. Therefore, the *working definition of this thesis reads:" A DSS is a computer-based information system that supports either a single decision-maker or a group of decision-makers when dealing with unstructured or semi-structured problems in order to make more effective decisions. The DSS supports one or more decision-making activities carried out in a decision process".*

When we convert this general definition of a DSS to a requirements engineering decision support system (REDSS) it reads: An REDSS is a computer-based information system that supports either a single RE decision-maker or a group of RE decision-makers when dealing with unstructured or semi-structured RE problems in order to make more effective decisions. The REDSS supports one or more RE decision-making activities carried out in an RE decision process. A definition gives us a starting point for painting a picture of what a DSS can be. The next step is to outline the characteristics a DSS can have.

2.3 Characteristics of DSS

Since there is no consensus concerning what DSS is, there is no consensus on standard characteristics (Turban et al., 2007). Instead, there are a number of characteristics, where some are more commonly agreed on, and others more rarely mentioned in the literature. All the characteristics are not included in every DSS (Mallach, 1994).

A DSS is a computer-based, interactive information system, i.e. it inherits the qualities about information systems in general. The term interactive implies that there is an exchange between the system and the user. A DSS primarily supports managerial activities at various levels. The purpose of a DSS is focused on improving the effectiveness of the decision-making process, rather than its efficiency. The effectiveness of decision-making concerns timeliness, accuracy, and quality, while efficiency is the cost of making the decision, e.g., cost of the decision-maker's working hours (Alter, 1980; Bidgoli, 1989; Keen & Scott Morton, 1978; Mallach 1994; Marakas, 1999; Turban et al., 2007).

DSS provides support for decision-makers when they deal with semi-structured and unstructured problems. Support is provided in all four phases of the decision-making process, i.e. intelligence, design, choice, and implementation. Thus, focus can be both on decision making as well as implementation of decisions. A DSS may provide support for both interdependent and multiple independent decisions (Bidgoli, 1989; Mallach, 1994; Marakas, 1999; Turban et al., 2007).

Decision-makers use a DSS actively, which means that the user initiates every instance of use, and should be in complete control of the decision process. Furthermore, the DSS should support, not replace the decision-maker. A DSS can support learning, so that the decision-maker can be trained to perform better in future decision situations (Alter, 1980; Bidgoli, 1989; Keen & Scott Morton, 1978; Mallach, 1994; Marakas, 1999; Turban, 1990; Turban & Aronson, 1998).

Decision-makers should be able to confront changing conditions. Therefore, a DSS has to be adaptive and flexible in order to meet the needs of decision-makers. There is an emphasis on ad hoc utilization. A DSS should be easy to use. Support is provided to individuals and groups, and a DSS can be tailored to support different decision making processes and decision styles, in order to fit the individual decision-maker (Alter, 1980; Bidgoli, 1989; Marakas, 1999; Turban et al., 2007).

End-users should be able to construct and modify a simple DSS themselves. In order to support the judgment of decision-makers, analytical techniques should be provided by the DSS. A DSS also incorporates models that enable experimenting with shifting conditions and data from a variety of sources, formats and types (Bidgoli, 1989; Keen & Scott Morton, 1978; Mallach 1994; Marakas, 1999; Turban et al., 2007).

These general characteristics of a DSS can be inherited by an REDSS. They can inspire us in the creation of empirically based domain-specific characteristics of an REDSS. As mentioned above, not all of these characteristics are present in every DSS. The same is true for our REDSS characteristics. However, they show the possible scope of an REDSS.

A reason why not all characteristics are present in every DSS is that there are several different types of DSS. Each type focuses on supporting decision-making in a certain way. Depending on the type of DSS some characteristics are more present than others, and different types of benefits can be gained.
Fundamentally, the main thrust of DSS is on decisions in which there is a sufficient structure for computer and mathematical models to be of value, but where the judgment of the manager is essential. Nadkarni summarized the characteristics of DSS as the following are (Nadkarni, 2000):

- Broad-based approach to supporting decision making-accent on 'management b perception'. Human/machine interface where human retains control over the decision making process.
- Support decision making for solving structured, semi-structured and unstructured problems.
- Utilization of appropriate mathematical and statistical models.
- Query capabilities to obtain information by request (ad-hoc report, 'what- if scenarios') – interactive mode.
- Output directed to organization personnel at all levels.
- Integrated subsystems.
- Comprehensive data base.
- Easy-to-use approach.
- Adaptive system over time.

2.4 Types of DSS

There are different types of DSS and one way to categorize decision support systems is provided by Power (2002). He introduces a framework, in which the term 'driven' is used, that points at the dominant functionality of the DSS. Power's (2002) categories are:

- Data-driven DSS.
- Model-driven DSS.
- Knowledge-driven DSS.
- Document-driven DSS.
- Communication-driven and group DSS.

Data-driven DSS provide access to large amounts of data and support analysis. They enable display and manipulation of data sets. Data-driven DSS can be divided into the subcategories: data warehouses, on-line analytical processing (OLAP) systems, executive information systems (EIS), and spatial DSS (Power, 2002; Turban et al., 2007). A data warehouse is defined as a "subject-oriented, integrated, time-variant, non-volatile collection of data in support of management's decisions" (Inmon & Hackathorn, 1994, p 2). It is concerned with the major subjects of an organization, and provides a base for integration of a separate system. The data can have a historical perspective, and the non-volatility characteristic means that "data is loaded into the warehouse and is accessed there, but once the snapshot of data is made, the data in the warehouse does not change" (Inmon & Hackathorn, 1994, p 10). Through data mining a decision-maker can obtain "answers" from a data warehouse. Data mining is defined as "the set of activities used to find new, hidden, or unexpected patterns in data" (Marakas, 1999, p 356). On-line analytical processing (OLAP) is software technology that carries out multidimensional analysis of data (Marakas, 1999). An EIS is a "computer-based system intended to facilitate and support the information and decision-making needs of senior executives by providing easy access to both internal and external information relevant to meeting the stated goals of the organization" (Marakas, 1999, p 185). Spatial DSS are described by Seffino et al. (1999, p 105) as "decision support systems where the spatial properties of the data to be analyzed play a major role in decision making".

Model-driven DSS mainly provide support through models, e.g., financial or optimization models (Power, 2002; Turban et al., 2007). According to Shim et al. (2002), a model-based decision support includes three stages: a) formulation, i.e. generation of an acceptable model, b) solution, i.e. the algorithmic solution of the model, and c) analysis, i.e. the what-if analysis and interpretation of the model solutions. Model-driven DSS can be compared with spreadsheet-oriented DSS (Holsapple & Whinston, 1996). Spreadsheets can be used to create models and do what-if analysis, and are often used in end-user developed DSS (Turban & Aronson, 1998).

Knowledge-driven DSS consist of knowledge, understanding of problems, and problem solving "skills" within a specific domain (Power, 2002; Turban et al., 2007).
Knowledge-driven DSS are related to, e.g., rule-based DSS and intelligent DSS (Power, 2002). Techniques from artificial intelligence (AI) and expert systems are used in knowledge-based DSS. With the help of these techniques an intelligent DSS behaves in a better (more "intelligent") manner (Turban & Aronson, 1998). A rule-based system is "a

system in which knowledge is represented completely in terms of rules (for example, a system based on production rules)" (Turban & Aronson, 1998, p867).

Document-driven DSS focus on gathering, retrieving, classifying, and managing unstructured documents, and where a search engine can be a useful tool. Such a system can deal with, for example, policies, procedures, and product specifications (Power, 2002; Turban et al., 2007). There are materials that decisions can be based on, which are not ordinary data and therefore cannot be put in a database, e.g., letters from customers, written reports, and news items. This information also needs to be handled in a DSS, and therefore information retrieval is important. Document-driven DSS can be compared to text-oriented DSS (Holsapple & Whinston, 1996), which keep track of textually represented information. Hypertext is a technique that can be used in text-based DSS (Holsapple & Whinston, 1996; Marakas, 1999).

Communication-driven and group DSS, where communication-driven DSS focus on supporting collaboration, communication, and coordination, while group DSS (GDSS) focus on supporting groups of decision-makers in analyzing problem situations and performing group decision-making tasks (Power, 2002; Turban et al., 2007). Examples of tools that support communication between decision-makers include web conferencing, interactive whiteboards, screen sharing, and online workspaces (Turban et al., 2007). Electronic Brainstorming that generates stimulating questions to the assembled participants (Power, 2002) is an example of a GDSS.

Several types can be of use for an REDSS. For example, requirements and their related information can be stored in a database, which points out a data-driven DSS. Moreover, several different types of documents are produced in RE and even more are used in it. This indicates that a document-driven DSS can be useful. Furthermore, there are several stakeholders in RE decisions, which imply that a communication driven or a group DSS can be beneficial. Thus, there are multiple ways of supporting decision-making.

2.5 Decision Making in Construction Management

The construction project present a unique situation to those involved in managing the construction process. Each project is different from all others, and must be carried out at a different location each time. The project must be formulated and executed by integrating the efforts of a large number of different organizations and individuals, all of whom have different and often conflicting priorities and objectives (Barton, 1985). The manager of the process must consider and assess different technologies and alternative combinations of labor and equipment.

Estimate and predictions must be made which attempt to forecast the future.
Inevitably the forecasted value will deviate from the actual outcome, due to a lack of complete information about future events. The many contributing factors to the construction problem are referred to collectively as uncertainty. Hypothesis of the global uncertainty can be subdivided into two major components, namely variability in the performance of a task, and interference from outside the task which frustrates its progress.

When making decisions, managers cannot be certain of good outcomes, because they cannot completely control external events nor have total foresight. Therefore, management should try to increase the probability of good outcomes by making good decisions. Where there is uncertainty as to which events might occur, the logic of the decision process should include that information There is a basic need to be able to quantify and assess the impact that uncertainty can have on a project, and to incorporate this knowledge in the project brief and the management of the project. This expanded awareness of the project gives executive management and the client a more complete view of the project and a basis for decision making. It provides a much higher quality of information on which to base a decision, and allows an assessment of both uncertainty and risk while incorporating the manager's own value judgment into the decision(Barton, 1985). .

The use in the simulator model of variability as a component of uncertainty is based on the factual observation of the construction process. However, neglect of this factor is often proposed by texts of 'classical' network analysis, with statement such as only occasional construction project will have variances in activity durations, while observation of the construction operation leads to the conclusion that it is pervasive and very large. Variability can be defined as the range and frequency distribution of possible durations in the execution of a particular task (Barton, 1985).

As well as an awareness of uncertainty, a manager requires a management tool to use in quantifying and assessing the impact this uncertainty may have on the project. The manager must aware of the effect uncertainty may have so that he may make a rational decision as to what level of risk to accept in the light of the circumstances at the time. A management tool incorporating uncertainty will not make decision making easier but it will present more and better information than is currently available on which to base decision and, therefore, arguably improve the possibility of a good decision. The technique which is employed to form a management tool to use in an uncertain environment, to augment the decision maker's intuition and experience, is simulation. Simulation is also referred to as the Monte Carlo technique (Barton, 1985).

The implementation of a Decision Support System (DSS) in the construction industry involves many variables. The nature of the problem to be solved is the key factor, but the methodological approach to the problem, the DSS technique and the nature of the data available must be considered. A rigorous content analysis was conducted by Bastias and Molenaar (2005) on over one-hundred journal articles spanning over thirty years from the Journal of Construction Engineering and Management published by the American Society of Civil Engineering (ASCE). Five different taxonomies were applied to analysis the nature of the problem, decision, complexity, data-system and tool-technique. The findings show that DSS are mostly static, unstructured, and model-centric, and that simulation and suggestion techniques are the most used for the industry. In general, there are many ways of solving DSS problems in the construction industry, but the decision maker must strive to find the best solution for each specific problem.

2.6 Research on Development of Decision Support System

Several decision support systems have been developed specifically for construction management (Nadkarni, 2000). DBID: DSS for Bidding in Construction is an analogy based decision support system, which assists contractors in preparing competitive bids for building projects (Moselhi, et. al. 1993). This DSS uses neural networks to help determine the optimum markup for new bids based on past projects in Canada and the United States. The neural networks are able to predict, the uncertainty in the assessment of the contractor of the project risks is accounted for by a sensitivity analysis performed using the Monte Carlo simulation technique which produces a measure of a probability of winning the bid at any desired level of markup.

In 1994, Kahkonen had developed an interactive decision support system for building construction scheduling. This DSS provides support for decisions made during early planning stages and helps define the logic of the plan. This DSS can also help in managing activity dependencies in the preparation of schedules.

Next is the Activity Duration Decision Support System (ADDSS) that evaluates the impact of different factors on activity durations. The ADSS employs fuzzy module ponens deduction (FMPD) techniques to assess the impacts of duration factors on activity durations. These factors, which in the past were interpreted in linguistic values, are quantified into numerical values using angular fuzzy act theory. These numerical values are used to modify the activity durations affected by the cumulative impact of different site climatic, resource, and management factors. A scheduler needs to provide information regarding each affecting factor to the ADDSS. In return, ADDSS will furnish the scheduler with an assessment of the optimistic and pessimistic durations of an activity (Wu and Hadipriono 1994).

In 1996, a decision support system was develop to help with decision related to the preservation of the civil infrastructure. The DSS provide assistance for decisions concerned with the three main tasks of infrastructure maintenance and rehabilitation: symptom observation condition diagnosis, and treatment Identification. The architecture of the system consists of knowledge bases, database, analysis programs, and various interfaces (Shen and Grivas, 1996).

A Decision Support System called DS^2 was developed to assist with decisions related to the construction of drilled shafts. DS^2 can reduced construction cost by providing expert advice that would otherwise be both difficult and very expensive to obtain. DS^2 is composed of three prototype expert systems that interface with spreadsheet, database, and graphics packages. DS^2 uses a heuristic, rule-based, backward chaining system to analyze geological information, suggests a construction method, prepares a preliminary cost estimate, and suggests key specification items (Fisher, et. al., 1995).

2.7 DSS Components

Typical DSS interactive and integrated components are:

- Data and information management. The data and information component is key and central in developing a DSS. The focus is integrating database and connecting data islands into a dynamic framework with advanced display, mapping, query and presentation capabilities.
- Analysis and modeling. The data framework provides the basis for further analysis and interpretation of data and information. Depending on stage and scope of the DSS the analysis can range from simple to complex including statistical and numerical models, economic and cost/benefit as well as User Defined and Custom tools.
- Scenario management and alternative formulation. The DSS framework is capable of supporting and providing information (costing and prioritization) for project feasibility and planning projects as well as design and implementation. Upon implementation the project may have an operations component that requires real time and online decision making.
- Decision making. Customizable GIS and Web based interfaces are tailored to meet specific needs and requirements. Advanced graphics, on-line access, custom rules and interpretations can be embedded into the DSS to support and provide the basis for decision makers to make timely, reproducible and well informed decisions (Keen, 1986).

The DSS can, depending on specific needs, remain specific in scope to support a very focused and dedicated decision process. The DSS may, on the other hand, also evolve into an enterprise DSS to support a wide range of users and a broad management scope (Fisher, et. al., 1995).

A DSS provides for cost-effective information management, which enables professional communication between colleagues, other technical staff, managers, decision makers, major stake holders and the public(Mallach, 1994).

These components integrate and provide information to formulate the decision logic of the DSS. Rules and interpretations are embedded into the DSS to support and provide the basis for definition of problems and objectives. Decision support systems are frequently build within the framework of a Geographical Information Systems (GIS), which provide a convenient platform for handling, compiling and presenting large amounts of spatial data essential to river basin management. Since GIS technology is often linked to information and knowledge management systems and is readily available to most governmental entities, a high degree of transparency in decision-making for stakeholders can be achieved(Fisher, et. al., 1995).

Mathematical models are indispensable in providing a stringent and integrated description of the interaction between water-related sector aspects, such as agriculture/ forestry, municipal and industrial water supply, hydropower, fisheries, tourism and wildlife could thereby be brought together in a framework allowing an integrate analysis. As a part of DSS models provide a sound scientific framework for co-ordinate management and planning. Advanced scenario and gaming tools support application of modeling software for planning and operational use. Technology transfer and capacity building is of paramount importance to ensure sustainability and viability of the DSS. This is providing through provision of hands-on training supported by comprehensive documentation and continued support and maintenance (Alter, 1980).

2.8 Benefits and limitations

There are many benefits from using a DSS, such as creating advantages over competing organizations (Marakas, 2003). However, every DSS does not provide all possible benefits. DSS also have limitations, such as that the "knowledge" and "skills" of a DSS are constrained and it cannot "perform" creativity and imagination (Marakas, 2003). The benefit categories are (Alter, 1980; Power, 2002):

- Improve individual productivity.
- Improve decision quality and problem solving.
- Facilitate interpersonal communication.
- Improve decision-making skills.
- Increase organizational control.

By improving individual productivity, it is possible to save time associated with tasks connected to decision-making (Alter, 1980; Keen, 1986; Marakas, 2003; Turban et al., 2007). This means the tasks should be accomplished in less time, be carried out more thoroughly in the same amount of time, or more appropriate tasks should be executed with less effort. This can be done by increasing the number of alternatives examined. For example, solutions imagined by the user, can be tested or simulated. With a proper DSS tool it should also be possible to make better use of data resources (Keen, 1986). The ability of decision-makers to process information and knowledge can be extended (Marakas, 2003).

In order to improve decision quality and support the overall problem solving, the ability of decision-makers to tackle large-scale, time-consuming, complex problems can be extended (Marakas, 2003). The DSS makes it possible to give fast responses to unexpected situations and to do ad hoc analyses. In addition, the quality of problem solving can also be enhanced. Through a better understanding of the business, e.g., improved abilities to see relationships between variables and through increased depth and sophistication of analysis, improved decisions can be made (Keen, 1989). This can also be done by revealing new approaches of dealing with the problem (Marakas, 2003).

A DSS can facilitate interpersonal communication (Alter, 1980; Keen, 1986; Turban et al., 2007), by providing communication support in at least two ways. It provides decision-makers with tools for persuasion and facilitates communication across organizational boundaries (Alter, 1980). The individual decision-maker can obtain substantiated arguments, which can be particularly useful when implementing decisions. As claimed by Marakas (2003), a DSS provides enhanced possibilities for generating new evidence in confirming existing assumptions and reliability of outcome. It is not clear what Marakas (2003) means by reliability of outcome, but it can be interpreted as enhancing the possibilities of evaluating possible consequences, for example, with the help of simulation. Alter (1980) claims that communication between organizational units can be made through standardizing the mechanics and vocabulary of negotiation and by providing a common conceptual basis. Groupware provides additional communication paths, which may improve the communication (Mallach, 1994) and obtain more effective teamwork (Keen, 1986).

A DSS can improve decision-making skills (Power, 2002). A DSS can promote both organizational and individual learning, for instance, by making it possible for decision makers to obtain a better understanding of the business. An example is a decision-making team in a company that used a strategic planning system. The decision-makers claimed that through using this system they obtained a better understanding of the strengths of the business, the constraints under which it operates, and what maneuvering room was available (Alter, 1980). Marakas (2003) confirms this view and suggests that a DSS can lead to new insights and learning, which can encourage decision-makers to explore.

A DSS can increase organizational control (Alter, 1980; Power, 2002). Organizational norms and requirements can constrain the individual decision-maker and ensure consistency across organizational units which can be made clear to the decision makers (Mallach, 1994). Summary data can be provided by a data-driven DSS and can be used by managers for organizational control purposes (Power, 2002).

There are, as described, a number of benefits. It is also important to measure the success of an implemented DSS, which can be done using some DSS success measures, summarized by Hung et al. (2007). There are two main categories of DSS success measures; process-oriented and outcome-oriented. Process-oriented measures include frequency or length of system usage. Efficiency is an example generally measured by decision speed or the number of alternatives that are considered. Outcome-oriented measured include decision performance and user satisfaction. For example, effectiveness is measures by decision outcome, e.g., user satisfaction and quality or accuracy of decision (Hung et al., 2007). Some of these success measures are probably not unique for DSS, but are to some extent the same for information systems in general.

There are also limitations to DSS use, not the least of which is that a good DSS cannot compensate for a bad decision-maker (Marakas, 2003). Marakas (2003) and Power (2002) list some limitations:

- A DSS cannot have human decision-making abilities, such as creativity, imagination, or intuition.
- A DSS is limited by its stored knowledge, data and models as well as by the operating computer system.
- The user interfaces are not sophisticated enough for full interaction between the user and the system in natural language.
- It is difficult to design a general DSS that is applicable in multiple contexts, but instead they often have a narrow scope of application.
- Often, a DSS needs to be integrated into decision processes.
- A DSS can only be supportive if a decision-maker chooses to use the system and integrates the analyses into ‘off line’ thinking and analysis.

- DSS is a type of behavioral engineering, and many managers refuse to accept such intrusions.

There can also be a problem, for instance, with trust or responsibility problems. The decision-maker must trust the DSS in order to really use it in decision-making. In addition, there can be disagreements about who is responsible for the decision. Is it always the decision-maker or can the persons behind the DSS be blamed for a bad decision?
All these generic benefits of DSS are also attractive in RE. Thus, REDSS can be a way to gain these benefits. Unfortunately, the generic limitations of DSS can also be transferred to REDSS and thus need to be considered when developing and implementing such a system (Marakas, 2003).

2.9 The Advantages and Disadvantages of DSS

The discussion of advantages builds upon the work of Hogue and Watson (1983). The following are the disadvantages:

- **Time Savings**

For all categories of decision support systems, research has demonstrated and substantiated reduced decision cycle time, increased employee productivity and more timely information for decision making. The time savings that have been documented from using computerized decision support are often substantial. Researchers have not however always demonstrated that decision quality remained the same or actually improved.

- **Enhance Effectiveness**

A second category of advantage that has been widely discussed and examined is improved decision making effectiveness and better decisions. Decision quality and decision making effectiveness are however hard to document and measure. Most research has examined soft measures like perceived decision quality rather than objective measures. For example, Hogue and Watson (1983) reported the most important reason managers cited for using a DSS was to obtain accurate information. Studies of model- driven DSS have examined this outcome more than research on other types of DSS.

- **Improve Interpersonal Communication**

DSS can improve communication and collaboration among decision makers. In appropriate circumstances, communications-driven and group DSS have had this impact. Model-driven DSS provide a means for sharing facts and assumptions. Data-driven DSS make "one version of the truth" about company operations available to managers and hence can encourage fact- based decision making. Improved data accessibility is often a major motivation for building a data-driven DSS. This advantage has not been adequately demonstrated for most types of DSS.

- **Competitive Advantage**

Vendors frequently cite this advantage for business intelligence systems, performance management systems, and web-based DSS. Although it is possible to gain a competitive advantage from computerized decision support, this is not a likely outcome. Vendors routinely sell the same product to competitors and even help with the installation. Organizations are most likely to gain this advantage from novel, high risk, enterprise-wide, inward facing decision support systems. Measuring this is and will continue to be difficult.

- **Cost Reduction**

Some research and especially case studies have documented DSS cost saving from labor savings in making decisions and from lower infrastructure or technology costs. This is not always a goal of building DSS.

- **Increase Decision Maker Satisfaction**

The novelty of using computers has and may continue to amaze analysis of this outcome. DSS may reduce frustrations of decision makers, create perceptions that better information is being used and/or create perceptions that the individual is a 'better' decision maker. Satisfaction is a complex measure and often researcher measure satisfaction with the DSS rather than satisfaction with using a DSS in decision making. Some studies have compared satisfaction with and without computerized decision aids

- **Promote Learning**

Learning can occur as a by-product of initial and ongoing use of a DSS. Two types of learning seem to occur that are learning of new concepts and the development of a better factual understanding of the business and decision making environment. Some DSS serve as actual training tools for new employees. This potential advantage has not been adequately examined.

- **Increase Organizational Control**

Data-driven DSS often make business transaction data available for performance monitoring and ad hoc querying. Such systems can enhance management understanding of business operations and managers recognize that this is useful. What is not always evident is the financial benefit from increasingly detailed data. On a more worrying note, some DSS provide summary data about decisions made, usage of the systems, and recommendations of the system. Managers need to be very careful about how decision-related information is collected and then used for organizational control purposes.

The discussion of disadvantages builds upon the work of Klein and Methlie (1995) and Winograd and Flores (1986). The following are the disadvantages:

- **Overemphasize Decision Making**

Implementing DSS may reinforce the rational perspective and overemphasize decision processes and decision making. It is important to educate managers about the broader context of decision making and the social, political and emotional factors that impact organizational success. It is especially important to continue examining when and under what circumstances DSS should be built and used. One must continue to ask if the decision situation is appropriate for using any type of DSS and if a specific DSS is or remains appropriate to use for making or informing a specific decision.

- **Assumption of Relevance**

According to Winograd and Flores (1986), “Once a computer system has been installed it is difficult to avoid the assumption that the things it can deal with are the most relevant things for the manager's concern.” The danger is that once DSS become common in organizations, that managers will use them inappropriately. There is limited evidence that this occurs. Again training is the only way to avoid this potential problem.

- **Transfer of Power**

Building DSS, especially knowledge-driven DSS, may be perceived as transferring decision authority to a software program. This is more a concern with decision automation systems than with DSS. One advocates building computerized decision support systems to improve decision making while keeping a human decision maker in the ‘decision loop’. In general, the value shows the need for human discretion and innovation in the decision making process.

- **Unanticipated Effects**

Implementing decision support technologies may have unanticipated consequences. It is conceivable and it has been demonstrated that some DSS reduce the skill needed to perform a decision task. Some DSS overload decision makers with information and actually reduce decision making effectiveness.

- **Obscuring Responsibility**

The computer doesn't make a ‘bad’ decision, people do. Unfortunately some people may deflect personal responsibility to a DSS. Managers need to be continually reminded that the computerized decision support system is an intermediary between the people who built the system and the people who use the system. The entire responsibility associated with making a decision using a DSS resides with people who built and use the system.

- **False Belief in Objectivity**

Managers who use DSS may or may not be more objective in their decision making. Computer software can encourage more rational action, but managers can also use decision support technologies to rationalize their actions. It is an overstatement to suggest that people using a DSS are more objective and rational than managers who are not using computerized decision support.

- **Status Reduction**

Some managers argue using a DSS will diminish their status and force them to do clerical work. This perceptual problem can be a disadvantage of implementing a DSS. Managers and Information System staff who advocate building and using computerized decision support need to deal with any status issues that may arise. This perception may or should be less common now that computer usage is common and accepted in organizations.

- **Information Overload**

Too much information is a major problem for people and many DSS increase the information load. Although this can be a problem, DSS can help managers organize and use information. DSS can actually reduce and manage the information load of a user. DSS developers need to try to measure the information load created by the system and DSS users need to monitor their perceptions of how much information they are receiving. The increasing ubiquity of handheld, wireless computing devices may exacerbate this problem and disadvantage.

2.10 Geographic Information System

2.10.1 Description

A GIS is defined as "an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information". (ESRI, 1992) GIS technology has been widely used in various fields, such as agriculture, business geographic, ecology, electricity and gas, emergency management and public safety, environmental management, forestry, health care, education, mining and geosciences, real estate, remote sensing, telecommunications, transportation and water distribution and resources.

More commonly, people use GIS to make maps; a GIS can also be used as a powerful analysis tool. It can be used to create and link spatial and descriptive data for problem solving, spatial modeling and to present the results in tables, graphics or maps. The most powerful feature of a GIS, from a planner's perspective, is probably the ability of GIS to integrate databases, through their spatial relationships, that would be difficult or impossible to do outside a GIS environment. (Methods, 2003).

2.10.2 Arc GIS Desktop Products

ArcGIS desktop products include ArcReader, ArcView, ArcEditor and ArcInfo, which are used to create, import, edit, query, map, analyze, and publish geographic information. (ESRI, 2005) Each of them provides high level functionality. All ArcGIS Desktop products share a common architecture, so users can share their work with others. ArcMap, ArcCatalog, ArcToolbox, ModelBuilder and ArcGlobe are ArcGIS Desktop Applications. They can be used in a union to perform mapping, geographic analysis, data editing and compilation, data management and storage, visualization, and geo- processing. The following GIS tools are clarified by ESRI website (2010).

1. ArcMap

ArcMap is the central application in ArcGIS Desktop for all map-based tasks including cartography, map analysis, and editing. ArcMap gives operators the power to visualize, create, solve, present and develop geodatabase. In ArcMap, geographic database is displayed on maps as layers; and each layer represents particular types of features, which can be used for future analysis. It references the data contained in coverages, shapefiles, geodatabases, images, grids and so on. In ArcGIS, it is very easy to achieve the data transfer among map documents (.mxd), shape files (.shp) and layer files (.lyr) (ESRI, 2005).

2. ArcCatlog

The ArcCatalog application organizes and manages all GIS information such as maps, globes, data sets, models, metadata, and services. In ArcCatlog, the users can perform database management, and get an overview of the contents of each database. ArcCatlog helps the user to browse, find, and manage data(ESRI, 2010).

3. ArcToolbox

ArcToolbox contains a comprehensive collection of geo-processing functions including tools for: data management, data conversion, coverage processing, vector analysis, geocoding, statistical analysis. ArcToolbox provides access to all of ArcInfo software's powerful coverage processing and analysis functions. (Tucker, 1999). The tools in ArcToolbox create and integrate a vast array of data formats into usable GIS databases, perform advanced GIS analysis, and manipulate GIS data. (Tucker, 1999). Common tools in ArcToolbox 9.1 are grouped into 3D analyst tools, analysis tools, cartography tools, conversion tools, data interoperability tools, data management tools, geocoding tools, geostatistical analyst tools, linear referencing tools, network analyst tools, network analyst tools, samples, spatial analyst tools and spatial statistics tools.

4. The Extract Toolset

Clip is to extract features or portions of features from an Input coverage that overlaps with a clip coverage polygon. Split is to clip coverage into several portions.
Select is to extract features from an Input coverage based on logical expressions or applying the criteria contained in a selection file. It includes select by attributers and

select by location. Table Select has the same function with Select but the difference is in table select, extracted features can only by output in table format. It simplifies statistical analysis (ESRI, 2010).

5. The Overlay Toolset

Erase is to get rid of features in the Input coverage that overlap with the erase coverage.
Identity is to compute the geometric intersection of two coverage's. All features of the Input coverage and those overlapping from the identity coverage are preserved.
Intersect is to computes the geometric intersection of two coverage's. Only the features in the area common to both coverage will be preserved.
Union is to computes the geometric intersection of two polygon coverage. All polygons from both coverage's will be split at their intersections and preserved in the output coverage (ESRI, 2010).
Update is to replace the features by the features from the overlapped coverage by using cut and paste.

6. The Proximity Toolset

Buffer is to create buffer polygons around points, polylines or polygons in order to calculate distance for features.
Multiple Ring Buffer has the same function with buffer, but the difference is that it creates multiple rings based on rules defined by users.
Near is to compute the distance from each point in coverage to the nearest arc, point, or node in coverage.
Point Distance is to compute the distances between point features in one coverage to all points in a second coverage that are within the specified search radius (ESRI, 2010).

7. The Statistics toolset

Frequency is a tool produces a list of the unique code occurrences and their frequency in an output table for a specified set of fields from an Input feature class or table.
Summary Statistics is a tool generates summary statistics for fields from an Input table or feature class and saves them in an output table. It also gives frequency.

8. The Joins and Relates toolset

Join is to append data from a layer or a table a selected table or layer. After join, the selected table or layer will have the features from the join table or layer.
Relate creates associations between the selected layer or table and another layer or table in a similar way of join.

9. SQL Expression

Structured Query Language (SQL) Expression is a standard tool for management of relational database. A GIS SQL is extended with functionality for spatial queries.

2.10.3 Geodatabase

Like other computer products, ArcGIS has a well-defined model for working with data, called geodatabase (short for geographic database). A geodatabase defines the data type that can be used in ArcGIS and how these types of data are represented, accessed, stored, managed and processed. (ESRI, 2005) The defining purpose of this data model is to let users make the features in GIS datasets smarter by endowing them with natural behaviors, and to allow any sort of relationship to be defined among features. (Zeiler, 1999) A geodatabase can contain four representations of geographic data:

- Vector data for representing features.
- Raster data for representing images, girded thematic data and surface.
- Triangulated irregular networks (TINs) for representing surfaces.
- Address and locations for finding a geographic position.

2.10.4 Analysis Technology

Spatial analysis is when all the hard work of digitizing, building a database, checking for errors and dealing with the details of projections and coordinate systems finally pays off in results. In order to make a clarified and logical analysis framework, what target one needs to achieve is necessary to define as the first step. However, how good the results can be is depending on data availability, operational skill, methodologies, data processes, and also needs good explanation and presentation methods to explain the results. GIS works best when the computer and the brain combine forces, and when the GIS is used to augment human intuition by manipulating and displaying data in way that reveal things that would otherwise be invisible. (Zeiler, 1999).

An interesting idea to explain GIS analysis is to Input useful shape files as transparent GIS map layers and users can abstract information from these layers by using various special analysis tools in GIS system. The processes are described as Figure 2.1.

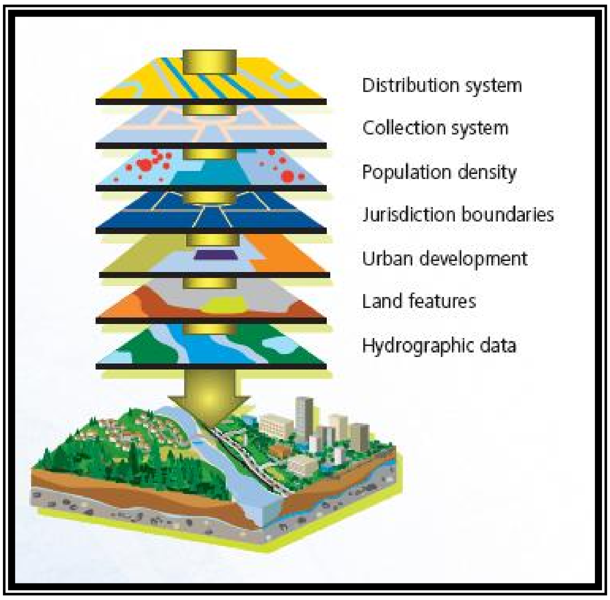

Figure 2.1: GIS Layers (Zeiler, 1999).

And here, the shape file is a homogeneous collection of features that contain either point, multipoint, polyline or polygon shapes. The efficient management of layers can speed up analysis processes and make a map more organized.

2.11 GIS and DSS relation

The concept of Decision Support Systems (DSS) is generally regarded as having originated with the work of Gorry and Scott-Morton (1971). While there are many definitions of a DSS, there is general agreement that these systems focus on decisions and on supporting rather than replacing the user's decision making process. There is also a general consensus in the definitions of DSS that both database and model component are usually required to fully support decisions.

In the period since the early 1970s DSS has emerged as an important component of information systems, with an increasing research output by DSS researchers. The growth is reflected in literature surveys of DSS applications research (Eom and Lee, 1990). This growth in the importance of DSS has taken place against a background of rapidly changing computer technology. The introduction of widely available personal computers and their one hundred fold increase in performance has facilitated the development of a wide range of DSS applications. Other new technologies such as multimedia or the use of CD-ROM storage open up possibilities for decision support applications which could not have been easily implemented in the early years of DSS.

One area of information systems that has expanded enormously in recent years is that of Geographical Information Systems (GIS). As is the case with DSS there are numerous definitions of GIS; for a review of these see Maguire (1991). The majority of these definitions describe a system for storing and displaying spatially or geographically related data. GIS has its origins in the fragmented use of computer technology in the 1960s for automated cartography and address matching software. The development of comprehensive GIS software required improvements in graphics and database techniques. By the 1980s a number of different forms of commercial GIS software became available, including widely used products.

By the 1990s many different types of commercial GIS software were on the market and the technology had achieved widespread use in its traditional areas of application, for example in forestry and natural resource applications. The increasing use of GIS was both facilitated by, and responsible for, the increasing volume of digital spatial data becoming available in developed countries.

A GIS makes use of geographical and attribute data. Attribute data, addresses, populations, etc., is associated with geographical data. Geographical data may be represented as points, lines or polygons. Attribute data can be handled easily using a conventional database management system (DBMS). It is the handling of the geographical data, such as the existence of rivers, roads or contour lines that requires the use of the special techniques that characterize the use of GIS. A GIS, as distinct from a mapping program, will have a database of geographic data, allowing linkages between different types of data and the ability to query this spatial data. For example a GIS database query might allow identification off all roads with a certain distance of a river.

Therefore, while traditional database approaches can support queries on the attribute data, GIS is defined by its ability to cater for spatial queries.

The growth of GIS has been driven by the importance of spatially related data. It is estimated that up to 80% of data needed for the activities of business and government is spatially related (Franklin 1992). The growth in GIS use also reflects the decreased cost of the technology. This explosion in the use of computer technology can also be seen in other areas, where a vicious cycle of declining hardware costs leads to larger software sales and therefore reduced software costs. This trend has lead to some mapping software becoming available on a mass market basis, for example the inclusion of mapping facilities in the Lotus 1-2-3 Release 5 spreadsheet. This mass market use of mapping and GIS products creates a large demand for spatial data, increasing amounts of which are becoming available. Decision makers who make use of basic mapping products, such as those provided with Lotus 123, are likely to become aware of the need for more sophisticated software. Recent improvements in mainstream PC technologies facilitate this increase in the use of spatial data. These include inexpensive gigabyte sized hard disks, large high resolution colour monitors, graphics accelerators and CD-ROM storage.

Many areas of DSS application are concerned with geographic data, including one influential early example of a DSS, the GADS system (Grace 1976). A more recent important prototype DSS, Tolomeo (Angehrn and Lüthi, 1990) uses a geographical context for the development of visual interactive techniques. However there has been limited impact by mainstream GIS techniques on DSS research. This situation is beginning to change. Recent DSS textbooks are including GIS as a component of management support systems (Mallach 1994, Turban 1995). While these texts stress the usefulness of geographically related information, they do not provide a complete picture of the relationship of GIS to other management support systems. GIS related research is beginning to make an appearance at conferences associated with DSS. For example a recent paper by Crossland and Wynne (1994) presented empirical evidence of the usefulness of a spatial approach to decision making. This paper was presented at the Hawaii International Conference on System Sciences, a conference associated with DSS rather than GIS based applications.

GIS techniques are beginning to have an impact on DSS applications. The survey by Eom, Lee and Kim (1993) identified marketing and routing as important areas of DSS application, both of these fields are recognized as areas of GIS application (Maguire 1991). In the area of routing Bodin, who was identified by Eom, Lee and Kim (1993) as an important author in routing DSS, has argued for incorporation of GIS in routing (Bodin and Levy 1994). Keenan (1995) proposed a classification of routing problems with respect to their spatial content and the usefulness of a SDSS. A number of GIS products are aimed at marketing applications, for example the Tactician GIS.
Within the field of GIS there are many who consider GIS software to provide decision support. Indeed as Maguire (1991) points out, some authors have argued that a GIS is a DSS. A substantial number of GIS based applications are described as being DSS. A recent GIS conference was entitled “DSS 2000”. This view of GIS as a DSS is not entirely without support in the existing definitions of DSS. Alter (1980) proposed an influential framework for DSS which includes data driven DSSs that do not have a substantial model component. Standard GIS software could be regarded as an analysis

information system in Alter's framework, the critical component of such a system being the database component.

However, in many cases, the description of these GIS applications as being DSS is not based on reference to the DSS literature. This may be a reflection of the trend identified by Keen (1986) for the use of any computer system, by people who make decisions, to be defined as DSS. Even where GIS contains the information relevant to a decision, they are usually general purpose systems, not focused on a particular decision. There are many problem areas where GIS techniques can make an important contribution but where models are needed to fully support the decision. For these areas at least, a GIS cannot be said to be a DSS as such a system lacks the support that the use of models can provide.

2.12 Building a DSS using a GIS

Because of the variety of decision making situations where spatial information is of importance, it is clear that SDSS will be an increasingly important subset of DSS in the future. It is useful to examine the relationship of GIS software to such systems. Densham (1991) discusses the development of DSS in the context of the framework proposed by Sprague (1980). In Sprague's framework a DSS may be built from tools, individual software components that can be combined to form a DSS. At a higher level in Sprague's framework are DSS generators, from which a specific DSS can be quickly built. Sprague envisioned that different specific DSS applications would require different combinations of the generator and tools. Sprague used GADS (Grace 1976), which can be regarded as a form of GIS, as an example of a DSS generator.

In building DSS, specific generators have been designed for certain classes of problem. In other situations general purpose software such as spreadsheets or DBMS packages have been regarded as generators. In modern DBMS and spreadsheet software, the use of macro and programming languages facilitates the creation of specific applications. Various generators have strengths and weaknesses in terms of their provision of the key components of a DSS; an interface, a database, and models. In the case of a spreadsheet, modeling is the basic function of the software; various interface features such as graphs are provided, but database organization is simplistic. DBMS software, such as Access or Paradox, has good database support, provision for interface design through the use of forms, report and charts, but almost no modeling support. In this case the modeling support has to be added to the specific DSS built from such a system (Peter, 2004).

The decision regarding the appropriate mix of DSS tools and the use of a generator is an important component of the process of building a DSS. However there is a very real sense in which the types of DSS design considered for a given class of problem are a function of the available DSS generators for that class of problem. In practice a small DSS project could be built, using an off-the-shelf spreadsheet or DBMS package, in less time than it would take to fully evaluate the full range of alternative methods of constructing the DSS. Therefore the DSS solutions actually constructed are strongly influenced by the perceived availability of suitable generators. Therefore the effective application of DSS technology can benefit from additional generator software becoming available. Awareness of the potential of the use of GIS based systems as DSS generators will lead to problems, currently being approached in other ways, being approached by using a SDSS(Peter, 2004).

There is evidence that GIS software is becoming increasingly suitable for use as a generator for a SDSS. As GIS designers gain a greater awareness of decision making possibilities, their systems will be designed to facilitate interaction with models. GIS software provides a sophisticated interface for spatial information. Even limited functionality GIS software will provide the ability to zoom and to display or highlight different features. GIS provides database support that is designed to provide for the effective storage of spatial data. Furthermore GIS software provides a link between the interface and database to allow the user to easily query spatial data. However in terms of the widely accepted definition of a DSS, a GIS is not a complete DSS because of the almost complete absence of models or support for the organization of models (Grace 1976).

The construction of a specific DSS from GIS software is possible however, by incorporating models that make use of the GIS database and interface. In this context low end GIS and desktop mapping products may prove more manageable for applications design than full workstation based GIS systems. While these desktop systems lack the power of a full GIS, they may be able to make effective use of data which has been prepared for a specific purpose using a full feature GIS Densham (1991).

However some developments in GIS software since 1990 may make possible the use of standard software as the basis for an SDSS. An example of this type of software is the ArcView package from ESRI. As its name suggests, this software is primarily designed as to allow the user view and query spatial data. ArcView is available for the Windows. Its intended that the full ARC/INFO package will be required for some GIS operations. ArcView has its own macro language; Avenue, the ability to interact with SQL database servers, and the ability to use platform specific links with other software. Together with its ability to support spatial queries, these characteristics make ArcView a potential generator for many types of SDSS software(ESRI, 2008).

