The Hashemite Kingdom of Jordan
Ministry of Water and Irrigation

Millennium Challenge Corporation

PREPARATION OF THE FEASIBILITY STUDY AND ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR ZARQA GOVERNORATE WATER SYSTEM RESTRUCTURING AND REHABILITATION

INVESTMENT MASTER PLAN

September 2010 (Final)

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THE HASHEMITE KINGDOM OF JORDAN
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WATER AUTHORITY OF JORDAN

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1. INTRODUCTION

1.1 On 13th October 2009, Nicholas O'Dwyer Ltd and ACEPO were appointed by the Ministry of Water and Irrigation to proceed with the Consultancy Services for the Preparation of the Feasibility Study and Environmental and Social Impact Assessment for Zarqa Governorate Water System Restructuring and Rehabilitation. A copy of the Notice to Proceed is contained in Appendix 1.

1.2 The Terms of Reference for the project provide for the preparation of three linked reports on the restructuring and rehabilitation of the water supply system in the Zarqa Governorate. These are :

1. **Investment Master Plan – this document**
2. Priority Investment Programme
3. Feasibility Study

In the preparation of this report – the **Investment Master Plan** – a detailed investigation of the existing water supply system in Zarqa and how it operates was initially undertaken. This included the review of a number of relevant background documents relating to water supply, financial and socio - economic matters. A schedule of the background documents consulted are contained in Appendix 2. In addition, extensive surveys and investigations of the existing water supply system and its components were undertaken. These assessments along with future demand calculation formed the basis for the development of the strategic Master Plan and the detailed investment proposals.

The **Priority Investment Programme** which is compiled as a separate document contains details of the selection criteria for project prioritisation and set outs a list of the prioritised projects.

The further document, the **Feasibility Study** assesses the economic viability of the proposed projects.

The results and conclusions of the Preliminary Environmental and Social Impact Assessment Report which was submitted in early February 2010, were also taken into consideration in development of these reports.

1.3 This report contains a total of 11 sections. Section 2 provides a detailed description of the existing water supply arrangement in Zarqa and highlights the current water supply deficiencies within both the transmission system and the distribution network. A description of current and recent capital projects in Water Supply in the Zarqa Governorate is contained in Section 3. The strategic master plan proposals take account of all current and recent projects and their proposed scheduling.

Following an assessment of the Future Demand in Section 5, proposals for the restructuring of the overall water supply transmission and distribution system are developed in Sections 6 and 7.

Section 8 contains the proposed Strategic Master Plan and the proposed work packages and cost estimates are set out in Sections 9 and 10.

Section 11 contains our Conclusion Statements and Recommendations.

1.4 It should be noted that this project relates specifically to the restructuring and rehabilitation of the water supply delivery (transmission and distribution) system in the Governorate of Zarqa. A separate study is currently being undertaken by others on water sources and water treatment requirements in the Zarqa Governorate. Accordingly, the investigations carried out under this study included neither quantitative nor qualitative assessment of existing or new water sources.

1.5 This report should be read in conjunction with the separate set of Drawings in A3 size. The list of accompanying drawings is given in Appendix 9.

2. EXISTING WATER SUPPLY SYSTEM IN THE ZARQA GOVERNORATE

2.1 Introduction

This project provides for the restructuring/rehabilitation of the water supply transmission, storage and distribution infrastructure in the Zarqa Governorate. A separate investigation is being conducted on the existing well sources and treatment requirements for the system and our study excludes any considerations relating to sources, source development and water treatment requirements.

2.2 Description of Existing Water Supply System

Layout plans and a schematic representation of the existing water supply system serving the Zarqa Governorate are shown in the separate book of drawings which accompany this report, in Drawings nos. 20445-FIG-2.01 to 20445-FIG-2.09.

The main source for the Zarqa Water Supply System is the wellfield at Azraq. Here water from up to 17 No. wells is collected at Azraq Reservoir (Cap.12,000m^3, BL 566 masl). After disinfection, the water is pumped to the receiving tanks at Khaw Pumping Station (Cap. 12,000m^3, BL 599.60 masl), via a 600mm Rising Main. Current supply from this source is of the order to 46,375m^3/day (2008, average). The collection facility at Azraq is also used to supply local requirements.

Water is also sourced from the Corridor wells located on both sides of the governorate boundary with Mafraq. Water from the Corridor wells source, following disinfection, is transferred to Khaw Reservoir and Pumping station via a 600mm pipeline. Current supply to Zarqa from this source is of the order of 22,635m^3/day (2008, average).

A third supply to Khaw is provided from the Hallabat Wells. In this case water collected from the Hallabat wells is disinfected at Hallabat Reservoir (Cap. 1,000m^3, BL 597 masl). The water is then pumped into the 600mm rising main from the Corridor wells source for onward transmission to Khaw Reservoir and Pumping station. The current output from the Hallabat wells is 17,100m^3/day (2008, average). The collection reservoir at Hallabat (Cap. 1,000m^3, BL 620 masl) is also used to serve the Hallabat and Dulail areas by a separate set of pumps. A connection off the 600mm Corridor wells pipeline feeds Tafeh pumping station which boosts water to the Tafeh area and the higher level areas in Dulail.

Water from a well at Al Mashaqba also feeds to the Khaw Reservoir and Pumping station via a 600mm pipeline.

From Khaw Pumping Station water is transferred to Zarqa and Russaifah via 4 No. rising mains as follows:

1. A 400mm/300mm rising main transfers water to Hashmeya Reservoir (Cap. 1,000m^3, BL 621 masl). This feed is boosted at the existing Hashmeya Booster Station. Water from Hashmeya Reservoir feeds the Hashmeya town and environs via a 300mm distribution main. A separate 300mm main gravity main feeds Sukhna Reservoir (Cap. 1,000m^3, BL 572 masl), which in turn feeds Sukhna Town and environs.

   A 150mm feed from the Hashmeya Booster Station feeds Hararieh Power station and is further boosted at Sukhna pumping station to feed Bani and the Hashem towns.

   Also in this region, a separate well source supplies the Qunaya region via the new Qunaya Reservoir (Cap. 500m^3, BL 577 masl) and this system can also back feed to the 150mm supply main (from the Hashmeya and Sukhna Boosters) to serve Bani and the Hashem towns. The average 2008 output for the Qunaya Well was 1,435m^3/day.

2. A 700mm rising main from Khaw serves the Batrawi Reservoir (Cap. 4,000m^3, BL 651 masl). This reservoir serves the Batrawi Low Level area. The adjacent pumping station transfers water to the Zarqa High Reservoir (Cap 2,500m^3, BL 716 masl) which serves the Batrawi High Level Zone.

3. A further 400mm Rising main from Khaw transfers water to the Zarqa Pumping Station for onward transfer to Batrawi Reservoir and to Russaifah.

4. A 600m rising main from Khaw transfers water southwards to the Amman system but a connection off this main also serves the Awjan High Reservoir (Cap 9,520m^3, BL 695.50 masl) and the Russaifah High Reservoir (Cap

1,800m^3, BL 803 masl). These reservoirs serve separate zones within the Russaifah area.

The Tamween Wells also feed to this 600m Rising main along with supplying the Jabal Tarek area. The average 2008 output from the Tamween source was 6,800m^3/day.

The Awajan wells feed into the 600mm supply line from Khaw Pumping Station to the Awajan High Reservoir. The average 2008 output for the Awajan wells was 5,800m^3/day. The Awajan High Reservoir serves the local high level areas in Russaifah along with feeding the Awajan Low Reservoir (Cap. 1,600m^3, BL 640 masl) which in turn serves the adjacent lower level areas. A booster station at the Awajan High site supplies the Dwaik area. The Awajan Low Reservoir also connects to a 400mm feed from the Zarqa Pumping Station to serve other supply zones in Russaifah.

The collection reservoir at the Zarqa Pumping Station Site (Cap.4,500m^3, BL 572 masl) is supplied by the Zarqa Wells, following desalination; from the Hashmeya Wells and from Khaw although provision exists for the Khaw supply to be directly boosted at this station to save energy. The average 2008 output for the Zarqa wells and Hashmeya wells was 12,260 m^3/day and 9,400 m^3/day respectively. The Zarqa Pumps transfer water to Batrawi Reservoir (Cap. 4,000m^3, BL 651 masl) via 2 No. 400mm rising mains. A separate set of pumps at the Zarqa station delivers water to the general Russaifah Supply area via a 400mm rising/transfer main, providing feeds to both the Awajan High reservoir (Cap. 9,500m^3/day, BL 697.5 masl) and the Basateen Reservoir (Cap 500m^3/day BL 630.50 masl).

The 400mm rising main from the Zarqa Pumping Station to the Awajan High Reservoir is also boosted with a separate supply from the Awajan Wells.

The Basateen Reservoir is also supplied separately from the Russaifah/Basateen Wells sources. The average 2008 output from the Russaifah/Basateen wells was 11,200m^3/day. The Basateen pumps deliver water from the Basateen Reservoir via 600mm rising main to the Hitteen Reservoir (Cap 4,000m^3, BL 763.20 masl) which serves the Hitteen camp. A booster station at the Hitteen reservoir site delivers water to the adjacent Hitteen Tower (Cap. 300m^3, BL 764 masl) to serve the High Level areas of the Hitteen Camp.

The wells at Merhib supply Merhib Reservoir (Cap. 1,200m^3, BL 634 masl). The average 2008 output from the Merhib wells was 2,100m^3/day. The average 2008 output from the wells at Berein was 2,070m^3/day.

A pumping station at the Merhib Reservoir site supplies local requirements and also feeds onto Berein Reservoir (Cap. 1,200m^3, BL 867 masl) and to the Awajan High Reservoir (Cap. 9,500m^3, BL 697.50 masl) if required. Berein Reservoir supplies the local area and also feeds northwards to Sarout, Jerash and Alouk and westwards to Um Rumanneh Reservoir (Cap. 500m^3, BL 762.90 masl). Water from the Berein wells supplements the feed to the Um Rumanneh Reservoir which is also supplied from a local well, the output which is 56m^3/day (2008, average). Um Rumanneh Reservoir supplies the local area by gravity and a boosted supply feeds to a number of small areas including Rujm Alshouk, the Balqa towns and the higher parts of Um Rumanneh.

Sarout is also supplied from its own spring source, the 2008 output of which was 154m^3/day.

The springs at Alouk are used to supply Alouk town and its environs. A supply from Berein Reservoir can also be used to feed Alouk town. The average 2008 output from Alouk springs was 92m^3/day.

In the desert areas outside of the water supply zones, there are up to 11 No. groundwater sources which feed the local requirements. These range from 1m^3/day at Wadi Rutm to 76m^3/day at Wadi Ghudf. The total daily yield for the desert wells in 2008 amounted to 399m^3/day

The total average supply from all sources in the Zarqa Governorate in 2008, averaged at 137,728m^3/day as shown in the summary Table 2.1 hereunder.