The incorporation in many GIS products of macro languages, such as Avenue in ArcView or Mapbasic in Mapinfo, facilitates their use to construct a DSS. In other cases GIS software allows the use of external procedures. Such linkages may not be entirely integrated, but nevertheless allow the useful combination of GIS software and models contained in external programs. An example of such software is found in Jankowski (1995), who discusses the integration of GIS software and multiple choice decision making (MCDM) techniques in a DSS. Routesmart (Bodin and Levy, 1994) provides vehicle routing functionality within the TransCad GIS.

The use of GIS as a DSS generator can make use of new facilities for interaction between software, techniques such as object linking (OLE), dynamic data exchange, and open database connectivity (ODBC). These techniques will allow data pass from the GIS to modeling software which can provide facilities not found in the GIS itself. Present software development trends suggest an object oriented future, in which small specialized applications, or applets, will be available for use as part of a larger package. In the Windows environment the development of such small applications will be facilitated by the use of development tools such as Microsoft Visual Basic or Borland Delphi. In this context the DSS generator, the GIS, will provide the main interface and database facilities, with applets used for additional modeling or interface requirements Sprague (1980.

2.13 Available decision support systems

In response to the challenge for improved pipeline replacement strategies, a number of decision support systems have been developed around the world. A review of Decision Support Systems applied in Norway was provided in Sægrov et al. (2003). Jarrett et al. (2000) also provided a review of asset management models available for pipeline networks. Notable examples of Decision Support Systems around the world are included in Table 2.1(Moglia et al., 2006).

Table 2.1: Decision Support Systems for pipeline replacement strategies (Moglia et al., 2006).

Name	Reference(s)	Comments
KANEW	Herz (1998)	Based on statistical analysis of pipe lifetimes for homogeneous cohorts of pipes. It can be used to identify appropriate lengths of pipes of different pipe material types to be replaced in each year. As it is a cohort based model, it does not allow for detailed prioritization of pipeline renewals
PRAWDS	Kleiner *et al.* (1998a, 1998b)	An exponential time model which statistically models breakage rates and an equation based model estimates pressure head loss with age. This model identifies optimized rehabilitation strategies.
WRAP	Geehman (1999)	Based on a scoring methodology where factors are given subjective weights. The failure predictions are not based on a strict statistical analysis of historical pipe failures, and improvements in failure predictions could allow for more cost-efficient strategies.
UtilNets	Hadzilacos *et al.* (2000)	A system which assesses the risk of a wider range of pipeline failures, within the same methodology. It was initially only developed for grey cast iron pipes. It utilizes a wide range of information.
PARMS-PLANNING	Burn *et al.* (2003)	The predecessor of PARMS-PRIORITY, which is a system for long-term planning and budget settings. Forecasts are based on a Non-Homogeneous Poisson burst count model. This model is used for predictions of failure rates, expenditure and costs for a range of strategies.
CARE-W	Sægrov (2004)	Supports Water Utilities in going from a reactive approach, to a proactive approach for pipeline replacement. It provides prioritized replacement strategies and incorporates hydrological modeling to assess pipeline reliability in the renewal prioritization methodology.

2.14 Experiences with DSS

The following sections which are clarified and build upon the work of Khaled Abu-Zeid and Sameh Afif (2004) show a cross-country comparison of the application and the effectiveness of the DSS tools and progresses used in multi-sectors are provided, also Annex I show more countries.

- **France**

In France, DSS tools were very often used by public services, industries in wide, and other sectors. The term of Decision Support System covered a large variety of tools laying emphasis on knowledge access (databases) or more complex analytical systems such as optimization or simulation models. The first one was called Primary Tools 38, and the second was considered as Operational Tools or Systems. In the field of Water Management, collecting data on water quality or quantity was the oldest concern. The first computerized database on these topics was made up in the Sixties. The 1964 Water Act did not only modify the French Water Management System by introducing Decentralization and Planning, but it also pointed out the need of Organized Data on water at local and national levels. The French Water Data Network was created in 1992 in order to collect, standardize and coordinate Water Data. At National Level, FNDN ensured the exploitation of Thematic Databases, HYDRO (hydrometry), PLUVIO (pluviometry), QUADRIGE (Coastal Water Quality). FNDN hosted the National Water Database (BNDE) that provided data processing required by users and spatial data (Geographical).

The SENEQUE Model elaborated within the Framework of the PIREN-Seine Program aimed to achieve a global vision on a River Basin Scale on a time-scale frame. SENEQUE enabled to calculate, under constraints, the main variables representative of water surface physico-chemical and microbiological quality for the overall River Basin.

This Tool associated a hydrologic Unit (Hydrostrahler) to a bio-geochemical process Unit (RIVE). GIS Data Bases supported the Model and were used to build the constraints needed for the calculations of the model. The model calibration allowed the illustration of impacts of different pressures on the aquatic environment and their relative role to estimate the effect of the socio-economic tendencies on the environment quality.
An Irrigation Water Demand Assessment tool (ADEAUMIS) was developed to contribute to Strategic Decisions of Water Resource sharing out between supply and demand. The efficiency has been showed to be reliable during the 2003 summer drought. This tool was based on coupling geographical database, simplified Corn Crop model and Irrigation Decision model. Irrigation strategies formalization, as decision rules, led to the development of MODERATO, a model allowing farmers strategies improvement and optimal strategies search for given production criteria and environmental quality.

A simulator for Water Management was developed with the main goal to provide economic argument tools allowing balance between resource availabilities (Supply) and users needs (demand). This approach combined the hydraulic simulation of River Basin Running model, crops allowing farmers' irrigation strategies calculation and optimization crops allowing model, and multi-uses economic calculation. The expected result addressed the development of a simulator that was able to test scenarios of agricultural and water policy assessing impacts and performances(Abu-Zeid, K, 1999).

- **Turkey**

The development of DSS in Turkey was an emerging issue during the last decade. Efforts towards DSS applications in water management have started in the early 90's, basically at academic levels through research carried out at universities and other research institutions. On the other hand, major water resources agencies were still behind in adapting DSS tools in actual water management practices. Since cooperation between research institutions and these agencies was rather weak, it has not been possible to convey research results to practice. Recently, these agencies have started to favor DSS tools; yet, they fail to use DSS effectively and sufficiently in decision- making since there has been a strong need for capacity building and personnel training.

Data availability has been yet another factor that hindered proper use of DSS tools. Accordingly, the case remains that there has been practically no substantial application of DSS in decision-making in real world problems.

The water implementation agencies kept their data in digital formats; however, they have not yet developed them into national or institutional databases. Furthermore, all data are subject to significant charges when they are made available to users. Only academic users could access the data at reduced rates. On the other hand, in recent years, activities started towards more refined means of monitoring hydrometric data. It was understood that by enhancing the development of databases in Turkey, would strengthen the utilization of DSS(Abu-Zeid, K, 1999).

- **Egypt**

Several Decision Support Systems have been developed during the last twenty years to assist in proper water resources management on the national scale in Egypt. Four examples are briefly introduced herein.

- WRMDSS: A Water Resources Management Decision Support System was developed by Abu-Zeid in 1994. It combined a simulation model, GIS, an expert system and multi-criteria evaluation for comparing environmental, ecological, social, political and economic impacts of different water management strategies.
- CEDARE-EIADSS: The Centre for Environment & Development for the Arab Region & Europe developed a decision support system for enhancing the evaluation/prediction of environmental impact assessment for irrigation project. The system used multi-criteria analysis coupled with weighting and ranking procedures. It evaluated different alternatives for implementing irrigation projects. The system evaluated the irrigation projects alternatives according to natural, biological, socio-economical, political and economical impacts (Abu-Zeid, K, 2003).
- EWRSES: The Egyptian National Water Research Center has developed a DSS entitled Egypt's Water Resources and Associated Socio-economic & Environmental Dynamic System (EWRSES). The model aimed at capturing the complex network of relationships relevant to Egypt's development linked with water resources and land-

use. Being a dynamic system model, it allowed investigating whether the desired end-of-horizon state could be actually reached or not, and how the system would evolve. The model was designed to generate the relevant information for Strategic Environmental Assessment addressing: i) the physical-technical performance of the system; ii) the quality of life of target groups of people; iii) the strategic decision making problem. The added value of the DSS implementing EWRSES was the systemic approach and the holistic view. It provided together with the capability to alternate from one level of analysis and evaluation to another by investigating the reasons underlying a given outcome, under explicit assumptions.

- MODAT: Another example for DSS was developed at Cairo University to assist the decision maker(s) in selecting among the various alternatives for the design of agricultural drainage systems and groundwater pollution with nitrates. Multi - Objective Decision Analysis Technique (MODAT) has been utilized. This system has been formulated in a user-friendly computer application name Drainage Ground Water Pollution with Nitrate (DGWPN). The system was initially tested in Zankalon Experimental Station (ZES) in Egypt. Furthermore, the system has been applied to test various alternatives for Irrigation and fertilizer applications for Rice Cultivations.
- The Ministry of Water Resources and Irrigation (MWRI) has undertaken a pilot project named Decision Support System for Water Resources Planning Based on Environmental Balance. The main objective was to develop a methodological approach to sustainable water resources planning. The project aimed at (i) assisting the MWRI and EEAA to draw sustainable policies b proposing a methodology for the integration of environmental and socio-economic aspects in the analysis of water resources scenarios; (ii) developing an integrated, open architecture computer based tool (DSS) to implement the above-mentioned methodology; (iii) developing a set of procedures, rules and relationships to facilitate exchange of information among different organizations; (iv) applying the methodology/DSS in a representative case study; and (v) contributing to capacity building of high level staff of NWRC, Planning Sector and EEAA.

There were various approaches for demonstrating and evaluating the impacts of irrigation projects on the different components of the environment. The simplest of these methods was known to be the checklists such as the widely acclaimed lists prepared by the World Bank and International Committee for Irrigation and Drainage (ICID). The first of the two lists was a comprehensive inventory of potential negative environmental impacts associated with irrigation projects and the corresponding mitigation measures. The main aim was to identify and to address the serious impacts at the early planning stages. However, the second list was a descriptive checklist that included more details about the environmental effects of irrigation projects and identified the necessary data for an assessment study. In this sense the ICID checklist would help non-specialist to conduct initial environmental examination by defining the critical effects that were studied by specialists and relevant aspects that suffer from lack of data. As a matter of fact, both checklists did not provide an absolute measure for environmental risk or relative magnitude for rating different project alternatives. A developed form of simple lists is the scaling checklist since it allowed the relative rating of each impact and guided the evaluation of the different criteria. The Battle Environment Evaluation System (ESS) is a typical example of scaled checklists for water resources projects (Dee et al, 1972). It consists of 78 parameters describing the different environmental components together with their corresponding fixed importance weights. The user had to assign a value between 0 and 1 that reflected the environmental quality of each item. The given scores were eventually transformed into one environmental impact unit for each specific alternative. The DSS became a useful for the project. However, the fixed weights and the need for scientific expertise for scoring reduced its flexibility. Another form of scaling checklists was the multi-attribute utility functions, developed for measuring the relative environmental quality of the parameters in the checklists. This involved fixing a scaling value for each parameter that reflected its importance and by combining the utility functions a total utility was generated for various project alternatives. This method was criticized for its complexity and involvement of certain subjectivity. Interaction matrices, unlike checklists, adopted an objective procedure for environmental impact assessment that enabled rating and weighing and consequently assisted in decision-making.

2.15 Operation and Maintenance

Operation and maintenance "O&M" are two expressions usually found attendant to each other, the reason is the operation as the maintenance and always in need for maintenance and maintenance is supporting the operation (Lambert & Mckenzie, 2002).

Operation is the utilization of the physical system water distribution system to deliver the service water supply the following definition could clarify the meaning of operation:

"Operation is procedure and activities in actual deliveries of the services.
Operation refers to the procedures and activities involved in the actual delivery of services e.g. abstraction, treatment, pumping, transmission, and distribution of drinking water" Clark et al. (1982).

The maintenance is keeping the physical system in good condition to be utilized. Maintenance is all activities aimed at keeping existing capital assets in serviceable condition e.g. by repairing water distribution pipes, pumps, and public taps.

In light of the increasing and pressing need to efficiently manage scarce water resources, there has been renewed interest by water distribution network owners to develop and implement water management strategies and tools that would assist in the integrated and automated management of those networks. Such asset management strategies should assist the network owners to evaluate the condition of the water distribution network, assess historical incident data (leakage or breakage) and risk of failure, visualise areas of high risk, propose “repair or replace” strategies and prioritize the work based on the inherent risk and cost of action (Kleiner et al.,1998).

To automate the O&M system it is needed to feed back a huge quantity of geographical and non-geographical data to a proper computer using proper computerized system. In additional to the nature of the needed data to be fed back to the needed system must has the property of the accessibility to the variable data in other software and integrate them to the fixed data which were manually fed back to it. This property of the needed computerized system is available in GIS, which can be applied in water utilities to assist its staff at all management levels in all fields "feasibility studies and strategic planning, financial management, scientific researching, & O&M management(Lambert & Mckenzie 2002).

GIS has other additional advantage such as the possibility of dealing with all types of data "geographical and non-geographical, fixed and variable data", which can be fed back to it either manually or by integrating it with other software such as quality and hydraulic modeling software. The importance of using GIS in O&M will increase if it was integrated with Decision Support System "DSS" which have to be developed as part of the O&M system to assist the O&M manager in decision making depending on different circumstances and uncertainties, which challenge the "O&M" system and recommend the most important decisions set to be treated by the proposed "DSS" (Christodoulou et al. ,2003).

Increased demands on resource usage, reliability of systems and of provided services placed on urban utility owners as a direct result of the ongoing globalization and urbanization have put a high strain on ageing urban infrastructure and water distribution agencies. This is even more evident and time-pressing in countries with limited water resources. In such cases, the complexity and severity of the problem is compounded and amplified by the inability of the owners of the distribution network to easily and cost-effectively replace utilized or lost resources (water and pipes) as they are faced with a lack of alternatives and a pressing need to provide these resources to the public in periods of extended drought. After all, in the case of water distribution networks the resource managed and provided to customers (water) is the essential element for life and no substitute can fulfill this resource's role(Fuertes et al., 1999).

Furthermore, in the case of most developing countries the managed distribution networks are based on ageing and neglected infrastructure that is highly unreliable and cost inefficient. As a result, utilities in charge of managing such water distribution networks are nowadays faced with the increasingly more complex task to intelligently and efficiently manage such networks in ways that maximize a system's reliability and minimize its operational and management costs. In these cases, life-cycle costing and maintenance strategies become of paramount importance to the utilities as they seek ways to increase system reliability and quality of service while minimizing costs of operation (Andreou et al., 1987). Central to this balancing act of operating costs and reliability is one of the most important dilemmas facing water distribution-organizations. Should an organization repair or replace ageing and/or deteriorating water mains and what, in any case, should the sequence of any such repairs be as part of a long-term network rehabilitation strategy?

The work presented outlines an integrated methodology and a decision support system for arriving at such "rehabilitate-or-replace" decisions, as part of a long-term pipeline asset management program that could be undertaken by a water utility to improve on the reliability of the water distribution networks. The International Water Association's Water Loss Task Force has been advocating and promoting four basic leakage management activities for leakage reduction, namely: pressure management, active leakage control, speed and quality of repairs and pipeline asset management, maintenance and renewal (Lambert & Mckenzie 2002).

To date, a number of studies have been undertaken on infrastructure assessment and deterioration modeling; with the intent of assisting owners of such systems to improve their understanding of a system's behavior over time, its deterioration rate and its reliability with respect to presumed risk factors. The intent has always been to assist owners and operators of water distribution networks in arriving at "repair-or-replace" decisions on a more scientific basis. The studies usually attempt to identify statistical relationships between water main break rates and influential risk factors such as a pipe's age, diameter and material, the corrosiveness of the soil, the operating pressure and temperature, possible external loads (including highway traffic) and recorded history of pipe breaks (Vanrenterghem, 2003).

Most studies in the literature show a relationship between failure rates and time of failure (age of pipes), and some of them suggest a methodology to optimize the replacement time of pipes. Shamir & Howard (1979) reported an exponential relationship, and Clark et al. (1982) developed a linear multivariate equation to characterize the time from pipe installation to the first break and a multivariate exponential equation to determine the breakage rate after the first break.

A study by Andreou et al. (1987) suggested a probabilistic approach consisting of a proportional hazards model to predict failure at an early age, and a Poisson-type model for the later stages, and further asserted that stratification of data (based on specific parameters) would increase the accuracy of the model. A non-homogeneous Poisson distribution model was later proposed by Goulter & Kazemi (1988) to predict the probability of subsequent breaks given that at least one break had already occurred. Finally, Kleiner et al. (1998) and Kleiner & Rajani (1999) developed a framework to assess future rehabilitation needs using limited and incomplete data on pipe conditions.

More recently, a simulation model was applied to an inventory of water mains in New York City to analyze replacement strategies, and Vanrenterghem (2003) developed models for the structural degradation of urban water distribution systems based on data from New York City. Additional work on the same case study was reported by Aslani (2003) and Christodoulou et al. (2003). The knowledge gained by the New York City case study was furthered and reported upon by Christodoulou et al. (2006) in a developed framework for integrated GIS based management, risk assessment and prioritization of water leakage actions.

In managing water distribution assets (water, pipes, valves, connections, etc.) water utility agencies need to implement asset management strategies, alongside operations and maintenance methodologies that improve on a system's reliability and cost-efficiency. To that effect, an integrated pipeline asset management system is of high importance. The system proposed in the following pages is an example of such a system as developed and implemented in Cyprus for the monitoring, rehabilitation and life-cycle-costing of urban water distribution networks. The described integrated system and the lessons learned from its implementation are in essence a knowledge-based system, complemented with analytical and numerical analysis tools and supplemented with a geographical information system (GIS) for the delivery to water distribution network owners and administrators of a complete decision support system (DSS) that can help them improve on the management of the water distribution networks (Aslani ,2003).

Water distribution network rehabilitation and maintenance Water Science & Technology Water Supply (WSTWS) impacts and life-cycle costing are important ingredients in the puzzle of "repair or replace" strategies and action prioritization, the proposed system envisions the integration of all these key elements in the delivery of one integrated management system which will help utilities manage their distribution networks more efficiently, such as:

- Data on system characteristics (such as pipe diameter, length, material, installation date, zoning, etc.).
- Historical data on pipe break incidents (date of incident, response time and cost to repair/replace, number of previously observed breaks, reason for and classification of break incident, etc.).
- Statistical analysis tool for the analysis of pipe break Incidents.
- Artificial neural network component for data pattern Identification.
- Fuzzy logic processor, for the development of fuzzy logic rules describing the behavior of the network.
- Risk assessment module (primarily a survival analysis module).
- Geographical information system (GIS) for visualization.
- Life cycle costing module for the aggregation of costs by area and pipe.
- Prioritization-of-work module.
- Data query and reporting system for the retrieval of needed information.

The system relies heavily on past knowledge acquired through operations and maintenance by the Water Boards, and historical records relating incidents on the network (primarily pipe failures) with internal and external parameters. Sample internal parameters include pipe materials, diameters, operating pressures, etc., and sample external parameters include external loading conditions, temperature, soil conditions, etc. The premise is that lessons learned through past incidents can significantly improve future operations and maintenance practices and thus improve the piping network's operational reliability and life-cycle costs. Furthermore, an integrated and automated methodology should help Water Boards more efficiently and intelligently address the "repair or replace" dilemma facing them, prioritize their actions and save on no revenue water (Christodoulou et al., 2006).

It asset management, operations and maintenance system relies on a company access-wide relational database (client-server application) that feeds into a decision support system (DSS). This database comprises the time related knowledge repository for the piping network, feeding related data to a neuro fuzzy system which then processes the information to arrive at estimated risk-of-failure calculations. On the one hand, the underlying databases are relational and integrated to minimize entry points by the users, standardize input, minimize risk of errors in data handling, and maximize automation of data analysis and reporting. On the other hand, the DSS and its neuro fuzzy elements allow for the numerical analysis of the data and the evaluation of key system parameters such as survival analysis curves and risk-of-failure metrics for each network element.

The latter (risk-of-failure metrics) is a key system characteristic of the piping network, for it provides the Water Boards with numerical appraisals on the condition of the city's pipe network. A high "risk of failure" index, or consecutively a low survival index, highlights to the Water Board a necessity to replace a failing pipe to avoid further escalation of the induced problem of repeated failures and downtime, as well as escalating operations and maintenance costs (Deligianni ,2006).

Historical data is processed by means of a combination of decision support tools, such as survival analysis, statistical analysis, artificial neural networks and fuzzy logic. This analysis aims to identify possible risk factors for pipe breaks and a ranking of them according to their severity and causal effect. Christodoulou et al. (2006) and Deligianni (2006) reported on the severity of a number of presumed factors (such as pipe diameter, material, length, age, number of previously observed breaks, etc.) and proceeded in listing the factors by means of a neurofuzzy system.

The study of a Water Supply System (WSS) needs to manage a huge amount of information, in order to know either its hydraulic performance or to drive an efficient management of the existing resources. This information has different nature, though it could be gathered in three main groups depending on its nature and its later usage. These groups are, basically, infrastructure information, customer's information and location of both infrastructure and customers (Lambert & Mckenzie, 2002).

In fact, since its appearance in the early 1960s, Geographical Information System (GIS) has been widely used for urban infrastructure management. First it was the electric utilities then the gas ones. The first water company to implement GIS was Denver Waters (Cesario, 1986). It wasn't really a GIS as known nowadays. It really was an Automated Mapping/Facilities Management (AM/FM). Anyway, it was the first step in the use of computerized mapping information management system within the water networks.

However, nowadays the need of linking spatial, economic and physical information together is more frequent. This will be possible only thanks to the implementation of a proper GIS. This system allows us not only to link geographic or spatial data with another alphanumeric data, but also to update in a simple way the included data, through an appropriate graphical interface.

Below an application for creating new pipes from diverse digital information will be presented, paying special attention to the estimation of the demand flows used to size these pipes.

2.16 Data for water supply network management

The information needed for managing a water supply network has different nature. Though, it could be gathered in three main groups depending on its origin and its later usage. These groups are, basically, infrastructure information, customer's information and geographical information about both infrastructure and customers.
Traditionally, this information has been saved in different formats. In any case, rarely a connection among the three information sources existed. Next, a brief overview of the information involved in the creation of new pipes is presented (Fuertes et al., 1999).

2.16.1 Element Data

The information about network elements includes basically (Cesario, 1995):

Pipes: diameter, length, date of installation, material, roughness; and leakage and maintenance history.
Pumps: number of pumps in the pumping station and pump curve or pumps characteristics.
Valves: diameter, minor losses coefficient, material, type of valve (ball, butterfly, angle, etc.) and type of operation (throttling, pressure reducer, check valve, etc.).
Reservoirs: shape, number of compartments, elevation, volume and connections.

This information was usually saved in work plots or small inventory databases. The main problem with this information was that in most of the cases, the graphic information was separated from the numeric data of each element.

The first step in its modernization was the use of relational databases for the alphanumeric data and Computer-Assisted Design (CAD) systems for the network plots. But this data structure is usually thought just as an inventory management without considering a future use in the model creation. Often there is no information on topology or connectivity other than the mentioned work plots.
Next, the graphic information was linked to the alphanumeric data through the AM/FM systems. The main developments in WSS modeling have been based on this type of data management.

Using GIS in the management of the network will allow combining connectivity and infrastructure information. Other kind of element information is the operation data, that is, measurements made on the network which allow automated control of certain devices of the water system. This has been traditionally made by the Supervisory Control and Data Acquisition (SCADA) systems.

2.16.2 Consumption data

The economic information was the most carefully kept database in the system, where all the consumers relating data were recorded: their demands, addresses, registering date and other relating data for a correct economic management of the system. In fact, in most of the WSS there is some Customer Information System (CIS) used mainly for demand accounting and customer billing.
However, there was no further information on the demand location other than the customer's address. This has been one of the most developed items in the use of GIS within the WSS management. In fact, CIS contains customer consumption data that are essential for network modeling. Besides, knowing its geographical location will allow getting short and medium term estimation of future demands. Probably, this is the main challenge for the users of GIS in water supply systems. Combining consumption data with infrastructure and geographical location will allow automatic model creation from the GIS, including the load allocation of the model. Some works are being developed in this direction (Fuertes et al., 1999). Other advantages of including consumption data in a

GIS arise from the possibility of advising the customer in case of service interruption due to maintenance operations (Cubillo et al. 1997).

2.16.3 Spatial information

Finally, spatial information was usually scattered in various topographic and thematic maps. Some of the attributes, which appear in those maps, are:

1. The elevation contour lines of the supplied geographic area.
2. The location of the reservoirs, mains, distribution pipes and the control devices of the network.
3. The land uses map.
4. The rest of the urban infrastructures layout.
5. However, most of the times this information is not updated. Even though it is possible that some of the data above does not exist in graphic format.

All this information should be the base for the model creation and in GIS are used to be stored in various layers of information (Aslani, 2003).

Chapter summary

This chapter introduces DSS definition, characteristics, types, component, benefits, limitation, and available DSS. And then talk about GIS and the relation between it and DSS. Also take about operation and maintenance for water networks management and data for water supply networks management.

According to data which related to thesis topic there are many researcher take about GIS and DSS, and more studies discuss relation between GIS and DSS and used it for management water resources and networks, and there are more research discus relation between GIS and water networks and how can use GIS for management water networks system. But in this thesis will discuss the relation between GIS, Hydraulic modeling, & DSS and how can use this relation to manage operation and maintenance for water networks pipes for Rafah area.

The benefits of collecting the above data and information related to thesis subject are to identify the relationship between GIS &DSS and used this relation as the base for studying how to use this relationship in the field of maintenance and operation for water networks systems.

CHAPTER3
METHODOLOGY

3.1 Introduction

This chapter clarifies the process and methods which are used during prepared thesis that will be applied through the collection of data, interview, site visit, and techniques which is used to establish the proposed O&M system for the study area by clarifying all of that in methodology flow chart methodology.

3.2 Research methodology

The methodology is essential to enable the compilation of data and information from various sources. Thus, it involved six main stages starting from collection of data, analysis of data, conclusion and recommendation related to the topic. The study can be broadly divided into six stages:

1. The first stage include literature review which based on the primary data collected through reading and searching from related articles, books, web site, and others.
2. The second stage includes selecting Rafah as a study area, the reason for selecting Rafah is due to the following:

    - From my previous work in Coastal Municipality Water Utility (CMWU) as a head of GIS department we noted that the percentage of efficiency for water networks is low comparing to others area.
    - Numbers of request for materials to be used for operation and maintenance for networks is high.
    - By observation of maintenance materials report we noted that the same pipe line fails more than once.
    - There is no specific program for distribution system, operation, maintenance for water networks in Rafah area.
    - Lack of knowledge of water networks information such as pipes types which feed the zone distribution area, control valves.
    - Rafah has high numbers of complaints about lack of water although that in fact the amount of water which is produced by wells covers the needed customer's consummation.
    - Number of development projects for Rafah water networks is high but there is no improvements of performance for water networks are noted to meet the needed of customers.
    - There is lack of base data for water networks information for Rafah area.

3. The third stage includes interview with relevant professionals in Rafah water networks department such as department manager, networks engineer, and operators by face to face interview and site visit for Rafah area. The objectives of interviews are the following:

- Collecting needed data about sources of water and existing water distribution system for Rafah area.
- Collection data about existing O&M system used in Rafah area.
- Collection data about existing staff that carry O&M responsibility.
- Collection data about procedures, tools which the staff used it to manage and solve the O&M problems.

The questions which are asked for Rafah Networks department during the interview are shown in the following:

- Number of employees in the provision of water services network. Organizational structure of the department.
- Network information such as length of the network, diameter, distribution system, and….etc.
- What are the standards and the steps involved in the operation and maintenance for water network?
- What is the rate of repairs and maintenance for water network and how much it cost?
- How decisions are made on the management for water network in terms of operation and maintenance or replacement of network?
- Is there any information of maintenance and operation for water networks are recorded?
- Is there any computer program or software used for managing operation and maintenance water networks?

The goal of site visit for Rafah area:

- Identify of distribution zones for Rafah area.
- Knowing the location of control valves.
- Knowing the steps for O&M system for water networks.

4. The four stages select the proposed systems to be included in the DSS system were ArcView GIS datasets and Water CAD/WaterGEMS.

   As matter of fact, in this thesis we will depend on integrated system between ArcGIS/ArcMap and hydraulic modeling programs by WaterCAD program, which shall be developed as part of the Rafah O&M system to assist and support the O&M Municipal Key-makers and technical *managers in decision making.*

   WaterCAD or what can be precisely described as "WaterGEMS V8 XM (Geographic Engineering Modeling System)" is a water distribution modeling solution that allows ArcGIS, AutoCAD and stand-alone users to work together around a single modeling project.

   This integration works with all flavors of ArcGIS, allowing WaterGEMS users to directly use the data editing, mapping and spatial analysis features available with each package.

ArcMap is the interface for WaterGEMS' integration with ArcGIS. WaterGEMS uses a geodatabase to seamlessly integrate modeling and GIS data. The geodatabase represents the WaterGEMS project, feature datasets represent modeling scenarios and point, line and polygon feature classes represent the different WaterGEMS elements, including reservoirs, junctions, tanks, pumps, valves, meters, pipes, service areas. By using GeoTables, WaterGEMS provides ultimate flexibility for using the visualization and rendering tools provided by ArcMap"

This stage includes the following:

a. Prepare shape file data such as:

- § Pipe, type of features stored in this feature class is line features.
- § Street, type of features stored in this feature class is line features.
- § Contour line, type of features stored in this feature class is line features.
- § Well, type of features stored in this feature class is point features.
- § Valve, type of features stored in this feature class is point features.
- § Water meter, type of features stored in this feature class is point features.
- § Elevation, type of features stored in this feature class is point features.
- § Tank, type of features stored in this feature class is polygon features.
- § Manhole, type of features stored in this feature class is polygon features.
- § Land use, type of features stored in this feature class is polygon features.
- § Water distribution zone, type of features stored in this feature class is polygon features.
- § Customer zone distribution, type of features stored in this feature class is polygon features.
- § Building, type of features stored in this feature class is polygon features.
- § Zone area, type of features stored in this feature class is polygon features.

The following Figures show maps for some features also.
Annex II show more figures about shape file data and attribute table.

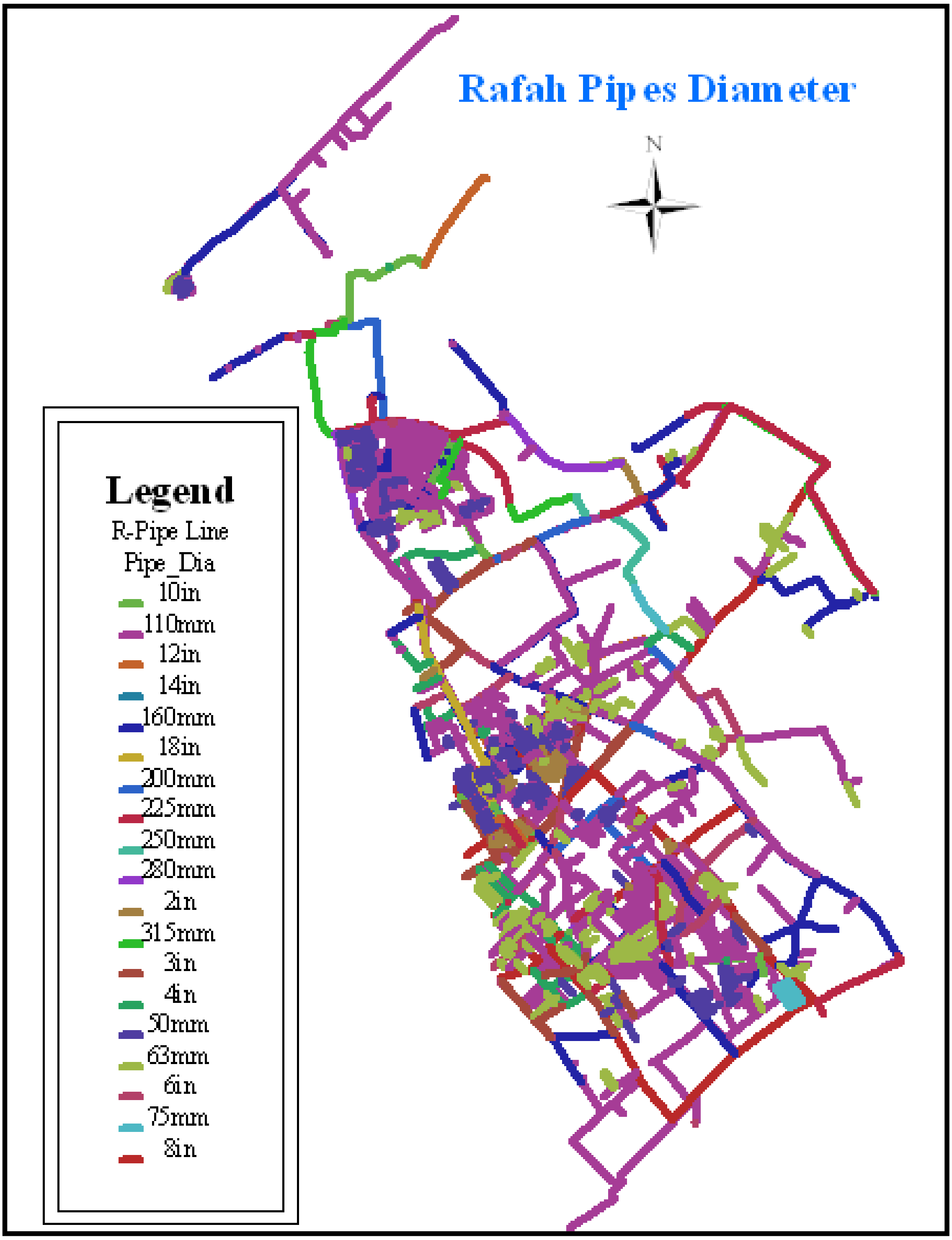

Figure 3.1: Distribution of pipes diameters for Rafah Municipality.

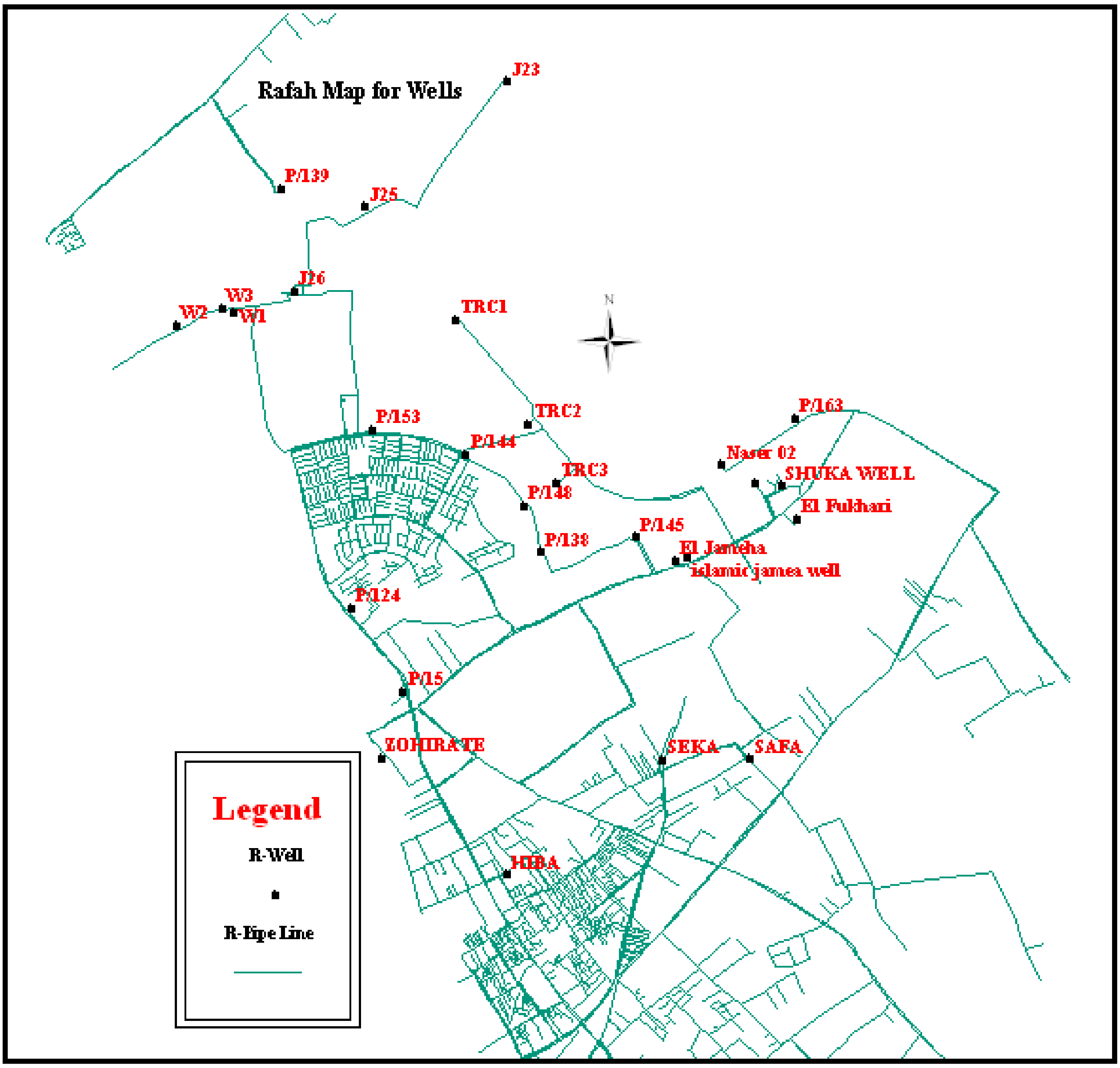

Figure 3.2: Distribution of Wells for Rafah Municipality.

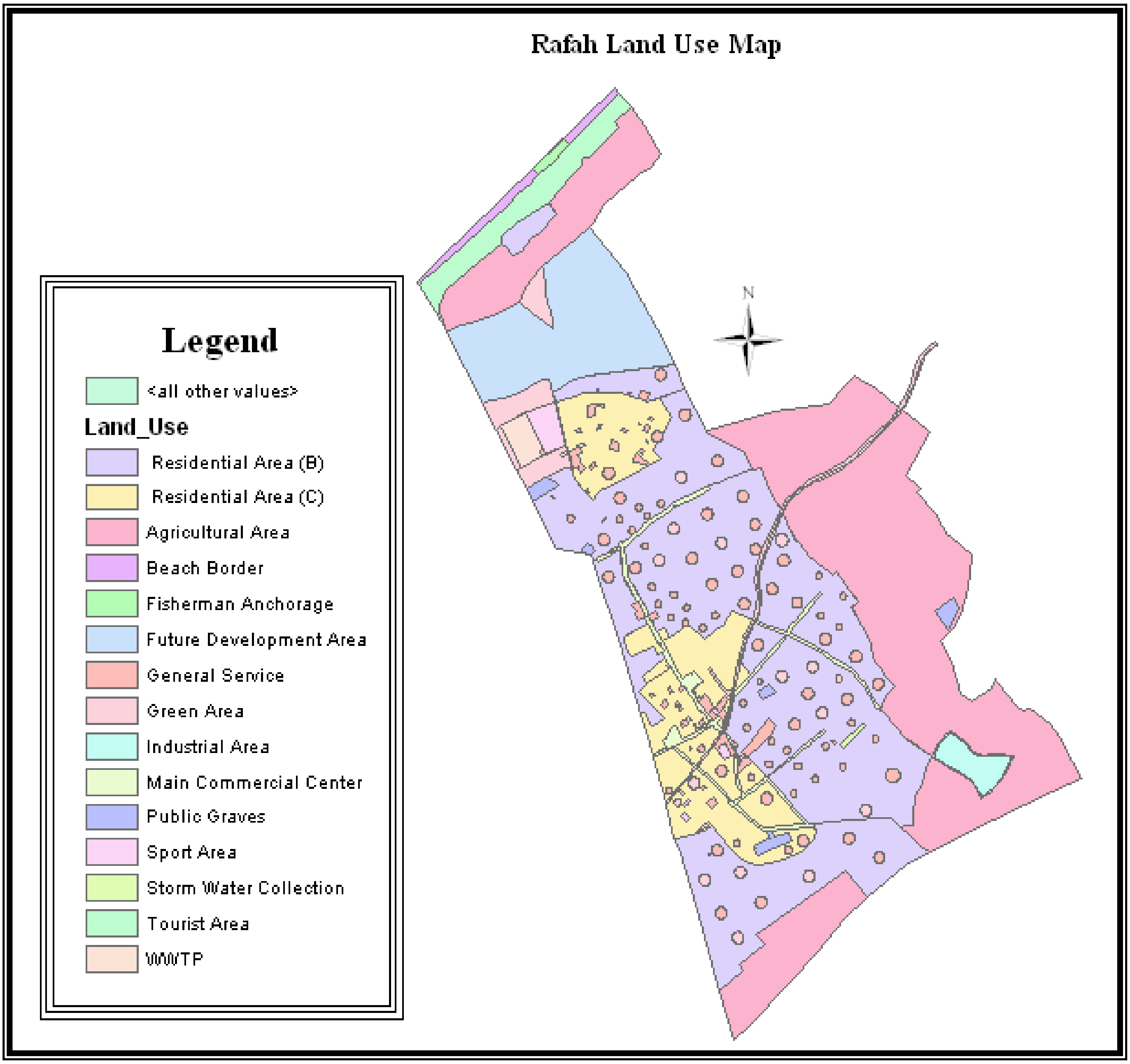

Figure 3.3: Land use map for Rafah Municipality.

b. Entering the data field for all shape files. The following figures show data filed for pipe featureless:

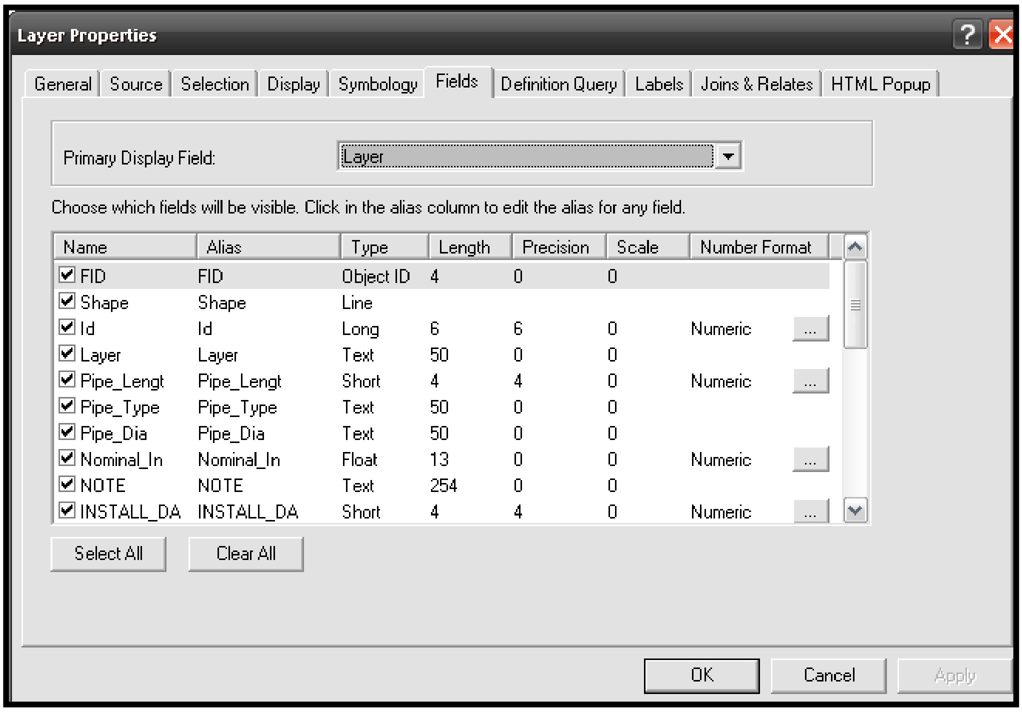

Figure 3.4: Data Fields for pipe line

For entering shape file data for all features AutoCAD files should be imported and then redrawing and entering data by editing tools for all features and edit the networks properties as shown in Figure 3.5.

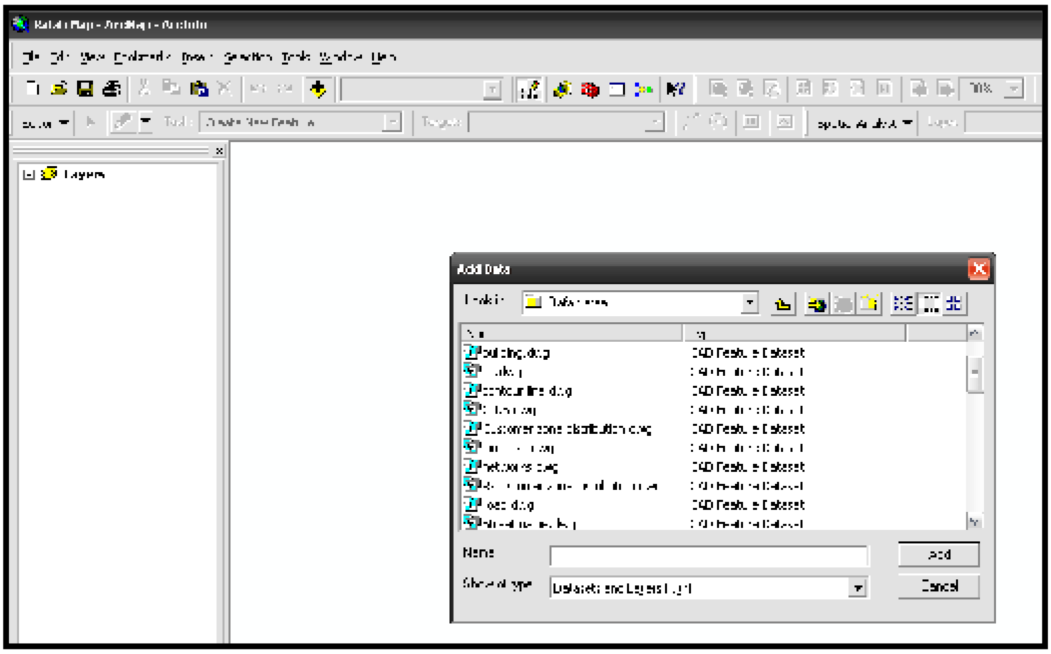

Figure 3.5: Import AutoCAD file for all features.

c. Building a network model, particularly if a large number of pipes are involved, is a complex process. The following categories of information are needed to construct a hydraulic model:

- Characteristics of the pipe network components (pipes, pumps, tanks, valves).

  Construction of the pipe network and its characteristics done manually.
  The initial step in constructing a network model is to identify pipes to be included in the model. Nodes are usually placed at pipe junctions, or at major facilities (tanks, pumps, control valves), or where pipe characteristics change in diameter, "C"value (roughness), or material of construction. Nodes may also be placed at locations of known pressure or at sampling locations or at locations where water is used (demand nodes). The required pipe network component information includes the following:

  1. Pipes (length, diameter, roughness factor),
  2. Pumps (pump curve),
  3. Valves (settings), and
  4. Tanks (cross section information, minimum and maximum water levels).

  5. The Distribution factors of average water consumption during Day and Night as show in Table 3.1.

Tables 3.1: Distribution factors of average water consumption during Day and Night.

Hour/from start	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
Time	7-9	9-11	11-13	13-15	15-17	17-19	19-21	21-23	23-1	1-3	3-5	5-7
Factor	1.5	1.1	1	1.1	1.2	2	1.3	0.8	0.5	0.3	0.5	2

6. The water demand that will be used in our study is 0.0029 m3/h for one caption(70 L/C/D)
7. The water demand for one building is 0.0145 m3/h (=0.0029*5).
8. We used in our study one connection for each building, and the distribution of connection is one connection each ten meter.
9. The existing distribution pipelines are considered for this system scenarios.
10. The hydraulic analyses characteristics are summarized as follow:
    a) Analyses: Extended period simulation.
    b) Friction method: Hazen-William formula.
    c) Accuracy: 0.001.
    d) Trials: 40.
    e) Starting time: 6.00 AM.
    f) Duration: 48 hours.
    g) Hydraulic time step: 1 hour.

- Water use (demands) assigned to nodes.

  Water consumption or water demand is the driving force behind the operation of a water distribution system. Any location at which water leaves the system can be characterized as a demand on the system. The water demands are aggregated and assigned to nodes, which represents an obvious simplification of real-world situations in which individual house taps are distributed along a pipe rather than at junction nodes. It is important to be able to determine the amount of water being used, where it is being used, and how this usage varies with time. Demand may be estimated by a count of structures of different types using a representative consumption per structure, meter readings and the assignment of each meter to a node, and to general land use. A universal adjustment factor should be used to account for losses and other unaccounted water usage so that total usage in the model corresponds to total production.

- Topographic information (elevations assigned to nodes).

  Hydraulic models use elevation data to convert heads to pressure. Actual pipe elevations should be used to establish the correct hydraulic grade line. Elevations are assigned to each node in a network where pressure information is required.

- Control information that describes how the system is operated (e.g., mode of pump operation).

  In order to apply model, it is necessary to define a set of rules that tells the model how the water system operates. This may be as simple as specifying that a particular pump operates from 6:00 AM to 12:00 AM each day. Alternatively, it may be a set of complex "logical controls" in which operations such as pump off/on, pump speed, or valve status are controlled using Boolean operators (including if-then-else logic) for factors such as tank water levels, node pressures, system demand, and time of day. For water systems that operate automatically based on a set of rules, determination of these rules are quite straightforward. For manual systems, the rules must be determined by interviews with system operators.

- Solution parameters (e.g., time steps, tolerances as required by the solution techniques).

Figure 3.6 Show water networks integrated with GIS data.

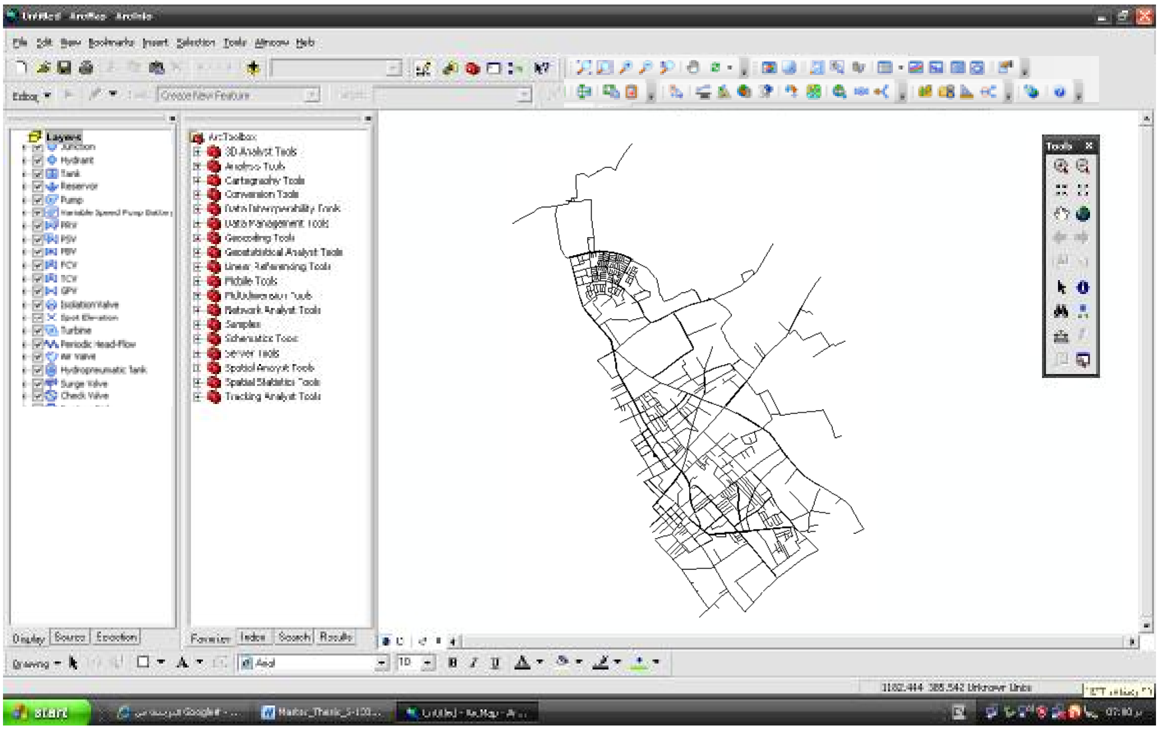

Figure 3.6: Networks integrated with GIS data.

Commonly used methods for these inputs are briefly described in the following subsections. Figure 3.7 show object model for the Distribution System.

d. Run the hydraulic model.

   The goal of hydraulic model is to prepare the base data for operation department in Rafah area help us to manage water networks and prepare a good program for distribution zone, also knowing the location of control valves and zone which controlled by it, away for controlling water networks, and knowing the affect done in water networks systems such as pressures and velocity if there any change done in networks.

e. Study the existing system of O&M for Rafa area.

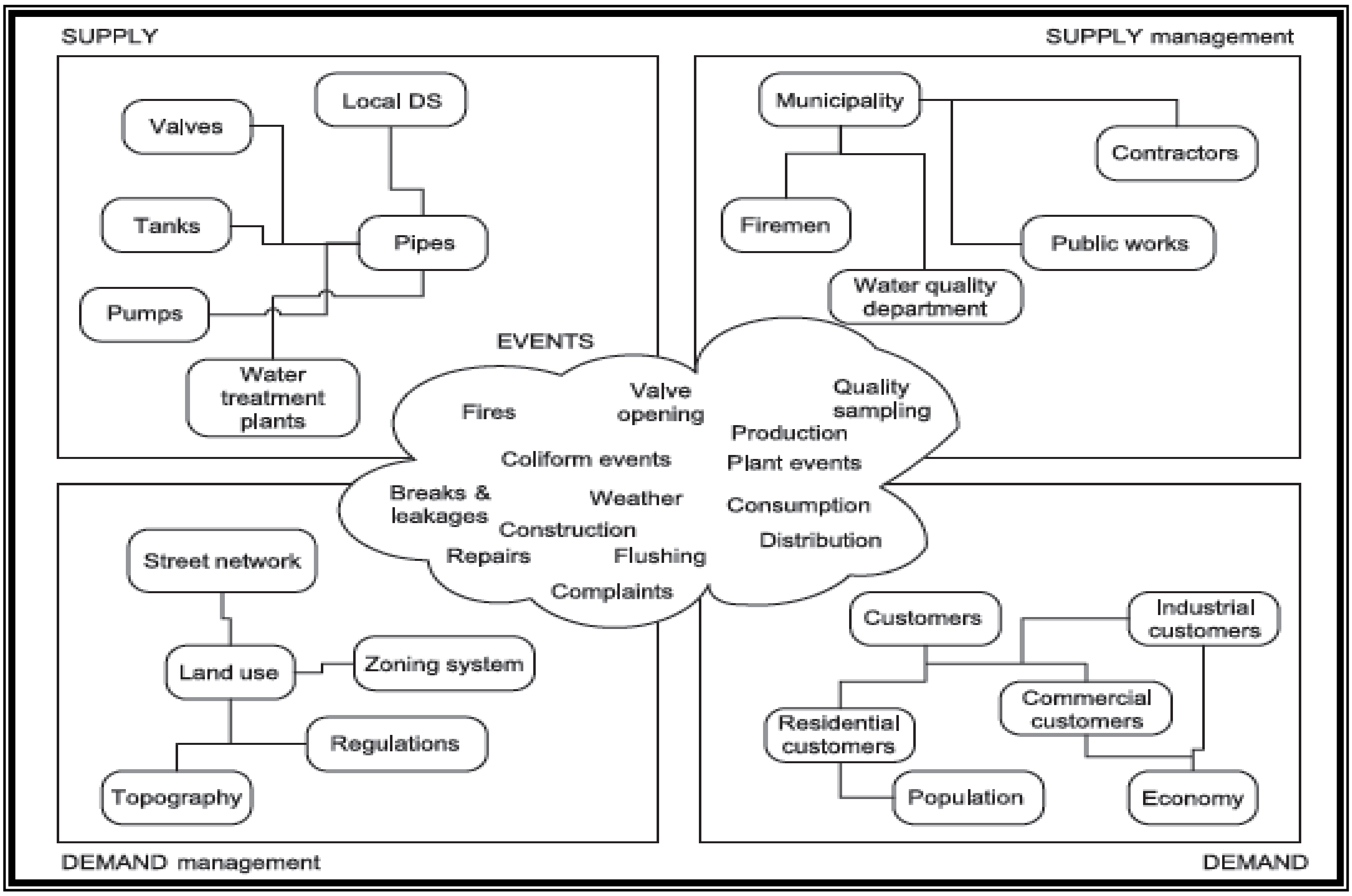

Figure 3.7: Object model for the Distribution System (M. Tre´ panier et al., 2006).

5. The five stages include use GIS & hydraulic modeling based on DSS for proposed O&M systems for Rafah area. This stage include the following:
    - Managing water networks for Rafah Municipality by using GIS and hydraulic model software.
    - Propose water distribution plane for networks.
    - Proposed pipe line condition index for maintenance water networks.

6. The final stage of this study is to define the conclusion and recommendation with reference to the objective, subsequent to the analysis by the area study and interviews.

3.3 Research structure

The process of research methodology can be summarized as Figure 3.8 below.
This Figure shows the process of research methodology starts from the literature review until to the conclusion and recommendation

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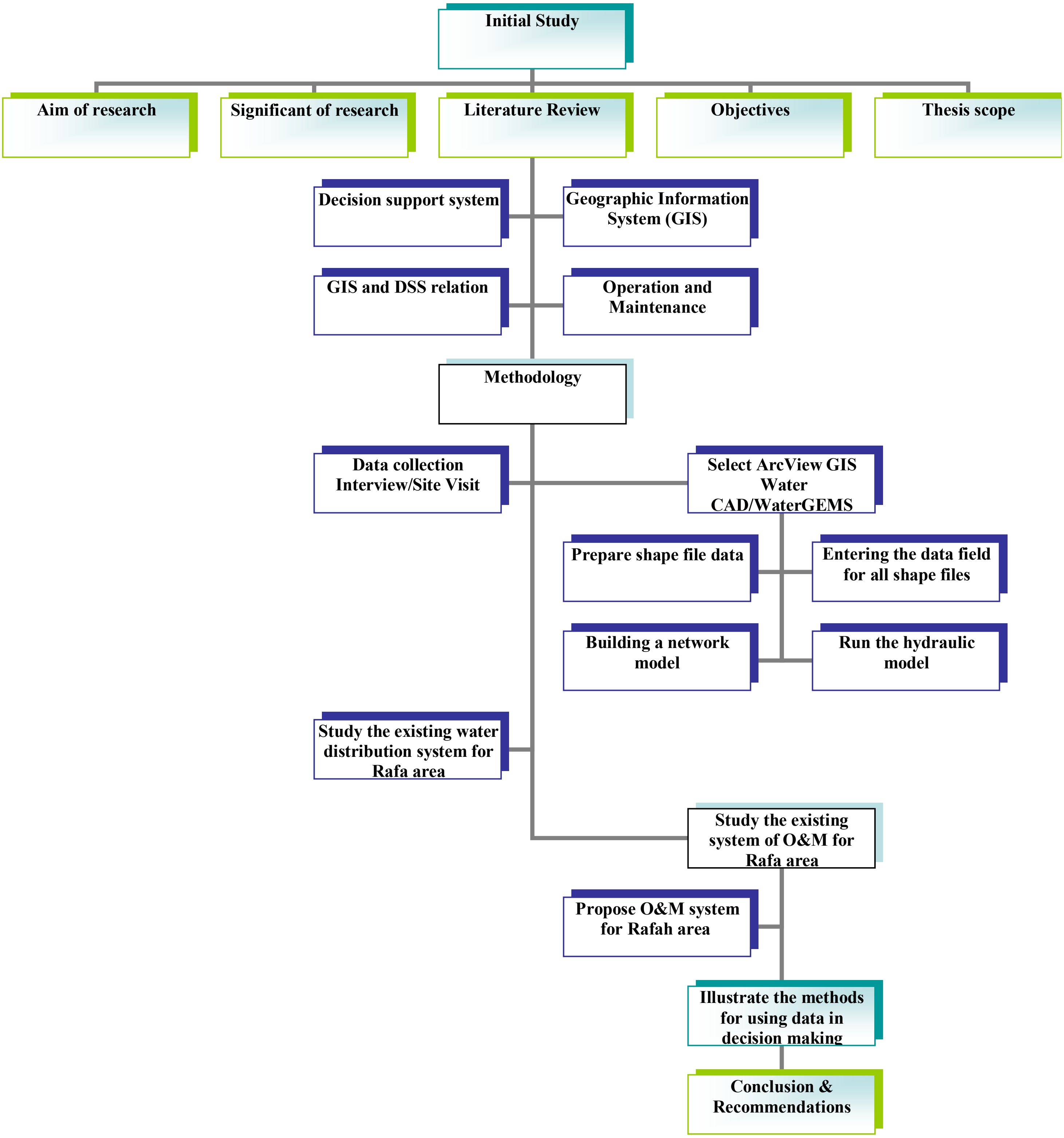

Figure 3.8: Methodology Flow Chart.

CHAPTER 4
USING GIS & HYDRAULIC MODELING BASED ON DSS FOR PROPOSED O&M SYSTEMS FOR RAFAH AREA.

4.1 Introduction

This chapter include proposed plan for distribution water networks, GIS with hydraulic modeling, Proposed procedure for O&M using GIS & DSS, pipe condition index, and clarify the methods for using data in decision making.

4.2 Proposed distribution plan for operating water networks

Proposed distribution plane for water networks can be divided into the following systems:

1. Direct Distribution Plan from Wells.
2. Direct Distribution Plan from Water Tank.

That done according to know the location of zones and control valve and need of water for each zone. And the goal of proposed distribution is to help the water department in Rafah to feed all zone by equal quantity of water for all customer 70 L/C/D.
Annex II show map which clarify Zone distribution with types of pipes and valve controls.

4.2.1 Direct Distribution Plan from Wells

This section will deal with the proposed areas that will be supplied directly from wells, these areas are: Mawasi area, Tal Elsultan area, Western Rafah area, El Salam Mosque area, Mosabeh, Kherbet El Adas area and part of El Shabora area. A detail planning on supplying nodes, time interval, and duration of supply is discussed separately in this section as follow:

a) Mawasi Zone

This area is considered as an agricultural area and the groundwater table is very shallow in this area because of two things, the first one is the area elevation where the elevation in this area is almost few meters above mean sea level, the second one is the groundwater flow where this area is considered as the natural outflow of the groundwater. The cost of drilling a well in this area is very cheap, for that reasons every house has his own private well inside his farm. So the supply water well (P/139) from the municipality will remain as the existing abstraction and time interval as it is (abstraction rate equal to 50 m3/hr and operating for 3 to 5 hours a day, the supply will be every day).

b) Tal Elsultan Zone

This area is one of the most populated areas in Rafah, the population reaching about 31,500 inhabitants. The supply for this area will be taken from three settlement wells for 12 hours a day, TRC wells, W wells, and partial from P/153 for 5 hours a day. The total supplied volume will be 2,200 m3/d and hence the quota per person will be about 70 L/C/D. The water supply will be every day instead of day after day. To achieve this within the existing facilities, the following control valves plan will be followed; V168 and V188 are open all the supplied times.

Add two end caps to eliminate supplying the area from well P/144A and P/148. Propos a direct connection from well P/153 with a control valve to the area. Figure 4.1 shows water distribution networks for Tal Elsultan Zone. Valves data which used to feed this area are shown in Table 4.1. Figure 4.2 shows output result for junction's pressure data during water consumption.

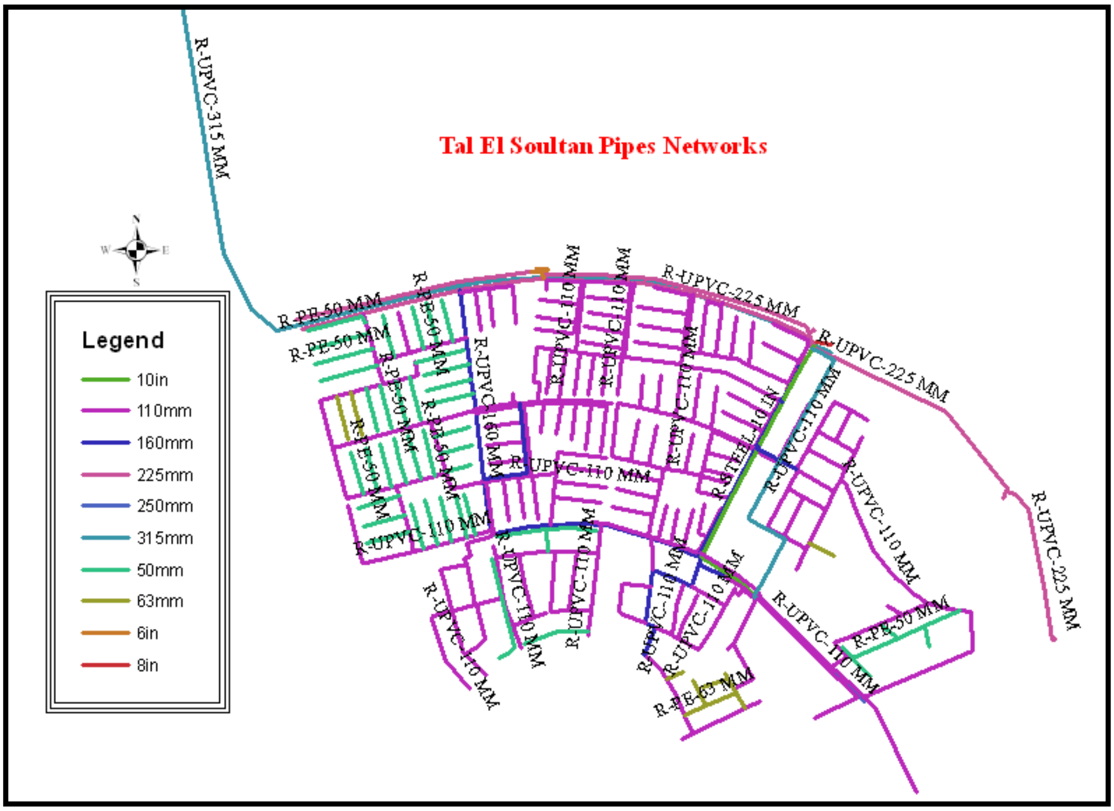

Figure 4.1: Water distribution networks for Tal Elsultan Zone.

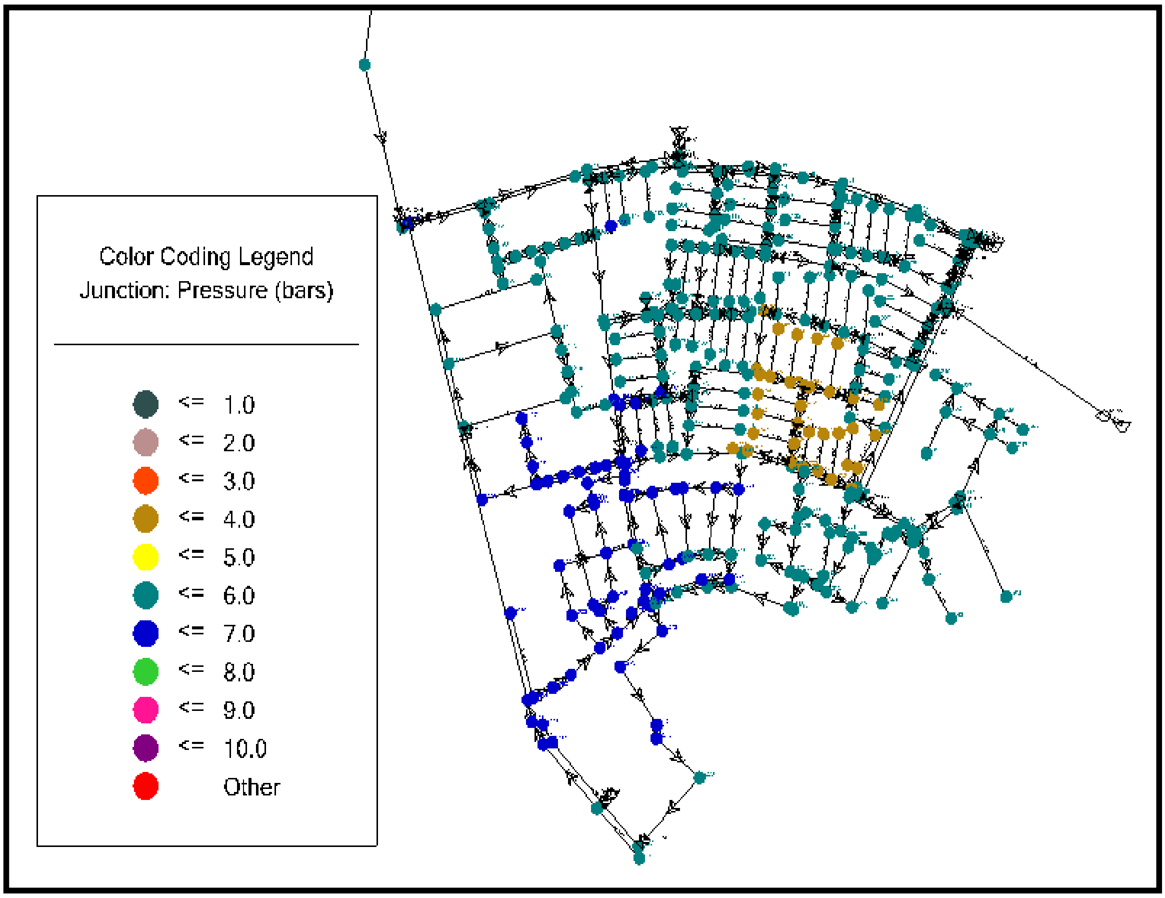

Figure 4.2: Output result for junction's pressure data during water consumption for Tal Elsultan Zone.

Table 4.1: Valve data for Tal Elsoultan Zone.

Label	Elevation (m)	Diameter (mm)	Control Status
GPV-244	30.00	150	Active
GPV-2	26.21	200	Active
GPV-3	26.21	200	Active
GPV-4	27.86	110	Active
GPV-222	27.64	110	Active
GPV-223	27.69	150	Active
GPV-220	29.44	200	Active
GPV-221	29.44	200	Active
GPV-209	29.41	110	Active
GPV-208	28.89	150	Active
GPV-189	29.40	110	Active
GPV-188	29.40	200	Active
GPV-14	28.60	200	Active
GPV-191	28.63	110	Active
GPV-192	28.63	110	Active
GPV-193	28.05	110	Active
GPV-200	28.61	110	Active
GPV-202	27.15	110	Active
GPV-199	27.67	110	Active
GPV-203	27.15	110	Active
GPV-205	27.80	110	Active
GPV-204	28.02	110	Active
GPV-207	28.97	150	Active
GPV-206	28.92	110	Active
GPV-211	27.80	110	Active
GPV-210	28.30	110	Active
GPV-224	27.48	110	Active
GPV-219	28.80	110	Active
GPV-213	26.88	110	Active
GPV-225	24.55	110	Active
GPV-218	23.87	150	Active
GPV-217	24.76	110	Active
GPV-216	24.80	110	Active
GPV-214	25.64	110	Active
GPV-215	24.76	110	Active
GPV-212	27.30	110	Active
GPV-198	25.44	110	Active
GPV-195	25.43	110	Active
GPV-196	25.43	110	Active
GPV-197	26.25	110	Active
GPV-185	26.75	110	Active
GPV-238	25.99	250	Active
GPV-174	31.51	110	Active
GPV-190	29.94	110	Active
GPV-201	27.93	110	Active
GPV-187	30.55	150	Active
GPV-186	30.55	150	Closed
GPV-48	28.60	110	Closed

c) Western Rafah and Al Salam Mosque Zones

This area is represented by zone 2 and 3 in the existing water distribution zones, the population in this area is about 18,000 inhabitant. The water supply source in this area is from well P/138. The average abstraction rate will be 65 m3/hr for 20 hour a day (1,300 m3/d). This quantity of water is sufficient to the people to have 70 L/C/D.
To enable us distributing this amount of water fairly according to the population densities between the Western Rafah (15,615 inhabitants) and Al Salam Mosque (2,300 inhabitants) areas, valves which used to control and feed the areas are shown in Table 4.2. Figure 4.3 & Figure 4.4 show water networks pipes for Western Rafah and Al Salam Mosque zones respectively. Also valves data which used to feed these areas are shown in Table 4.3 & Table 4.4 for Western Rafah and Al Salam Mosque zones respectively. Figure 4.5 shows output result for junction's pressure data during water consumption.

Table 4.2: Valve Scheme System for Western Rafah and Al Salam Mosque Zones.

Supply Area	Opened Valve	Closed Valve
Western Rafah area (Zone 2)	V183, PV01, V173, V155, &V176	V182, V177,V172, V169, V157, &PV02
Al Salam Mosque Area (Zone 3)	V183, V177, V145, V148, V128, &V132	V182, PV01, V157, V146, V147, V144, V143, V129, V130, V134, &V122

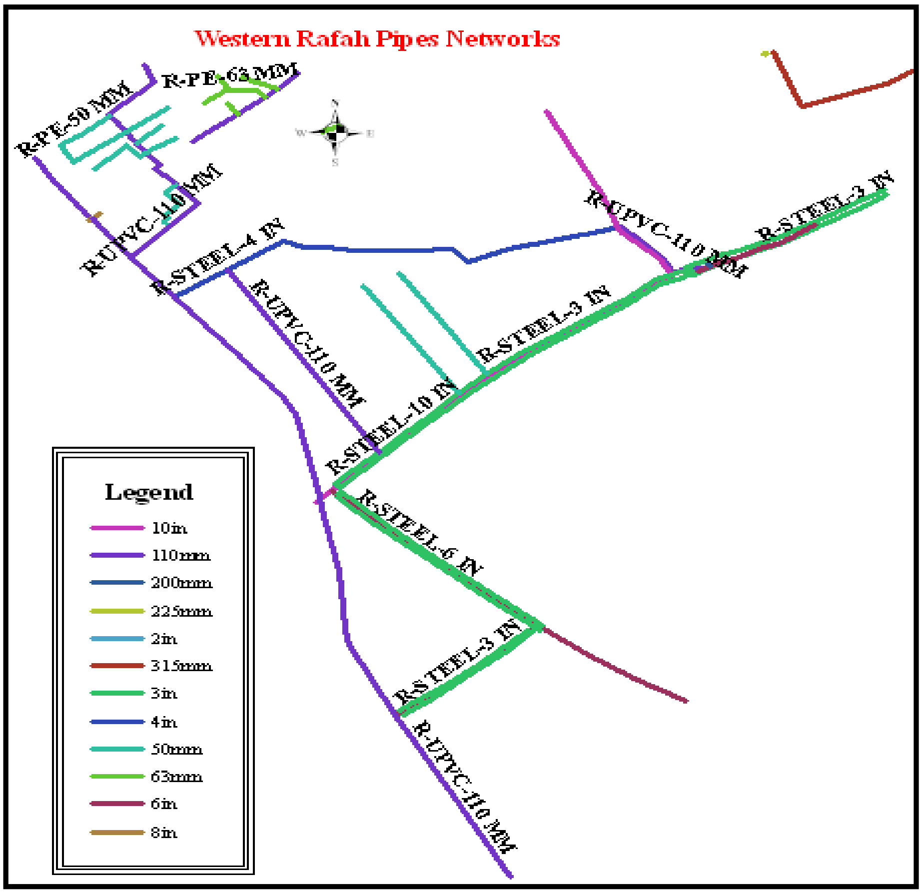

Figure 4.3: Water distribution networks for Western Rafah Zone.

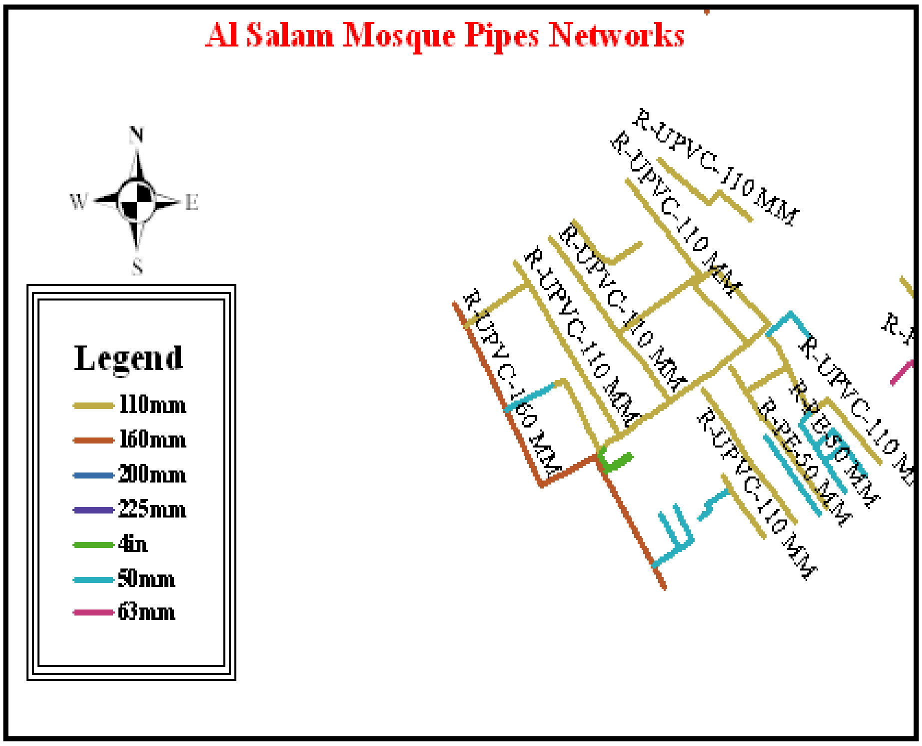

Figure 4.4: Water distribution networks for Al Salam Mosque Zone.

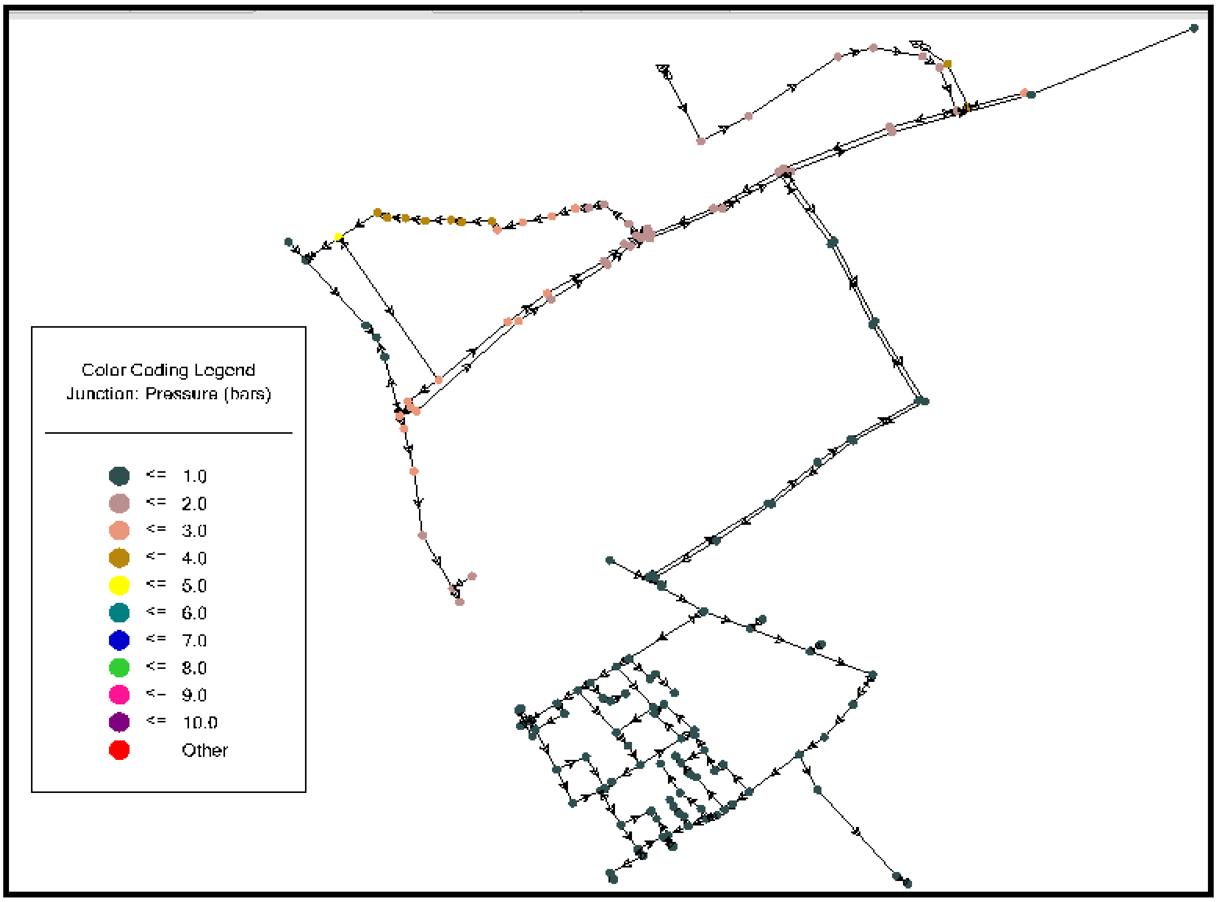

Figure 4.5: Output result for junction's pressure data during water consumption for Western Rafah and Al Salam Mosque Zones.

Table 4.3: Valve data for Al Salam Mosque Zone.

Label	Elevation (m)	Diameter (mm)	Control Status
GPV-181	45.43	250	Active
GPV-183	45.43	250	Active
GPV-176	41.06	110	Active
GPV-173	15.20	110	Active
GPV-145	53.53	160	Active
GPV-148	64.87	160	Active
GPV-132	69.76	160	Active
GPV-128	50.60	160	Active
GPV-PV02	41.84	200	Active
GPV-182	45.43	250	Closed
GPV-184	41.84	160	Closed
GPV-177	41.84	160	Closed
GPV-172	21.81	110	Closed
GPV-169	26.35	110	Closed
GPV-155	38.14	160	Closed
GPV-157	48.23	200	Closed
GPV-146	54.89	110	Closed
GPV-147	63.04	110	Closed
GPV-122	69.10	110	Closed
GPV-130	68.56	110	Closed
GPV-129	57.53	160	Closed
GPV-144	49.81	160	Closed
GPV-143	49.81	450	Closed

Table 4.4: Valve data for Western Rafah Zone.

Label	Elevation (m)	Diameter (mm)	Control Status
GPV-181	45.43	250	Active
GPV-183	45.43	250	Active
GPV-177	41.84	160	Active
GPV-176	41.06	110	Active
GPV-173	15.20	110	Active
GPV-145	53.53	160	Active
GPV-148	64.87	160	Active
GPV-132	69.76	160	Active
GPV-128	50.60	160	Active
GPV-182	45.43	250	Closed
GPV-184	41.84	160	Closed
GPV-172	21.81	110	Closed
GPV-169	26.35	110	Closed
GPV-155	38.14	160	Closed
GPV-157	48.23	200	Closed
GPV-146	54.89	110	Closed
GPV-147	63.04	110	Closed
GPV-122	69.10	110	Closed
GPV-130	68.56	110	Closed
GPV-129	57.53	160	Closed
GPV-144	49.81	160	Closed
GPV-143	49.81	450	Closed
GPV-PV02	41.84	200	Closed

The only control valves to divert waters from one zone to another will be PV01 and V177. In Case of supplying waters to zone 2, then PV01 will be opened and V177 will be closed. While in case of supplying zone 3, then PV01 will be closed and V177 will be opened.

To make the life of the water distribution employee easy, they have only to open and close the following valves only one in a normal situation, while the control valves are the switch on and off according to the supply time for these areas.

The above valving scheme system will be followed as a normal situation, while there is other emergency schemes solutions that can be followed in case of failed to operate well P/138. The emergency solution is temporally for short term until the maintenance team fixes the damaged water well. In this emergency situation well P/145 will supply these two zones for shorter time and valve V181 will be closed while valve V182 will be opened for the whole duration time interval that well P/145 is supplying zone 2 and 3 while the entire system valving inside zone 2 and 3 will remain as discussed before except when diverting waters from one zone to another.

d) El Mosabeh, Kherbet El Adas and El Shabora Zones

These areas are representing zone 11, 12A, 12B and 6. Table 4.5 shows a summary data that will be followed in designing the water distribution system in these zones.
Figure 4.6, Figure 4.7, & Figure 4.8 show water networks pipes for El Mosabeh, Kherbet

El Adas and El Shabora Zones respectively.

Table 4.5: Zone 11, 12A and 12B Summary Data.

Zone	Population	Target Quota	Water Needed Based on the Target Quota
11	8976	70 L/C/D	628 m^3/d
12A & 12B	8815	70 L/C/D	617 m^3/d
Partially 6	2000	70 L/C/D	140 m^3/d

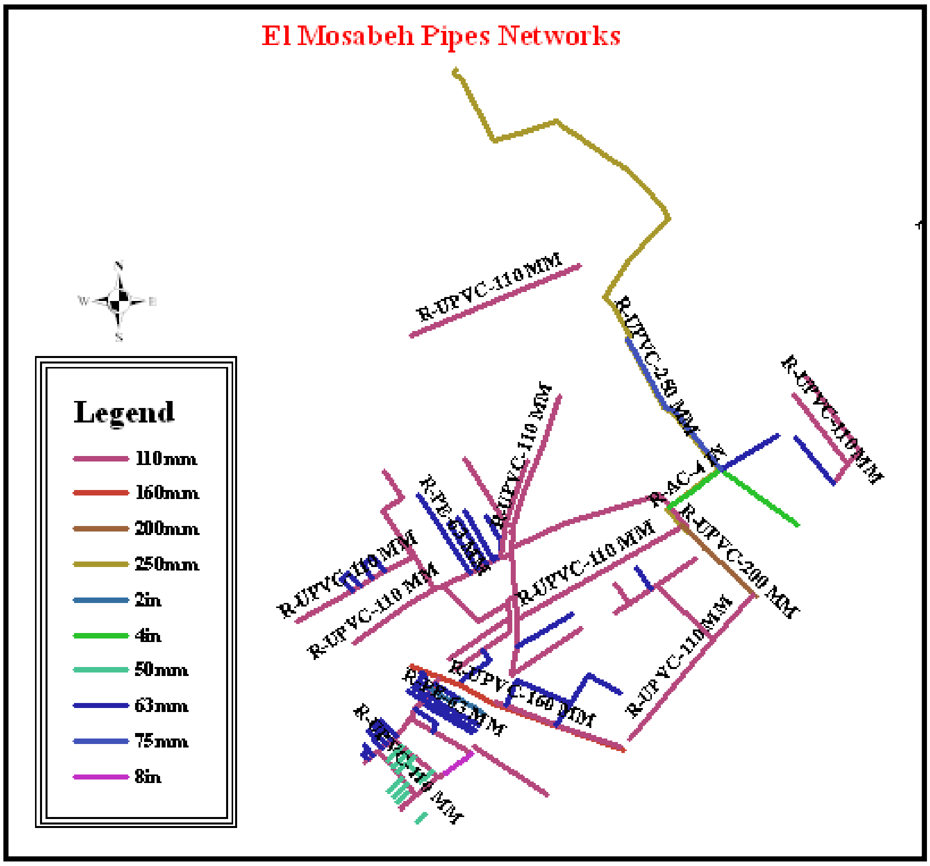

Figure 4.6: Water distribution networks for El Mosabeh Zone.