Source Name	m^3/day	m^3/year
Azraq Wells	46,375	16,973,137
Corridor Wells	22,573	8,261,617
Hallabat Wells	17,053	6,241,567
Zarqa Wells	12,264	4,488,601
Tamween Wells	6,798	2,488,068
Awajan Wells	5,800	2,122,710
Russaifah/Basateen Wells	11,198	4,098,468
Hashmeya Wells	9,377	3,431,825
Qunaya Springs	1,432	523,932
Merhib Wells	2,094	766,263
Berein Wells	2,065	755,821
Um Rumanneh Wells	56	20,393
Sarout Springs	154	56,301
Alouk Springs	92	33,617
Desert Wells	399	146,034
Total	**137,728**	**50,408,354**

Table 2-1: Water Production from Zarqa Wells and Springs 2008.

2.3 Details of Existing Water Supply Components

Detailed Technical Information relating to the existing Installations at each of the project sites is contained in Appendix 3. Layout drawings for each of the installations are shown on Drg. Nos. 20445-Fig-2.20 to 20445-Fig-2.56.

2.3.1 Azraq Source and Pumping Installation

A. <u>Source, Reservoir and Pumping Station</u>

Ground water from the Azraq wellfield following a water treatment stage is collected at the existing ground level Reservoir at Azraq (Cap. 12,000m^3, BL 566 masl).

From the reservoir, the treated water is transferred to the main Zarqa supply area (Via Khaw Pumping Station) by two separate parallel pumping facilities. At the “Old” pumping station, 3 No. of the existing pumps are operational while at the “New” pumping station 5 No. (4 duty, 1 standby) pumps are currently operational. The 3 No. 850kW operational pumps at the “old” station are at the end of the service life and require replacement. The control panels contain old liquid start starters which would not meet current standards and all panels should be replaced.

At the “New” Pumping Station which was completed in 1993, 5 No. of the original 8 No. 550kW pumps are currently operational. These pumps are also at the end of their service life and should be replaced. The Control panels at the "New" station which also contain the old liquid start systems should also be replaced in full.

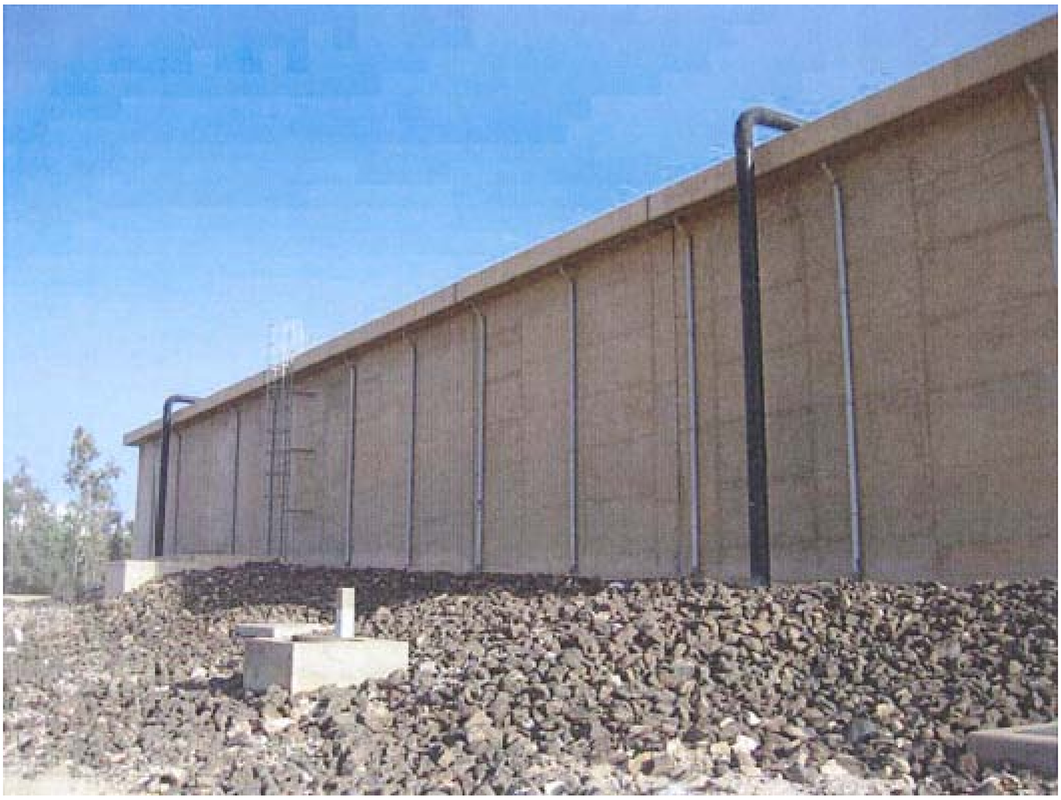


Plate 2-1: Azraq Reservoir (Cap. 12,000m^3, BL 566 masl).

B. Other Plant and Equipment

There is an existing chlorination (Gas) facility at this site.

C. Power Supply

The "old" pumping station is supplied from the JEPCO grid via 2 No. 2,500 kVA transformers with 660V secondary voltage.

The "new" pumping station is supplied from the JEPCO grid via 2 No. 1,000kVA and 2 No. 1,500 kVA transformers with 400V secondary voltage.

D. Instrumentation

Instrumentation such as level sensors, pressure sensors, flowmeters etc. were generally found to be defective or their accuracy questionable (refer to Appendix 3 for further details). It is recommended that all instrumentation is replaced.

E. SCADA/Telemetry/Communications

There is no SCADA/Telemetry system at this location.

There is a hardwired telephone link and good GSM coverage.

F. Civil Infrastructure

The old 5,000m^3 and 2,800m^3 reservoirs which are not in service are in poor condition and are no longer required. They should be disconnected from the existing site infrastructure and demolished. The existing buildings and site infrastructure are in fair condition, although some upgrading and rehabilitation works are required. It is proposed to demolish the old pumping station. The transfer of piping from the old pumping station to the new pumping station is currently underway. A brief status report on the existing buildings and site infrastructure is given hereunder in Table 2.2:

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing		✓	
Site Roads		✓	
12,000 m^3 Reservoir	✓		
5,000 m^3 Reservoir			(to be removed)
2,800 m^3 Reservoir			(to be removed)
Old Pumping Station			(to be removed)
New Pumping Station	✓		
Chlorination Building		✓	

Table 2-2: Azraq Facilities and Site Infrastructure.

2.3.2 Hallabat Source and Pumping Installation

A. Source, Reservoir and Pumping Station

Groundwater from the Hallabat wells is collected at the existing Hallabat Reservoir (Cap. 1,000m^3, BL 597 masl).

A photograph of the existing installation is given hereunder:

Plate 2-2: Hallabat Reservoir (Cap. 1,000m^3, BL 597 masl).

At the Hallabat Pumping Station, 2 No. 200kW pumps (2 No. Duty, No Standby) deliver water to Khaw Reservoir via a 400m rising main which links to the main 600mm transmission main from the Corridor Wells. A separate set of 315kW pumps (1 Duty, 1 Standby) delivers water to the local area and onto Tafeh.

Both sets of pumps are in reasonable condition as are the panels which can be retained. A standby pump should be provided for the supply system to Khaw.

B. Other Plant and Equipment

There is an existing chlorination (Gas) facility at this site which is in need of full rehabilitation/replacement.

C. Power Supply

The Pumping Station is supplied from the JEPCO grid via 2 No. 1,000kVA transformers with 400V secondary voltage.
There are no standby generators at this station.

D. Instrumentation

Instrumentation such as level sensors, pressure sensors, flowmeters etc. were generally found to be defective or their accuracy questionable (refer to Appendix 3 for further details). It is recommended that all instrumentation is replaced.

E. SCADA/Telemetry/Communications

There is an existing Telemetry system at this location. There is a hardwired telephone link and good GSM coverage.

F. Civil Infrastructure

The existing buildings are in need of partial rehabilitation and a brief status report site infrastructure is given hereunder:

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing	✓		
Site Roads	✓		
1,000 m^3 Reservoir	✓		
Pumping Station		✓	
Chlorination Building		✓	
Chlorination equipment			✓

Table 2-3: Hallabat Facilities and Site Infrastructure.

2.3.3 Tafeh Pumping Installation

A. Pumping Station

Water from the Corridor and Hallabat wellfields is transferred to Khaw via a 600mm diameter pipeline. At Tafeh, a branch connection from this pipeline transfers water into a 200 m3 holding tank. Here, 2 No. 90kW pumps (1 Duty, 1 Standby) deliver water to the Tafeh area and the higher location in Dulail.

Both the pumps and control panel are in acceptable condition and can be retained.

A photograph of the existing installation is given hereunder:

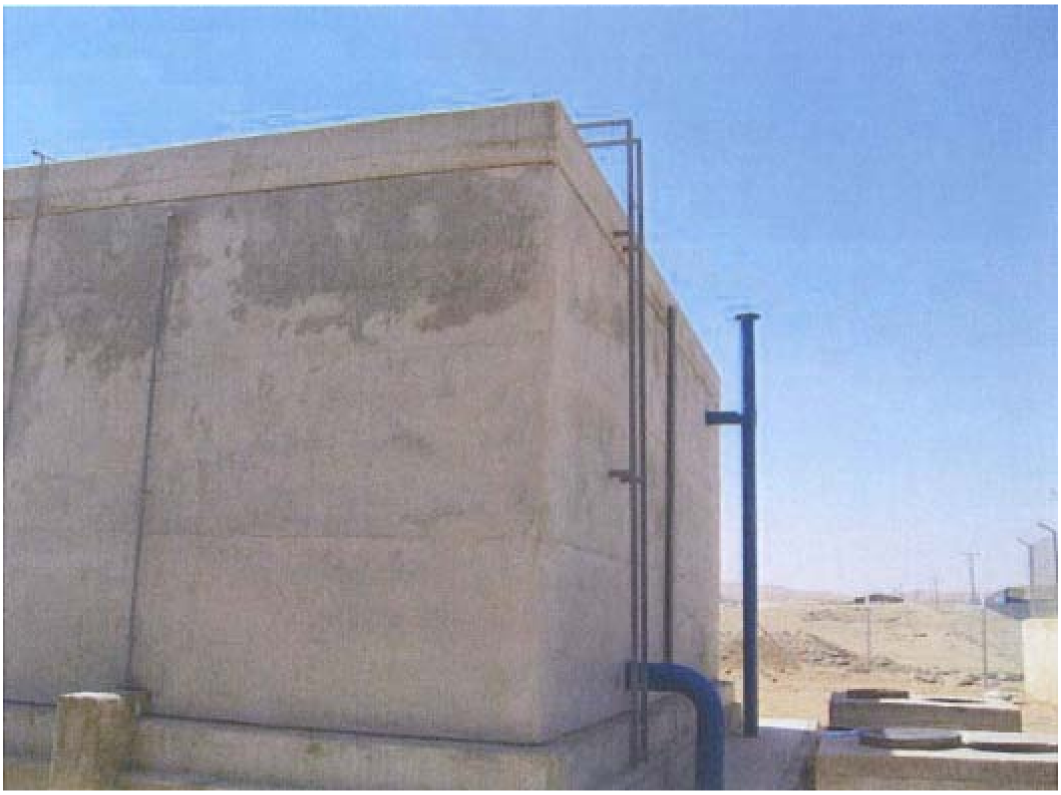


Plate 2-3: Tafeh Reservoir (Cap. 200m^3, BL 598 masl).