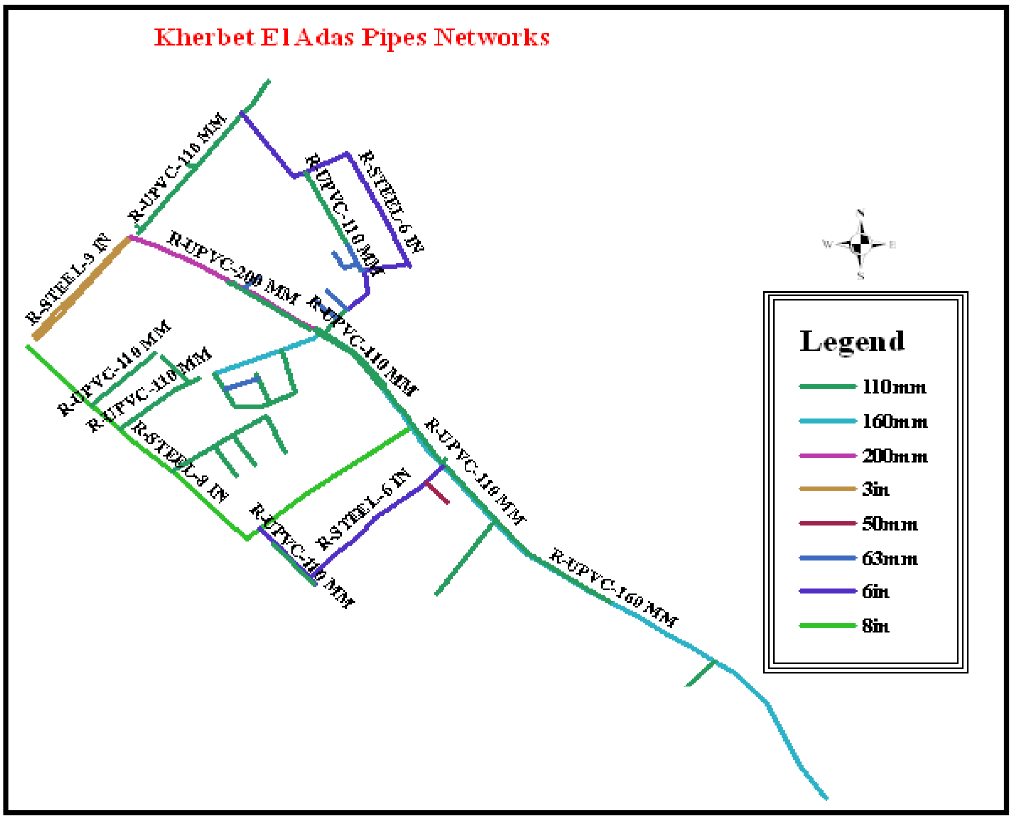

Figure 4.7: Water distribution networks for Kherbet El Adas Zone.

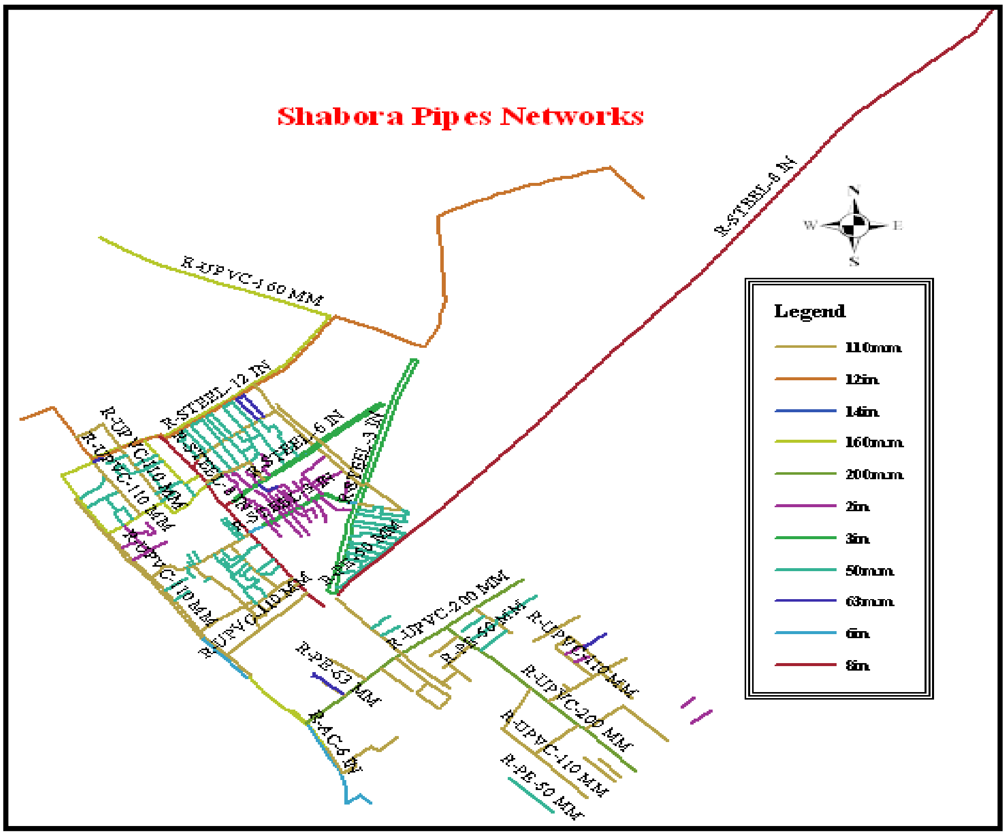

Figure 4.8: Water distribution networks for El Shabora Zone.

The water source for these zones will be from well P/145. The average abstraction rate for this well is 101 m3/hr and operate 24 hour a day as in year 2006. This plan the well will operate for 24 hour a day. 20 hours for supplying the designated zones and 4 hours for supplying the main water tank. This plan will take 30% losses from the water source to reach its target zone and that because the long distance between the water source and the distribution zones.

This proposal will divide the previously identified zones to parts as follow:

Part 1: Include partially zone 11 and partially zone 6. The estimated population in this area is about 6000 inhabitants. The needed water volume is about 550 m3/d and to achieve the supply criteria 6 hours supply every day for this zone will be satisfying.
Valves data which used to feed this area are shown in Table 4.6. Figure 4.9 shows output result for junction's pressure data during water consumption.

Table 4.6: Valve data for partially Zone 11 and partially Zone 6.

Label	Elevation (m)	Diameter (mm)	Control Status
GPV-181	48.35	250	Active
GPV-159	67.69	110	Active
GPV-158	71.27	110	Active
GPV-136	68.80	200	Active
GPV-135	74.47	110	Active
GPV-138	76.65	110	Active
GPV-160	76.43	110	Active
GPV-166	80.21	110	Active
GPV-164	80.21	110	Active
GPV-165	80.21	110	Active
GPV-182	48.35	250	Closed
GPV-146	64.00	110	Closed
GPV-147	63.04	110	Closed
GPV-122	72.00	110	Closed
GPV-99	70.98	160	Closed
GPV-92	70.00	200	Closed
GPV-91	70.00	200	Closed
GPV-120	75.29	200	Closed
GPV-163	73.69	200	Closed

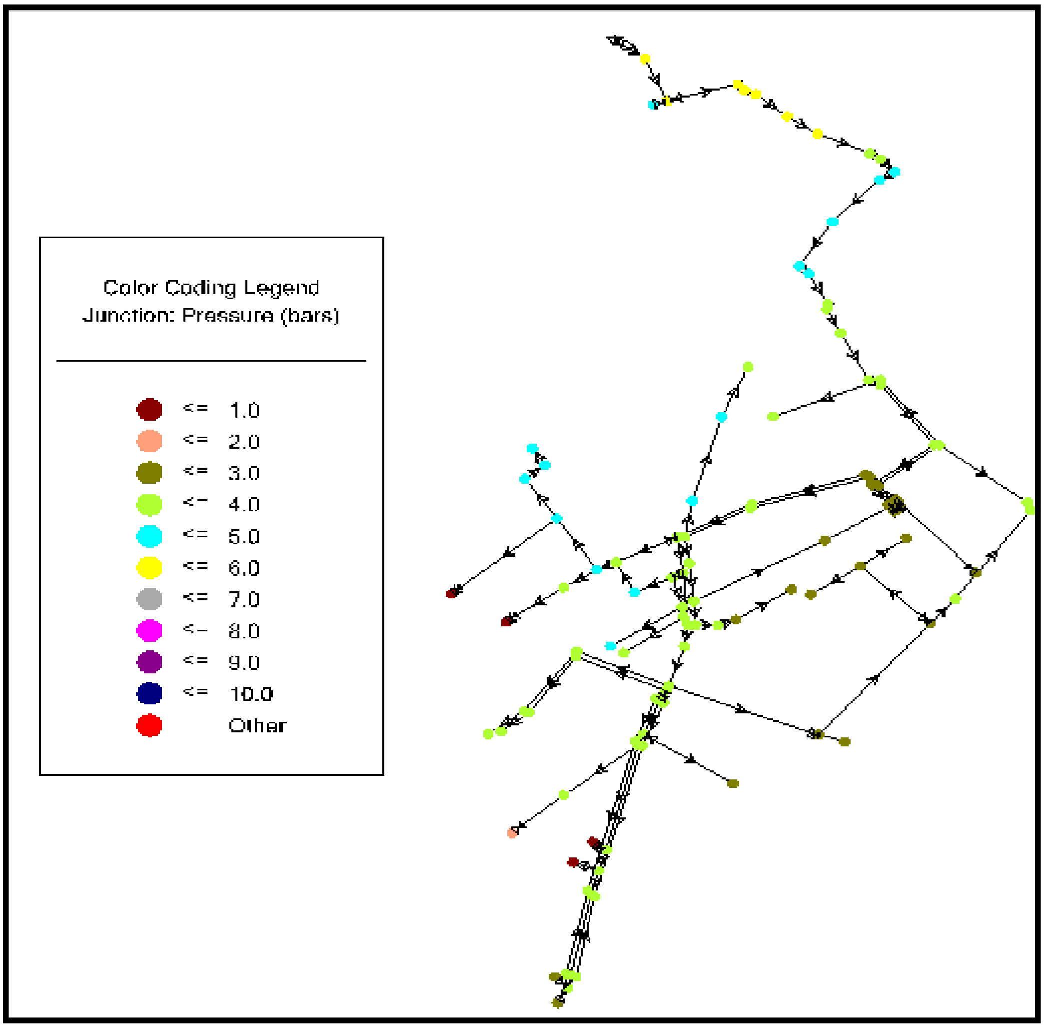

Figure 4.9: Output result for junction's pressure data during water consumption for Zone 11 and partially Zone 6.

Part 2: Include partially zone 11 and zone 12B. The estimated population in this area is about 6000 inhabitants. The needed water volume is about 550 m3/d and to achieve the supply criteria 6 hours supply every day for this zone will be satisfying. Valves data which used to feed this area are shown in Table 4.7. Figure 4.10 shows output result for junction's pressure data during water consumption.

Table 4.7: Valve data for partially Zone 11 and Zone 12B.

Label	Elevation (m)	Diameter (mm)	Control Status
GPV-181	48.35	250	Active
GPV-163	74.25	200	Active
GPV-162	74.25	200	Active
GPV-161	74.25	200	Active
GPV-240	73.78	160	Active
GPV-179	64.52	160	Active
GPV-180	64.00	110	Active
GPV-140	75.53	160	Active
GPV-178	74.76	200	Active
GPV-164	80.21	300	Active
GPV-182	48.35	250	Closed
GPV-166	80.21	110	Closed
GPV-139	75.42	200	Closed
GPV-98	73.03	110	Closed
GPV-165	81.21	300	Closed

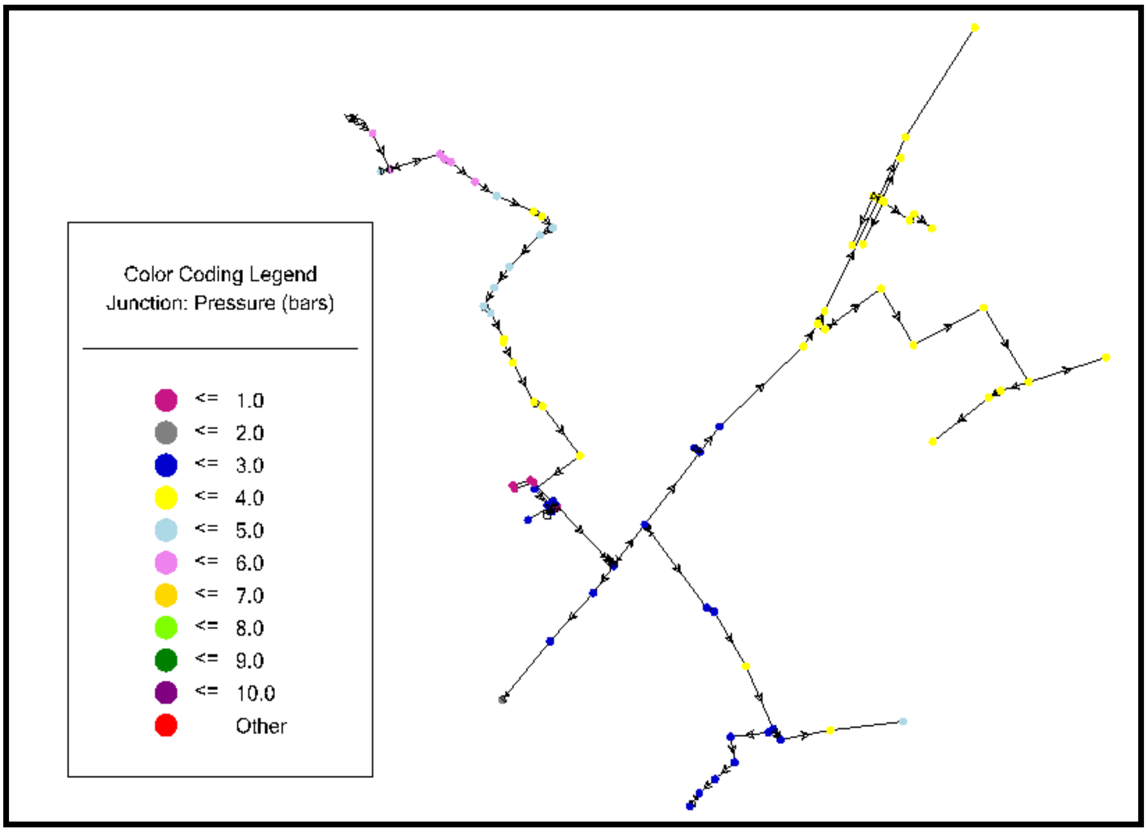

Figure 4.10: Output result for junction's pressure data during water consumption for zone 11 and zone 12B.

Part 3: Include partially zone 6 and zone 12A. The estimated population in this area is about 8000 inhabitants. The needed water volume is about 730 m3/d. and to achieve the supply criteria 8 hours supply every day for this zone will be satisfying. Valves data which used to feed this area are shown in Table 4.8. Figure 4.11 shows output result for junction's pressure data during water consumption.

Table 4.8: Valve data for partially Zone 6 and Zone 12A.

Label	Elevation (m)	Diameter (mm)	Control Status
GPV-181	48.35	250	Active
GPV-164	80.21	300	Active
GPV-163	74.25	200	Active
GPV-162	74.25	200	Active
GPV-139	73.31	200	Active
GPV-137	73.31	200	Active
GPV-243	73.31	200	Active
GPV-97	73.00	160	Active
GPV-39	73.00	200	Active
GPV-66	62.13	110	Active
GPV-48	59.29	110	Active
GPV-67	65.98	250	Active
GPV-76	70.74	250	Active
GPV-79	70.74	160	Active
GPV-95	76.95	200	Active
GPV-96	76.95	200	Active
GPV-94	76.95	200	Active
GPV-38	53.95	160	Active
GPV-182	48.35	250	Closed
GPV-166	80.21	110	Closed
GPV-165	80.21	300	Closed
GPV-161	74.25	200	Closed
GPV-98	73.00	110	Closed
GPV-36	53.19	160	Closed
GPV-37	52.30	160	Closed
GPV-40	56.07	200	Closed
GPV-41	56.07	200	Closed
GPV-45	56.98	200	Closed
GPV-93	72.46	200	Closed

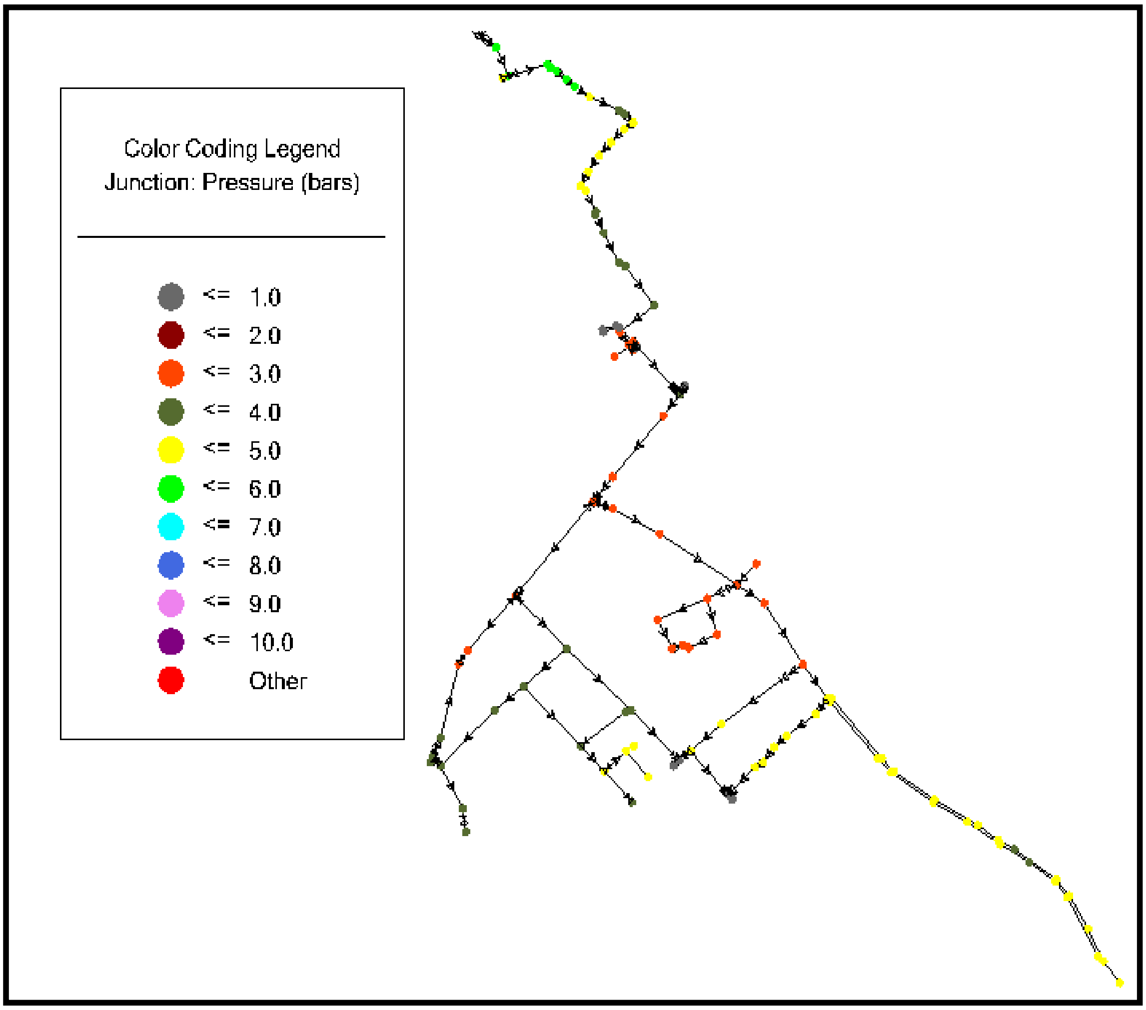

Figure 4.11: Output result for junction's pressure data during water consumption for zone 6 and zone 12A.

The above 3 parts will cover 20 hours a day, the rest of the day will supply the major water tank by an amount of 400 m3 through the 12" steel pipe. A detail valve scheme system to be followed for each part is shown in Table 4.9.

Table 4.9: Valve Scheme System.

Supply Area	Opened Valve	Closed Valve
Partially Zone 11 & Partially Zone 6 Estimated Population 6000 Inhabitants	V182, V165, V164, V166, V159, V158, V138, V160, V136, & V135	V182, V163, V146, V147, V122, V99, V120, V92, V91,& V133
Zone 12B & Partially Zone 11 Estimated population 6000 Inhabitants	V181, V163, V162, V161, V241, V140, V178, V179,& V180	V182, V165, V166, V139,& V98
Zone 12A & Partially Zone 6 Estimated population 8000 Inhabitants	V181, V163, V162, V139, V97, V39, V38, V137, V96, V94, V95, V66, V48, & V243	V182, V165, V161, V166, V98, V40, V37, V36, V41, V93, PV03, & V45
Water Tank	V181, V165, V133,& V118	V182, V164, V166, V159, V158, V136, V131, V138

4.2.2 Direct Distribution Plan from Water Tank

The main water tank capacity is 6000 m3 as described before. This water tank will feed from wells P/144A, P/148, P/15, P/124 for 20 hours a day and keeping 4 hours as backup time for any maintenance process, well P/153 will feeding the water tank for 16 hour a day, while well P/145 will feeding the water tank for 4 hours every day. Table 4.10 shows the water quantity delivered to the water tank area.

Table 4.10: Delivered Water Quantities to the Tank Area.

Well No.	Time (hr)	Avg. Q(m^3)	Total Produce Q at the Well (m^3)	Total Received Q at Water Tank 5% losses(m^3)
P/144A	20	157	3,140	2,983
P/148	20	77	1,540	1,463
P/15	20	54	1,080	1,026
P/124	20	177	3,540	3,363
P/153	16	80	1,280	1,216
P/145	4	101	404	384
Total Q Delivered to the Tank Every Day				**10,435**

This amount of water will be distributed to about 100,000 inhabitants, taking into account average water network system efficiency as 70% from the water tanks to the target area (7,305m3/d) which will led us to delivering 70L/C/D as quota per person. The following paragraphs will summarize the new distribution system plan for the rest of the zones in Rafah.

a) Yebna and Shabora Zone (Z5 and Z6).

The population in this area is about 30,500 inhabitants but because part of Shabora area has been covered in the direct supply from wells discussed in previous section which was covering 2000 inhabitants, the assumed net population in these areas will be 28,500 inhabitants. The water needed for these zones are 2,594m3/d based on water quantity as 70 L/C/D and considering 30% losses in the network system from the water tank. To deliver this amount of water into these zones and according to the booster pump stations (120m3/hr.), we need 8 hours operation for those pumps to these zones. Table 4.11 shows the valving system to be followed for Yebna and Shabora zones respectively and that to achieve an equitable distribution plan. Figure 4.12 shows water distribution networks for Yebna Zone. Also valves data which used to feed these areas are shown in Table 4.12 & Table 4.13 for Yebna and Shabora zones respectively. Figure 4.13 & Figure 4.14 show output result for junction's pressure data during water consumption for Yebna and Shabora zones respectively.

Table 4.11: Valve Scheme System for Yebna area and Shabora area.

Supply Area	Opened Valve	Closed Valve
Yebna area (Zone 5)	V83, V84, V228, V227, V104, V105, V109, V107, V106, V111, V110, V119, V114, &V115	V82, V81, V80, V103, V115, V108, V112, V117, V113, &V90
Shabora Area (Zone 6)	V86, V87, V89, V78, V79, V65, V101, V102, V100, &V121	V91, V92, V99, V120, V131, V134, V130, V129, V93, V90, &V75

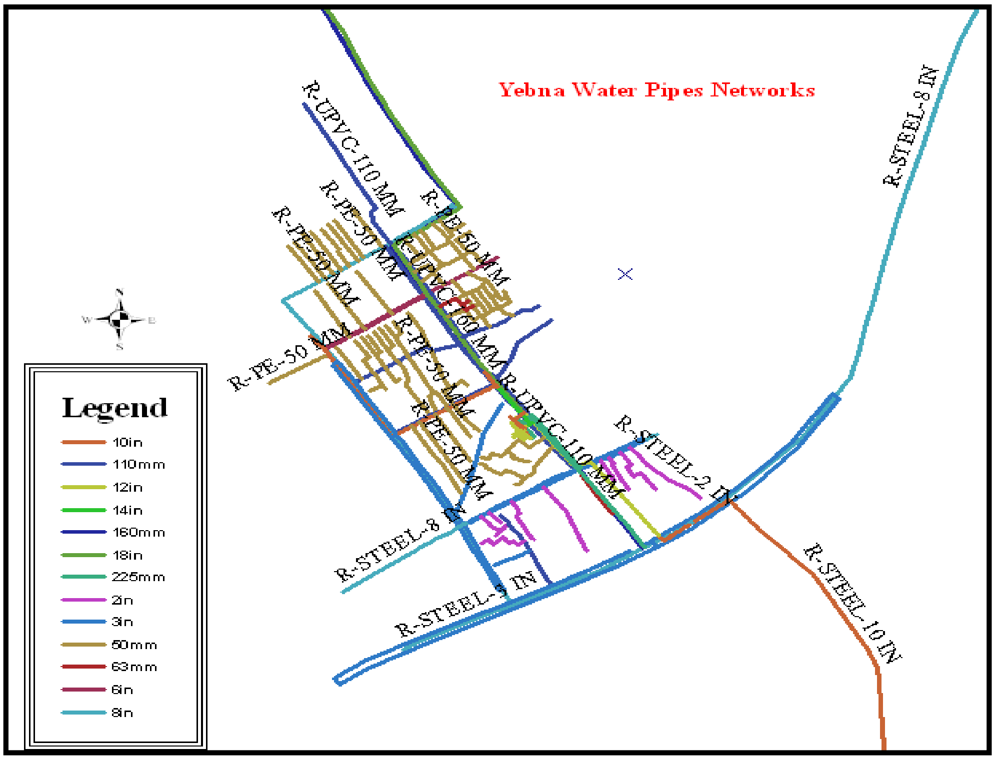

Figure 4.12: Water distribution networks for Yebna Zone.

Table 4.12: Valve data for Yebna Zone.

Label	Elevation (m)	Diameter (mm)	Control Status
GPV-119	69.00	200	Active
GPV-111	73.80	75	Active
GPV-110	73.00	75	Active
GPV-106	75.00	200	Active
GPV-107	75.00	250	Active
GPV-83	75.50	200	Active
GPV-84	74.00	110	Active
GPV-105	81.00	110	Active
GPV-104	81.00	110	Active
GPV-228	81.00	200	Active
GPV-114	70.00	160	Active
GPV-109	77.00	110	Active
GPV-227	81.00	200	Active
GPV-117	69.00	110	Closed
GPV-115	70.00	110	Closed
GPV-112	74.00	160	Closed
GPV-81	75.00	110	Closed
GPV-82	74.00	110	Closed
GPV-80	75.00	110	Closed
GPV-90	69.00	160	Closed
GPV-103	76.60	200	Closed
GPV-113	69.00	160	Closed
GPV-108	77.00	250	Closed

Table 4.13: Valve data for Shabora Zone.

Label	Elevation (m)	Diameter (mm)	Control Status
GPV-121	74.07	160	Active
GPV-101	74.00	110	Active
GPV-102	74.00	110	Active
GPV-78	71.04	160	Active
GPV-79	71.04	160	Active
GPV-89	71.04	160	Active
GPV-65	59.78	110	Active
GPV-80	74.00	200	Active
GPV-87	71.00	200	Active
GPV-129	68.56	110	Closed
GPV-130	69.61	110	Closed
GPV-131	69.76	200	Closed
GPV-134	72.74	200	Closed
GPV-120	75.29	200	Closed
GPV-99	74.54	160	Closed
GPV-92	72.46	200	Closed
GPV-93	72.46	200	Closed
GPV-91	72.46	200	Closed
GPV-75	71.04	160	Closed
GPV-90	71.04	160	Closed

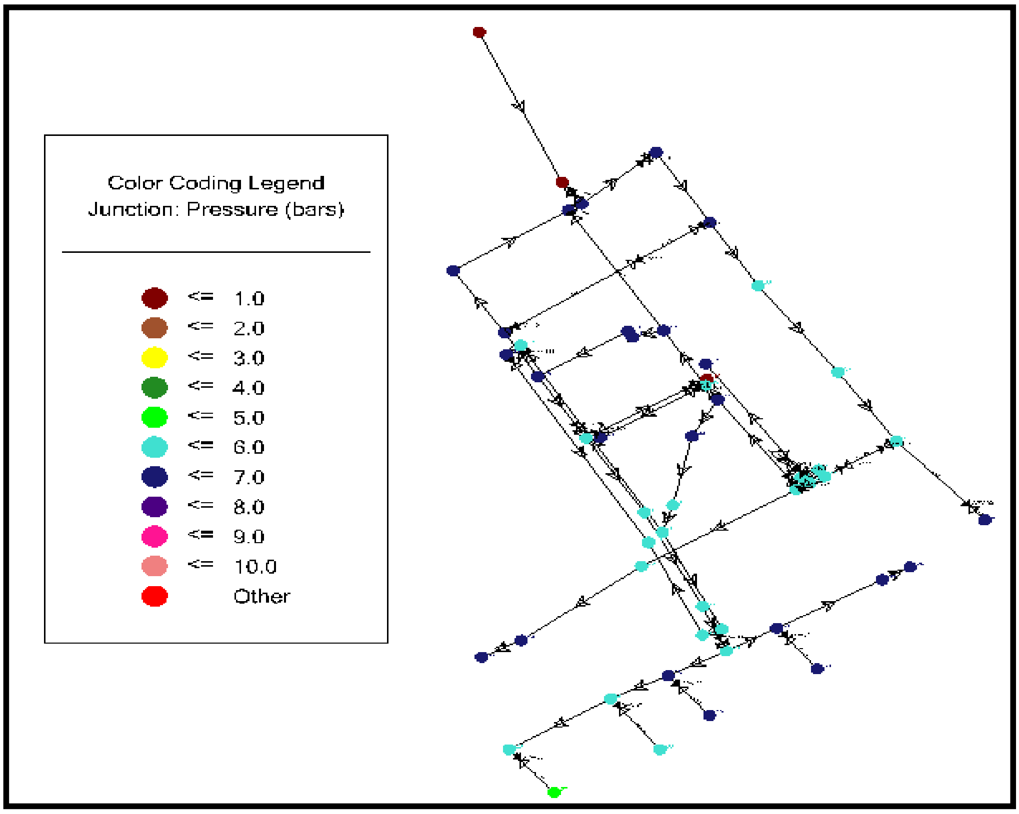

Figure 4.13: Output result for junction's pressure data during water consumption for Yebna Zone.

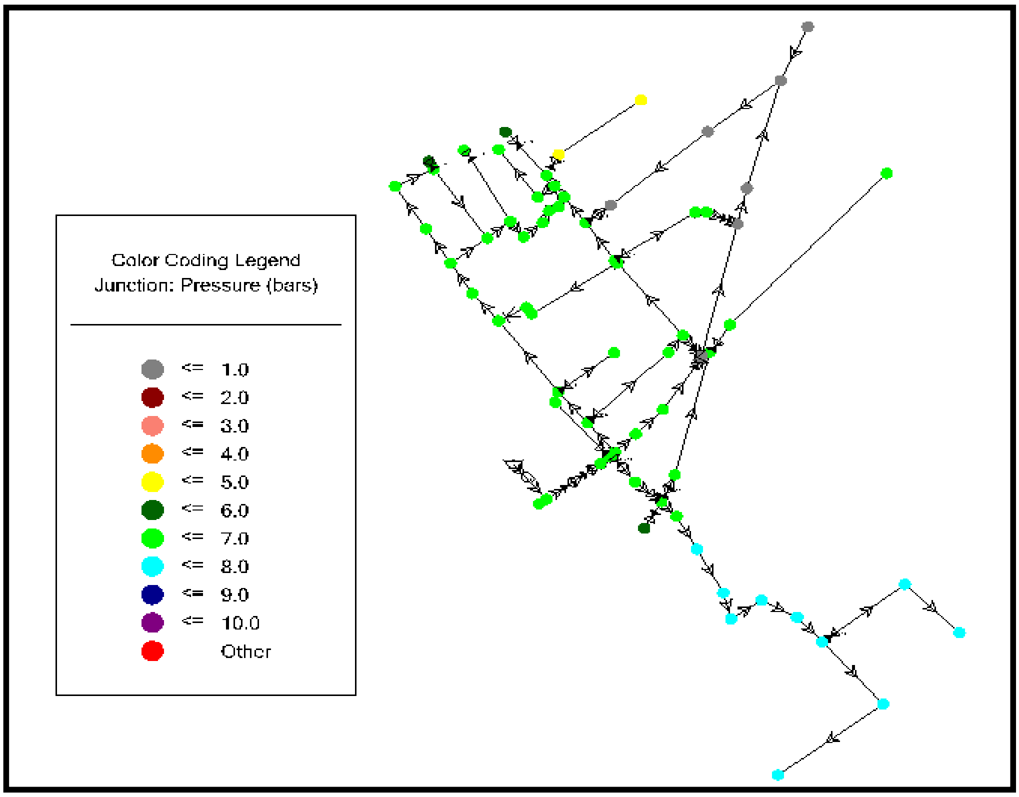

Figure 4.14: Output result for junction's pressure data during water consumption for Shabora.

b) El Brazil Zone.

The population in this area is about 19,283 inhabitants. The water needed for this zone is 1,755m3/d based on 70 L/C/D as water quantityota for every person and considering 30% losses in the distribution network system from the water tank. To deliver this amount of water into this zone and according to the booster pump stations (250m3/hr.), we need 7 hours operation for one of the three booster pumps. Table 4.14 shows the valving system.
Figure 4.15 shows water distribution networks for El Barazil Zone. Valves data which used to feed this area are shown in Table 4.15.
Figure 4.16 shows output result for junction's pressure data during water consumption.

Table 4.14: Valve Scheme System for El Brazil Zone.

Supply Area	Opened Valve	Closed Valve
El Brazil area (Zone 7)	V85, V88, V74, V242, V69, V86, V70, V71, V72, 73, &V9	V77, V75, V80, V81, V82, V59, V64, V63, V62, 61, V60, 7, &V1

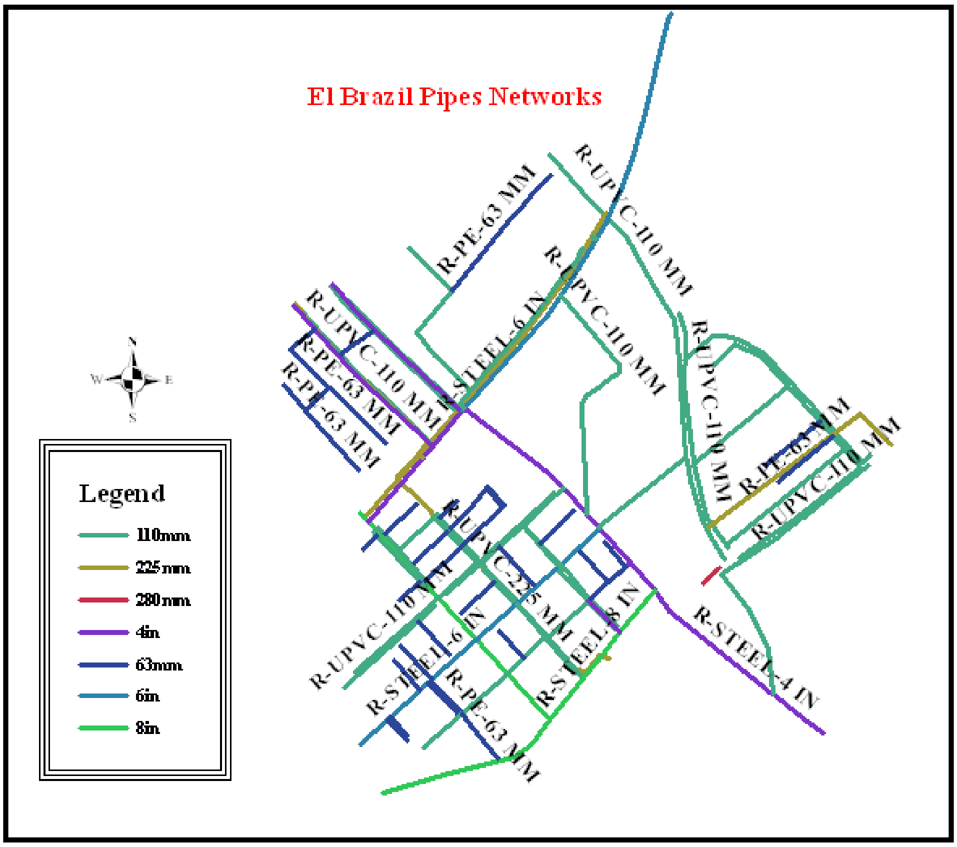

Figure 4.15: Water distribution networks for El Brazil Zone.

Table 4.15: Valve data for El Brazil Zone.

Label	Elevation (m)	Diameter (mm)	Control Status
GPV-85	75.37	300	Active
GPV-88	75.37	250	Active
GPV-76	72.48	250	Active
GPV-74	71.04	160	Active
GPV-242	71.04	200	Active
GPV-73	68.29	110	Active
GPV-72	67.74	160	Active
GPV-71	68.29	110	Active
GPV-70	66.09	110	Active
GPV-9	61.6	110	Active
GPV-68	65.25	110	Active
GPV-69	65.62	250	Active
GPV-77	72.48	250	Closed
GPV-75	71.04	160	Closed
GPV-12	63.58	110	Closed
GPV-13	61.9	160	Closed
GPV-60	60.39	200	Closed
GPV-59	60.72	200	Closed
GPV-61	60.79	110	Closed
GPV-62	60.79	200	Closed
GPV-80	74.43	200	Closed
GPV-81	74.79	110	Closed
GPV-82	68	110	Closed
GPV-1	61.6	110	Closed
GPV-7	61.6	160	Closed

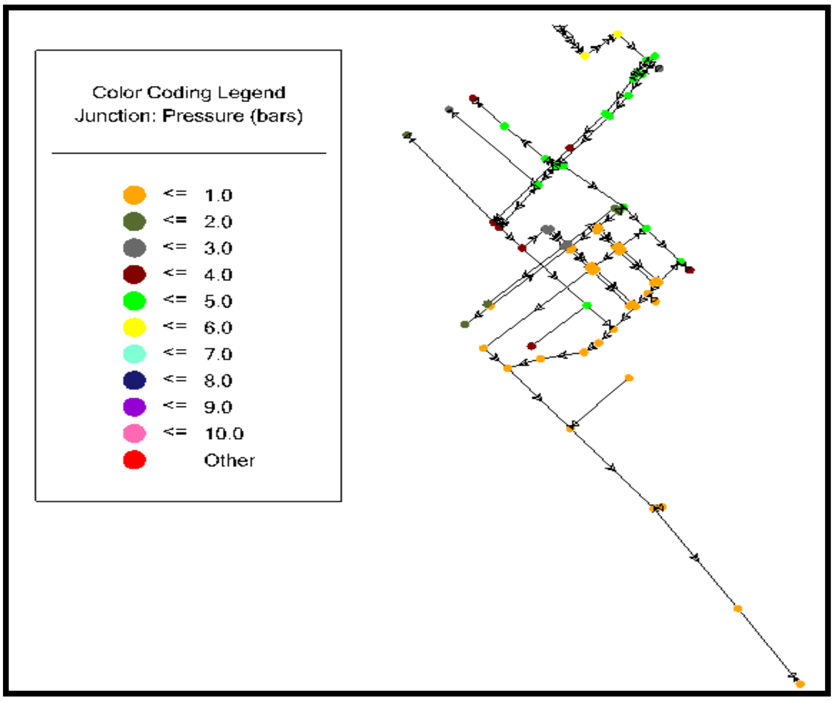

Figure 4.16: Output result for junction's pressure data during water consumption for El Brazil Zone.

c) Al Salam Zone

The population in this area is about 15,500 inhabitants. The water needed for this zone is 1,411m3/d based on 70 L/C/D as water quantity for every person and considering 30% losses in the distribution network system from the water tank. To deliver this amount of water into this zone and according to the booster pump stations (250m3/hr.), we need 6 hours operation for one of the three booster pumps. Table 4.16 shows the valving system to be followed in Al Salam zone. Figure 4.17 shows water distribution networks for Al Salam Zone. Valves data which used to feed this area are shown in Table 4.17.
Figure 4.18 shows output result for junction's pressure data during water consumption.

Table 4.16: Valve system for Al Salam zone.