B. Other Plant and Equipment

There is an existing chlorination (Gas) facility at this site.

C. Power Supply

The station is supplied from the JEPCO grid via 1 No. 630kVA transformer with 400V secondary voltage. There is no standby generator at the site.

D. Instrumentation

Instrumentation such as pressure sensors, flowmeters etc. were found to be defective or their accuracy questionable. The reservoir level sensor was operational. It is recommended that all instrumentation is replaced (refer to Appendix 3 for further details).

E. SCADA/Telemetry/Communications

There is no SCADA/Telemetry system at this location.

There is a hardwired telephone link and good GSM coverage.

F. Civil Infrastructure

The existing buildings and site infrastructure are in fair condition as indicated hereunder:

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing		✓	
Site Roads		✓	
200 m^3 Reservoir	✓		
Pumping Station		✓	
Chlorination Building		✓	

Table 2-4: Tafeh Facilities and Site Infrastructure.

2.3.4 Khaw Reservoir and Pumping installation

A. Reservoir and Pumping Station

The supplies from the Azraq, Hallabat and Corridor Well sources are collected in the 12,000m^3 Reservoir (BL 599.60 masl) at Khaw. The old supply from Za'atari is now replaced with a feed from a well at Al Mashaqba. The old 4,000m^3 is in poor condition and not currently in service.

A photograph of the existing installation is given hereunder:

Plate 2-4: Khaw Reservoir (Cap. 12,000m^3, BL 599.60 masl).

There are two separate pumping installations at Khaw as follows:

1. **New Pumping Station**

   This station draws water from the 12,000m^3 Reservoir and pumps to the Batrawi Reservoir, the Zarqa Pumping Station and to Hashmeya.

   There are 6 No. operational pumps at the station, ranging in power output from 355kW to 185kw as follows:

   2 No. 355kW units – one with Liquid Starters
   2 No. 320kW units – one with Liquid Starters
   1 No. 200kW unit with ATR Starter
   1 No. 185kW unit with ATR Starter
   The power supply limits the operation to a maximum of 4 No. pumps. The control panel with liquid starters should be replaced.

2. **Old Pumping Station**

   This installation also draws from the 12,000m^3 reservoir and pumps to the Amman network.

   The 4 No. remaining operational pumps are in continuous duty. These comprise:

   2 No. 710kW units with ATR Starters
   1 No. 663kW unit with ATR Starter
   1 No. 420kW unit with ATR Starter

   2 No. additional pumping units are required to provide 50% standby and this opportunity should be used to replace the existing Control/Starter Panel to provide for all 6 No. units.

B. <u>Other Plant and Equipment</u>

There is a new chlorination facility at this site.

C. Power Supply

The new pumping station is supplied from the JEPCO grid via 2 No. transformers with 400V secondary voltage.

The old station is supplied with power via 6 No. 100kVA and 1 No. 1500kVA transformers with 400V secondary voltage. There are no standby generators at the site.

D. Instrumentation

Some of the instrumentation was found to be defective or their accuracy questionable. 3 No. flowmeters were found to be operating correctly along with the 1 No. level monitor (refer to Appendix 3 for further details). It is recommended that all defective instrumentation is replaced.

E. SCADA/Telemetry/Communications

There is a Telemetry link between Khaw, Corridor Well No. 6 and the Hallabat Pumping Station.

F. Civil Infrastructure

The old 4,000m^3 reservoir and the old pumping station are in poor condition and should be rehabilitated/replaced. There is a leak in the 12,000m^3 reservoir. The existing site roads and fencing is in fair condition as indicated in the status report hereunder:

Buildings and Facilities	Status		
	Acceptable	**Minor Rehab.**	**Full Rehab. / Replacement**
Gates & Fencing		✓	
Site Roads		✓	
12,000 m^3 Reservoir		✓	
4,000 m^3 Reservoir			✓
New Pumping Station	✓		
Old Pumping Station			✓

Table 2-5: Khaw Facilities and Site Infrastructure.

2.3.5 Zarqa Reservoir and Pumping Installation

A. <u>Reservoir and Pumping Station</u>

This installation is supplied from the Zarqa Desalination Plant, Khaw Pumping Station and Hashmeya Wells. The existing collection reservoir (Cap. 4,500m^3, BL 572 masl) acts as a blending station for these supplies.

It is possible to bypass the reservoir to feed directly to the pumping stations. The old 500m^3 reservoir is in poor condition and currently out of service.

Plate 2-5: Zarqa Pumping Station and Reservoir (Cap. 4,500m^3, BL 572 masl).

There are two separate installations at the site as follows:

1. **Internal Pumping Station**

   This station delivers water to Batrawi Reservoir and to the local Zarqa area. There are four pumps (3 No. 160kW and 1 No. 132 kW) at this station and all four are required to satisfy current requirements. There is no standby provision and the Control Panel/Starters are in poor condition.

2. **External Pumping Station**

   This station delivers water to Russaifah and to the local Zarqa area. There are 7 No. operational pumps at this station but there are only 5 No. starter units operational at present. Three of the pumps (500kW) are used to serve the Russaifah area and two (200kW and 160kW) are used to serve local Zarqa requirements. In general the Control Panel and Starters are in poor condition and should be replaced.

B. Other Plant and Equipment

There is an existing chlorination (Gas) facility at this site.

C. Power Supply

The station is supplied from the JEPCO grid via 4 No. 1,000kVA transformers with 400V secondary voltage.

There are no standby generators at this site.

D. Instrumentation

3 No. flowmeters were found to be operational and 1 No. level monitor. It is recommended that all defective instrumentation is replaced (refer to Appendix 3 for further details).

E. SCADA/Telemetry/Communications

There is no SCADA/Telemetry system at this location.

There is a hardwired telephone at the site and good GSM coverage.

F. Civil Infrastructure

The existing buildings and site infrastructure are in need of substantial rehabilitation as indicated in the status report below. The existing 500m3 reservoir is out of service and potentially hazardous, and should be demolished. Plans already exist to replace the pumping station.

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing			✓
Site Roads within site			✓
4,500 m^3 Reservoir	✓		
500 m^3 Reservoir			(to be removed)
Internal Pumping Station			✓
External Pumping Station			✓
Chlorination Building		✓	

Table 2-6: Zarqa Facilities and Site Infrastructure.

2.3.6 Tamween Source and Pumping installation

A. Source, Reservoir and Pumping Plant

Groundwater from the existing Tamween wells is collected at a 1,000m^3 Collection Tank at the Pumping Station site.

3 No. pumps (2 No. 250kW, 1 No. 220kW and 1 No. 160kW) deliver water to the 600mm transfer main from Khaw to Amman and to the Russaifah High Reservoir. A separate supply is provided to the Jabel Tarek area.

Plate 2-6: Tamween Reservoir (Cap. 1,000m^3, BL 611.50 masl).

In general the existing pump sets and Control/Starter panels are in acceptable condition. However there is currently no available standby units. It is recommended that 2 No. standby units together with Control Panels are provided.

B. Other Plant and Equipment

There is an existing chlorination (Gas) facility at this site.

C. Power Supply

The station is supplied from the JEPCO grid via 2 No. transformers with 400V secondary voltage.

D. Instrumentation

Instrumentation such as level sensors, pressure sensors, flowmeters etc. were generally found to be operational (refer to Appendix 3 for further details).

E. SCADA/Telemetry/Communications

There is no SCADA/Telemetry system at this location.

There was no hardwired telephone but GSM coverage is good.

F. Civil Infrastructure

The existing buildings and site infrastructure are generally in good condition as indicated in status report below:

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing	✓		
Site Roads	✓		
1,000 m^3 Reservoir	✓		
Pumping Station	✓		
Chlorination Building	✓		

Table 2-7: Tamween Facilities and Site Infrastructure.

2.3.7 Merhib Source, Reservoir and Pumping Installation

A. Source, Reservoir and Pumping Station

Groundwater from the existing Merhib Wells is collected at a 1,000m^3 collection tank at the Pumping Station site.

5 No. Pump sets (4 Duty, 1 Standby) transfer water to the Berein Reservoir (Cap. 1,200m^3, BL 869 masl) and to the Awajan High Reservoir (Cap. 9,500m^3, BL 697.50 masl). The 5 No. existing pumpsets at this installation comprise 1 No. 55kW, 2 No. 75kW, 1 No. 110kW and 1 No. 132kW. At present water is transferred to Berein Reservoir only.

Plate 2-7: Merhib Reservoir (Cap. 1,000m^3, BL 633.50 masl).

B. Other Plant and Equipment

There is an existing Water Treatment Plant including Sand Filtration and Chlorination at this site.

C. Power Supply

The station is supplied from the JEPCO grid via 1 No. 1,000kVA transformer with 400V secondary Voltage.

D. Instrumentation

3 No. existing Ultrasonic Flow Meters, two on the existing discharge lines and one on the feed line from Well No. 2 are operational. There is no flow meter on the line from the other well source and there is no level monitor in the existing collection tank (refer to Appendix 3 for further details).

E. SCADA/Telemetry/Communications

There is no SCADA/Telemetry system at this location.

There is a hardwired telephone and good GSM coverage.

F. Civil Infrastructure

The Pumping Station and well installations are in fair condition as indicated in the status report hereunder:

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing		✓	
Site Roads		✓	
1,000 m^3 Reservoir	✓		
Pumping Station		✓	
Chlorination Building		✓	

Table 2-8: Merhib Facilities and Site Infrastructure.

2.3.8 Um Rumanneh Source and Pumping Installation

A. Source and Pumping Station

Groundwater from the existing well source is collected in the existing 500m^3 Reservoir at the Pumping Station site.

There are 3 No. operational pump sets at this site (1 No. 200kW, 1 No. 75kW and 1 No. 132kW which acts as a standby).
There are two separate discharge lines, one to the local distribution and the other to Berein and Jerks.

The existing installed plant is in acceptable condition.

B. Other Plant and Equipment

There is an existing chlorination (Gas) facility at this site.

C. Power Supply

The pumping station is supplied from the JEPCO grid via 1 No. 250kVA transformer with 400V secondary voltage.

D. Instrumentation

The Ultrasonic Flow Meter on the line to Um Rumanneh is operational. There is no flow meter on the line to Berein or there is no level monitor in the 500m^3 Reservoir (refer to Appendix 3 for further details).

Plate 2-8: Um Rumanneh Reservoir (Cap. 500m^3, BL 796.90 masl).

E. <u>SCADA/Telemetry/Communications</u>

There is no SCADA/Telemetry system at this location.

There is a hardwired telephone and good GSM coverage.

F. <u>Civil Infrastructure</u>

The existing buildings and site infrastructure are in poor condition as indicated in the status report hereunder:

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing			✓
Site Roads			✓
500 m^3 Reservoir	✓		
Pumping Station			✓

Chlorination Building			✓

Table 2-9: Um Rumanneh Facilities and Site Infrastructure.

2.3.9 Sarout Source, Pumping Installation and Reservoir

A. <u>Source, Pumping Station and Reservoir</u>

Groundwater from the existing springs is collected in an existing 100m^3 storage tank at the pumping station site.