Supply Area	Opened Valve	Closed Valve
Al Salam (Zone 8)	V85, V88, V77, V76, V67, V240, V56, V2, V3, V4, V8, V58, V25, &V28	V74, V242, V79, V75, PV03, V54, V29, V1, V27, V7, V60, V55, V57,&V61

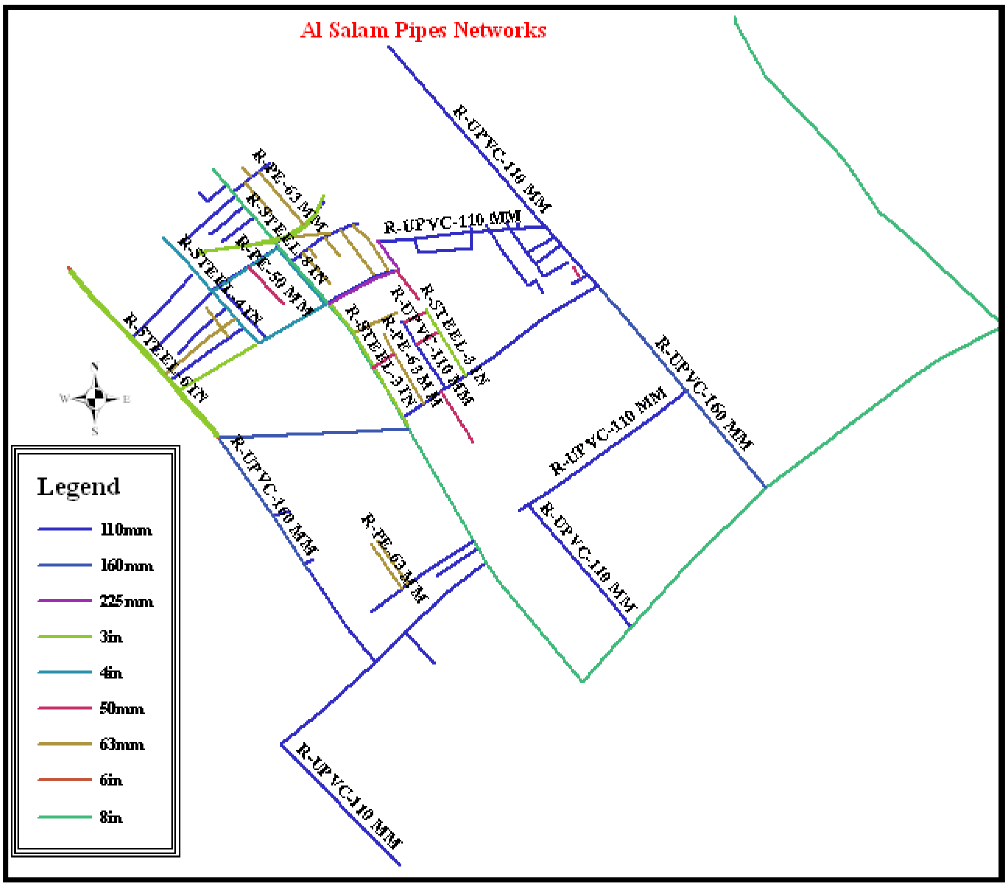

Figure 4.17: Water distribution networks for Al Salam Zone.

Table 4.17: Valve data for Al Salam Zone.

Label	Elevation (m)	Diameter (mm)	Control Status
GPV-88	81	250	Active
GPV-76	75.73	250	Active
GPV-77	81	250	Active
GPV-67	65.75	250	Active
GPV-240	58.83	250	Active
GPV-56	64.94	250	Active
GPV-58	61.3	200	Active
GPV-28	57.71	110	Active
GPV-25	57.71	110	Active
GPV-4	74.3	200	Active
GPV-3	74.3	200	Active
GPV-2	73.3	150	Active
GPV-8	60.51	110	Active
GPV-85	81	300	Active
GPV-79	75.73	160	Closed
GPV-75	75.73	160	Closed
GPV-74	75.37	160	Closed
GPV-242	75	250	Closed
GPV-61	60.07	110	Closed
GPV-10	60.03	200	Closed
GPV-57	61.3	110	Closed
GPV-55	58.62	110	Closed
GPV-54	58.62	160	Closed
GPV-7	63.05	160	Closed
GPV-29	57.71	250	Closed
GPV-27	57.71	110	Closed
GPV-1	73.3	110	Closed

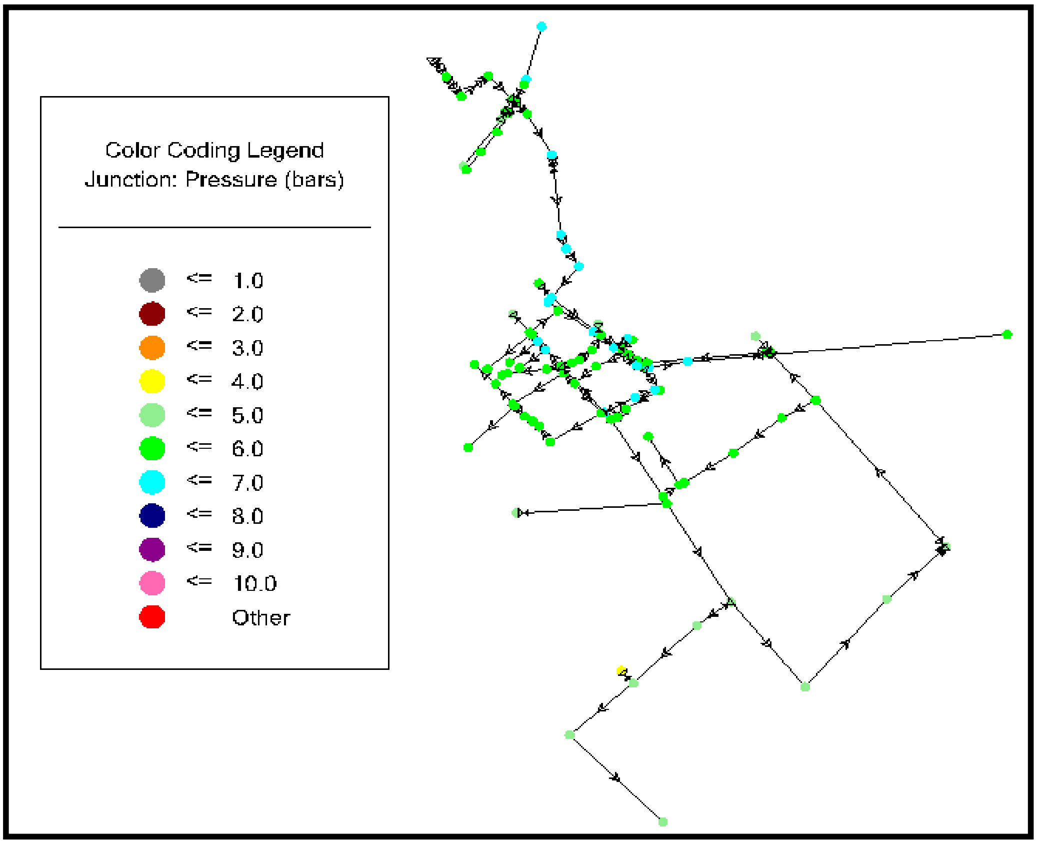

Figure 4.18: Output result for junction's pressure data during water consumption for Al Salam Zone.

d) El Gunina Zones

This zone is divided into two zones, the upper and lower zone. The population for the whole areais about 20,810 inhabitants and we assumed that the population density in the upper Gunina is 1/3 of the lower Gunina and based on this assumption, the population density will be as follow; Upper Gunina population is around 7000 inhabitants, while the lower Gunina population will be around 14,000 inhabitants. The water needed for upper and lower Gunina are 640 and 1275m3/d respectively based on 70 L/C/D as water quota for every person and considering 30% losses in the distribution network system from the water tank. To deliver this amount of water into the upper and lower Gunina zones and according to the booster pump stations capacity of 250m3/hr., we need 3 and 5 hours operation for one of the three booster pumps respectively. Table 4.18 shows the valving system to be followed in the upper and lower Gunina zones.

Figure 4.19 & Figure 4.20 show water networks pipes for upper and lower Gunina zones respectively. Also valves data which used to feed these areas are shown in Table 4.19 & Table 4.20 for upper and lower Gunina zones respectively. Figure 4.21 & Figure 4.22 show output result for junction's pressure data during water consumption for upper and lower Gunina zones respectively.

Table 4.18: Valve system for El Gunina Zone.

Supply Area	Opened Valve	Closed Valve
Upper Gunina area (Zone 9)	V85, V88, V77, V76, V67, V54, V51, V50, V57, V52, V240, V29, V26, V30, V20, V34, V33, V32, V31, V49, V47, V46, V44, V43,& V42.	V74, V242, V55, V53, V27, V56, V24, V19, V21, V36, V37, V45, V41, &V40
Lower Gunina area (Zone 10)	V85, V88, V77, V76, V67, V240, V29, V22, V24, V23, V6, V5, V12, V11, V17, &V18	V74, V242, V56, V26, V19, &V14.

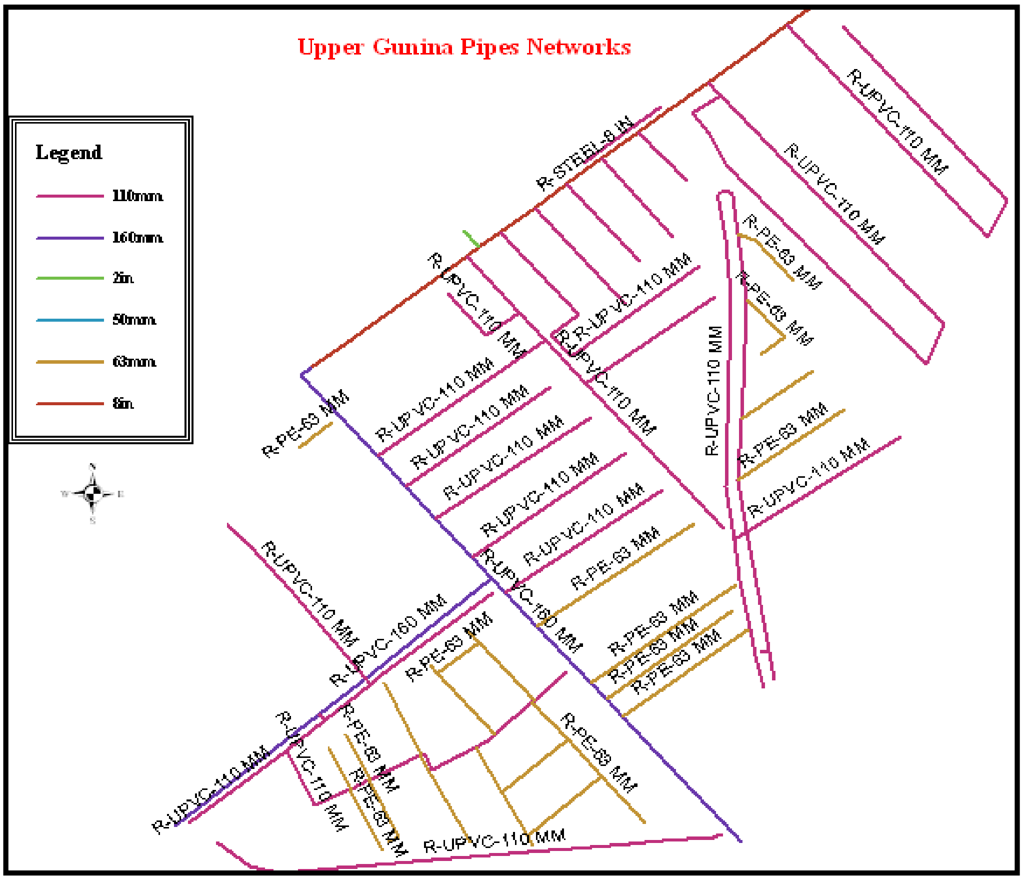

Figure 4.19: Water distribution networks for upper Gunina Zone.

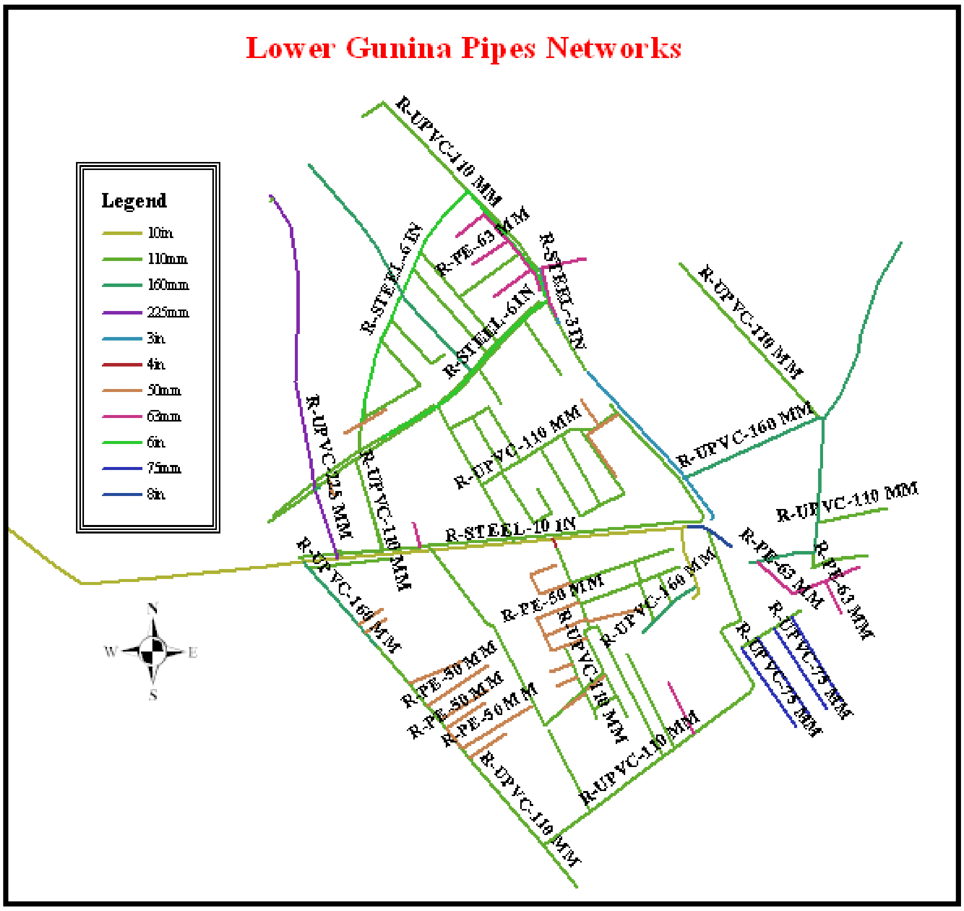

Figure 4.20: Water distribution networks for lower Gunina Zone.

Table 4.19: Valve data for upper Gunina Zone.

Label	Elevation (m)	Diameter (mm)	Control Status
GPV-85	81.00	300	Active
GPV-88	81.00	250	Active
GPV-77	81.00	250	Active
GPV-76	81.00	250	Active
GPV-67	65.75	250	Active
GPV-54	58.22	160	Active
GPV-51	56.78	160	Active
GPV-52	56.78	110	Active
GPV-30	56.95	160	Active
GPV-29	58.39	250	Active
GPV-26	57.85	160	Active
GPV-240	58.83	250	Active
GPV-31	57.13	160	Active
GPV-32	57.13	110	Active
GPV-20	59.55	160	Active
GPV-34	54.33	160	Active
GPV-45	56.59	200	Active
GPV-44	56.59	110	Active
GPV-46	57.17	160	Active
GPV-47	57.88	160	Active
GPV-49	58.78	200	Active
GPV-50	58.78	110	Active
GPV-33	55.72	110	Active
GPV-43	55.09	110	Active
GPV-42	55.81	110	Active
GPV-35	60.74	110	Active
GPV-242	75.37	250	Closed
GPV-74	75.37	250	Closed
GPV-55	58.22	110	Closed
GPV-53	56.94	110	Closed
GPV-27	57.85	110	Closed
GPV-25	57.85	110	Closed
GPV-24	57.85	160	Closed
GPV-56	64.94	250	Closed
GPV-19	59.55	110	Closed
GPV-41	56.07	200	Closed
GPV-40	56.07	200	Closed
GPV-37	51.98	160	Closed
GPV-36	51.98	160	Closed
GPV-21	64.71	160	Closed

Table 4.20: Valve data for lower Gunina Zone.

Label	Elevation (m)	Diameter (mm)	Control Status
GPV-5	57.71	110	Active
GPV-11	74.44	160	Active
GPV-12	74.43	110	Active
GPV-14	73.98	250	Closed
GPV-26	57.71	160	Closed
GPV-29	57.71	250	Active
GPV-23	57.71	110	Active
GPV-24	57.77	160	Active
GPV-56	64.94	200	Closed
GPV-240	58.83	250	Active
GPV-67	65.75	250	Active
GPV-76	75.73	250	Active
GPV-77	81	250	Active
GPV-242	75	250	Closed
GPV-74	75.37	250	Closed
GPV-88	81	250	Active
GPV-85	81	300	Active
GPV-17	72.63	110	Active
GPV-18	72.34	110	Active
GPV-19	67	110	Active
GPV-6	57.71	160	Active
GPV-22	57.71	110	Active

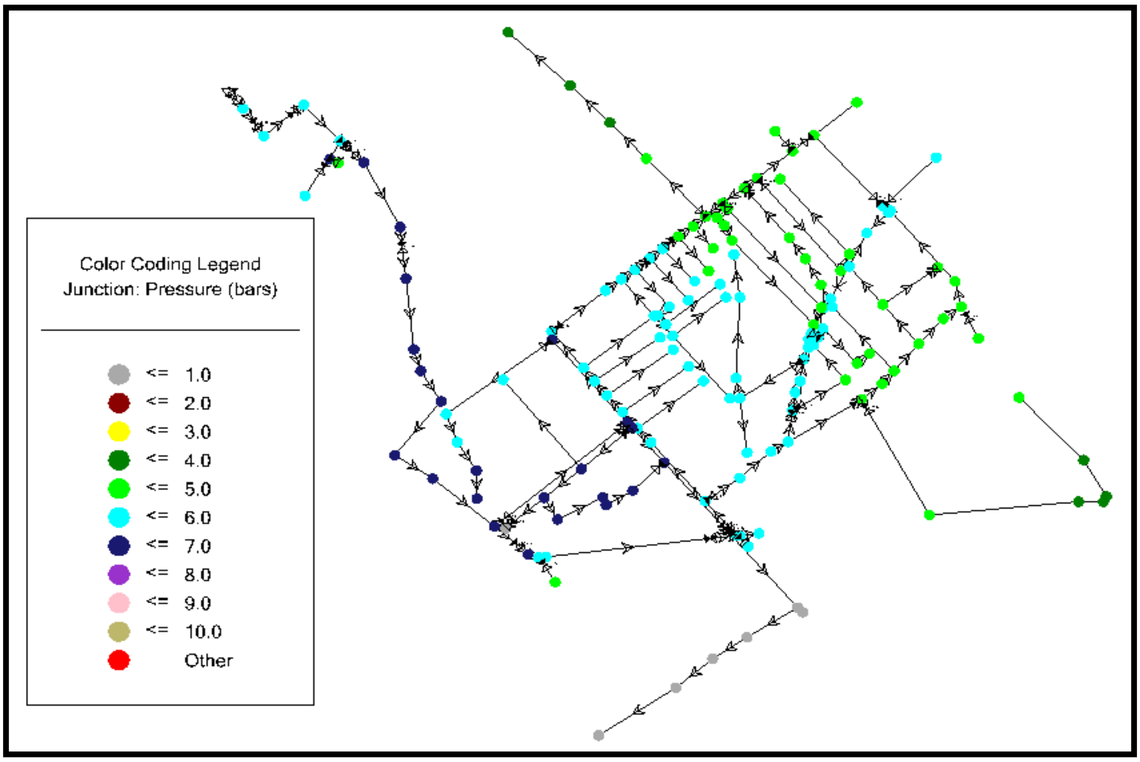

Figure 4.21: Output result for junction's pressure data during water consumption for upper Gunina Zone.

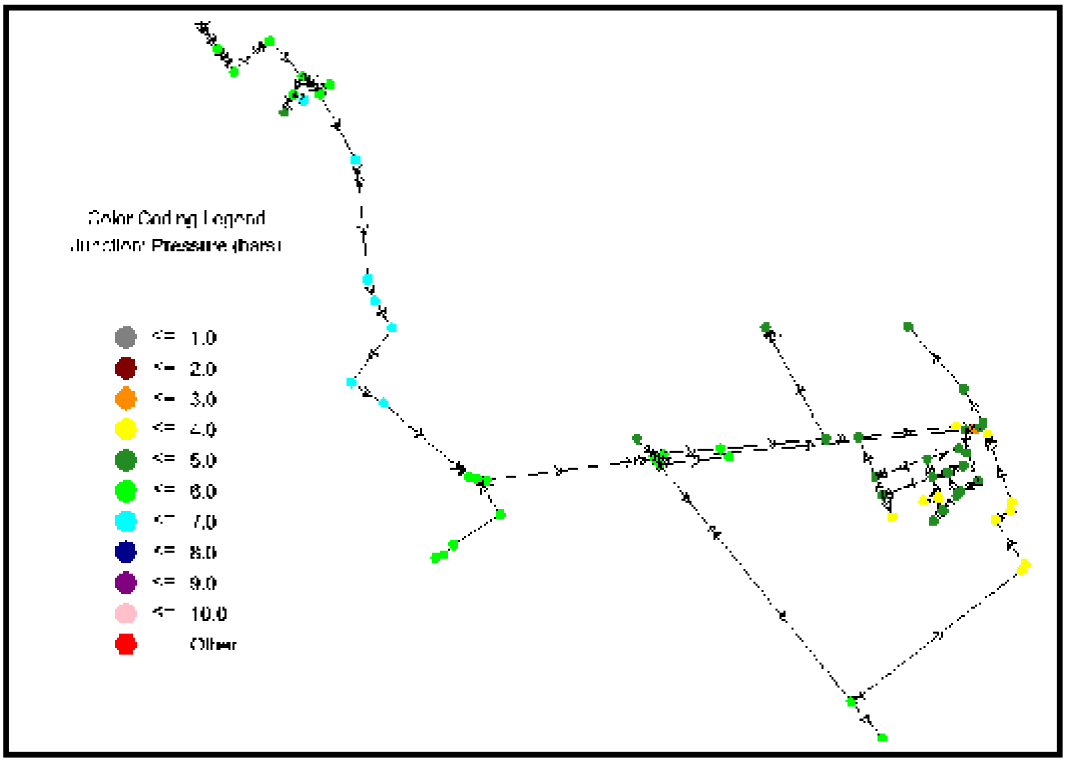

Figure 4.22: Output result for junction's pressure data during water consumption for lower Gunina Zone.

e) Shouat Zone

The population in this area is about 15,500 inhabitants. The water needed for this zone is 1,411m3/d based on 70 L/C/D as water quantity for every person and considering 30% losses in the distribution network system from the water tank. This area is lower in elevation than the water tank area, so the water is being delivered to this area by gravity flow passing 6" UPVC pipe to reach the distribution network of Shouat zone. To deliver this amount of water into this zone by gravity, we need 6 hours. Table 4.21 shows the valving system to be followed in Shouat zone. Figure 4.23 shows water distribution networks for Shouat Zone. Valves data which used to feed this area are shown in Table 4.22. Figure 4.24 shows output result for junction's pressure data during water consumption.

Table 4.21: Valve system for Shouat zone.

Supply Area	Opened Valve	Closed Valve
Shouat area (Zone 4)	V116, V127, V126, V141, V151, V152, V150, V153, V156, V167, &V168	V108, V117, V125, V143, V124, &V149

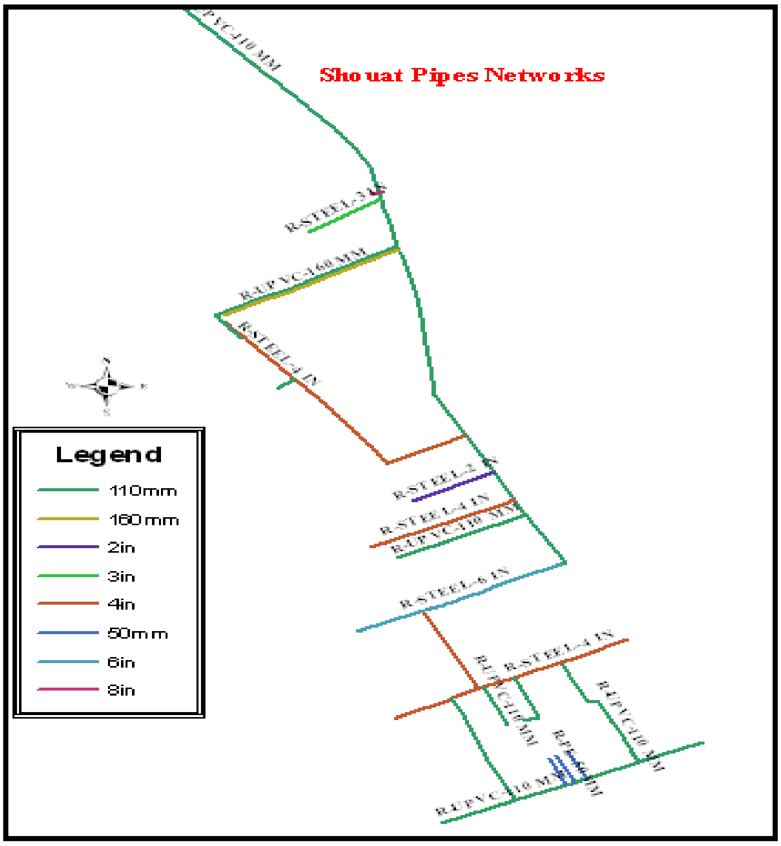

Figure 4.23: Water distribution networks for Shouat Zone.

Table 4.22: Valve data for Shouat Zone.

Label	Elevation (m)	Diameter (mm)	Control Status
GPV-166	26.35	110	Active
GPV-167	26.43	125	Active
GPV-156	36.74	110	Active
GPV-153	37.78	110	Active
GPV151	42.21	160	Active
GPV-152	42.21	110	Active
GPV-141	50.14	110	Active
GPV-150	39.09	50	Active
GPV-126	58.07	110	Active
GPV-127	57.36	110	Active
GPV-116	65.01	160	Active
GPV-149	39.09	160	Closed
GPV-124	60.21	250	Closed
GPV-125	60.21	110	Closed
GPV-117	65.01	110	Closed
GPV-108	81.00	250	Closed
GPV-143	50.14	160	Closed

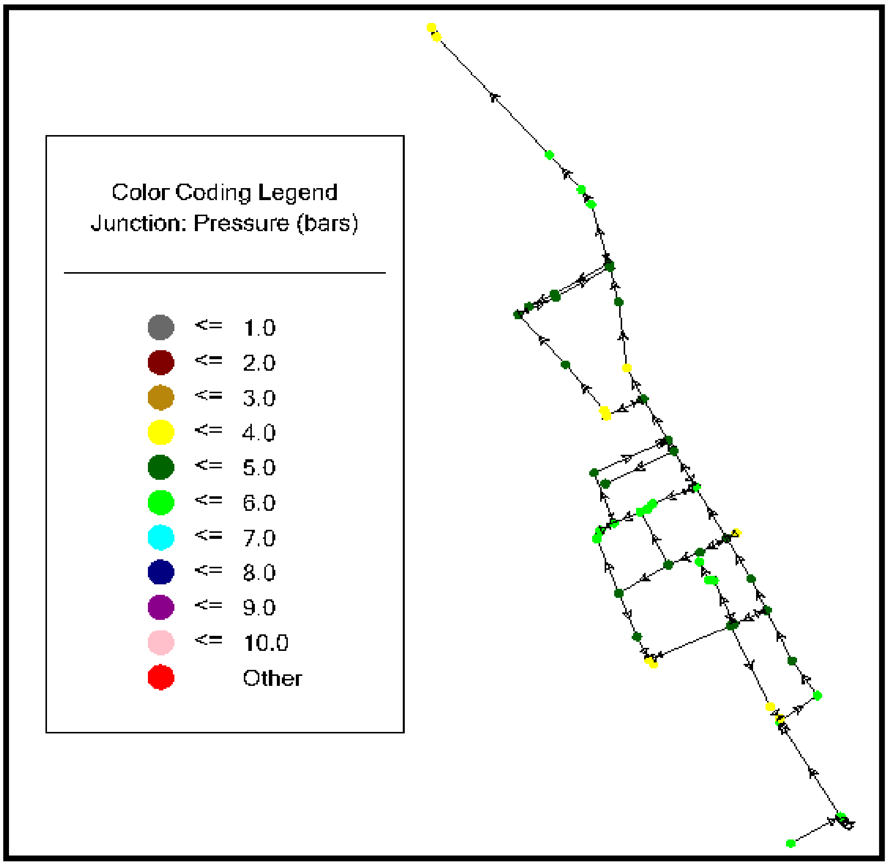

Figure 4.24: Output result for junction's pressure data during water consumption for Shouat Zone.

According to the previous section detail and based on the water supply district area, we suggest having monitoring points on every water supply district entrance (control valve).

4.3 Proposed procedure for O&M using GIS & DSS

In order to manage maintenance and operation systems for managing water pipe networks pipe condition index proposed as a methods for manage water networks.

The methods illustrate the effect of pipe condition, assumes the pipeline index from one to ten. The pipeline index means the condition of the pipeline, which number one represents the requirement for immediate repair and number ten expresses the new pipe.
This number depend on failure history of pipes, types of pipes construction date, and diameters which refer the quantity and pressures which the pipe can bears it.
And all of that depend on have attribute data about water networks which clarify all data of pipes and networks facility and ArcMap which is the interface with WaterGEMS is the best software selection help the manager to knowing water networks pipes situation.
For example Asbestos pipe should have number one which means must be replacement due to risk pollution cause by Asbestos material and effect on water which located in pipes. Pipe with low diameters and carry amount of water and pressure over loaded and has more than one failure also pipe condition index for it is one.
Department manager can add the number for all networks according to knowing of history of water networks with assistance with his crews who are follow up daily operation and maintenance of networks.

Also by runing the hydraulic model we can know the pipes which have pressure problem and these pipes can select by using GIS queries tools and have the pipe index numbers which mean there is decision should be done for it to solve this problem as we discus below, another example can be mention by historical data of installation data of pipes and number of failure which is also can be indicate that is pipes needed to repair, replace or don't do any action for it according to pipe index numbers.

4.3.1 Steps for integrated proposed method pipe condition index

a) Prepare GIS shape file and attribute table about for available water networks functions data and prepared hydraulic modeling data.

b) Prepare data about water networks pipes failures using GIS attribute table or Excel sheet, the same table can prepare for other failures for others function in water networks such as valve or pumps.

c) Before start numbering the water networks pipes from one to ten according to failure or construction history, water manager should evaluate water networks which the municipality own. The evaluation steps can be divided into the following steps.

1. Collection data about water networks which the municipality own.

A complete water networks pipes inventory is the foundation of a structured management process, allowing Municipality to proceed to the next step of the process, evaluation of the networks' condition and adding index numbers for pipe from one to ten. This step includes the following:

a) Identification of the descriptive and geographic data necessary to integrated water networks management at the municipality.
b) Maximum recovery of the area's existing data, whose format, accuracy, worth and scope is valuable to the process.
c) Identification of the remaining data needed and planning for its collection.
d) Collection of remaining data (in the field or from original construction plans. Municipality approach, combined with the re-utilizations of the area existing data.
e) Collected information is added to the Municipality's water networks database and GIS tools, types of data as Table 4.23, and Figure 4.25.

Table 4.23: Rafah Water networks Data.

Water Distribution Information	Data
Pipe Length	280030 M
Vlave	462
Tank	4
Water Meter	2
Well	28
Manhole	438

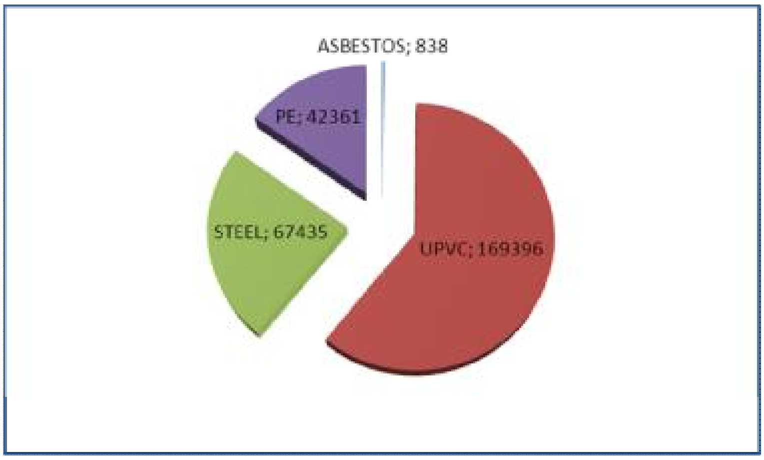

Figure 4.25: Material Length and Types.

2. **Evaluate the condition of water network.**

   In this step, a careful, field-verified gives a precise condition assessment of water network. This step includes the following:

   a) The assessment is field-verified for accuracy.
   b) System parameters are adjusted for the results of field verification.

The following information describing the condition of water network, which should be added to the Municipality water networks database:

- Physical Integrity of the networks (Break History, Materials, & Water Loss).
- Functional Integrity of the networks (Hydraulic capacity, & Water Quality).
- Related network (Water Meter, & Valves).
- Socioeconomic impact (Claims, Duration of Repairs, &Traffic).

This process benefits on many levels. Municipality approach, combining its systems and close coordination with the Rafah city's internal and external resources, guarantees a precise condition assessment for each network. Field verification improves the definition of problem sectors, increasing savings in data collection. Rafah city asset managers substantially increase their depth of knowledge in the Rafah city's water networks, improving risk management.

A final condition assessment indicates the improvement status of water network segment: Imperative (pipe condition index from 1 to 3), Desirable (pipe condition index from 4 to 6), Segment to be Monitored (pipe condition index from 7 to 8), or No Improvement Necessary (pipe condition index from 9 to 10). Figure 4.26summarizes the condition of the Rafah Municipality water networks:

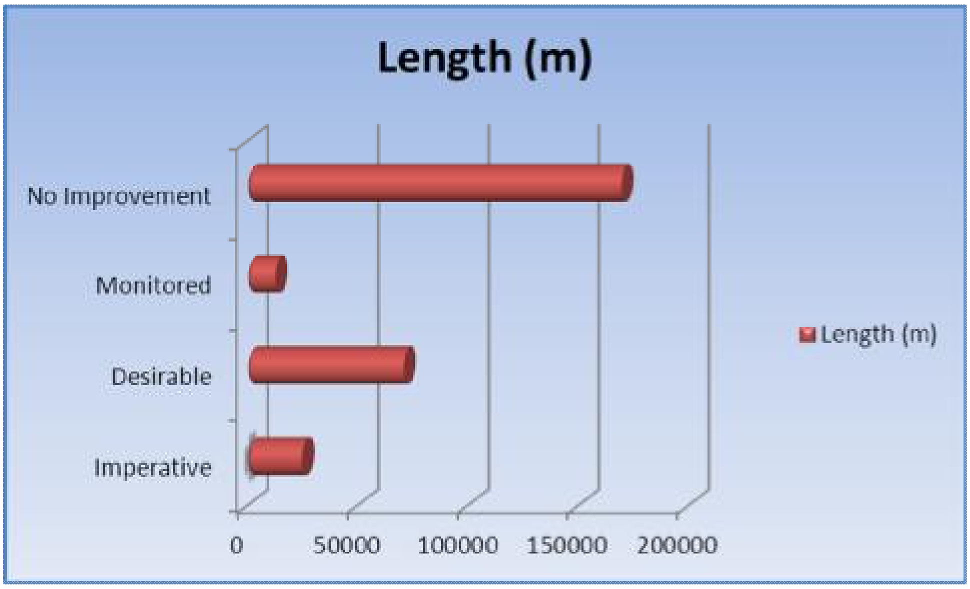

Figure 4.26: Network conditions at the Rafah City.

3. **Clarify the remaining service for water networks needed upgrade.**
4. **Clarify and study available proposed solution for problem in water networks.**

The following Figures & Tables summarize the condition index for all Rafah zones.

4.3.2 Condition index for all Rafah zones

Figures 4.27 summarize pipes condition index for all Rafah zones.

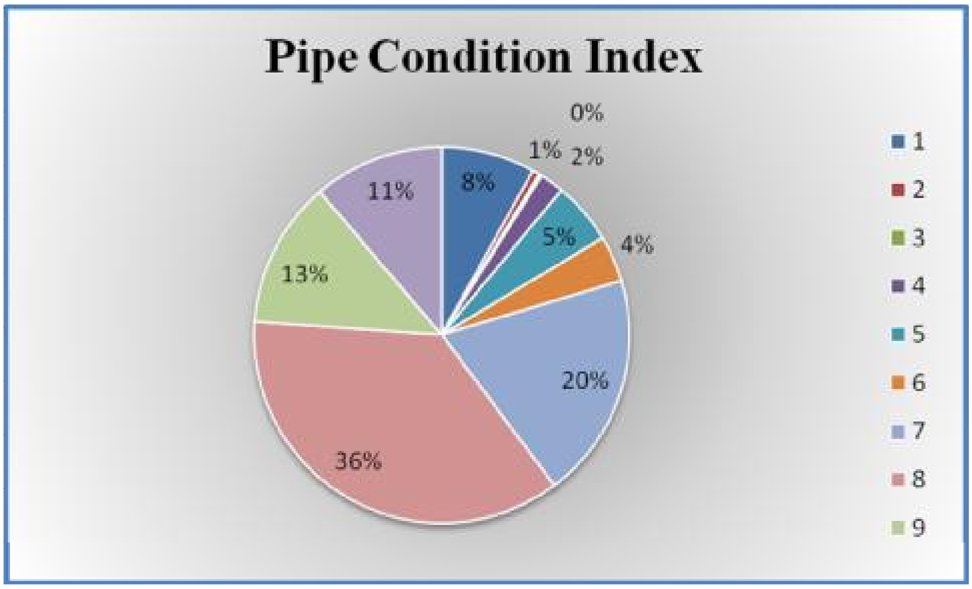

Figure 4.27: Pipes Condition Index for All Rafah Zones.

a) **Tal Elsultan Zone:** Figure 4.28 & Figure 4.29 summarize pipes condition index for this zone.

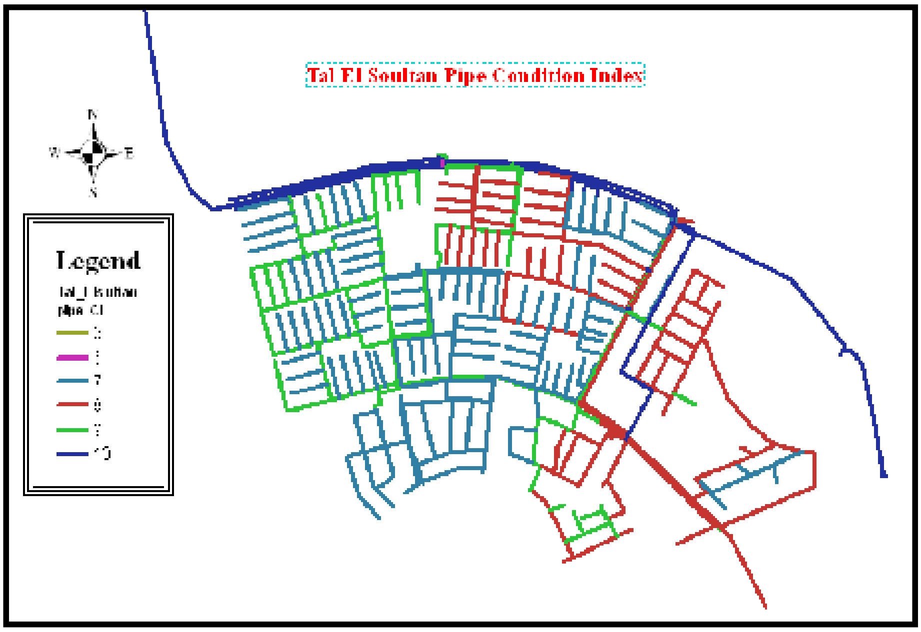

Figure 4.28: Tal Elsoultan zone Pipes Condition Index.

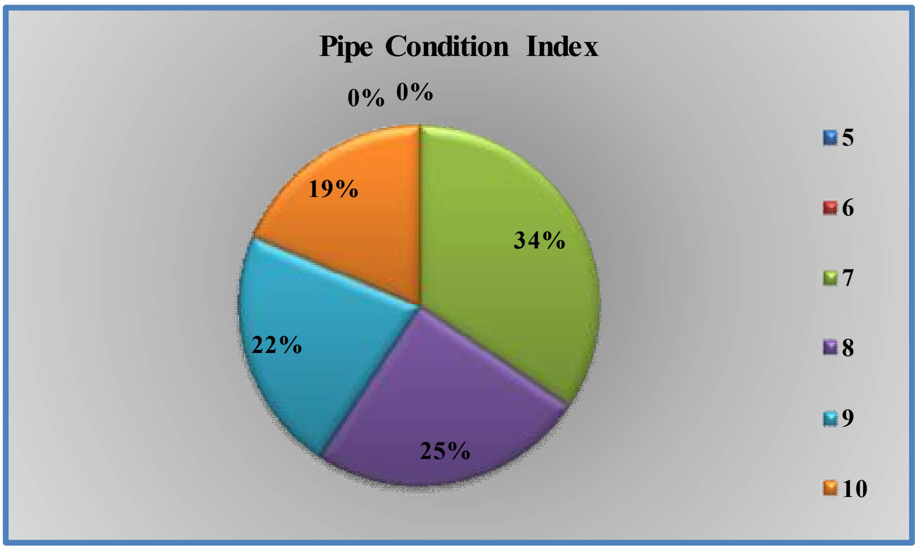

Figure 4.29: Ratio of Tal Elsoultan zone Pipes Condition Index.

By the above figures we note that final condition assessment indicates the improvement status of Tal Elsoultan water network can clarify as 0% imperative, 0.06 % desirable, 59.30% segment to be monitored, and 40.63 % no improvement necessary.

b) **Western Rafah Area:** Figure 4.30 & Figure 4.31 summarize pipes condition index for this zone.

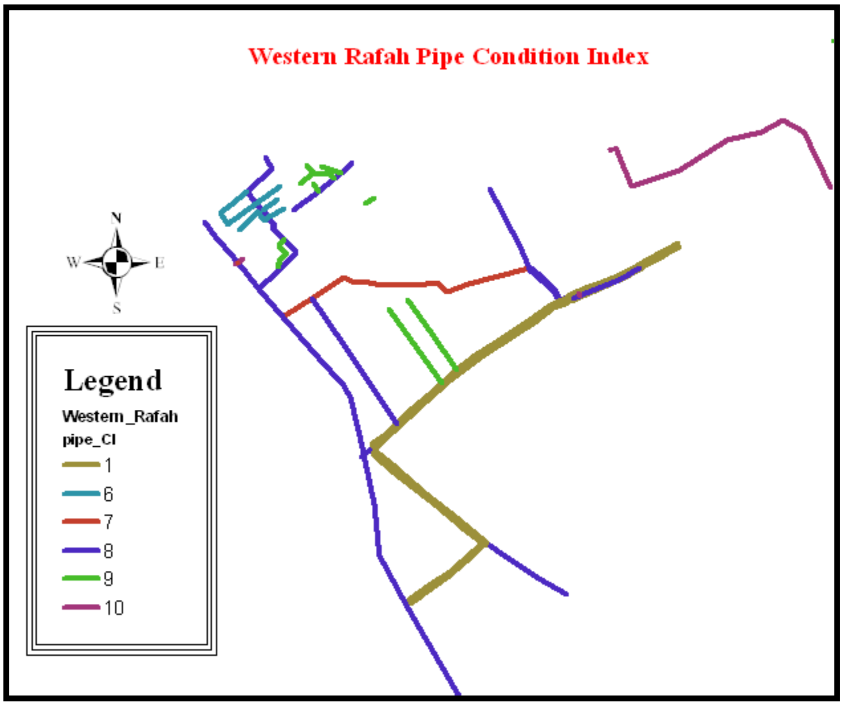

Figure 4.30: Western Rafah zone Pipes Condition Index.