2 No. 55kW pump sets (1 Duty, 1 Standby) transfer water to the existing 400m^3 Reservoir (Cap. 400m^3, BL 769 masl) located on an elevated site for distribution to the Sarout town. The 400m^3 Reservoir can also be served by gravity from the Berein Reservoir (Cap 1,200m^3, BL 867 masl).

Plate 2-9: Sarout Reservoir (Cap. 400m^3, BL 769 masl).

The existing pumping plant and control equipment is in poor condition and should be replaced.

B. <u>Other Plant and Equipment</u>

There is an existing Chlorine facility (Gas) at this site.

C. Power Supply

The pumping station is supplied from the JEPCO grid via 1 No. 250 kVA transformer with 400V secondary voltage.

There is no standby generator at the site.

D. Instrumentation

There are no operational flow meters or level monitors at the site (refer to Appendix 3 for further details).

E. SCADA/Telemetry/Communications

There is no SCADA/Telemetry system at this location.

There is no hardwired telephone but GSM coverage is good.

F. Civil Infrastructure

The existing buildings and site infrastructure are in need of substantial rehabilitation as indicated in the status report.

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing			✓
Site Roads			✓
500 m^3 Reservoir	✓		
Pumping Station			✓
Chlorination Building			✓

Table 2-10: Sarout Facilities and Site Infrastructure.

2.3.10 Alouk Source and Pumping Installation

A. Source and Pumping Station

Groundwater for the existing Alouk springs is collected in an existing 85m^3 tank. 2 No. 37kW pump sets (1 Duty, 1 Standby) transfer water to the local distribution system. The village of Alouk can also be back fed from the Berein network. The existing pumps are located out of doors and in very poor condition.

Plate 2-10: Alouk Reservoir (Cap. 85m^3, BL 604 masl).

B. Other Plant and Equipment

There is an existing chlorination (Gas) facility at this site, in poor condition.

C. Power Supply

The pumping station is supplied from the JEPCO grid via 1 No. 100kVA transformer with 400V secondary voltage.

There is no standby generator at the site.

D. Instrumentation

There are no operational flow meters or level monitors at the site (refer to Appendix 3 for further details).

E. SCADA/Telemetry/Communications

There is no SCADA/Telemetry system at this location.
There is no hardwired telephone but GSM coverage is good.

G. Civil Infrastructure

The existing buildings and site infrastructure are in poor condition and in need of substantial rehabilitation / replacement as indicated in the status report.

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing			✓
Site Roads			✓
85 m^3 Reservoir			✓
Pumping Station			✓
Chlorination Facility			✓

Table 2-11: Alouk Facilities and Site Infrastructure.

2.3.11 Qunaya Sources and Treatment Plant

A. Sources and Treatment Plant

Groundwater from the Qunaya Springs is collected in a $100m^3$ storage tank and transferred to the adjacent treatment plant where it is subjected to treatment by Ultrafiltration.

A separate raw water supply from Mafraq is treated for iron removal.

The treated water is pumped to the new Reservoir (Cap. $500m^3$, BL 577 masl). A 132kW Pumpset currently delivers water to Qunaya Reservoir.

(A 75kW pump set can act as an emergency standby but does not have a separate starter panel). A separate pump (160kW) at the station supplies water to Mafraq.

B. Other Plant and Equipment

There is a chlorination plant at the treatment plant which is in need of minor rehabilitation.

C. Power Supply

The treatment plant is supplied from the JEPCO grid via 1 No. 1,500kVA transformer with 400V secondary voltage.

Plate 2-11: Qunaya Treatment Plant

D. Instrumentation

There are no operational flowmeters at the pumping station site (refer to Appendix 3 for further details).

E. SCADA / Telemetry / Communications

There is no hardwired telephone but GSM coverage is good.

H. Civil Infrastructure

The existing buildings and site infrastructure at the Springs are in need of substantial rehabilitation as indicated in the status report.

I. Spring

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing			✓
Site Roads			✓

II. Pumping Station

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing	✓		
Site Roads	✓		
100 m^3 Reservoir	✓		
Pumping Station	✓		
Chlorination Facility		✓	

Table 2-12: Qunaya Facilities and Site Infrastructure.

2.3.12 Qunaya Reservoir

F. Reservoir

The new Reservoir (Cap. 500m^3, BL 577 masl), is located at a separate elevated site from where the treated water is distributed to the Qunaya network.

G. Other Plant and Equipment

There is no chlorination plant at the Reservoir site.

H. Power Supply

The site is supplied from the JEPCO grid.

Plate 2-12: Qunaya Reservoir (Cap. 500m^3, BL 577 masl).

I. Instrumentation

The 2 No. electrical float switches and flow meters at the 500m^3 reservoir are operational (refer to Appendix 3 for further details).

J. SCADA/Telemetry/Communications

There is no hardwired telephone but GSM coverage is good.

I. Civil Infrastructure

The existing buildings and site infrastructure are in good condition as indicated in the status report.

I. Reservoir

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing	✓		
Site Roads	✓		
500 m^3 Reservoir	✓		

Table 2-13: Qunaya Facilities and Site Infrastructure.

2.3.13 Hashmeya Pumping installation

A. <u>Pumping Station</u>

This pumping station is fed from Khaw Pumping Station via a 300mm Rising Main.

4 No. pump sets (2 Duty, 2 Standby) transfer water to Hashmeya Reservoir (Cap. 1,500m^3, BL 621 masl) or direct to Hashmeya and the second feed is to the Hararieh Power Station and Sukhna Booster Station.

The capacity of the pumps is as follows:

1 No. 132 kW
2 No. 110 kW
1 No. 75 kW

The condition of the pump sets and Control Panels is poor and should be replaced. Groundwater from the Hashmeya wells is now delivered back to the Zarqa Reservoir (and Pumping Station) via an old 400mm main.

A photograph of the existing installation is given hereunder:

Plate 2-13: Hashmeya Pumping Station (BL 638 masl).

B. Other Plant and Equipment

There is a manual chlorination (Gas) system on the well supply to Zarqa Pumping Station.

C. Power Supply

The pumping station is supplied from the JEPCO grid via 1 No. 1,500kVA transformer with 400V secondary voltage. There is no standby generator at the site.

D. Instrumentation

None of the flowmeters or level monitors etc. were found to be in an operational condition (refer to Appendix 3 for further details).

E. SCADA/Telemetry/Communications

There is no hardwired telephone but GSM coverage is good.

F. Civil Infrastructure

The condition of buildings and site infrastructure is very poor as indicated in the status report below:

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing			✓
Site Roads			✓
Pumping Station			✓
Chlorination Facility			✓

Table 2-14: Hashmeya Pumping Station Facilities and Site Infrastructure.

2.3.14 Sukhna Pumping Station

A. Pumping Plant

This pumping station is supplied from the Hashmeya pumping station via a 150mm rising main. 2 No. pump sets – 1 No. 55kW and 1 No. 90kW – (1 Duty, 1 Standby) deliver water directly to a network serving Bani and the Hashem towns. The entire installation is in poor condition and should be replaced.

A photograph of the existing installation is given hereunder:

Plate 2-14: Sukhna Pumping Station (BL 490 masl).

B. <u>Other Plant and Equipment</u>

There is an existing chlorination (Gas) facility at the site, in very poor condition.

C. <u>Power Supply</u>

The pumping station is supplied from the JEPCO grid via 1 No. 1,000kVA transformer with 400V secondary voltage. There is no standby generator at the site.

D. <u>Instrumentation</u>

There is a flowmeter in the discharge line which is not reading correctly. All instrumentation is to be replaced (refer to Appendix 3 for further details).

E. <u>SCADA/Telemetry/Communications</u>

There is a hardwired telephone and GSM coverage is good.

F. <u>Civil Infrastructure</u>

The buildings and site facilities are in very poor condition as indicated in the status report below:

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing			✓
Site Roads			✓
Pumping Station			✓
Chlorination Facility			✓

Table 2-15: Sukhna Pumping Station Facilities and Site Infrastructure.

2.3.15 Basateen Reservoir and Pumping Installation

A. <u>Reservoir and Pumping Station</u>

The Basateen Reservoir (Cap. 500m^3, BL 630.50 masl) receives supplies from the Russaifah/Basateen Wells and from Zarqa Pumping Station.

3 No. 225kW – 313kW pump sets (2 Duty, 1 Standby) delivers water to the Hitteen Reservoir (Cap. 4,000m^3, BL 763.20 masl) and directly to the networks serving Jabel Fasal, Al Rasheed and Ja'afar.

The other 3 No. 225kW-320kW pump sets (2 Duty, 1 Standby) serve other parts of the Russaifah network.

Plate 2-15: Basateen Reservoir (Cap. 500m^3, BL 630.50 masl).

The overall condition of the pumping installation and control system is poor and should be replaced.

B. Other Plant and Equipment

There is an existing chlorine (Gas) dosing facility at the site, in poor condition. Dosing is manually controlled.

C. Power Supply

The pumping station is supplied from the JEPCO grid via 1 No. 1,500kVA transformer with 400V secondary voltage.

D. Instrumentation

The existing flow meters are operational as are the level monitors in the 500m^3 Reservoir (refer to Appendix 3 for further details).

E. SCADA/Telemetry/Communications

There is no SCADA system at this site. There is a hard wired telephone link and good GSM coverage.

F. Civil Infrastructure

The existing buildings are in reasonably good condition - requiring a basic level of rehabilitation. The gates, fencing, roads and site infrastructure generally requires full rehabilitation.

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing			✓
Site Roads			✓
500 m^3 Reservoir	✓		
Pumping Station			✓
Chlorination Facility			✓

Table 2-16: Basateen Pumping Station Facilities and Site Infrastructure.

2.3.16 Awajan High Reservoir and Pumping Installation

A. Reservoir and Pumping Station

The existing reservoirs (Cap. 4,500m^3 and 6,300m^3, BL 695.50 masl) are fed from the 600mm rising main from Zarqa Pumping Station, from the Awajan wells (via the 600mm Rising Main) and from the Merhib Pumping Station (if required).

The Awajan Reservoir serves the local Awajan supply area and feeds into the existing Awajan Low Reservoir (Cap. 1,600m^3, BL 640 masl).

The Awajan Pumping Station serves the local high level area from 2 No. 30kW pumpsets (1 Duty, 1 Standby) which are externally located and in very poor condition.

B. Power Supply

The existing pumps are served from the local JEPCO network. There is no standby generator at the site.

C. Instrumentation

There are 3 No. operational flow meters at this site and 1 No. level sensor in the new reservoir.

Plate 2-16: Awajan High Reservoir (Cap. 6,500m^3, BL 695.50 masl).

D. Other Plant and Equipment

There are no disinfection facilities at this site.

E. <u>SCADA/Telemetry/Communications</u>

There is no SCADA system at this site. There is a hard wired telephone link and good GSM coverage.

F. <u>Civil Infrastructure</u>

The new reservoir and associated siteworks are in good condition. The old reservoir and associated infrastructure is in fair condition. The Pumping station is in poor condition.

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing	✓		
Site Roads	✓		
6,300 m^3 Reservoir	✓		
4,500 m^3 Reservoir		✓	
Pumping Station			✓

Table 2-17: Awajan High Reservoir Facilities and Site Infrastructure.

2.3.17 Batrawi Reservoir and Pumping Installation

A. <u>Reservoir and Pumping Station</u>

The existing Batrawi Reservoir (Cap. 4,000m^3, BL 651 masl) is supplied via a 700mm Rising main from Khaw Pumping Station and via 2 No. 400mm Rising mains from Zarqa Pumping Station. A new 14,000m^3 reservoir is currently under construction at the site.

Plate 2-17: Batrawi Reservoir (Cap. 14,000m^3, BL 651.80 masl).

The existing pump plant comprises 2 No. (1 Duty, 1 Standby) 132kW pumpsets which deliver water to the new Zarqa High Reservoir (Cap. 2,500m^3, BL 716 masl) and direct to the local high level supply network (if required).

B. Other Plant and Equipment

There is a Chlorination (Gas) dosing facility at the site which works on automatic in proportion to flow.

C. Power Supply

This pumping station is supplied from the JEPCO grid via 1 No. 1,000kVA transformer with 400V secondary voltage.

D. Instrumentation

All flowmeters, level monitors etc. were found to be operational.

E. SCADA/Telemetry/Communications

There is no SCADA system at this site. There is a hard wired telephone link and good GSM coverage.

There is a new MIMIC Display unit in Pumping Station giving details of flow and reservoir levels etc.

F. Civil Infrastructure

The existing buildings are in good condition. The site infrastructure should be improved when the current construction project is complete.

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing	✓		
Site Roads	✓		
4,000 m^3 Reservoir	✓		
14,000 m^3 Reservoir	✓		
Pumping Station	✓		
Chlorination Facility	✓		

Table 2-18: Batrawi Reservoir Facilities and Site Infrastructure.

2.3.18 Zarqa High Reservoir

A. <u>Reservoir</u>

The new Zarqa High Level Reservoir (Cap. 2,500m^3, BL 716 masl) is supplied from the Batrawi Pumping Station.

The new reservoir provides a gravity supply to the local high level areas including Batrawi high, Ma’soon etc.

B. <u>Other Facilities</u>

There are no chlorination facilities at this site.

C. <u>Power Supply</u>

This site is supplied from the JEPCO grid.

There is no standby generator at this site.

Plate 2-18: Zarqa High Reservoir (Cap. 2,500m^3, BL 716 masl).

D. Instrumentation

New flow meters and level monitoring equipment has been provided.

E. SCADA/Telemetry/Communications

There is no SCADA system at this site. There is a hard wired telephone link and good GSM coverage.

F. Civil Infrastructure

The new reservoir and site infrastructure is in good condition.

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing	✓		
Site Roads	✓		
2,500 m^3 Reservoir	✓		

Table 2-19: Zarqa High Reservoir Facilities and Site Infrastructure.

2.3.19 Russaifah High Reservoir and Pumping Installation

A. Reservoir and Pumping Station

The construction of the new Russaifah High Reservoir (Cap. 1,800m^3, BL 803 masl) and Pumping Station were completed in 2007.

Plate 2-19: Russaifah High Reservoir (Cap. 1,800m^3, BL 803 masl).

The reservoir is supplied primarily from a 400mm feed from the 600mm Rising Main from Khaw Pumping Station to Amman. The reservoir can also be supplied from the Basateen Pumping Station.

The new pumping station at the reservoir site comprises 2 No. (1 Duty, 1 Standby) pump sets which can feed the local high level area including Hai Gafar.

B. Other Plant and Equipment

There is no disinfection equipment at this site.

C. Power Supply

Power supply to this site is from the JEPCO grid. There is no standby generator at this site.

D. Instrumentation

New flow meters and level monitoring equipment are all operational.

E. SCADA/Telemetry/Communications

There is no SCADA system at this site. There is a hard wired telephone link and good GSM coverage.

F. Civil Infrastructure

The new reservoir, pumping station and site infrastructure are in good condition.

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing		✓	
Site Roads		✓	
1,800 m^3 Reservoir	✓		
Pumping Area	✓		
Control Room	✓		

Table 2-20: Russaifah High Reservoir Facilities and Site Infrastructure.

2.3.20 Russaifah Low Level Reservoir

A. Reservoir

The construction of the Russaifah Low Reservoir (Cap. 6,200, BL 751 masl) was completed in 2007.

The reservoir is supplied from the Russaifah High Reservoir (Cap. 1,800m^3, BL 803 masl). The Russaifah Low Reservoir provides a gravity supply to the Russaifah City area.

B. Other Plant and Equipment

There are no disinfection facilities at this site.

C. Power Supply

Power supply is from the JEPCO grid. There is no standby generator at this site.

Plate 2-20: Russaifah Low Reservoir (Cap. 6,200m^3, BL 751 masl).

D. Instrumentation

New flow meters and level monitoring equipment are all operational.

E. SCADA/Telemetry/Communications

There is no SCADA system at this site. There is a hard wired telephone link and good GSM coverage.

F. Civil Infrastructure

The new reservoir and site infrastructure is in good condition.

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing	✓		
Site Roads	✓		
6,200 m^3 Reservoir	✓		

Table 2-21: Russaifah Low Reservoir Facilities and Site Infrastructure.

2.3.21 Hashmeya Reservoir

A. Reservoir

The construction of the Hashmeya Reservoir (Cap. 1,500m^3, BL 621 masl) was completed in 2009.

A photograph of the existing installation is given hereunder:

Plate 2-21: Hashmeya Reservoir (Cap. 1,500m^3, BL 621 masl).

The reservoir is supplied from the Khaw Pumping Station with inline boosting at the Hashmeya Pumping Station.

The Hashmeya Reservoir provides a gravity supply to Hashmeya Town and environs and a gravity bulk supply to the Sukhna Reservoir (Cap. 1,000 m^3, BL 572 masl) for distribution to the Sukhna area.

B. Other Plant and Equipment

There are no disinfection facilities at this site.

C. Power Supply

Power supply will be from the JEPCO grid. There is no standby generator at this site. This site currently has no power supply.

D. Instrumentation

Two new flow meters and level monitoring equipment are operational. There is no flow meter on the outlet pipeline to Hashmeya Town.

E. SCADA/Telemetry/Communications

There is no SCADA system at this site. There is a hard wired telephone link and good GSM coverage.

F. Civil Infrastructure

The new reservoir and site infrastructure is in good condition.

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing	✓		
Site Roads	✓		
1,500 m^3 Reservoir	✓		

Table 2-22: Hashmeya Reservoir Facilities and Site Infrastructure.

2.3.22 Sukhna Reservoir

A. Reservoir

The construction of the Sukhna Reservoir (Cap. 1,000m^3, BL 572 masl) was completed in 2009.

The reservoir is supplied from the new Hashmeya Reservoir (Cap. 1,500m^3, BL 621 masl).

The Sukhna Reservoir provides a gravity supply to Sukhna Town and environs.

B. Other Plant and Equipment

There are no disinfection facilities at this site.

C. Power Supply

Power supply is from the JEPCO grid. There is no standby generator at this site.

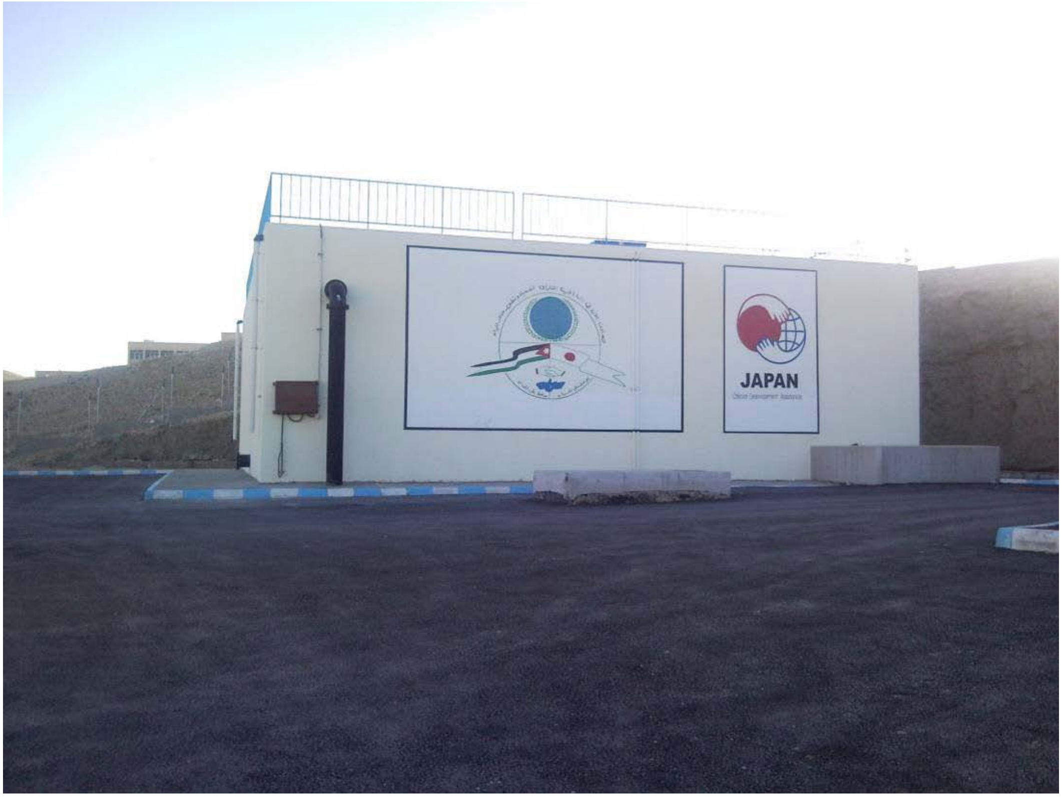


Plate 2-22: Sukhna Reservoir (Cap. 1,000m^3, BL 572 masl).

D. Instrumentation

New flow meters and level monitoring equipment are all operational.

E. SCADA/Telemetry/Communications

There is no SCADA system at this site. There is a hard wired telephone link and good GSM coverage.

F. Civil Infrastructure

The new reservoir and site infrastructure is in good condition.

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing	✓		
Site Roads	✓		
1,000 m^3 Reservoir	✓		

Table 2-23: Sukhna Reservoir Facilities and Site Infrastructure.

2.3.23 Hitteen Reservoir and Water Tower

A. <u>Reservoir and Tower</u>

The main reservoir which is at ground level (Cap. 4,000m^3, BL 763.20 masl) is supplied via a 300mm Rising Main from the Basateen Pumping Station. The main 350mm outlet pipeline serves the main part of the Hitteen Camp.

A small pumpset (1 duty, 1 standby) delivers water to the adjacent Hitteen Tower (Cap. 300m^3, BL 764 masl). The 200mm outlet main from the tower serves the higher parts of the Hitteen Camp.

A photograph of the existing installation is given hereunder:

Plate 2-23: Hitteen Tower & Reservoir (Cap. 300m^3 & 1,000m^3, BL 764 & 763.20 masl).

B. <u>Other Plant and Equipment</u>

There are no disinfection facilities at this site.

C. <u>Power Supply</u>

Power supply is from the JEPCO grid. There is no standby generator at this site.