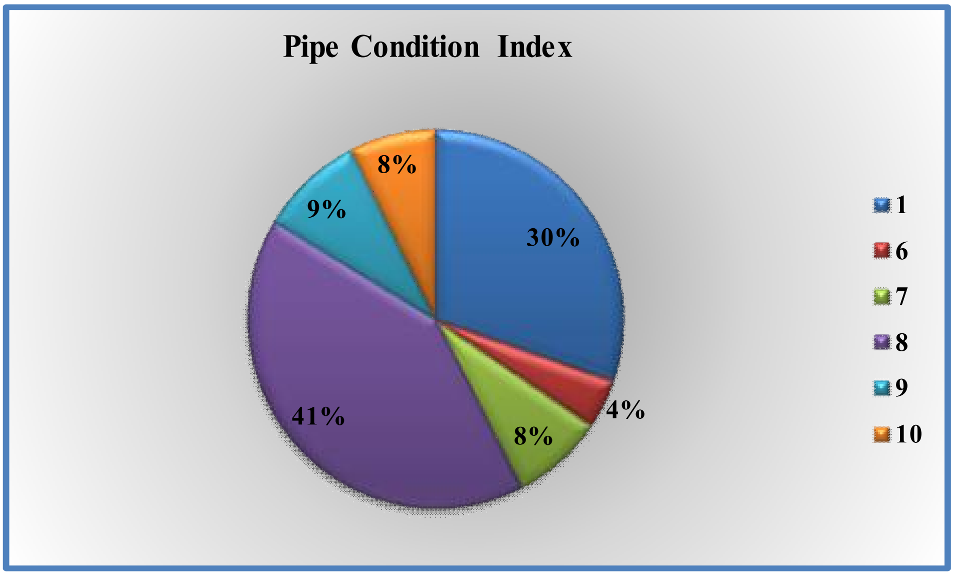

Figure 4.31: Ratio of Western Rafah zone Pipes Condition Index.

By the above figures we note that, final condition assessment indicates the improvement status of Western Rafah water network can clarify as 30.29% imperative, 0.04 % desirable, 49.10% segment to be monitored, and 16.39 % no improvement necessary.

c) **Al Salam Mosque Area:** Figure 4.32 & Figure 4.33 summarize pipes condition index for this zone.

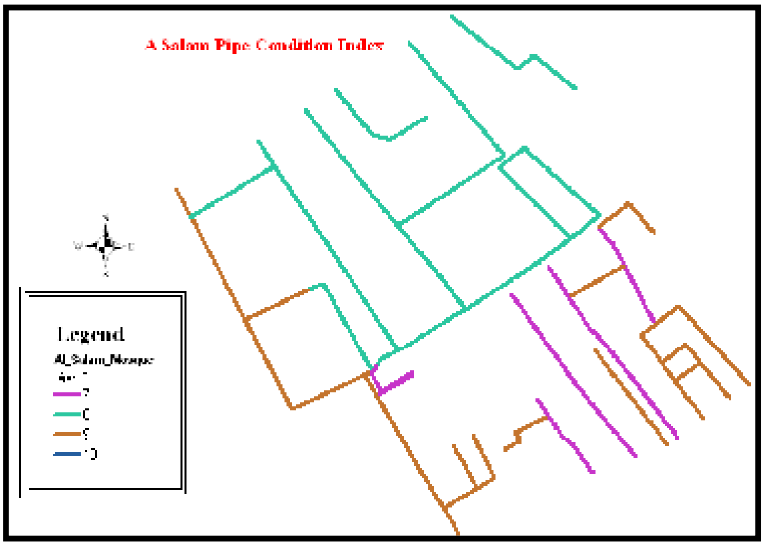

Figure 4.32: Al Salam Mosque zone Pipes Condition Index.

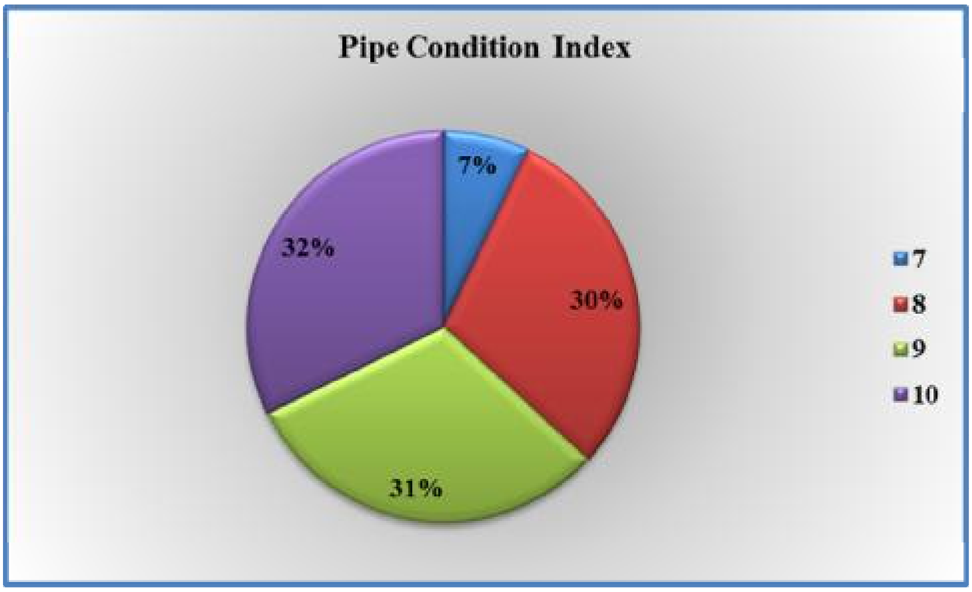

Figure 4.33: Ratio of Al Salam Mosque zone Pipes Condition Index.

By the above figures we note that, final condition assessment indicates the improvement status of Al Salam Mosque water network can clarify as 0.0% imperative, 0.0 % desirable, 36.79% segment to be monitored, and 36.21 % no improvement necessary.

d) **El Shouat Area:** Figure 4.34 & Figure 4.35 summarize pipes condition index for this zone.

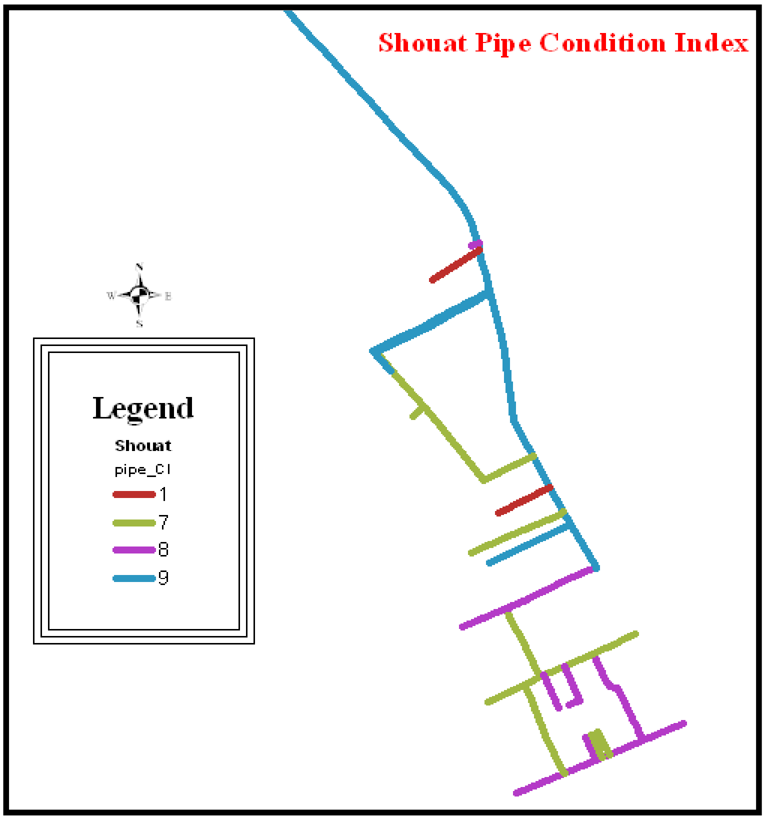

Figure 4.34: El Shouat zone Pipes Condition Index.

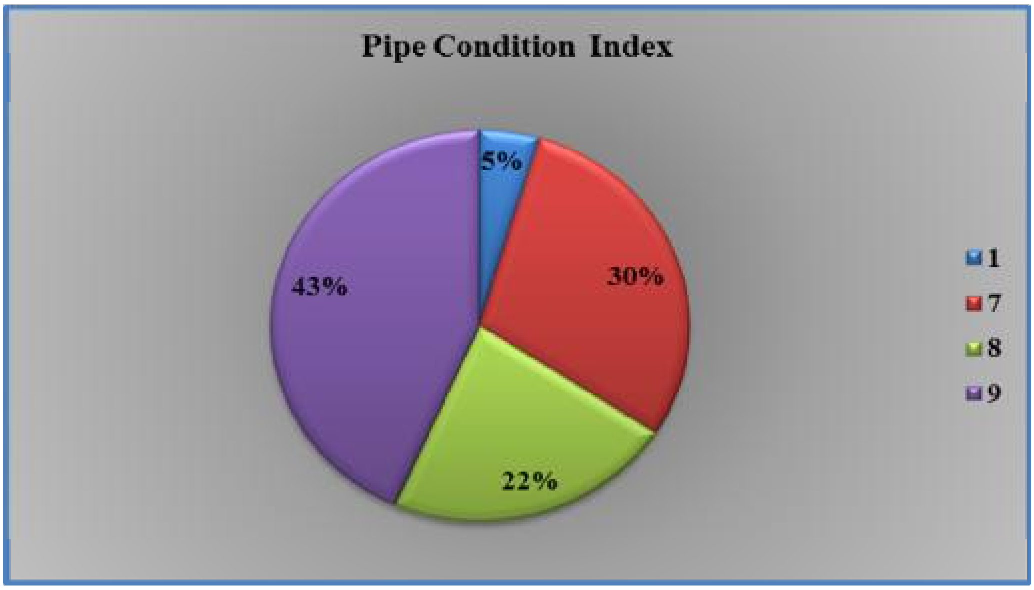

Figure 4.35: Ratio of El Shouat zone Pipes Condition Index.

By the above figures we note that, final condition assessment indicates the improvement status of El Shouat zone water network can clarify as 4.59% imperative, 0.0 % desirable, 52.05% segment to be monitored, and 43.37 % no improvement necessary.

e) **Yebna Area:** Figure 4.36 & Figure 4.37 summarize pipes condition index for this zone.

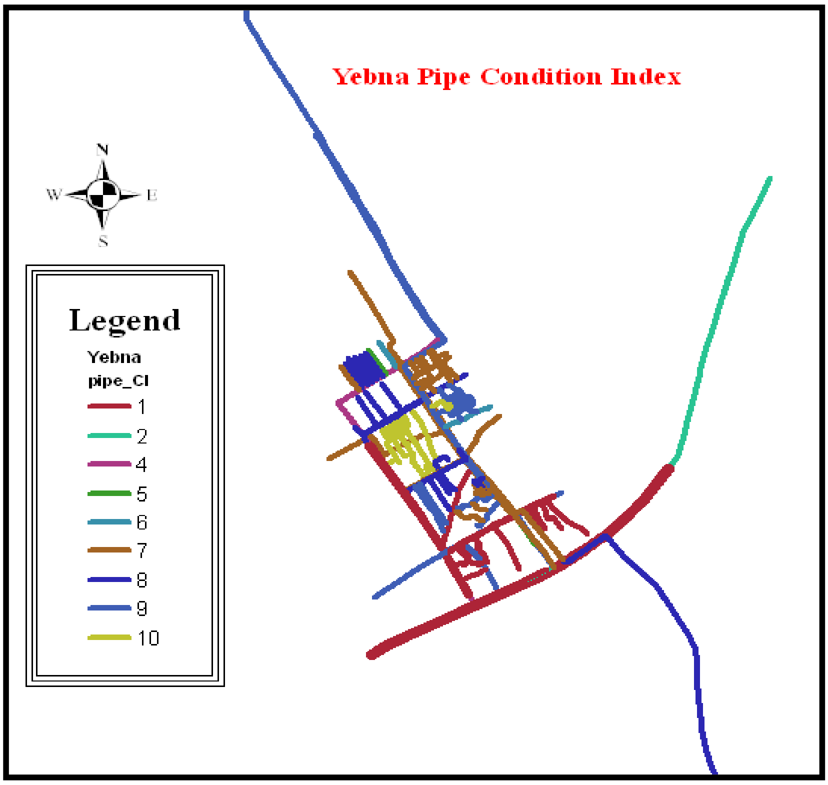

Figure 4.36: Yebna zone Pipes Condition Index.

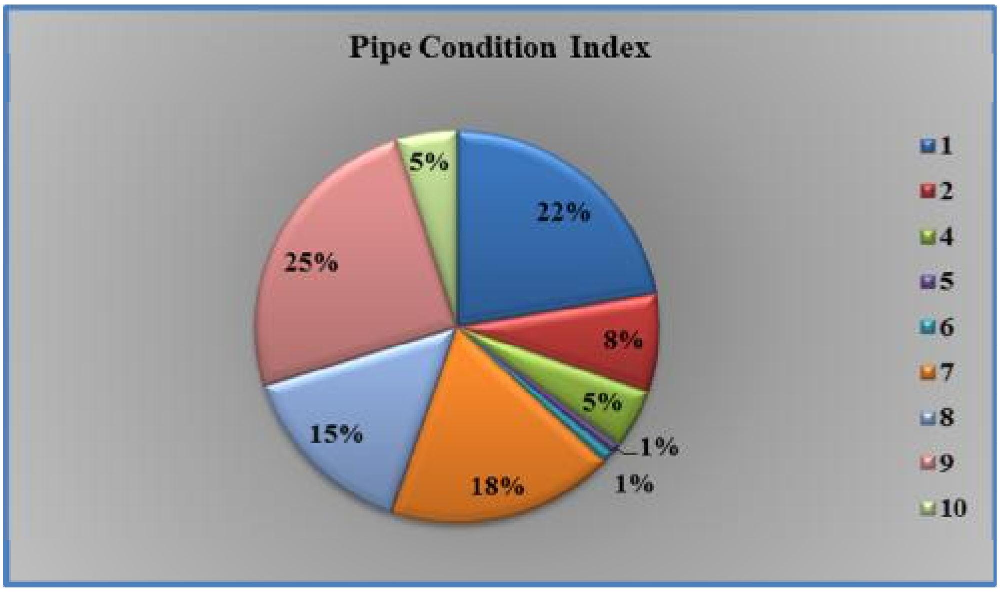

Figure 4.37: Ratio of Yebna zone Pipes Condition Index.

By the above figures we note that, final condition assessment indicates the improvement status of Yebna zone water network can clarify as 30.35% imperative, 6.67 % desirable, 33.19% segment to be monitored, and 29.79 % no improvement necessary.

f) **El Shabora Area:** Figure 4.38 & Figure 4.39 summarize pipes condition index for this zone.

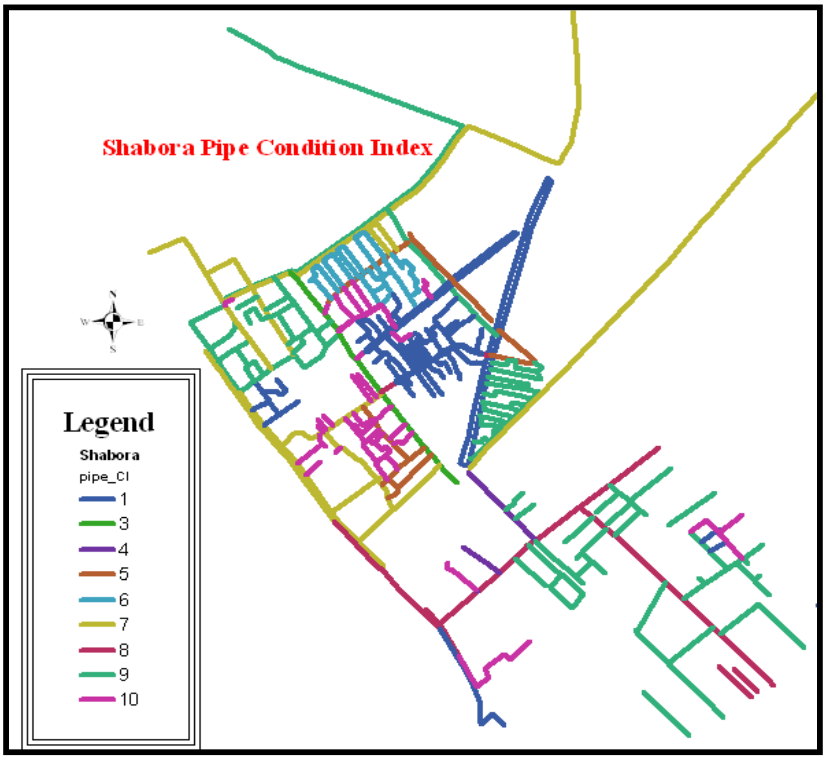

Figure 4.38: El Shabora zone Pipes Condition Index.

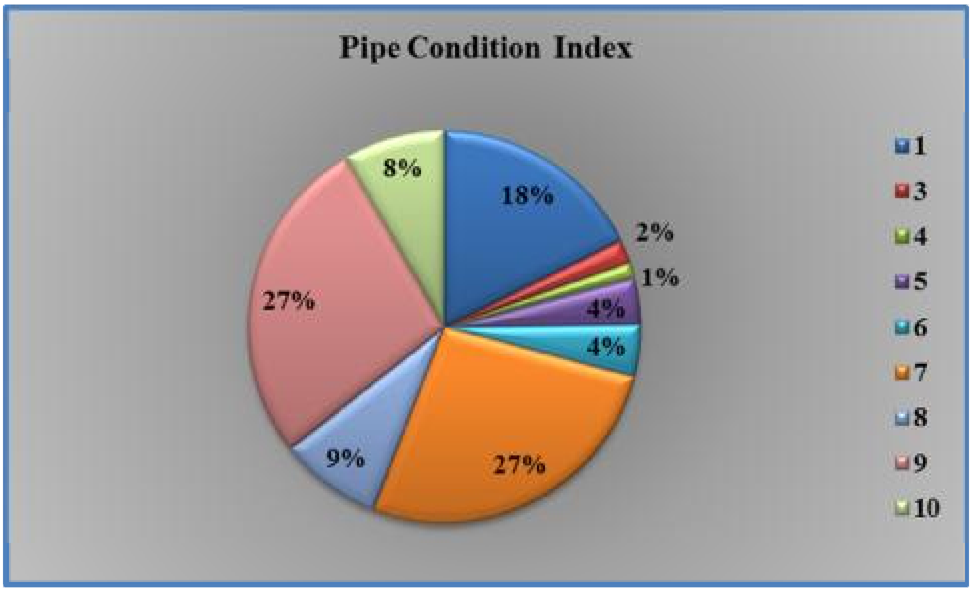

Figure 4.39: Ratio of El Shabora zone Pipes Condition Index.

By the above figures we note that, final condition assessment indicates the improvement status of El Shabora zone water network can clarify as 19.72% imperative, 9.39 % desirable, 35.26% segment to be monitored, and 35.62 % no improvement necessary.

g) **El Brazil Area:** Figure 4.40 & Figure 4.41 summarize pipes condition index for this zone.

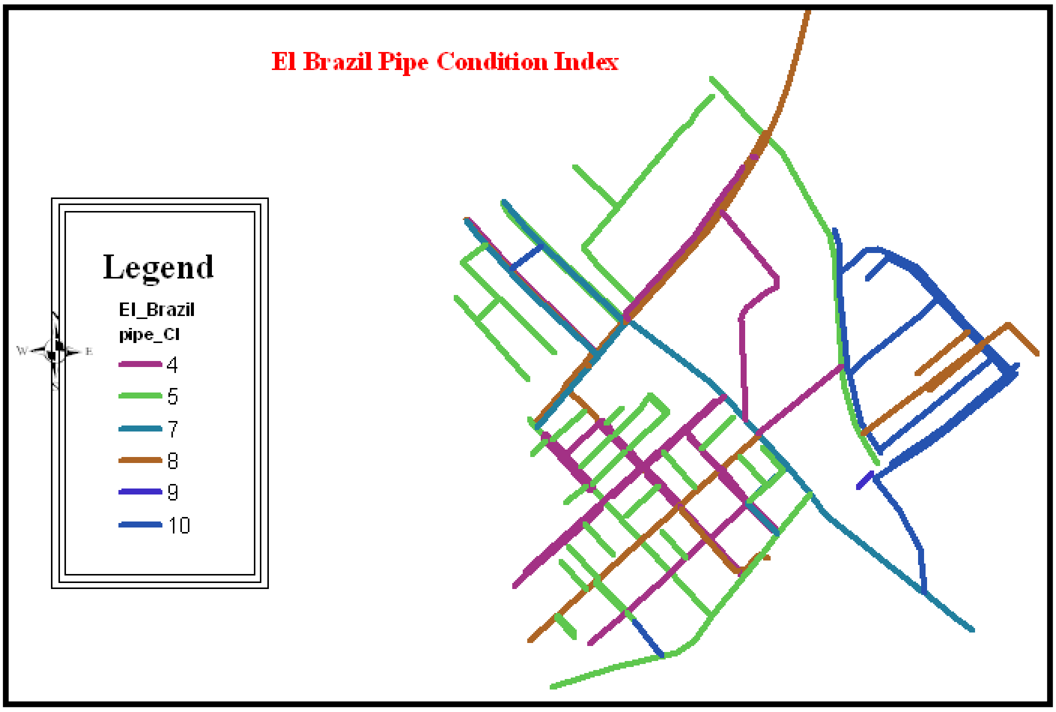

Figure 4.40: El Brazil zone Pipes Condition Index.

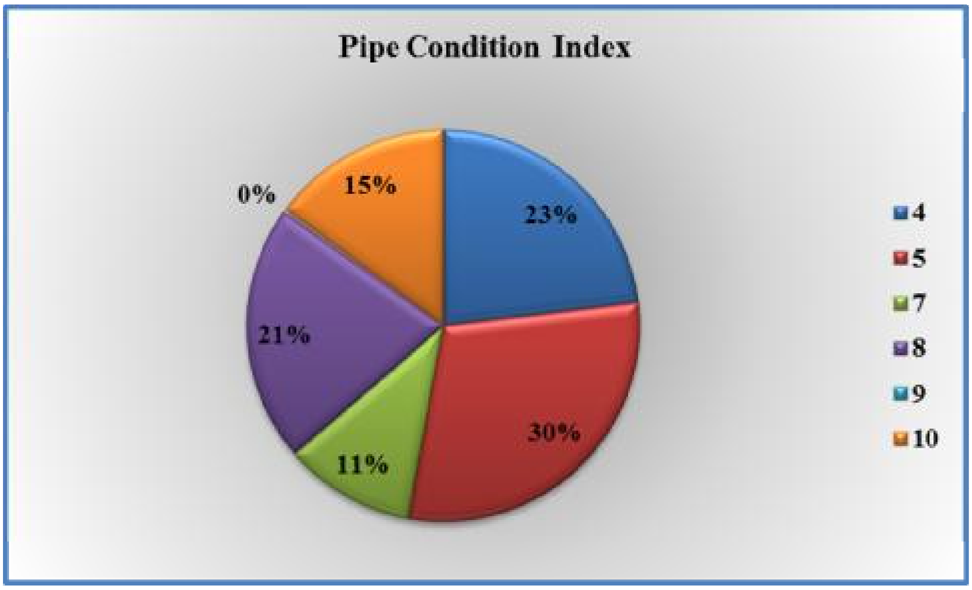

Figure 4.41: Ratio of El Brazil zone Pipes Condition Index.

By the above figures we note that, final condition assessment indicates the improvement status of El Brazil zone water network can clarify as 0.0% imperative, 52.86 % desirable, 32.03% segment to be monitored, and 15.12 % no improvement necessary.

h) **El Salam Area:** Figure 4.42 & Figure 4.43 summarize pipes condition index for this zone.

Figure 4.42: El Salam zone Pipes Condition Index.

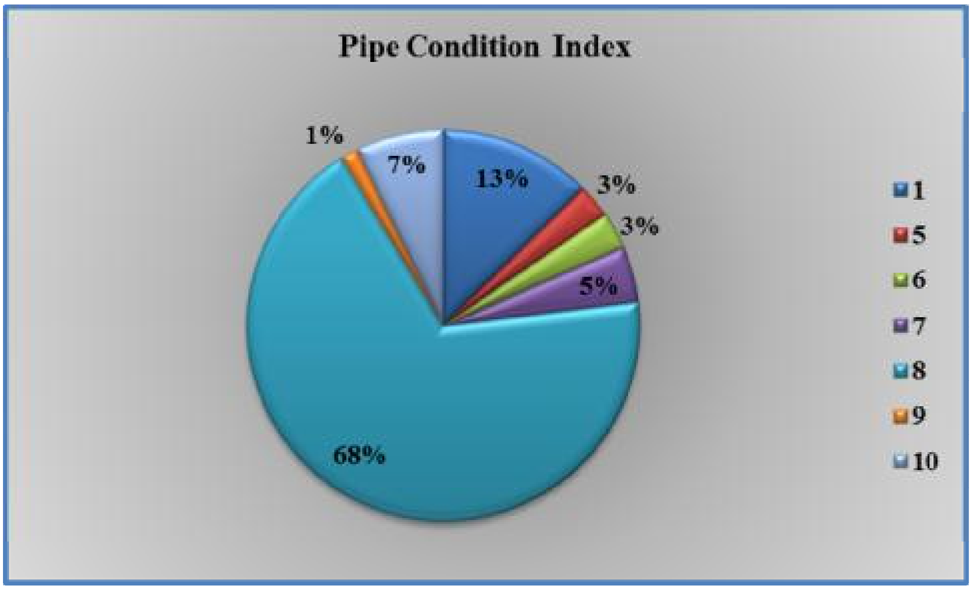

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Figure 4.43: Ratio of El Salam zone Pipes Condition Index.

By the above figures we note that, final condition assessment indicates the improvement status of El Salam zone water network can clarify as 12.65% imperative, 5.86 % desirable, 72.85% segment to be monitored, and 8.65 % no improvement necessary.

i) **El Gunina –Upper:** Figure 4.44 & Figure 4.45 summarize pipes condition index for this zone.

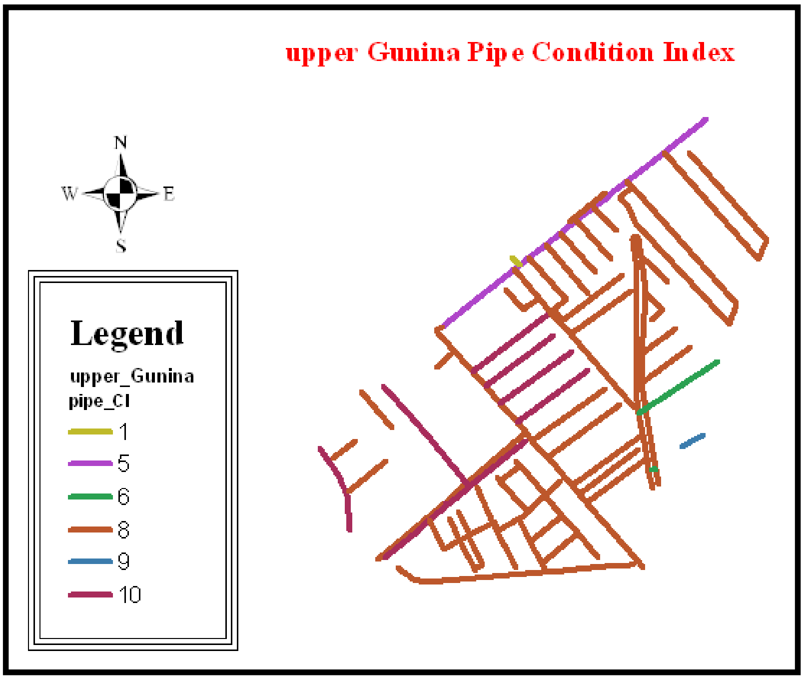

Figure 4.44: El Gunina –Upper zone Pipes Condition Index.

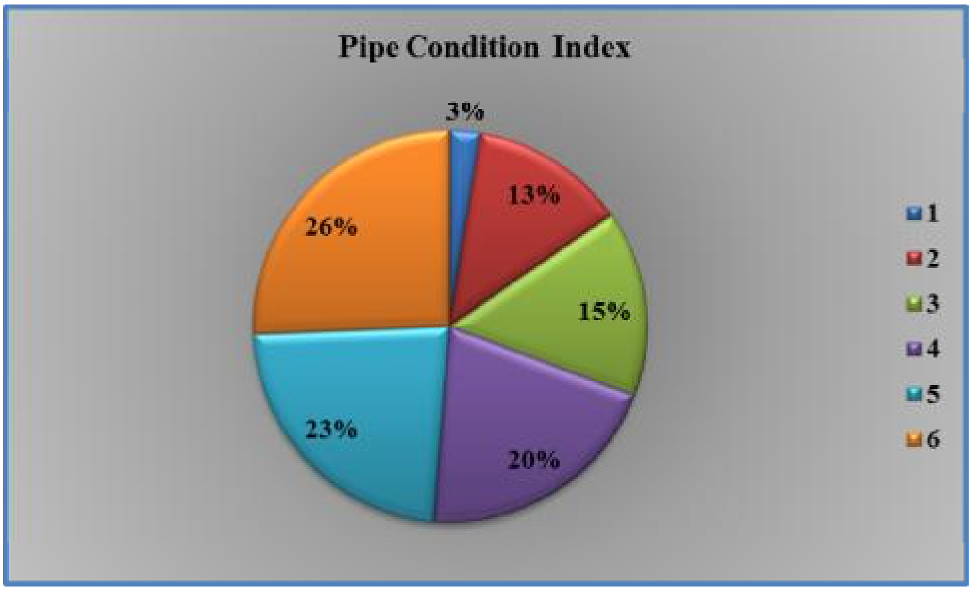

Figure 4.45: Ratio of El Gunina –Upper zone Pipes Condition Index.

By the above figures we note that, final condition assessment indicates the improvement status of El Gunina –Upper zone water network can clarify as 0.21% imperative, 8.13 % desirable, 76.78% segment to be monitored, and 14.87 % no improvement necessary.

j) **El Gunina 2 –Lower:** Figure 4.46 & Figure 4.47 summarize pipes condition index for this zone.

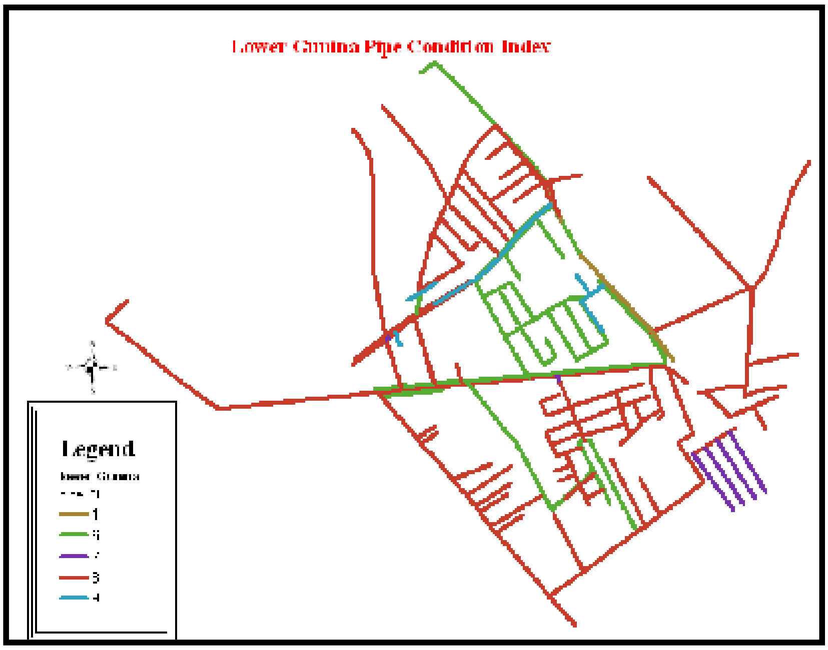

Figure 4.46: El Gunina –Lower zone Pipes Condition Index.

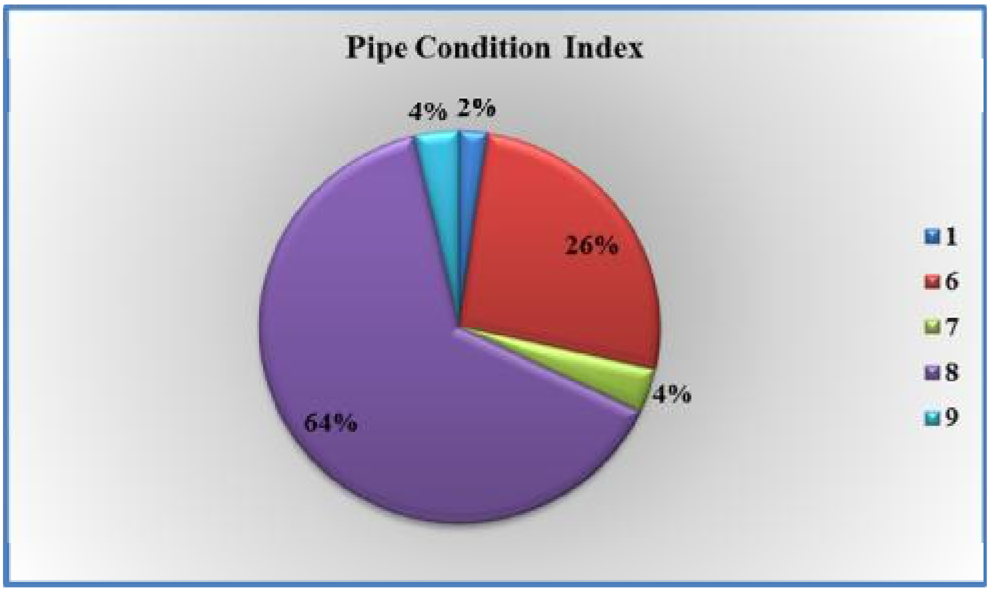

Figure 4.47: Ratio of El Gunina –Lower zone Pipes Condition Index.

By the above figures we note that, final condition assessment indicates the improvement status of El Gunina –Lower zone water network can clarify as 2.30% imperative, 26.13 % desirable, 67.92% segment to be monitored, and 3.65 % no improvement necessary.

k) **El Mosabeh Area:** Figure 4.48 & Figure 4.49 summarize pipes condition index for this zone.

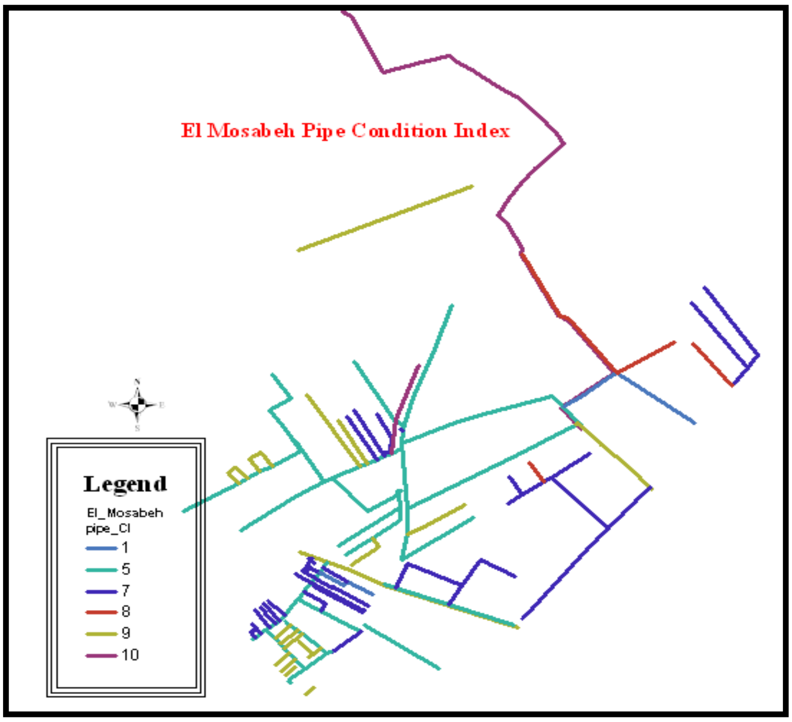

Figure 4.48: El Mosabeh zone Pipes Condition Index.

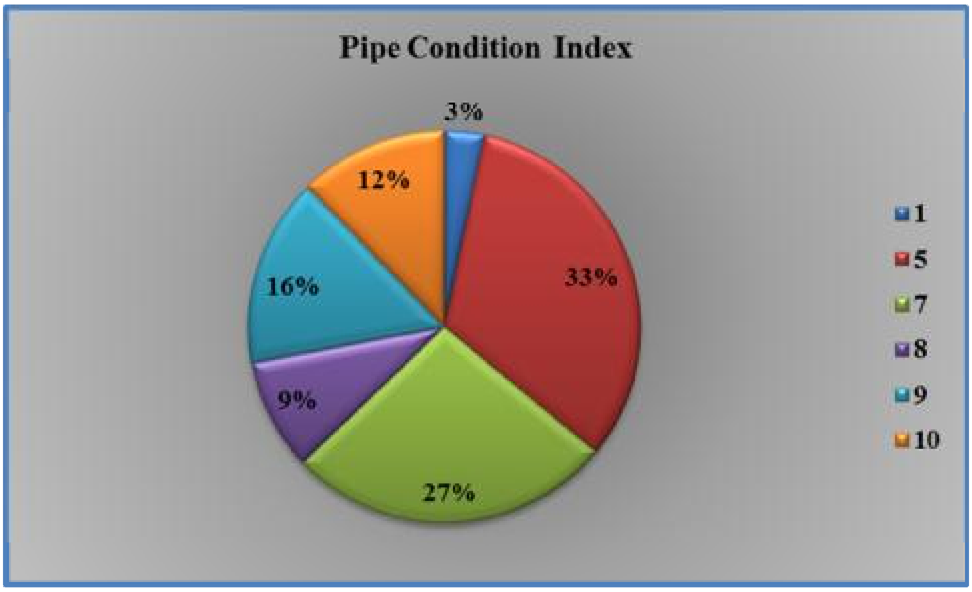

Figure 4.49: Ratio of El Mosabeh zone Pipes Condition Index.

By the above figures we note that, final condition assessment indicates the improvement status of El Mosabeh zone water network can clarify as 3.31% imperative, 32.67 % desirable36.11% segment to be monitored, and 27.92 % no improvement necessary.

l) **Kherbet El Adas:** Figure 4.50 & Figure 4.51 summarize pipes condition index for this zone.

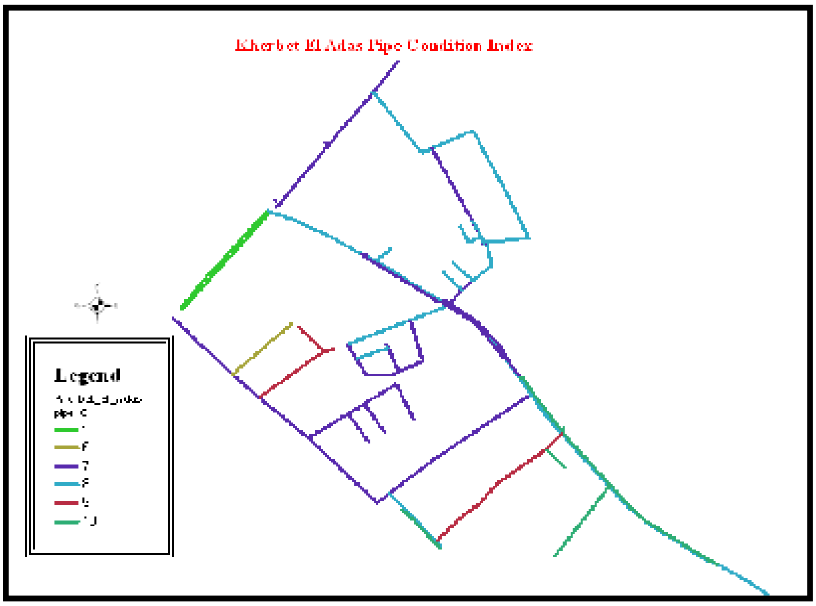

Figure 4.50: Kherbet El Adas zone Pipes Condition Index.

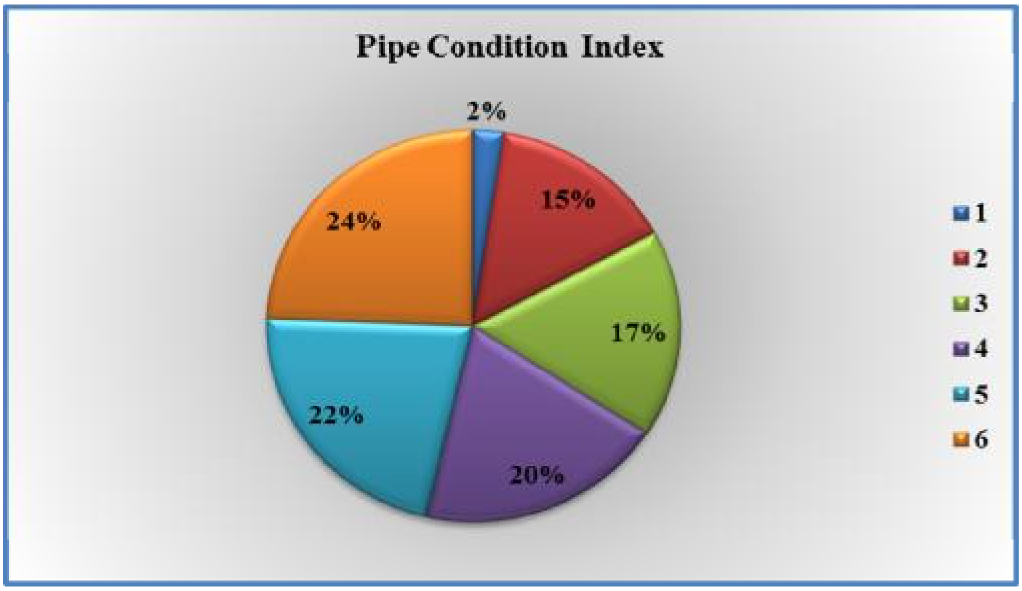

Figure 4.51: Ratio of Kherbet El Adas zone Pipes Condition Index.

By the above figures we note that, final condition assessment indicates the improvement status of Kherbet El Adas zone water network can clarify as 6.10% imperative, 1.85 % desirable 74.65% segment to be monitored, and 17.50 % no improvement necessary.

4.3.2 Practical Application.

Using GIS is important to apply the decision. The following is a practical application for pipe lines replacement decision. The first step is to create WaterGEMS model inside AecMap. The benefit for this step is to get hydraulic model data such as pipes pressure &velocity and use this data as a tool for pipe condition index method.

- **Steps for create WaterGEMS model inside ArcMap.**

In the ArcMap Interface, the first step is to bring in the WaterGEMS .wtg file. This is achieved using the following steps as shown in Figure 4.52.

1. Click Bentley WaterGEMS v8 - Project - Add Existing Project.

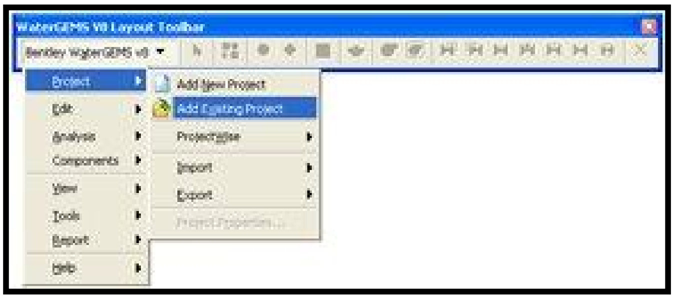

Figure 4.52: Bring WaterGEMS data in ArcMap.