D. <u>Instrumentation</u>

New flow meters and level monitoring equipment are all operational.

E. SCADA/Telemetry/Communications

There is no SCADA system at this site. There is a hard wired telephone link and good GSM coverage.

F. Civil Infrastructure

The new reservoir and site infrastructure are in fair condition.

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing	✓		
Site Roads	✓		
100 m^3 Tower	✓		
1,000 m^3 Reservoir	✓		

Table 2-24: Sukhna Reservoir Facilities and Site Infrastructure.

2.3.24 Awajan Low Reservoir

A. Reservoir

The existing reservoir (Cap. 1,600m^3, BL 640 masl) is fed from the Awajan High Reservoir via a 200mm gravity main. The Awajan Low reservoir feeds the existing distribution system serving the low level areas of Awajan.

B. Other Plant and Equipment

There are no disinfection facilities at this site.

C. Power Supply

Power supply is from the JEPCO grid. There is no standby generator at this site.

D. Instrumentation

All instrumentation is new and in good condition.

E. SCADA/Telemetry/Communications

There is no SCADA system at this site. There is a hard wired telephone link and good GSM coverage.

Plate 2-24: Awajan Low Reservoir (Cap. 1,600m^3, BL 640 masl).

F. <u>Civil Infrastructure</u>

The existing reservoir is in good condition. The existing site infrastructure is in fair condition requiring minor rehabilitation.

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing	✓		
Site Roads	✓		
1,600 m^3 Reservoir	✓		

Table 2-25: Awajan Low Reservoir Facilities and Site Infrastructure.

2.3.25 Berein Reservoir

A. <u>Reservoir</u>

The existing reservoir (Cap. 1,000m^3 BL 867masl) is supplied from the Merhib pumping station via a 300mm Rising main. This high level reservoir feeds the local high level areas including Berein and onto the Jerash towns via a 250mm gravity main. A separate 250mm gravity main feeds onto Rumanneh Reservoir (Cap. 500m^3, BL 762.90 masl) by gravity.

Plate 2-25: Berein Reservoir (Cap. 1,000m^3, BL 867 masl).

B. Other Plant and Equipment

There are no disinfection facilities at this site.

C. Power Supply

Power supply is from the JEPCO grid. There is no standby generator at this site.

D. Instrumentation

The existing flowmeters and level monitoring equipment are not operational.

E. SCADA/Telemetry/Communications

There is no SCADA system at this site. There is a hard wired telephone link and good GSM coverage.

F. Civil Infrastructure

The existing reservoir is in good condition. The existing site infrastructure is in fair condition requiring minor rehabilitation.

Buildings and Facilities	Status		
	Acceptable	Minor Rehab.	Full Rehab. / Replacement
Gates & Fencing			✓
Site Roads		✓	
1,000 m^3 Reservoir		✓	

Table 2-26: Berein Reservoir Facilities and Site Infrastructure.

2.4 Current Demand and Supply Zoning

2.4.1 Current Source Production Rates

The Zarqa Governorate Water Supply System is currently supplied from up to 99 wells and springs at 14 different locations as set out in Table 2.1. The 2008 annual production for each of the source locations together with average daily production rates is also set out in Table 2.1. The total average production rate amounts to 137,728m^3/day or 50,408,354m^3/annum.

A description of these sources is contained in Sub-section 2.2 and 2.3.

2.4.2 Water Demand/Supply Balance

While total production amounted to 50,408,378m^3 in 2008 or 137,728m^3/day, there were additional imports to the Zarqa Governorate from Zatari, in the Mafraq Governorate, of 3,677,248m^3/annum or 10,047m^3/day on average (refer to Drg. 20445-FIG-2.01 for further details).

There were also exports from the Governorate which must be taken into account, these include an export to Amman of 7,047,988m^3/annum or 19,257m^3/day. This gives a net system input figure of 44,836,506m^3/annum or 122,504m^3/day. Details of water produced in the Zarqa Governorate in 2008 together with imports and exports are contained in Table 2.27.

IWA Water Balance Categories	Water Volume	
	Total	Av. Day
	m^3/annum	m^3/d
System Input - Production	50,408,378	137,728
System Input - Imports	3,677,248	10,047
Export - Azraq Conservation Area	727,207	1,987
Export - to Amman from Khaw	7,047,988	19,257
Export - to North - Mafraq from Qunaya	124,350	340
Export - to West - Jerash and Balqa from Um Rumanneh	272,027	743
Export - to Desert	146,035	399
System Input Total	**45,768,019**	**125,049**
Domestic Billed Metered Consumption	17,437,114	47,642
Non-Domestic Billed Metered Consumption	900,440	2,460
Billed Metered Consumption Total	**18,337,555**	**50,103**
Unbilled Unmetered Consumption - Zarqa Backwash	931,513	2,545
Unbilled Metered Consumption - Agriculture	133,333	364
Unbilled Metered Consumption - Tankers	18,969	52
Unbilled Consumption Total	**1,083,815**	**2,961**
Unaccounted-for Water: UFW	**26,346,649**	**71,985**
UFW %	57.6%	
Non-Revenue Water: NRW = UFW + Unbilled Cons.	**27,430,464**	**74,947**
NRW %	59.9%	

Table 2-27: Zarqa Governorate Imports, Exports and Water Production.

On the consumption side, the total billed consumption (both domestic and non-domestic) amounted to 18,337,555m^3/annum.
Unbilled but authorised consumption for system flushing, agriculture and supply to tankers amounted to a further 1,083,815m^3/annum. This leaves a total Unaccounted-for Water (UFW) figure of 71,985m^3/day – 57.6% of production. The quantity of Non-Revenue Water (NRW) amounts to 74,947m^3/day (system input less billed consumption) or 59.9%.

It is clear from the forgoing that the current levels of UFW and NRW are excessive and unsustainable. This is the primary reason why the Governorate could not cover its operating and maintenance cost from the revenues obtained from customers.

Accordingly, the reduction in the level of Non-Revenue Water is a key objective of this project along with the reduction of energy costs associated with excessive and inefficient pumping.

2.4.3 Population Data and Preliminary Water Audit

Table 2.28 hereunder provides key statistical information relating to supplies to both Residential and Non-Residential customers as it currently stands.

Total Population of Zarqa Governorate	871,600
Population on Public Water Supply System %	98%
Population on Public Water Supply System no.	854,325
Customer Meters Total	120,841
Length of pipe mains (km)	3,515
Average Supply Continuity (hours per week)	37
Unit per capita System Input Volume (SIV) - l/d	146.4
Unit per capita domestic metered consumption - l/d	55.8
Unit per capita non-domestic metered consumption - l/d	2.9
Unit per capita total consumption - l/d	58.6

Table 2-28: Zarqa Governorate Key System Statistics.

It will be noted that approximately 98% of the population are served by the public water supply system. The number of metered connections is 120,841 of which 77% are also connected to a public sewer.

The gross per capita consumption, expressed in terms of the total System Input Volume (SIV) amounts to 146.4l/person/day. The per capita consumption expressed in terms of actual metered supplies amounts to only 58.6l/person/day. The difference between the gross and actual per capita consumption figures again highlights the significant volumes of UFW in the distribution network.

UFW can also be expressed in terms of litres per connection per day or m3 per km of watermain per day. The estimated current level of unaccounted for water as determined in table 2.27 amounted to 71,985m3/day or 57.6% of the distribution input. Based on the figures included in Table 2.28 for the number of connections and for the length of watermain, the level of UFW per connection per day (counting only the 37 hrs/week time that the water is “on”) and per kilometre of watermain per day (for 37 hrs/week “on”) amount to 2,039 l/connection/day and 70.1 m^3/km/day respectively. These figures are extremely high when compared to the normal accepted range for such parameters.

The low level of per capital consumption at 58.6l/person/day also reflects the restricted nature of the available water supply. In the Governorate of Zarqa and in Jordan generally, the quantity of water supplied to consumers is dictated by the limited quantity of water available for supply from the existing sources. It is clear that consumers would use more water if it were available, a negative water demand/supply balance therefore exists. In the absence of sufficient water to meet demand, WAJ currently operate a rationing system to ensure that all available water is distributed as evenly as possible across the supply areas.

2.4.4 Water Supply Areas

Currently the water distribution network in the Zarqa Governorate is operated as 6 operation/maintenance areas: Zarqa, Azraq, Berein, Hashmeya, Dulail and Russaifah. There are numerous cross-connecting pipelines between adjacent areas, and these are operated differently depending on the various supply/demand conditions that arise in the network in various situations, on day-to-day, seasonal and occasional emergency bases. Over recent years, significant investment has been undertaken on the construction of primary network facilities, notably large elevated storage reservoirs at Zarqa, Awajan, Russaifah, Hashmeya and Sukhna. Taking account of this new infrastructure, and the associated future infrastructure which is described in Section 6 of this report, it is practical to consider the network as being divided into 9 Water Supply Areas (WSAs). While the existing pipe links across the boundaries between WSAs are not currently closed, or controlled, nevertheless the WSAs provide a rational basis for assessing the structure and performance of the current water supply arrangements, and for use as a basis for planning of future improvements. The 9 WSAs are further divided into 29 Distribution Areas (DAs), each of which will eventually be supplied separately from other DAs, generally from a dedicated elevated storage reservoir. Drawing No. 20445-FIG-2.04 shows the boundaries of the 9 WSAs. The current System Input Volume (SIV) for each WSA and DA is shown in Table 2.29 below.

The System Input Volume (SIV) is concentrated in the three main built-up zones of Zarqa (43,708m^{3}day), Russaifah (38,022m^3/day) and Awajan (22,809m^3/day). The SI to King Abdullah City WSA will increase significantly in the near future as planned developments proceed in this zone.

WSA	Distribution Area (DA)	Population (persons)	System Input Volume (SIV) (m3/d)
Azraq	Azraq	7,396	1,937
Sub-Total		**7,396**	**1,937**
Dulail	Hallabat	3,213	414
	Dulail	33,568	4,271
	Tafeh	1,009	296
Sub-Total		**37,790**	**4,981**
Kaba	King Abdullah City	0	278
Sub-Total		**0**	**278**
Tatweer	Tatweer	8,501	1,697
Sub-Total		**8,501**	**1,697**
Zarqa	Zarqa High	26,308	4,163
	Zarqa Mid - Batrawi	253,728	38,991
	Zarqa North	3,490	555
Sub-Total		**283,526**	**43,708**
Awajan	Awajan High	61,196	9,291
	Awajan Low	37,024	5,666
	Awajan West	22,922	3,530
	Awajan North	28,028	4,323
Sub-Total		**149,171**	**22,809**
Russaifah	Russaifah North West	4,704	616
	Russaifah High	96,064	11,961
	Russaifah Low	69,265	8,713
	Hitteen Tower	12,157	1,497
	Hitteen Reservoir	121,259	15,234
Sub-Total		**303,448**	**38,022**
North	Khaw	1,356	219
	Hashmeya South	623	101
	Hashmeya Town	26,139	4,194
	Hashmeya Rural	3,471	562
	Sukhna	20,040	3,249
Sub-Total		**51,629**	**8,325**
WNW	Merhib	1,454	381
	Berein	2,647	676
	Um Rumanneh	3,449	870
	Berein North	1,043	276
	Sarout/Alouk	3,304	822
	Qunaya	966	266
Sub-Total		**12,864**	**3,291**
TOTAL for WSAs		**854,325**	**125,049**

Table 2-29: WSA and DA Populations and System Input Volumes 2008.

2.4.5 Current Water Supply Arrangements

Due to the negative water supply/demand balance that exists in the Governorate as referred to in 2.4.3, it is necessary to ration the quantity of water available for supply across the supply area to ensure that all areas receive a supply for a certain set period each week.

Some of the outlying and rural areas are excluded from the rationing arrangement since their own local sources can currently meet their requirements.

The supply zones where rationing currently takes place are in the Zarqa City, Russaifah, Awajan and Tatweer WSAs, and parts of the North WSA.

Drawings Nos. 20445-FIG-2.10 and 20445-FIG-2.11 provide details of the current water rationing arrangements in the supply zone affected. These arrangements provide for supplies to be available on a set number of days each week and sometimes split between morning and afternoon.

It is expected that the new DISI water project, when complete, will eliminate the requirement to export water from Zarqa to supply Amman and that supply surpluses from Amman will be made available for Zarqa's future requirements. In addition, it is proposed that the proposed Water Supply Restructuring and Rehabilitation project for Zarqa will significantly reduce the losses in the existing system thereby providing additional water for consumers in the future.

It is anticipated that these measures if implemented would substantially redress the negative water demand/supply balance that currently exists.

2.4.6 Water Supply Operations and Maintenance

As referred to earlier, there is a very high level of unaccounted for water in the supply network. This has resulted from deficiencies associated with water metering and leaks. An increase level of metering together with the replacement of defective meters will deal with the inadequacies associated with metering. However, it was noted during our investigation that there are significant deficiencies associated with the pipe network particularly in the secondary and tertiary network. One of the major issues is the large quantity of both polyethylene and steel pipes that have been laid over ground. Surveys undertaken by GT2 in the Zarqa and Russaifah areas have shown that up to 20% of tertiary network comprised above-ground polyethylene (PE) and galvanised steel pipes. In addition, considerable lengths of PE have been laid with inadequate cover, often at depths as shallow as 50mm to 100mm. These sections of piping are therefore exposed to damage by traffic, weathering and illegal connections.

In the course of our Pilot leakage detection activities in Hashmeya, sections of overground pipes or pipe with inadequate cover were encountered and a number of leaks were detected by visual inspection principally at connection locations, where compression fittings have failed.

Apart from the shortcomings noted in regard to pipe laying/installation standards, deficiencies also exist in regard to repair and maintenance. These include:

a) Lack of adequate tools and equipment due to inadequate budget allocation.
b) The continuing practice of laying PE pipe above ground or with inadequate cover, due to inadequate supervision/quality control.
c) Material failure due to the use of sub-standard materials and poor quality control.
d) Lack of fittings and pipes for repairs due to inadequate budget allocation.
e) Lack of training for staff and staff motivation.

In recent years, a computer based Maintenance Management system has been established in the Zarqa Governorate. This provides a formal procedure for the logging and analysis of all bursts, customer complaints etc. and for recording the response made by O & M personnel in each case.

Pilot studies have shown that the vast majority of leaks are in small diameter PE pipes which have been laid overground. This finding is confirmed by our experience in the Hashmeya area where the majority of the leaks have been found in the secondary/tertiary network and at connection locations.

2.5 Socio-Economic Details and Water Charges

As indicated earlier in Section 2.4, approximately 98% of the population of the Zarqa Governorate is supplied from a public water supply. This high percentage indicates that the public supply is generally available to all sectors of society.

Substantial analysis of socio-economic income levels in the different neighbourhoods across the WSAs in the Zarqa Governorate was undertaken as part of the “Study of the Benefits to the Poor of Millennium Challenge Corporation Financed Projects in the Water Sector”, which is discussed in Section 5 of this report. The primary conclusion of the Study, in relation to the current operation and performance of the public water distribution network, is that there is no discernible relationship between income levels and current levels of municipal water use.

In regard to water charges, the current tariff structure for domestic and non-domestic users are shown in Appendix 4.

Tables 2.30, 2.31 and 2.32 provide details of water charges imposed for the period 2003 to 2006 based on water consumption per quarter.

	2003			2004			2005			2006		
m^3 per quarter	No. of bills Water	Consumption Water	Charges Water	No. of bills Water	Consumption Water	Charges Water	No. of bills Water	Consumption Water	Charges Water	No. of bills Water	Consumption Water	Charges Water
0---50	286,186	7,731,444	861,501	283,238	7,290,685	632,206	310,253	8,010,775	922,633	328,009	8,845,258	1,750,321
51---100	82,310	5,546,023	1,229,234	75,616	5,056,897	1,044,992	84,814	5,726,950	1,282,010	89,042	6,024,120	1,677,978
101---150	9,180	1,079,682	440,625	7,234	852,333	350,222	9,035	1,063,621	461,949	10,240	1,206,343	550,187
151--->	2,985	692,541	384,466	2,229	540,331	347,512	4,475	1,024,873	458,356	3,797	911,722	576,626
	380,661	**15,049,690**	**2,915,826**	**368,317**	**13,740,246**	**2,374,932**	**408,577**	**15,826,219**	**3,124,948**	**431,088**	**16,987,443**	**4,555,113**

Table 2-30: Zarqa Governorate Residential Customer Water Usage Statistics 2003-2006 and Derivation of Non-Domestic Municipal Water Usage.

	2003			2004			2005			2006		
m^3 per quarter	No. of bills Water	Consumption Water	Charges Water	No. of bills Water	Consumption Water	Charges Water	No. of bills Water	Consumption Water	Charges Water	No. of bills Water	Consumption Water	Charges Water
0---50	15,937	195,619	203,791	16,102	199,592	198,701	15,751	187,682	201,773	16,081	201,513	267,868
51---100	1,337	95,351	86,328	1,390	99,108	87,797	1,209	88,244	83,346	1,210	87,806	87,597
101---150	535	66,813	60,721	476	58,178	52,941	470	58,071	55,414	559	70,138	68,862
151--->	1,300	1,629,612	1,145,138	960	479,920	435,782	1,195	1,754,042	841,082	1,234	2,481,901	774,561
	19,109	**1,987,395**	**1,495,978**	**18,928**	**836,798**	**775,220**	**18,625**	**2,088,039**	**1,181,616**	**19,084**	**2,841,358**	**1,198,889**

Table 2-31: Zarqa Governorate Non-Residential Customer Water Usage Statistics 2003-2006 and Derivation of Non-Domestic Municipal Water Usage.

	2003			2004			2005			2006		
	Bills	Water Usage m^3	Revenue	Bills	Water Usage m^3	Revenue	Bills	Water Usage m^3	Revenue	Bills	Water Usage m^3	Revenue
Sum	**399,770**	**17,037,085**	**4,411,804**	**387,245**	**14,577,044**	**3,150,152**	**427,202**	**17,914,258**	**4,306,564**	**450,172**	**19,828,801**	**5,754,002**
Res	380,661	15,049,690	2,915,826	368,317	13,740,246	2,374,932	408,577	15,826,219	3,124,948	431,088	16,987,443	4,555,113
Non-Res	19,109	1,987,395	1,495,978	18,928	836,798	775,220	18,625	2,088,039	1,181,616	19,084	2,841,358	1,198,889

Table 2-32: Zarqa Governorate Residential and Non-Residential Apportionment.

It will be noted that the vast majority of bills are issued in respect of the lowest consumption category of 0-50m^3 per quarter.

In overall terms, for the period 2003-2006,, the gross consumption per household per day varied from 434 l/day in 2003 to 410 l/day in 2004.

The mean charge level per m^3 for residential customers varied from JD O.17/m^3 in 2005 to JD 0.27/m^3 in 2006. This would indicate that while the tariff levels are low, the level of charge is gradually increasing in order to cover the cost of providing the service.

2.6 Water Administration in Zarqa Governorate

The Water Authority of Jordan (WAJ) is responsible for water operations throughout the country. In terms of regional administration the country is divided into three regions as follows:

- The Northern Region (Ajlom, Mafreq, Jerash and Irbid)
- The Middle Region (Amman, Balqa, Zarqa and Madaba)
- The Southern Region (Karak, Ma'am and Tafileh)

An Assistant Secretary General is responsible for each region. In the context of the Middle Region, where Zarqa is located, the Director of the Zarqa Governorate Water Administration reports to the Assistant Secretary General for the Middle Region.

The Water Administration for the Zarqa Governorate is based in Zarqa City, with district offices in Russaifah, Hashmeya and Dulail. The Zarqa Governorate Water Administration which employs 689 personnel (2008), is responsible for the Operation and Maintenance of both the water supply and sewerage services within the Governorate.

The departments within the Zarqa GWA include:

- Water Department
- Sewage Department
- Russaifah Directorate
- Technical Department

Under the heading of Water Supply, the Zarqa GWA is responsible for 3,500 km of pipelines serving approximately 126,000 subscribers.

The Water Department is responsible for water network operations in all of Zarqa Governorate with the exception of Russaifah. The Russaifah Water Directorate is responsible for water network operations and for subscriber and administrative tasks within Russaifah, this effectively being a Regional Operational Unit (ROU).

The water distribution and network maintenance of the Water Department is further sub-divided into 5 different maintenance areas. These are;

1. Zarqa
2. Azraq
3. Berein
4. Hashmeya
5. Dulail

The Russaifah Water Directorate covers Russaifah which is considered one maintenance area.

In relation to Network Operations and Maintenance, Working Paper No. 193 (GTZ) dated March 2008 refers to the inadequacies that currently exist, these include:

1) the difficulties in dealing with overground piping which is very susceptible to damage and unauthorised connections.
2) the use of sub-standard materials
3) the lack of financial resources to provide adequate equipment, tools, fittings and spares.
4) staffing structure and other issues.

The paper recommended the following improvements :

- improved supervision of pipelaying schemes to ensure that proper standards for pipelaying operations are established and implemented so that all pipes, house connections etc. are laid underground and that proper materials are used; This could be facilitated by the provision of standard specifications for materials and workmanship.

- that adequate resources are made available to ensure that equipment for repairs and that an adequate supply of repair materials is available at all times;
- that repair crews are properly trained and motivated and that all changes to the pipe network and connections are logged on the GIS.

The re-laying of the very substantial length of above ground pipework is a major exercise and it is proposed, as part of this Masterplan report, to re-lay or replace all sections of above ground piping under this project.

2.7 Water Supply Operations and Maintenance Costs

Working paper No. 197 (GTZ) dated June 2008, contains the profit and loss statement for the Zarqa Water Administration for the year 2007, which is the first year for which a separate financial statement was prepared for the Zarqa Water Administration.

Table 2.33 hereunder shows the profit and loss summary for the Zarqa water Administration for the year 2007.