2. Next, select your .wtg file, and then attach a Geodatabase file as prompted in the new window that opens:

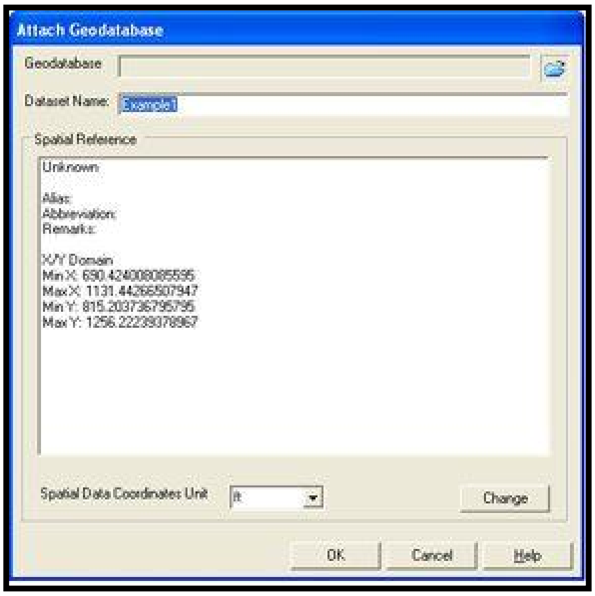

Figure 4.53: Attach A Geodatabase in ArcMap.

3. Input a new name for your new personal geodatabase, or browse to an existing geo-database under Geodatabase field. Then, enter a new Feature Dataset name under the Dataset field.

WaterGEMS v8 requires a geodatabase file to be specified as shown above. This geo-database can be either a new or an existing Personal Geodatabase, but using a new Personal Geodatabase is recommended. This database file cannot be the WaterGEMS database itself (the .wtg.mdb file).

4. Specify the appropriate units and click the Change button to specify or import a Spatial Reference. Click OK to bring your WaterGEMS model into the interface and create a new set of WaterGEMS Feature Classes in the Table of Contents area in ArcMap.

- **Selection of the pipe lines to be replaced.**

A certain criteria should be established by the decision makers to select replacement pipes. The selection depends on installation date of pipes, historical data about number of repair and failure, and quantity of water which this pipe feed the zones by it. Decision maker depend on GIS map and attribute tables data to get this information about the pipe line which selected to replace by use querying tools. Figure 4.54 illustrate a query of the pipe line which is needed replacement such as Asbestos pipe line (Asbestos pipes due to harmful effect on customers. Also Figure 4.55 illustrate a query of the pipes line which have pipe condition index equal one and located in El Shabora zone.

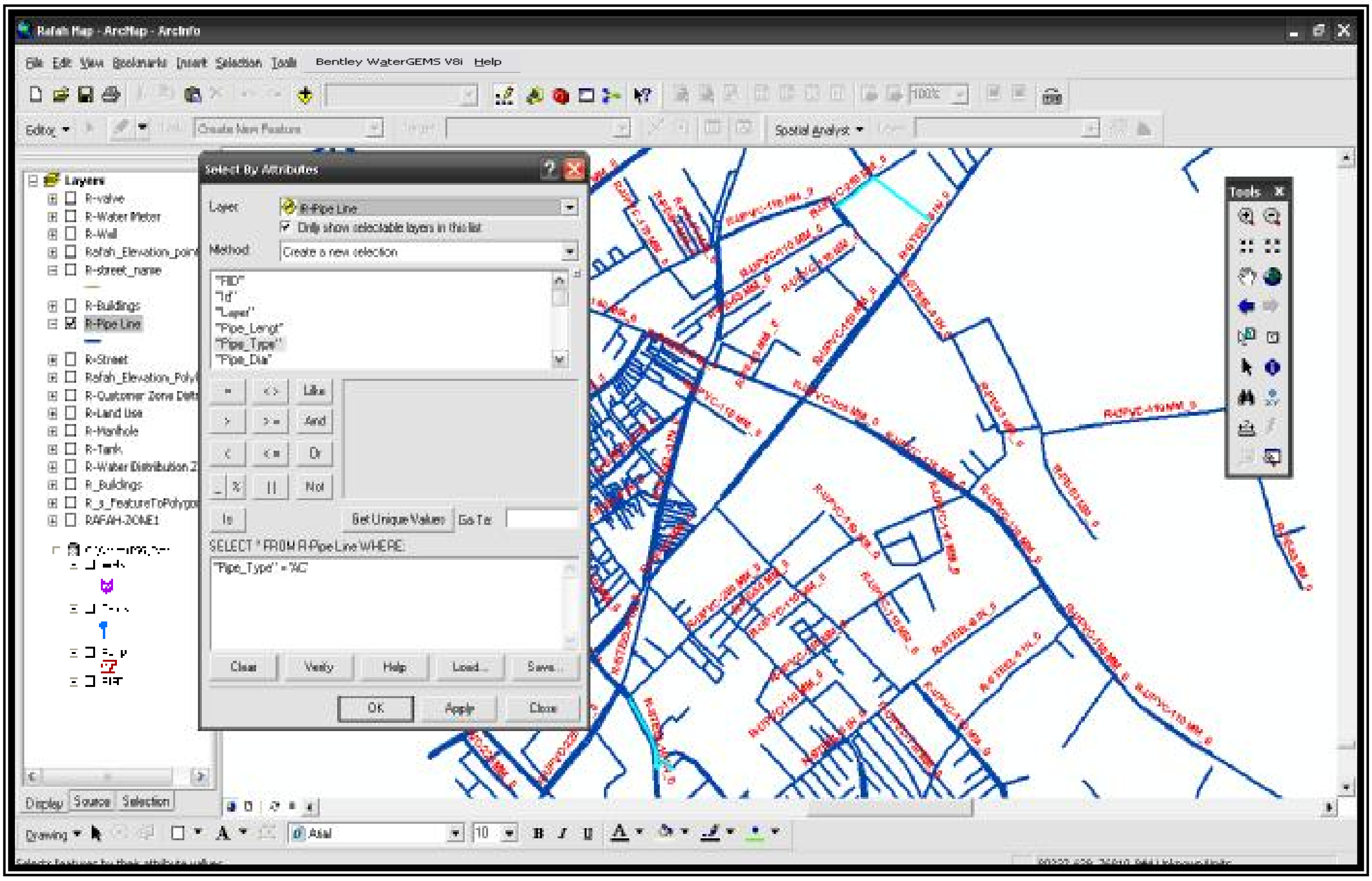

Figure 4.54: Use Querying tools for selecting pipes which needed to be replaced.

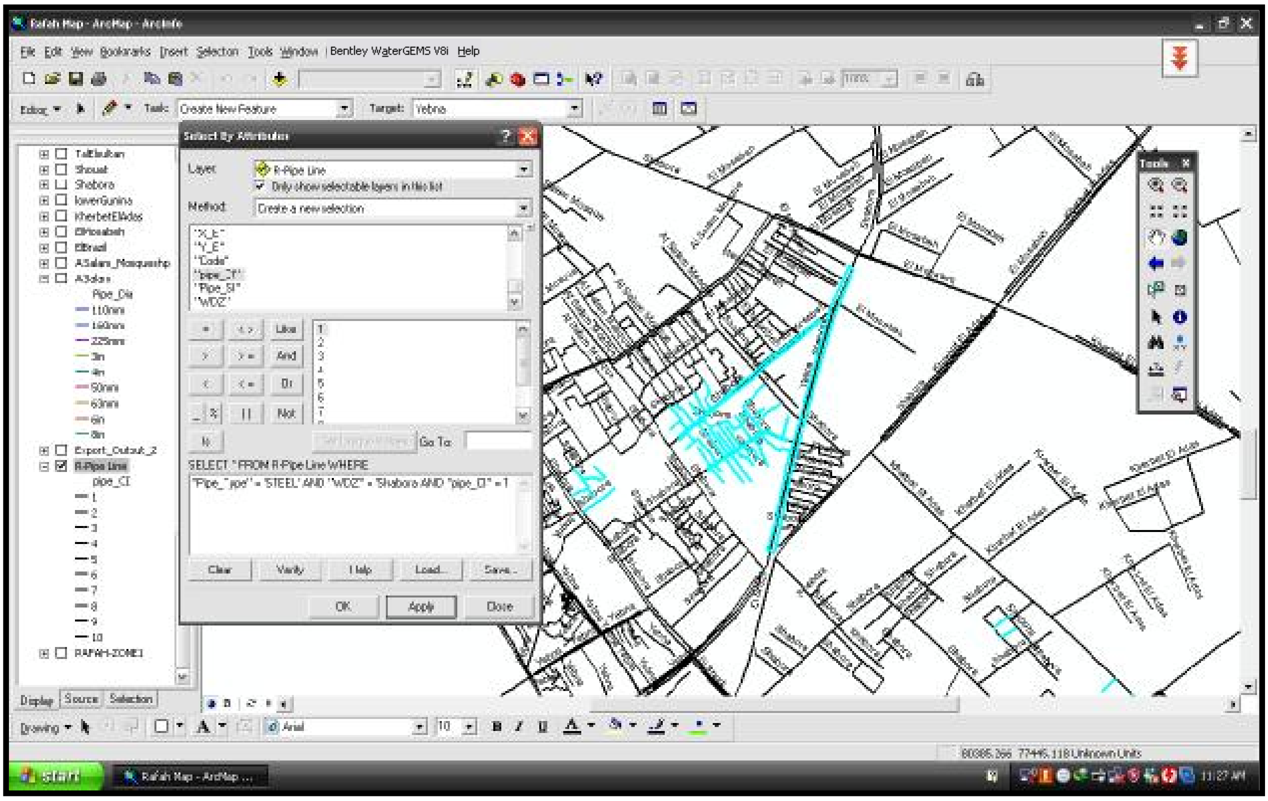

Figure 4.55: Use Querying tools for selecting pipe condition index equal one and located in El Shabora zone.

1. **Pressure Calibration**

In this decision maker get data by GIS map, attribute table data, hydraulic modeling output which clarify the pipe line pressure data. GIS by querying tools can clarify location and properties of pipes. Figure 4.56 clarify this scenario by selection pipe types UPVC with diameter 110 mm and pressure less than 2.0 bars. The decision maker will be provided necessary information to decide the proper decision such as changing valve statues, replace some pipe lines, or installing a poster pump.

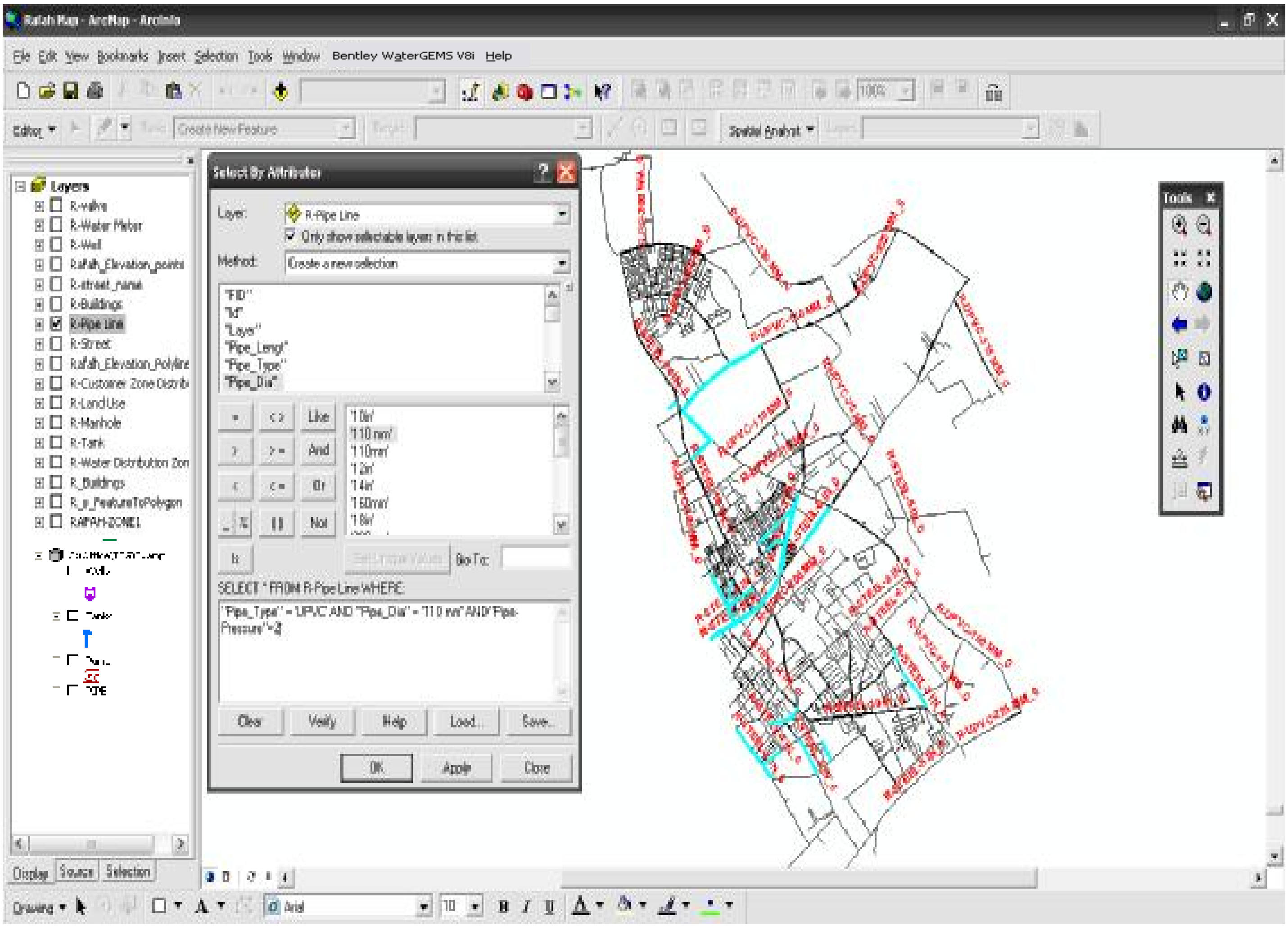

Figure 4.56: Use GIS Querying tools for selecting pipe types UPVC with diameter 110 mm and pressure less than 2.0 bars.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

1.1Introduction

This chapter includes the conclusion and recommendation about the use of GIS and DSS for management O&M for water networks pipe. Rafah area is selected as area' study and that is due to low percentage of deficiency for water networks comparing with other areas located in Gaza strip and that is due to old pipe networks, illegal connections without any monitoring or control, and the un-stable situation in Rafah .I observed that during my works as a head of GIS department in CMWU.

Also it was observed that there is no specific program for distribution system, operation, maintenance for water networks in Rafah area, numbers of request for materials to be used for operation and maintenance for networks is high, Lack of knowledge of water networks information such as pipes types which feed the zone distribution area, control valves, and maintenance martial report refer that the same pipe line failure more than one time without taking any action to solve this problem or find the cause of it.

To clarify the existing water distribution system in Rafah municipality area, interview is made with head, manger, and water networks operators to clarify WDS and describe O&M system which the municipality depend on for management water networks, and site visit is done by me to identify of distribution zone for Rafah area, knowing the location of control valve, and knowing the steps for O&M system for water networks which done by maintenance staff in the site.

The important of this study come from it is topic and from its result. The topic of this study is total new in Gaza Strip, where it is the first study was done related to O&M system for WDS. This is the first study for applying GIS with hydraulic modeling in creating O&M system for water distribution system in Gaza Strip. The study discusses one of the existing time most important technology GIS & DSS for management O&M which occupy the first level in database technology around the world.

1.2 Conclusion

Finally we can conclude that there is no clear O&M system for the water distribution system in Rafah, which insures the needed for establishing an effective O&M system for Rafaf area.

The proposed O&M system depends on the use of the integration between GIS and hydraulic modeling based on DSS for management O&M water networks to take the best decision at the needed time for all daily works.

It is clear at this thesis study using GIS and DSS in the proposed O&M system will assist the water networks department in Rafah by:

- Providing data base for water networks in Rafah area include shape files, AutoCAD file, and hydraulic modeling data which can minimize the human mistake.
- Help the water department in Rafah to feed all zone by equal quantity of water for all customer by the proposal water distribution systems.
- Clarify the valves which control water networks in Rafah area.
- Provide a clear program for distribution water networks for all zones.
- Clarify water networks pipes and diameters.

Use GIS and hydraulic modeling by use ArcView map and waterGEMS provide dealing with all types of data such as geographical data , non-geographical data, fixed , and variable data.it also integrating the database with accurate electronic maps, integrating the data for each component with AutoCAD maps, remote, control, and monitoring for all water networks facility, assist all department team for exchanging data needed to O&M by an effective communication tools which give accurate data, and finally assist the manger to give the best decision with saving the time, cost, and mistake in the field.

The goal of hydraulic model is to prepare the base data for operation department in Rafah area help us to manage water networks and prepare a good program for distribution zone, also knowing the location of control valves and zone which controlled by it, away for controlling water networks, knowing the pipes which have a pressure problem, and knowing the affect done in water networks systems such as pressures if there any change done in networks. Also out but result use as a guide for using pipe condition index method.

Proposed pipe condition index help the water department in Rafah area for assessing, current and future risk levels of a particular pipe and groups of pipes, investigating scenarios for risk reduction and cost efficiency of pipeline failure mitigation options, thus allowing for prioritization between pipeline replacement or pipeline management work packages, exploration of pipe asset and failure data, reporting capabilities allowing Water Utilities to quickly collect data for reports.

Also if there is any failure in water networks pipes, and needed to close pipe zone and use other distribution pipe zone to feed other area by it we can by pipe condition index know if this zone can pipe can bear the quantity and pressure or not.

The proposed system saving time, effort, and cost by guarantee an immediate corrective action for the whole defects of the water distribution system component.

1.3 Recommendation

The study clarify the benefit for use GIS and hydraulic modeling based DSS for propped O&M system to manage water pipes networks but is worth to recommend the following recommendations, which is very important to performed the goal of this thesis and promote the sustainability of the proposed O&M system in the Gaza Strip.

1- Applying GIS in O&M system for water network in all Gaza strip areas due to advantages of it for raising efficiency and improvement of management water network

2- To apply GIS integrate with hydraulic modeling Rafah Municipality should prepare its staff to use the software program by selecting some of the expected staff to attend training course in applying GIS and hydraulic modeling in the field of water service.
3- The proposed O&M system to contribute in water conservation, it should form apart of effective total management system in the municipality.
4- Any amendment or change in the data to relate to water networks facility must be entered on the database for water network where they help the manger to manage water networks and have a good decision about O&M for water network.

1.4 Further recommended studies

1. Use GIS server which help other department to know and get information related to Rafah area geographical information and water networks data which help them to manage other infrastructure networks such sewer, storm water, and roads networks.
2. The same can be done for sewer and storm water networks.
3. Establishment base data include all information of infrastructure networks (water, sewer, storm water, and roads) help the manger to have an effective management system for O&M system for all networks.

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Annex I

Cross-country Experiences with DSS

1. **Algeria**

There is no real DSS process in the water domain. Recently some projects dealing with GIS and management have been conducted within the bilateral cooperation between Algeria and Germany (GTZ). In water management context, such actions were related to the Regional Water Plan (PRE). The main outputs were: multi-sources data collection, Geographic Information System (GIS), and management approaches. During the period 2000-2003, a relevant study was conducted for the basin agencies in Algeria. The study took into account the following considerations:

- Conditions of evaluation and quantitative mobilization of the water resources.
- Existence of huge problems (protection of aquifers in dangers, overexploitation, pollution, fail management).
- Various strategies and policies of the economic development.
- Various needs (urban, industrial, tourism, agriculture).
- Conditions of use of non-conventional water (desalination, waste water).
- Absence of decision tools in order to meet the best conditions of a sustainable development.

The initial evaluation revealed problems affecting the data information in terms of restrictive access, inadequate integration of computing tools, absence of monitoring and evaluation processes, multiplicity of the sources of data, fail coordination among data producers, limited knowledge of the GIS potential. The project promoted the use of different kinds of models and tools and their applications at the basin scale (Mike Basin tool using at the basin scale, data management and related tools, analysis of sources of information, analysis of human and financial resources, GIS and potential use, institutional analysis). However, this study included elements of decision system but cannot be considered as a study tool for DSS(Abu-Zeid, K, 2003).

2. **Croatia**

DSS for water management in Croatia has not been developed and used in operative terms. However, various elements of the system, such as hydrometeorological and water resource database in addition to the information system were partially developed. Operative managing of key hydrometeorological data/information was carried out in the State Meteorological Institute, not at Hrvatske Vode, which is a state agency for water management. At the State Hydrometeorological Institute, the data was collected, analyzed and organized, as well as data on water level of watercourses and river flows in Croatia, and water level forecasts were made. The forecasts were regularly performed during flood flows and low water. However, data and information based on experience, not simulation models, were used in forecasts. Hrvatske Vode Water Protection Department conducted fresh water quality monitoring and had a corresponding data bank, but not an operative information system. Integral and organized monitoring of ground water were not performed, thus, an integral and operative data bank and information system did not exist. On the other hand, there was a partial data bank on water resources (rivers, lakes, underground water) and water structures (embankments, pumping stations etc.). Preparation of an integral data bank and basic gaodetic data was in progress. The other elements of DSS, such as models (simulation and optimizational) and expert systems were not developed, nor in use. There was no operative model of the river basin, watercourse or groundwater system/basin. Most attention was given to the realization of simulation model of the Sava River. During the 80-ies one option of the Sava river model was in use over a short period of time. However, the use of the model didn't progress. Initiatives were given to the preparation of DSS, but serious action has not begun. There was continuous attempt of creating the water information system. A new project of the integral Croatian water information system was under preparation. The project was expected to be finished in three years. Models of rivers or water entities were being made within scientific projects during preparation of various dissertations(Dee et al, 1972).

3. Cyprus

The mechanisms were in place in terms of decisions making related to water policies developed during the last decades since the foundation of the Republic of Cyprus in 1960. This could be described as an evolutionary process where mechanisms were adapted as available knowledge and data that addressed the pattern of water uses and historical variations. It should be emphasized that there was no systematic endeavor at developing a DSS in Cyprus; hence no specific reference could be made to past successes and failures(Abu-Zeid, K, 2003).

4. Greece

DSS models for water management in Greece have been developed to serve the purposes of the Water Framework Directive and, consequently, were expected to play important role in influencing the relevant policy making. The DSS developed for the Athens Water Supply and Sewerage Company (EYDAP S.A.) has been widely used by the company and the up to date results have been utilized to improve water management in Athens focusing on the interrelation of water resource usage, efficiency, and economic viability. Three DSS modules on water management have been developed and applied in different geographical areas of Greece (Abu-Zeid, K, 2003).
A working example was the DSS for Integrated Water Resource Management in Crete. It was designed by the Planning and Development Department for Water Resource Management of the Periphery of Crete with the objectives of:

- Developing an integrated/holistic approach for the effective, flexible and sustainable management of water resources in the island of Crete, aiming at (i) preserving the sustainable management of the island's water resources, (ii) covering current water demands and securing water quality for any use, (iii) ensuring the qualitative and quantitative characteristics of the water resources and the water systems.

- Providing the capability for efficiency control of the proposed solutions (projects and actions). The acquisition of overall control of the water dynamic and of the management problems.

- Developing a decision support tool to be used in introducing policies for the implementation of certain water related projects and interventions to water resources management.

- The development of the framework for the implementation of the Framework Directive for the Water Resources (2000/60).

Basic criteria for the development of the DSS included the assessment of the water resources quantity and quality, water demand and supply, the current conditions (favorable or not), and the time span of the project. After gathering and evaluation quantitative and qualitative data on water resources and studies applied in the island I relation to the hydrological and hydro geological conditions, as well as on the development of the relevant infrastructure, a hydrological and hydro-geological database was formed with GIS. The results from the simulation of the hydrological and hydro geological systems as well as from surface water and groundwater balance estimation were used in the development of the DSS. The DSS was tested for different scenarios o water management. Economic analysis of the scenarios and training of the DSS mode users also took place. This DSS provided the potential for future evaluation of project and interventions in the water sector, enhanced design of the existing infrastructure fo water supply, scenarios development, and sustainable planning for water resource management (Abu-Zeid, K, 1999).

5. Italy

Despite the wide and growing interest towards the development of tools and techniques for integrated planning and management of water resources at the catchments scale, relatively few of them have been actually and regularly applied over the last few years to real world decision-making. Although several DSSs have been made available thanks to the efforts of the academic community and of specialized private companies, these tool were not widespread in Italy. On the other side, an increasing number of regions another territorial institutions, such as river basin authorities and ATOs, have been acquiring data base and information systems on meteorology, water and land resources as a tool to improve their monitoring, planning and management activities. Relevant progress has been made in the collection and storage of a great deal of land information thanks to the extensive use of the GIS techniques along with an increasing availability of simulation models of complex water resource systems. This constituted a major pre-condition for a significant development of decision support systems that should integrate the capacity to measure and represent the environmental variables with the ability to predict their evolution resulting from alternative planning and management decisions(Dee et al, 1972). Some of the most recent DSSs focused on the role of stakeholders' participation in decision-making and were designed to involve a wide range of actors and stakeholders. Examples are as follows:

- TwoLe: A DSS for planning and managing multi-purpose reservoir networks; it supported and improved participation to decision-making. By reproducing the structure of decision-making and using a particular class of models, Twole suggested how to extensively involve stakeholders and decision makers at all stages of decision-making. TwoLe has been developed by a group of researchers from Milan Polytechnic and has been applied to three large projects.

- Aquaroute. A DSS to help decision-makers to define sustainable water management policies. The tested alternative scenarios were different in terms of network layout and/or management options. Aqua route adopted a multi-criteria approach (economic, environmental and social criteria) under the condition of uncertain information and several stakeholders. A team of researchers from the University of Basilicata has developed Aqua route.

- Mulino-DSS. An operational support system for the management of complex mult sectoral problems of water resources and water quality at the catchments and river basin scale in Europe. It integrated the conceptual framework, hydrological model, multi-criteria evaluation and sensitivity analysis. The use of the DSS has been conceived as part of a larger process of involvement of the different stakeholders that were requested I collecting data, declaring their preferences for the alternative options, giving suggestions for decision criteria and their ranking, explaining the role, responsibilities and relationships between different stakeholders. It was carried out in the context of a European project – MULINO - by a group of partners from Romania, Portugal, United Kingdom Belgium and Italy. Throughout the project the DSS has been tested in si selected catchments that range in size, topography, climate, socio-economic an cultural context.

- Mondrian. An Integrated DSS (IDSS) for planning and managing different water uses especially for agriculture at the river basin level. IDSS's main characteristics integration of different specialized monitoring/evaluation/simulation models (such as ground and surface water dynamics models, crop water requirement models, economic and environmental evaluation models etc.) and a participatory approach, consisting in the involvement of local actors in water use and management for the implementation of the IDSS. It was based on a GIS named SIGRIA (Information System on Water Resources Management in Agriculture) developed by INEA (National Institute of Agricultural Economics). Used by several Land Reclamation an Irrigation Consortia, SIGRIA is an important tool to implement a homogeneous information system on water irrigation schemes useful to support evaluation an decision-making, i.e. to calculate crop irrigation requirements. Financed by the Italian Ministries of Research and Agriculture, it has been carried out by a group of public research institutions and private enterprises. It has been tested in three river basins.

6. Lebanon

In Lebanon, several attempts have been made to apply DSS tools for the management of the water resources at the national and regional levels. Such projects have bee primarily initiated by international agencies, mainly the United States Agency for International Development (USAID) and the European Commission (EC). Unfortunately to date there is not a single successful experience of use of DSS in decision-making most tools were either left at the developmental stage or are currently under development(Abu-Zeid, K, 2003).

7. Morocco

Elements of DSS were utilized in Morocco but the whole system was not applied. The research carried out focused on improving the performance of the irrigation system through either rehabilitation of infrastructure, modeling water uses and irrigation planning, and strengthening irrigation agencies by searching best irrigation practices an water delivery, and water maintenance recovery cost. It also focused on improving lan productivity and irrigation agencies improvement in terms of managerial skills. Th research on water monitoring and quality control was encouraged. The social impact o the new law 10-95 and the inter-relations of sectors using available water resource wer considered of prime importance in the research agenda. An example of developin applied research with DSS approaches was given by th project SWIM (Souss Basin, South of Morocco), whose objective was to improve water resource management in S-W Morocco. In addition to addressing policies and government management of water, the project aimed to involve the participation of different stakeholders as well as to implement pilot projects and disseminate best practices of integrated water management. The project also had a part-time gender advisor on staffs that was able to ensure that gender issues were monitored. The evaluators made several suggestions for improving women's participation in water user associations and to make gender integration an explicit criterion for receiving funding for micro-project grants. The development of Moroccan agriculture and economy was based in the last three decades on maximizing capture of surface water resources and optimizing their use for irrigated lands (90%) and for public services, domestic uses, industry and energy generation (10%). Almost 90 dams were constructed to control surface water flows and hence an enormous investment was carried to use more than 2/3 of surface water potential. The main constraints to the development of the approach or a DSS are 1) lessening in water availability and drought, 2) inadequate maintenance of hydraulic infrastructures, 3) watershed degradation, 4) downgrading of water quality and silting of reservoir, 5) reduced efficiency in water irrigation systems and 6) low access of rural population to safe and reliable supplies of water(Dee et al, 1972).

8. Portugal

Similar to many DSS users, the experience of using DSS as a software tool to take decisions related with water resources management was recent in Portugal. Some references referred to DSS tools such as cases of GIS applications and database development. Some occurrences of the DSS applications originated from the research activity. Occasionally, DSS applications were used to fulfill the needs of research activity, and in several cases didn't have reactions from the stakeholders. The country encouraged the increase of performance in the use of water, energy and labor, and the conservation of natural resources. The DSS composed of database, design models for alternative design and impact analysis, and a multiple criteria decision-making model that evaluated and ranked the alternative designs. It was verified with data collected from field experimentations in Lower Mondego Valley (center of Portugal) and another in the Alqueva Dam (Alentejo). A new European project to manage the international river basins utilizing DSS was expected to start. The cooperation between the Portuguese and Spain governments on the Guadiana river basin was an example of utilizing the elements of DSS(Abu-Zeid, K, 1999).

9. Spain

Decision Support Systems relevant to water management were developed and used at two levels: (a) for indicator development and monitoring; and (b) for contingency planning. Since decisions could not be derived from measured data alone, such as precipitation and stream flow, Basin Authorities relied on synthetic series of data. Observational records cannot not be directly used in most cases because the natural regime was strongly altered due to reservoirs, diversions and consumptive uses. Synthetic series for the natural regime was computed with the Sacramento model. This model reproduced stream flow from rainfall observations. The Sacramento model has been calibrated in the Tagus unaltered basin, and was used to generate runoff series for the 216 sub-basins for the period 1940/41 to 2000/01. The synthetic calibrated time series were used to compute operational indicators that characterized the hydrological conditions of the basin. The indicators had the following characteristics:

- Differentiate to a reasonable degree between different levels of water scarcity intensity; and
- Validate the results from more detailed studies.

In the Tagus basin the operational indicators were stored volume and the Surface Water Supply Index (SWSI), that had the advantage of combining hydrological and climatologically features in a single index and allowed for the consideration of reservoir storage in the Tagus basin. SWSI was computed for a hydrographic basin or for a water resources system by obtaining the probability of non-exceeding for the values of precipitation, runoff and stored water in the basin. Each component was assigned a weight depending on local conditions. These weighted components were summed to determine the global SWSI value for the entire basin. Threshold values of -2 and –3 of SWSI have been chosen, corresponding to moderate and severe drought respectively. Once the variables and the indicators became known from the physical and hydrological point of view, optimum management was reached relying on mathematical models that reflected the system operation and were used to analyze the operational rules that led to the best exploitation of the resources or to the justification of the requirements to create new elements -- such as reservoirs, conduction and capture, etc – that increased the availability of water resources. The mathematical operation for the physical operation of each system element was developed and there were sufficient tools for the analysis of related problems (Abu-Zeid, K, 2003).

10. Syria

Elements of DSS were used in policy making for water management in Syria in the project of the pilot basin of the Asnober River. Modeling was used as a tool to evaluate the alternative water resources development strategies in the costal basin. Part of the COWARM project was to study the options for using the river basin simulation modeling software. For this purpose, the software package WEAP, developed by the Stockholm Environment Institutes Boston Centre (SEIB) at the Tellus Institute, was chosen. WEAP was available free of charge for water management project in developing countries. The software was designed to assist in the planning and management of river basins with limited available data.

The Coastal Water Resources Management Project (COWARM) was carried out by the General Directorate of the Coastal Basin (GDCB) and by a consortium of Dutch and Syrian consultants in order to optimally develop the costal basin area. An assessment of the stakeholders, the authorities and the organizations that had interest in the water issues of the costal basin was made. The DSS of the pilot basin Asnober in the coast basin was developed at regional level, implementing the WEAP software, developed by the Stockholm Environment Institutes Boston centre (SEIB) at the Tellus Institute at basin scale. Scenario analysis was carried out to test and demonstrate the ability of the software to serve as corner stone of a Decision Support System.

DSS proved to be useful for making decisions regarding water management. DSS assisted in the conceptual analysis of the existing surface water resources system, the evaluation and optimization of the use of surface water resources, and the evaluation of new water resources infrastructure (Dee et al, 1972)..

11. Tunisia

DSS was used in industrial and socio-economic studies, but remained of limited utilization in water management. DSS-tools were used in synthesizing data and strategies rather than decision-making. Hydro system responses to imposed constraints were studied according to technical issues independently from the related sociosystem.

However, some research projects were centered on the use DSS in water management.
For the most, these projects were achieved at regional level. Very few projects could be extrapolated to the national level because results remained tightly related to the studied hydro system. In the same way, these projects remained within the research context without being implemented in decisional strategies. This was due to the fact that decision-makers were rarely included in these projects and were often limited to water data supply.

The Project MERGUSIE in collaboration with France and Tunisia (started in 1996) targeted the basin of Merguellil (1540 km2) to understand the hydrological phenomena and to identify ways of improvement of water management. The second phase of this project was focused on the construction of tools to support decision making for the management of hydraulic planning in the basin. The project led to the conceptualization and the implementation of models to simulate the hydro system under different variables including climatic and socio-economic impacts (Abu-Zeid, K, 2003).

Annex II

Shape File Maps & Attribute Tables Figures.

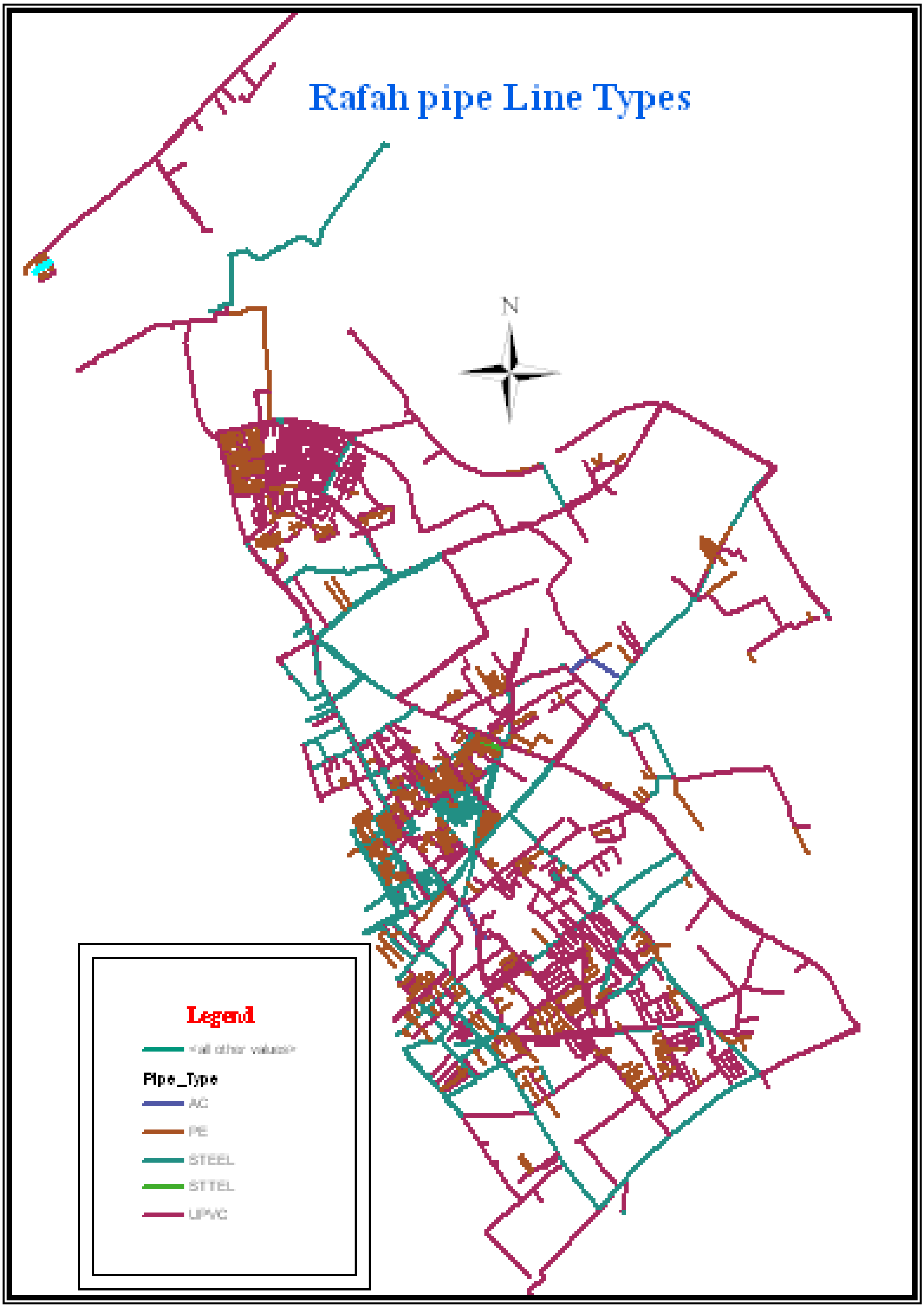

Figure 1: Distribution of pipes material for Rafah Municipality.

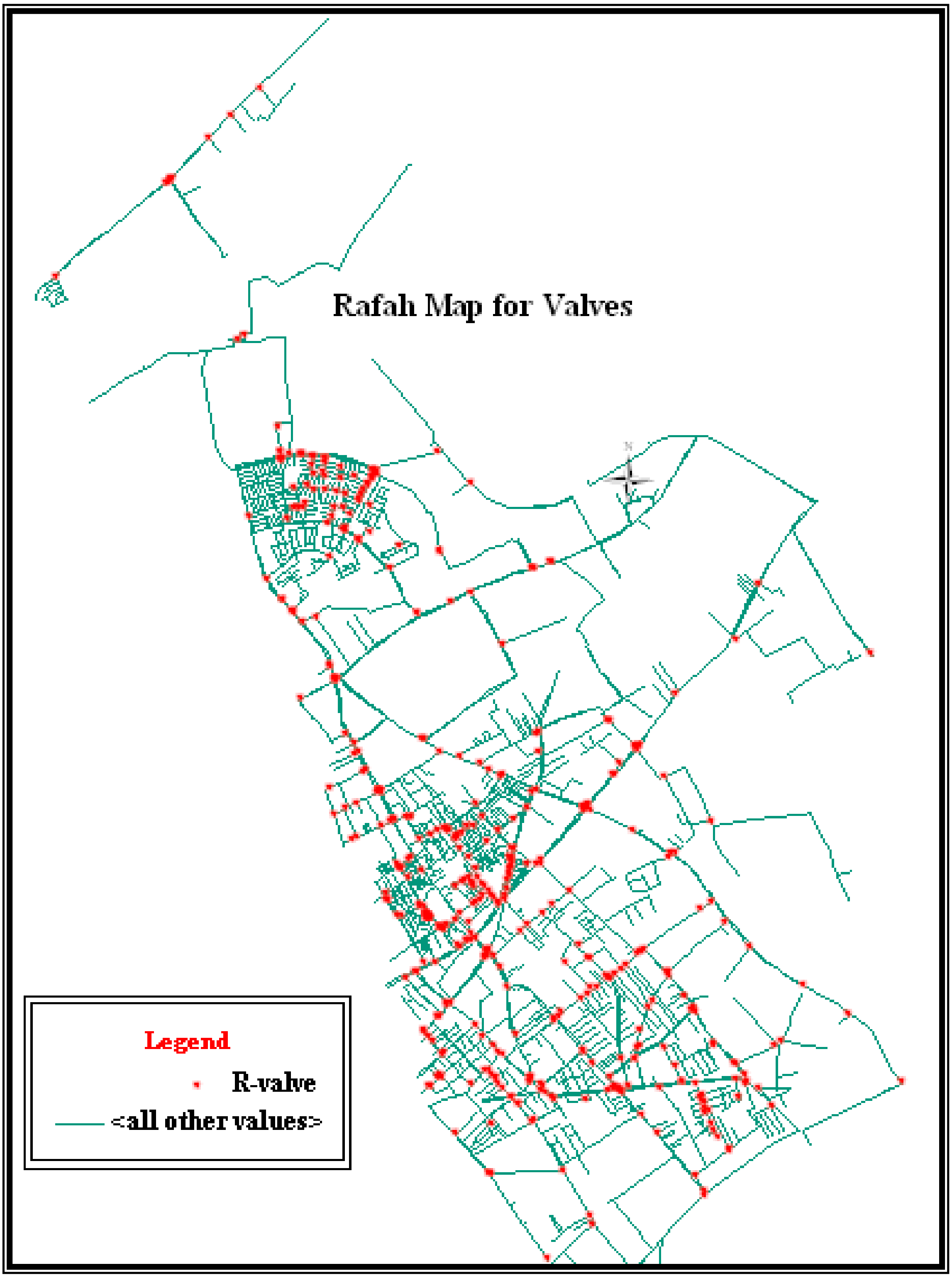

Figure 2: Distribution for Valves for Rafah Municipality.

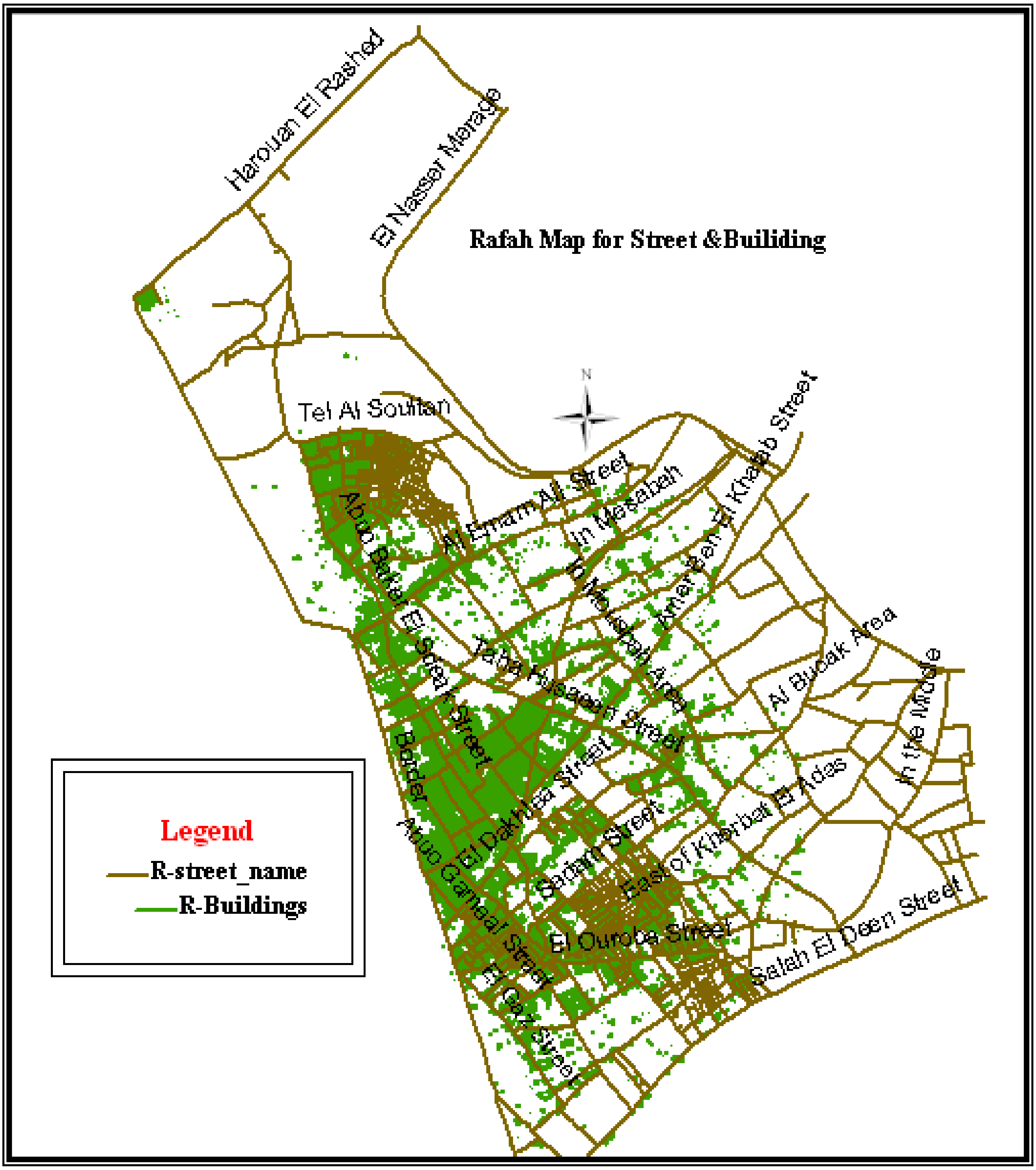

Figure 3: Maps for Streets and Buildings for Rafah Municipality.

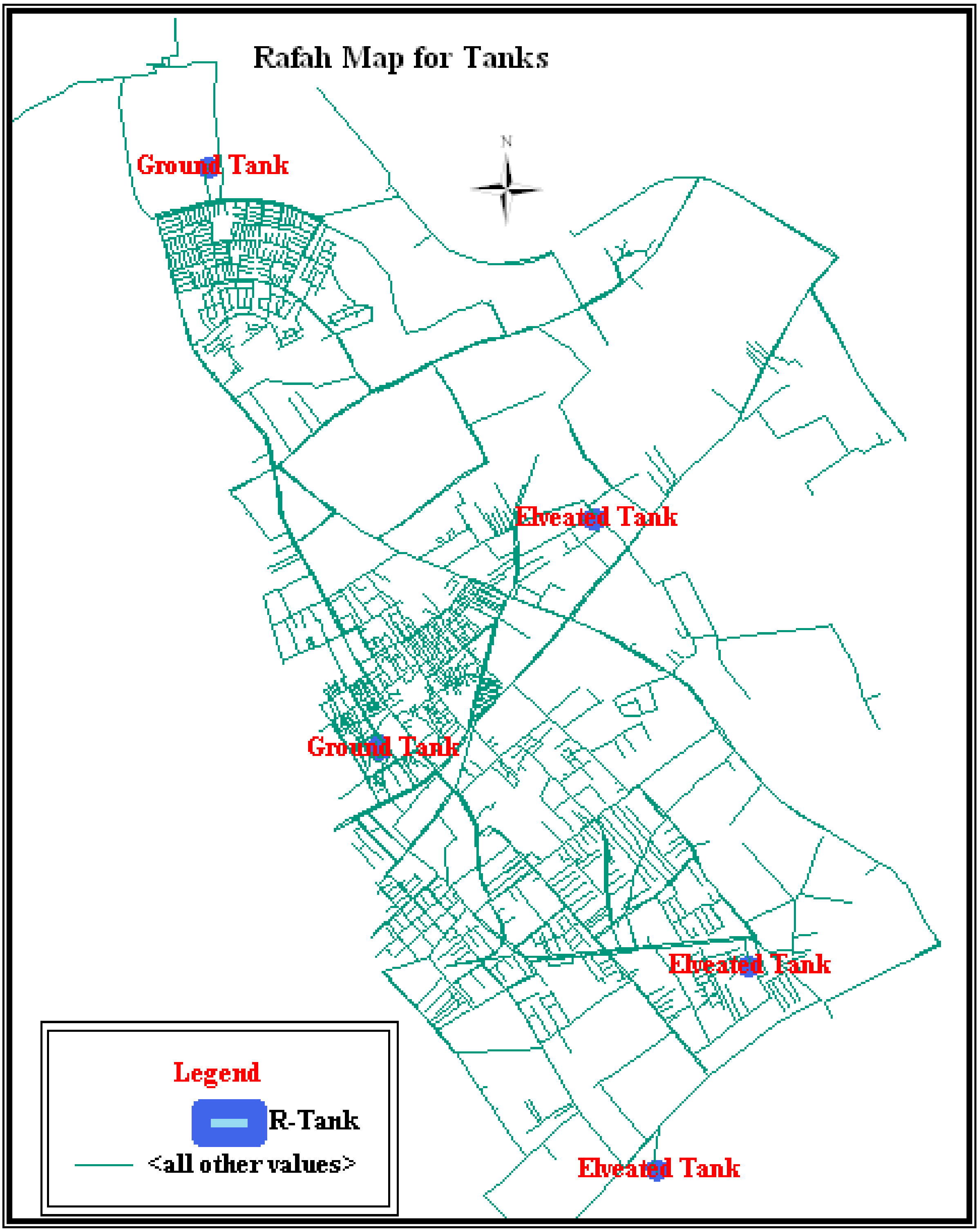

Figure 4: Distribution for Tanks for Rafah Municipality.

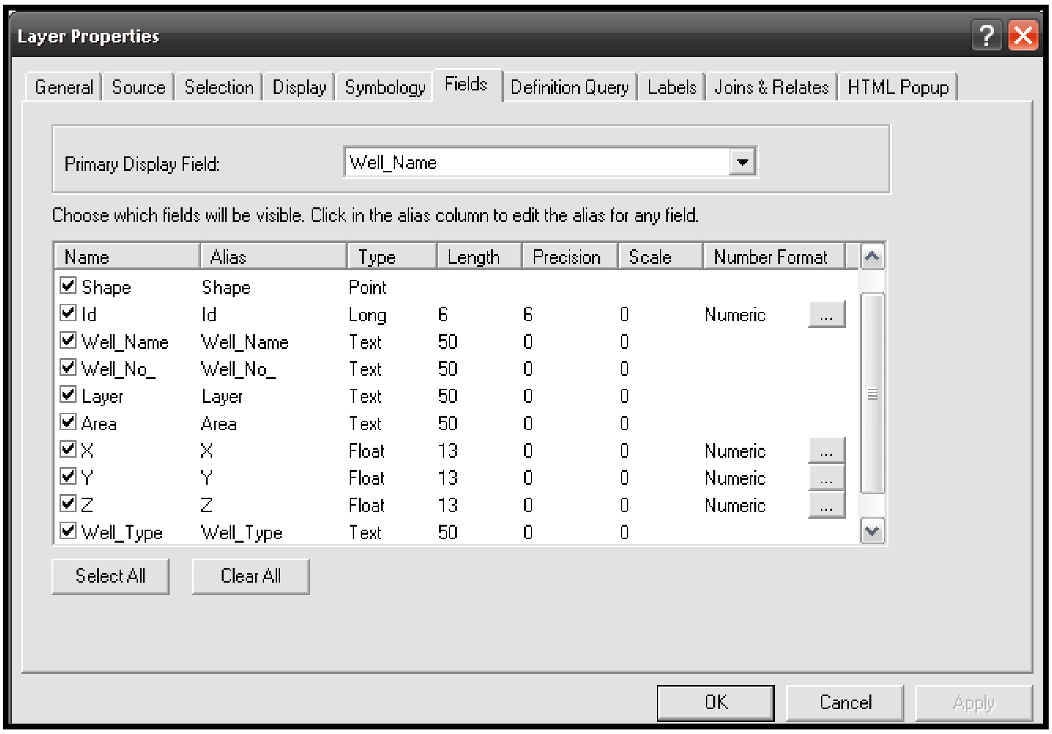

Figure 5: Data Fields for wells.

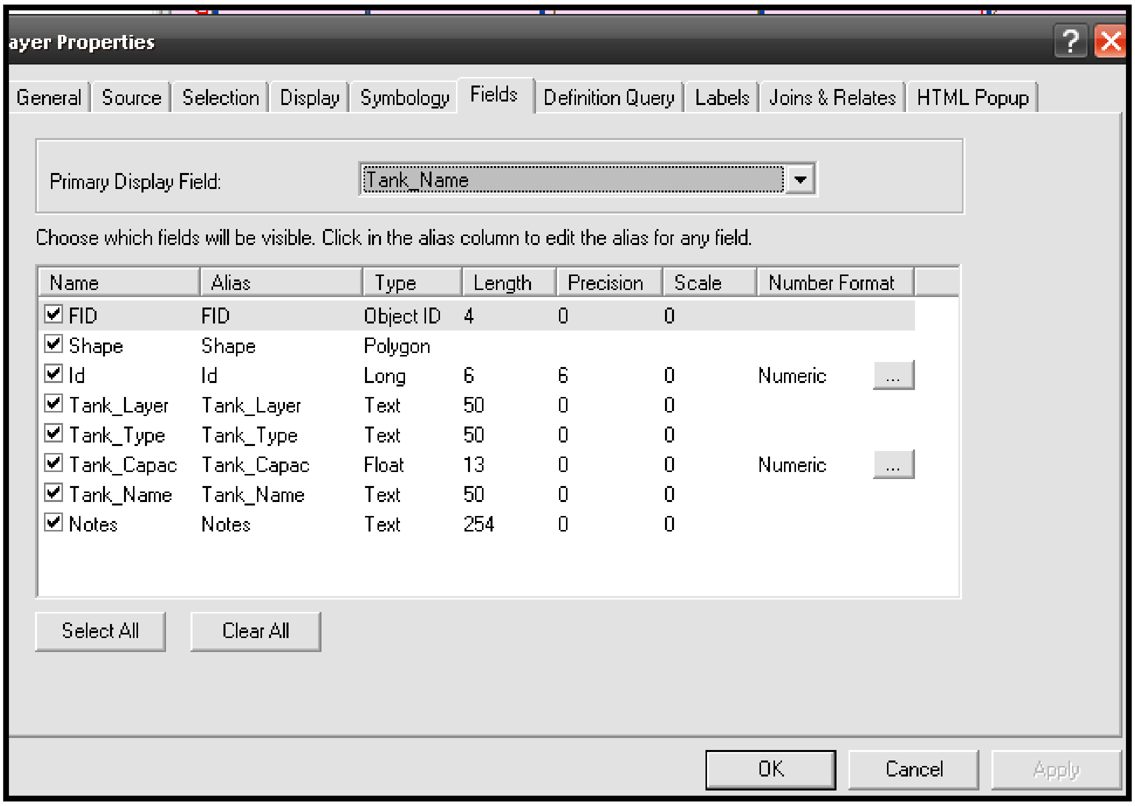

Figure 6: Data Fields for tanks

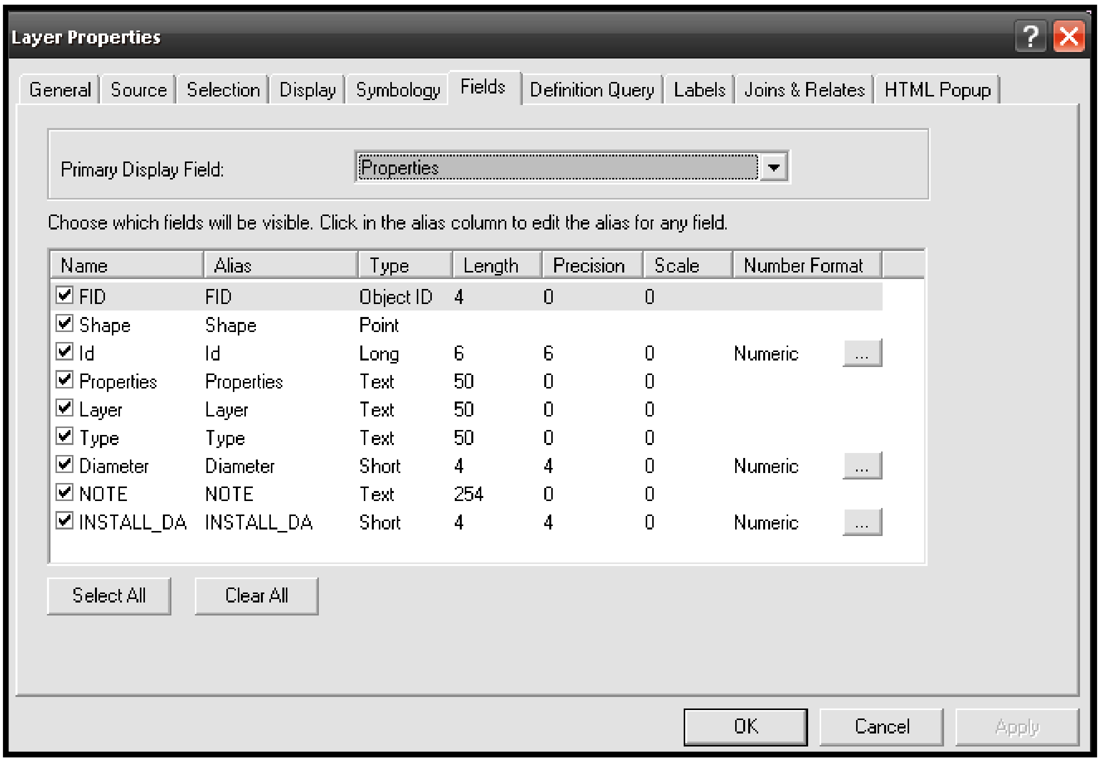

Figure 7: Data Fields for valves.

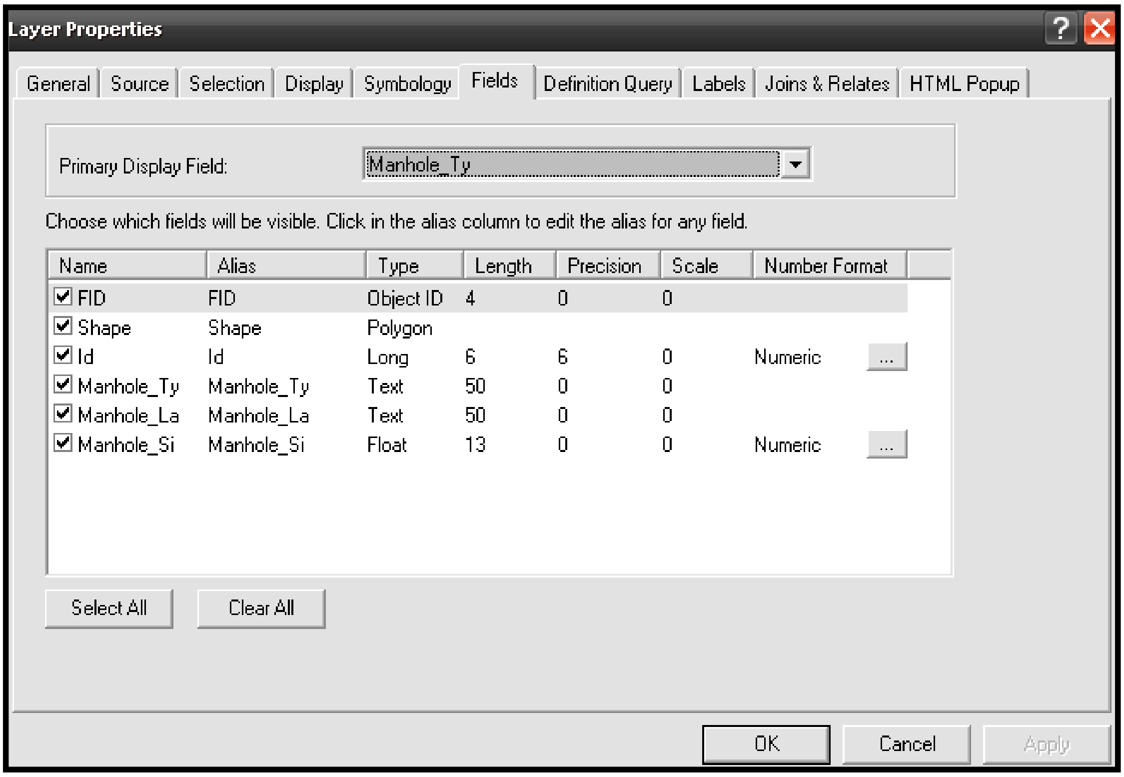

Figure 8: Data Fields for Manhole.

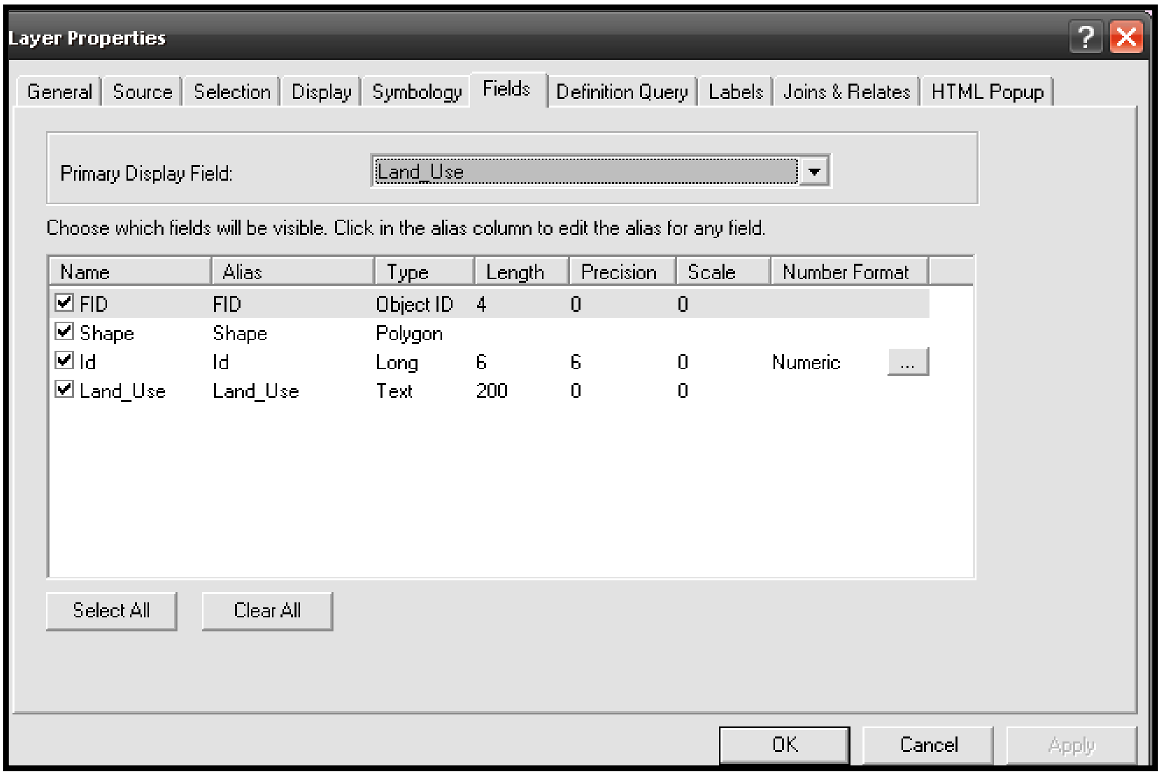

Figure 9: Data Fields for land use.

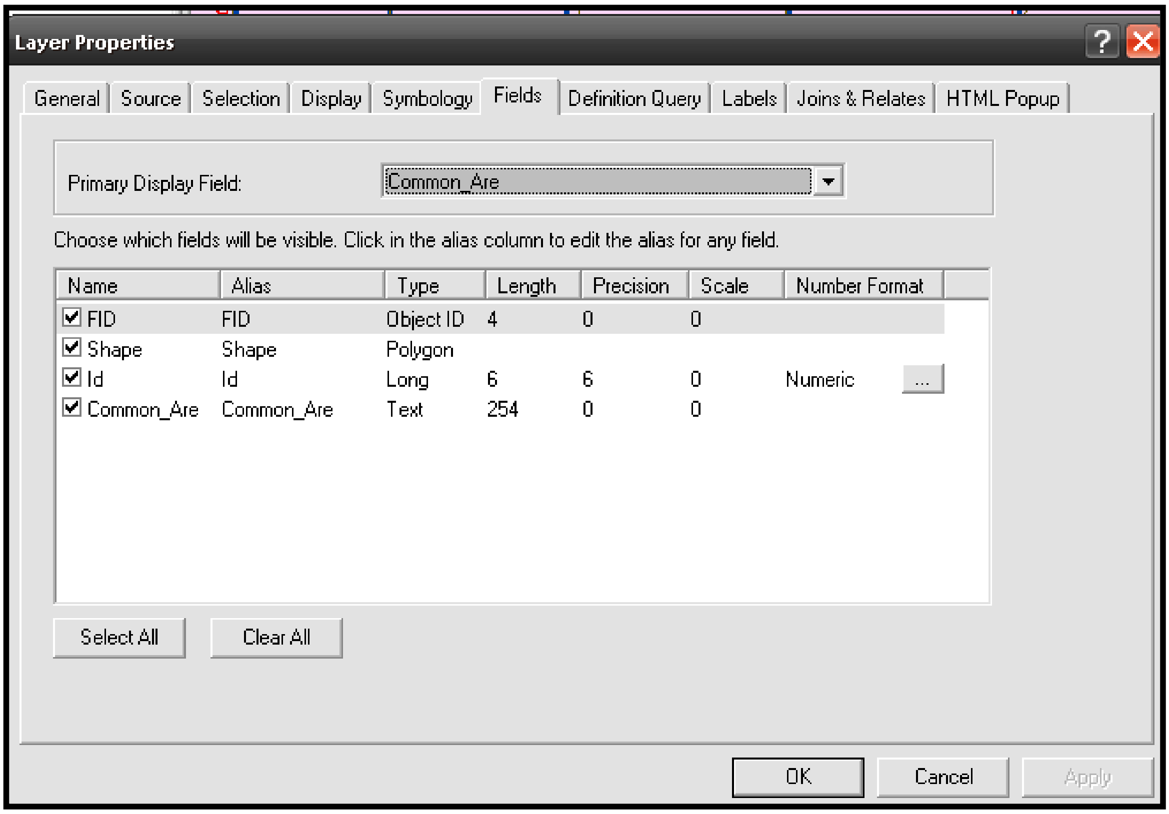

Figure 10: Data Fields for water distribution zone.

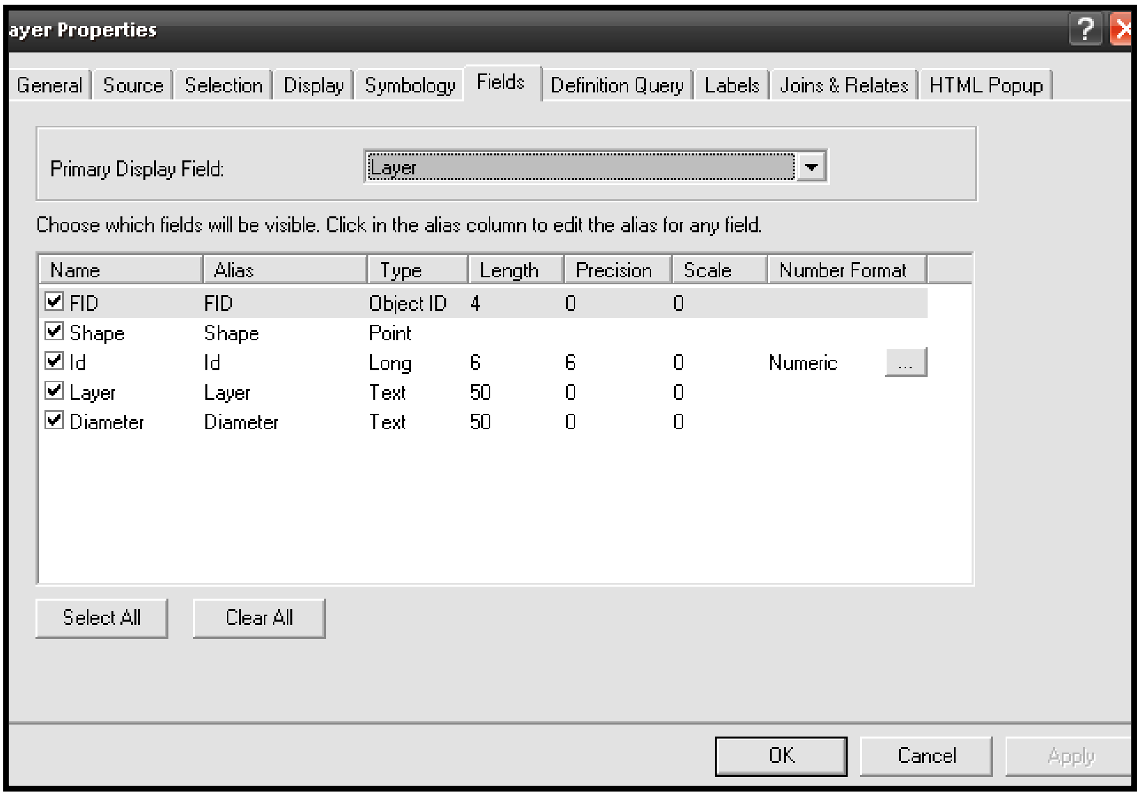

Figure 11: Data Fields for water meter.

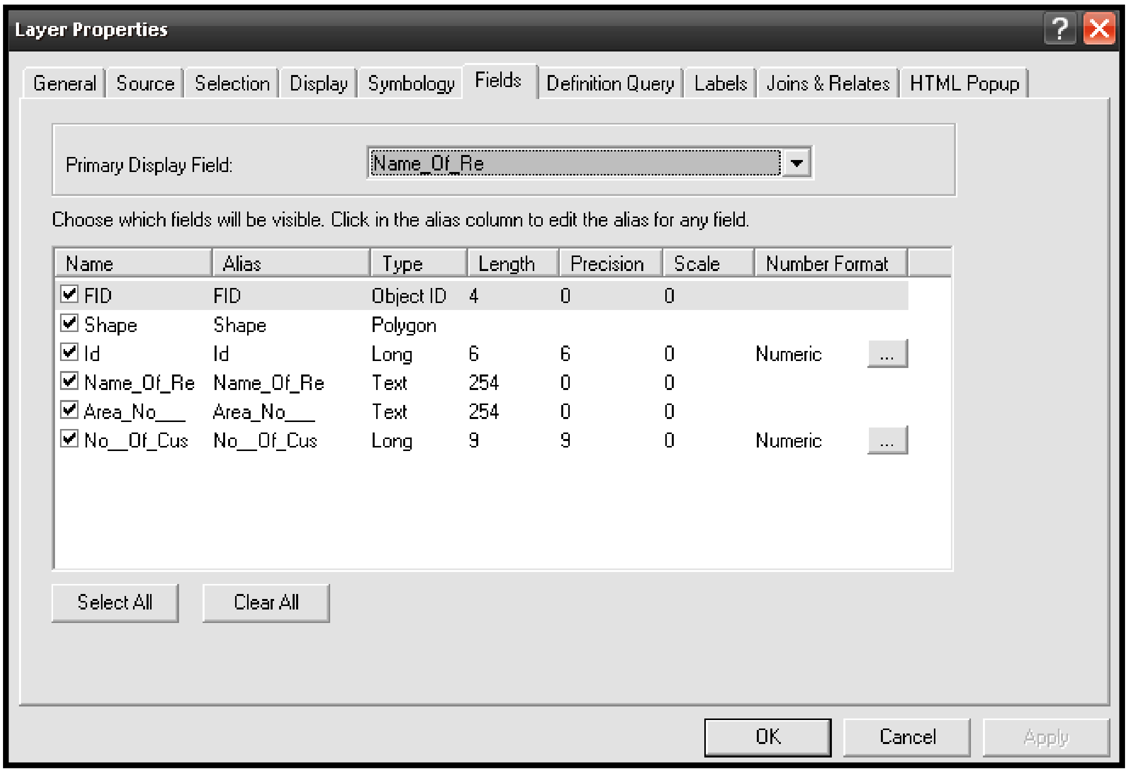

Figure 12: Data Fields for customer zone distribution.

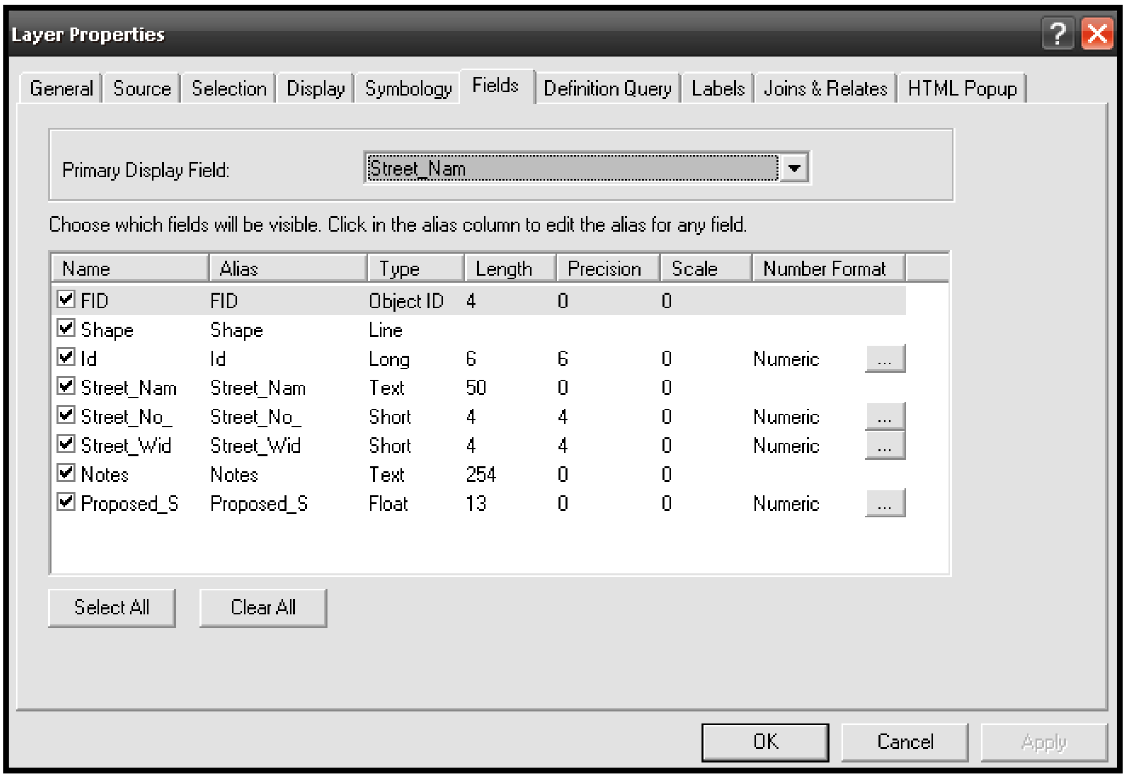

Figure 13: Data Fields for streets.

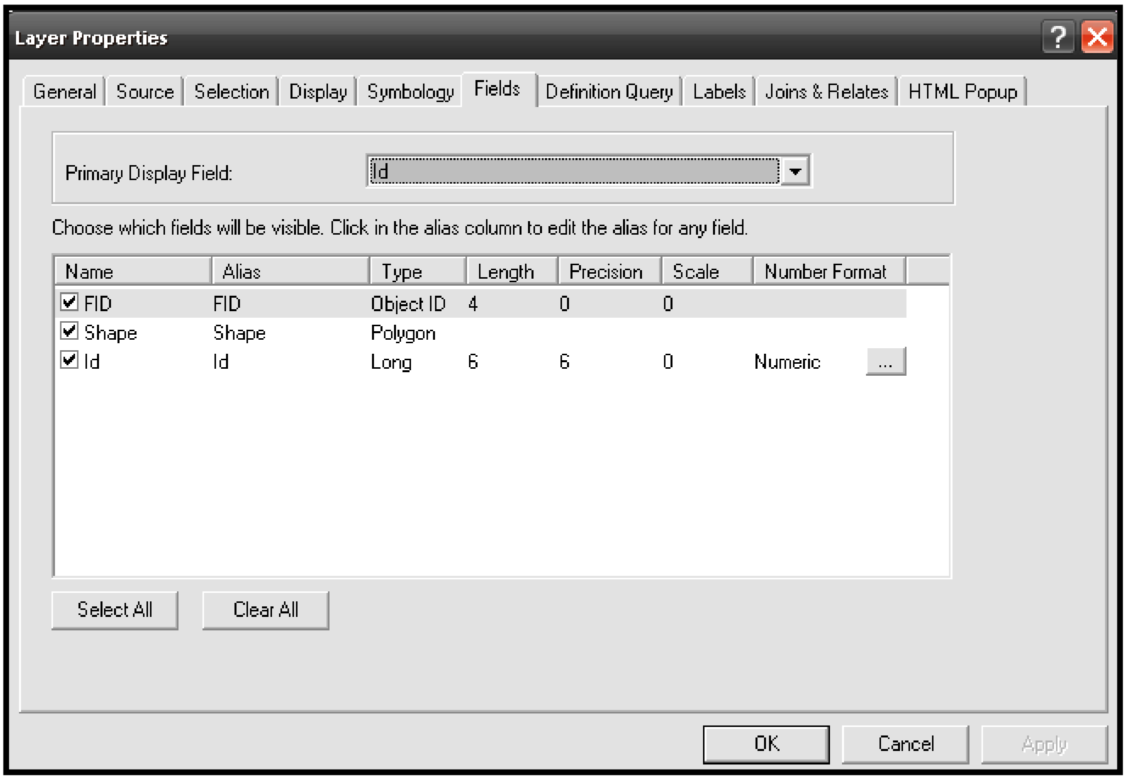

Figure 3.14: Data Fields for building.

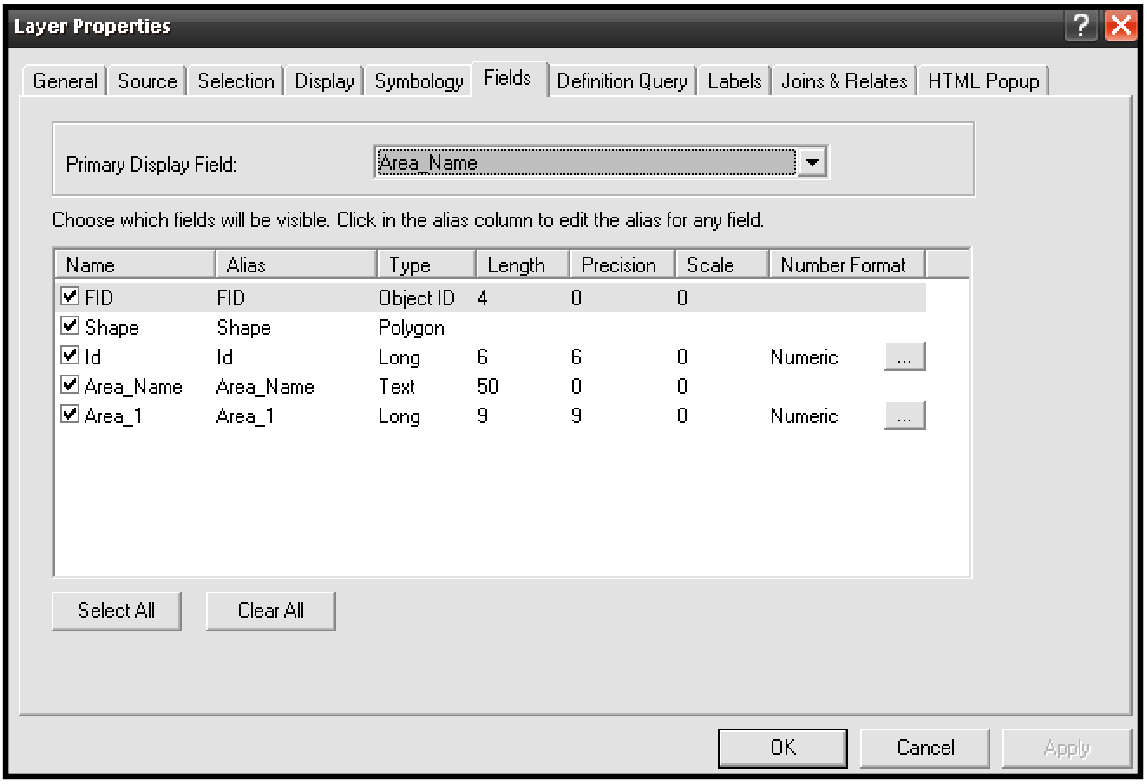

Figure 3.15: Data Fields for area zone.

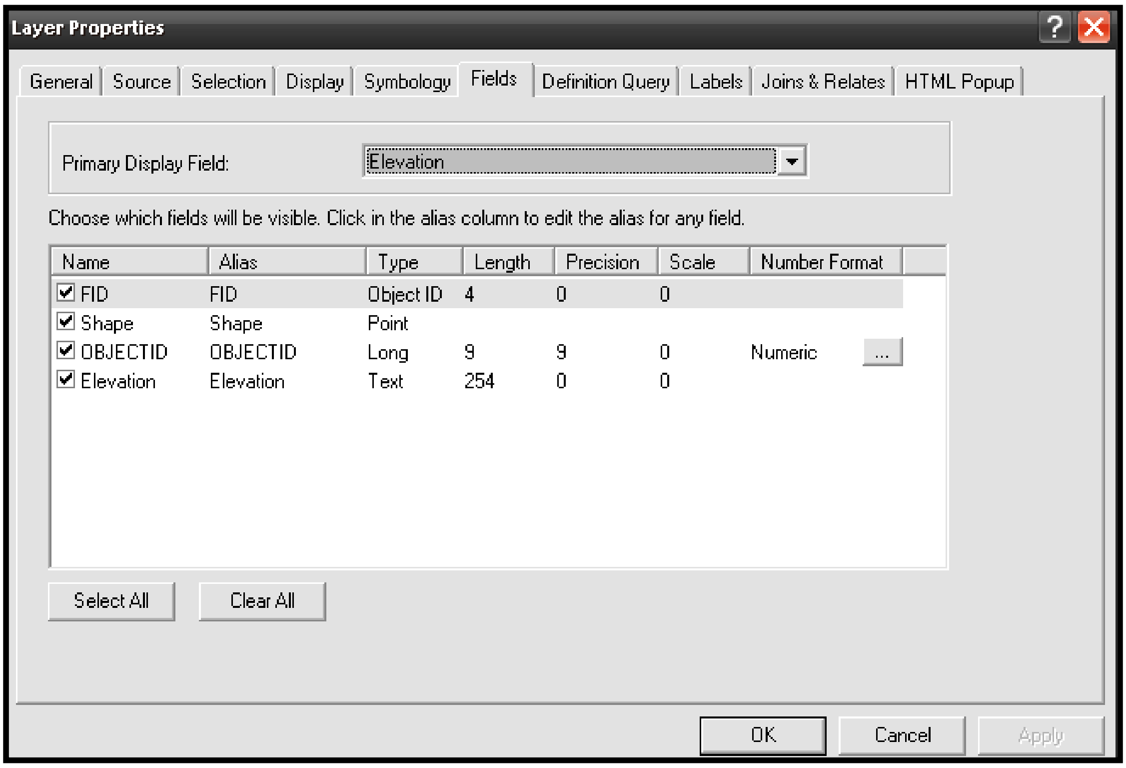

Figure 16: Data Fields for elevation point

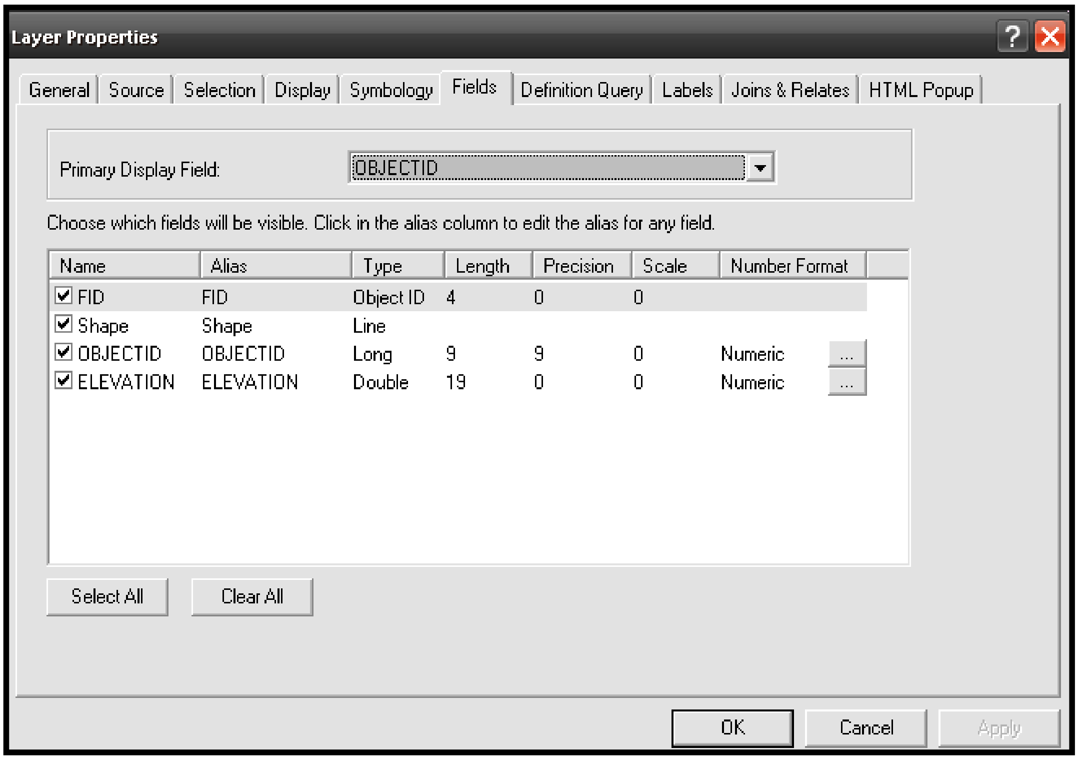

Figure 17: Data Fields for contour line.

Annex III

Control Valves Maps &Water Distribution Zones (Proposed Distribution)