Description	Total	Water	Sewerage	W.Tankers	Desert Wells
	JOD	JOD	JOD	JOD	JOD
Revenues					
Operational Revenue	9,249,410	7,585,604	1,635,897	27,909	
Non Operational Revenue	1,502,837	898,366	604,471		
Total Revenues	10,752,247	8,483,970	2,240,368	27,909	-
Revenue %	100%	79%	21%	0%	0%
Expenditures					
Wages & Salaries	1,905,527	1,446,090	396,299	9,476	53,661
Electricity	3,138,396	2,745,558	392,838		
Water Imports	3,776,139	3,776,139			
Wastewater treatment plant	3,679,200		3,679,200		
Vehicles Maintenance	317,796	167,436	123,206	27,154	
Network Maintenance	781,918	668,206	92,563		21,149
A&G Expenses	391,200	320,784	66,504	3,912	
Other Expenses	513,291	423,185	31,939	25,314	32,853
Total Expenditures	14,503,467	9,547,398	4,782,549	65,856	107,663
Expenditures %	100%	66%	33%	0%	1%
Absolute Profit/Losses	- 3,751,220	-1,063,428	-2,542,181	- 37,947	- 107,663
Profit/Losses %		28%	68%	1%	3%

Table 2-33: Profit and Loss summary 2007

This table shows that an overall loss of JOD 3.7m was recorded in 2007 representing an operational recovery ratio of 74%. The main areas of high expenditure include Wastewater Treatment (26%), Water imports (26%) and electricity costs (22%). In relation to the water supply account specifically, a loss of JOD 1.06m was recorded in 2007, representing a recovery ratio of 89%. The cost of water imports represents 39.6% of the total loss, electricity costs are at 29% and wages and salaries 15%.

It is clear on the basis of these figures that reductions in level of Non Revenue Water (NRW) from its current level of 59.9% could quickly rebalance this account.

In regard to energy costs, Working Paper No. 192 (GTZ) dated February 2008 sets out clearly the position regarding energy costs associated with water supply operations in the Middle Governorate of Jordan, which includes the Governorate of Zarqa. This indicates that a 25% reduction in energy costs should be achievable through improved pumping efficiencies.

In October 2009, a report was prepared by JICA on how energy could be conserved through a combination of upgrading of the existing pumping installations and network improvements. This report entitled "The Preparatory Survey on the Programme for Energy Conservation through Upgrading Water Supply Network in The Hashemite Kingdom of Jordan – Preparatory Survey Outline Report – dated October 2009", sets out clearly the goals of this intervention, the works involved and the ensuing benefits. The proposal included the replacement of the pumping plant and equipment (including valves, flow meters, electrical plant etc.) at Azraq, Hallabat and Zarqa Pumping Stations, the provision of a new Pumping Station at Zarqa and a new rising main from Zarqa Pumping Station to Batrawi Reservoir.
This programme will significantly reduce energy consumption at the main water pumping stations in the Zarqa Water Transmission Network by proving high efficiency pumps and motors at these high volume water transfer stations and by relatively minor adjustments to the pipe network. These proposals have been taken into consideration in the development of proposals for the Master Plan.

The proposed restructuring/rehabilitation proposals contained in this Master Plan, which will provide for sufficient reductions in Non Revenue Water and more energy efficient pumping arrangements, will lead to a substantial reduction in expenditure particularly in the area of water imports and energy costs. This should allow the current financial deficit to be eliminated in the short to medium term.

2.8 Zarqa Water Supply Network

The construction of the GIS of the Zarqa water supply distribution is an ongoing project within the Zarqa Governorate Water Operation at the present time. In the course of our investigations we provided some further updates of the existing GIS and included these in some 120 No. drawings which we recently returned to water operations personnel. However, we also noted that there are considerable lengths of the existing secondary and tertiary network which have not been mapped to date.

For the purposes of our study, we have had to make certain assumptions relating to the elements of the supply network which we currently mapped. Our estimation of the total length of the water supply network amounts to 3,515 km while the total length of network as indicated on the updated GIS to date is 2,380 km.

2.9 Modelling of Existing Water Supply Network

2.9.1 General

In order to assess the performance of the existing water supply and distribution system in the Zarqa Governorate a hydraulic model was constructed using Bentley WaterCAD v8i.

The model was constructed using information on the physical details of the network provided by the Water Authority of Jordan (WAJ), existing documentation on the Zarqa Water Network as well as through site visits and surveys of key facilities in the system. Particulars of the operation of the system were gained from the study of available records and from consultations with the operations staff at WAJ.

This section should be read in conjunction with the following figures and tables appended at the end of this section:

- Table 2.34 – Headloss in Main Transmission Lines
- Figure 2.1 – Existing Model at Russaifah, Average Demand (continuous supply)

- Figure 2.2(a) – Existing Model at Russaifah, Peak Demand (continuous supply)
- Figure 2.2(b) – Existing Model at Dulail, Peak Demand (continuous supply)
- Figure 2.3(a) – Existing Model Thursday Morning (Water Rationing)
- Figure 2.3(b) – Existing Model Thursday Evening (Water Rationing)
- Figure 2.4 – Headloss Gradient in Existing Network

Network model outputs and results are contained in Appendix 5.

2.9.2 Objectives

The objectives of the network model study are summarised as follows:

- Development of a Base Model which is representative of the existing water supply network using WaterCAD.
- Assessment of the performance of the existing network under various demand scenarios including; continuous supply, rationed supply, average demand and peak demand scenarios.
- The establishment of the limitations associated with the existing distribution system and identification of vulnerable areas.
- The development of proposals for a long term distribution strategy to ensure satisfactory network performance.

2.9.3 Model Construction

Current Geographic Information System (GIS) watermain records covering the Zarqa Governorate were supplied by WAJ in digital format. These records were substantially updated by NOD-ACEPO following extensive investigation and discussions with operations personnel. Updated GIS data has now been returned to Zarqa Water Operations and this updated information has been used in the modelling exercise. The GIS data contains details of the pipe lengths, materials and diameters. For the purposes of this modelling exercise it was decided that only pipe diameters greater than 100mm would be included in the model as this was sufficient to determine the hydraulic capacity of the trunk supply and main distribution system in Zarqa. The Hazen Williams formula was used for hydraulic analysis and “C” roughness values for pipes were chosen on the basis of pipe material and age. The following C values were initially selected for Pipe roughness:

PE Pipes	130
PVC Pipes	130

Ductile Iron	120
Galvanised Steel	100

The GIS data was imported directly into WaterCAD using the "Model Builder" function which automatically created network nodes at all pipe junctions and pipe end points. Nodal elevations were then added to the model from topographical data obtained from available mapping.

Reservoirs and pumping stations were then added to the model with relevant elevations, volumes and pumping rates assigned based on site surveys, available records and discussions with WAJ staff.

2.9.4 Model Demands

Section 2.4 contains details of current demand together with details of the nine Water Supply Areas (WSAs): Azraq, Dulail, Zarqa, Awajan, King Abdullah Bin Aziz City, Russaifah, Tatweer, North and West North-West. For the purposes of assessing the existing network performance, the model demands were based on the nine WSAs with the demand (litres/sec) per WSA distributed over the nodes within each zone. The major water supply sources contained in the model include the wellfields at Azraq, Hallabat, Corridor, Tamween, Awajan, Russaifah, Hashmeya, Merhib and Sarout. These are modelled as dimensionless reservoirs with control valves set to the average daily output (2008) shown in Table 2.1. The export to Amman (approx. 19 MLD) via the 600mm rising main from Khaw was also included in the model.

2.9.5 Modelling Scenarios –Continuous Supply

The first modelling scenario carried out represents the steady state continuous supply assuming that sufficient source water was available. This is an instantaneous picture of flow and average daily demand in the network assuming that all WSAs are being fed simultaneously and no rationing is being undertaken. The model was run at Average Demand and peak hourly demand (1.65 times Average Demand).

Figure 2.1 shows that the capacity of the system to supply all parts of the network is stretched at certain locations. Areas of particular vulnerability include parts of East Russaifah which are fed both via Russaifah High and Low reservoirs.

Low to Negative pressures (shown in yellow and red) are also experienced in Russaifah through the 400mm main from Zarqa. Elsewhere, residual pressures as a result of pumping into the system are greater than 60m or 6bar. Very high pressures (approximately 20bar) are noted along the 600mm rising main from Khaw Pumping Station to Tamween, Awajan, however, due to losses in the system this reduces to 9bar by the time it reaches Russaifah and the supply link to Amman. The 600mm feed from Azraq pumping station to Khaw experiences high friction losses of approximately 6m/km. This represents a pressure drop of 38bar over the 63km long pipeline.

The system capacity is further stressed under peak demand conditions with negative pressures occurring in East Russaifah, at the network extremities north of Hashmeya, throughout Dulail and the high level areas of Awajan and can be seen in Figures 2.2 and 2.3. This indicated that the network would be working beyond its capacity and would be unable to supply all regions at once.

2.9.6 Modelling Scenarios – Rationed Supply

At present supply is unable to meet demand as referred to in Section 2.4. This results in there being insufficient water supply to feed all the WSA's in Zarqa at the same time. Therefore, WAJ have a water rationing system in place to ensure that all areas receive a supply for a certain set period each week and this weekly rationing system is shown in Drawings Nos. 20445-FIG-2.2 and 2.3.

In order to represent this rationing system on the hydraulic model a separate model was created with a demand pattern to mimic the actual rationing system. The model was run over 14 steps to represent morning and evening supply over 7 days. Due to the reduced frequency of supply it was necessary to increase the nodal demands initially by a peak demand factor of up to 7. This peak factor increases the hydraulic loading on the network. This is shown in Figure 2.4 and Figure 2.5 which represents the supply to Zarqa City in the existing system on Thursday morning and Thursday Evening, respectively. In the morning the area is rationed so with no demands the residual pressures are high, however, with the area supplied in the evening the high demand (7 times Average Demand) the system cannot cope and negative pressures occur.

2.9.7 Conclusions from the Modelling Process

Results from the model highlight problems that are currently experienced within the Zarqa water supply network. These problems include:

- Insufficient capacity in network pipes to deliver a full continuous supply
- Heavy reliance on pumping directly into supply leading to high network pressures and high variance in pressures throughout the system.
- Inadequate storage volumes.

Table 2.34 below shows the headloss in the primary transmission mains in the Zarqa system and with the exception of the 700mm Ductile Iron main from Khaw to Batrawi it is clear that there are significant energy losses in the supply network. This is reinforced in Figure 2.4 which shows the headloss gradient for the entire network under average flow conditions where much of the network has a headloss of greater than 5m/km.

Pipe ID	Route	Diameter (mm)	Hazen-Williams C	Material	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
3904	Khaw to Russaifah / Amman	600	100	Steel	435.12	1.54	5.43
3913	Khaw to Zarqa	400	100	Steel	263.3	2.10	15.46
3928	Hallabat to Khaw	600	100	Steel	389.76	1.38	4.43
3933	Azraq to Khaw	600	100	Steel	469.65	1.66	6.26
3915	Khaw to Batrawi	700	120	Ductile Iron	513.94	1.34	2.49

Table 2-34: Headloss in Main Transmission lines

The network model of the existing supply system provides a useful tool in determining the strategic infrastructural improvements required to improve the current supply situation and to meet the future water demand to the year 2030.

Additional details on the network model inputs and outputs are set out in Appendix 5.

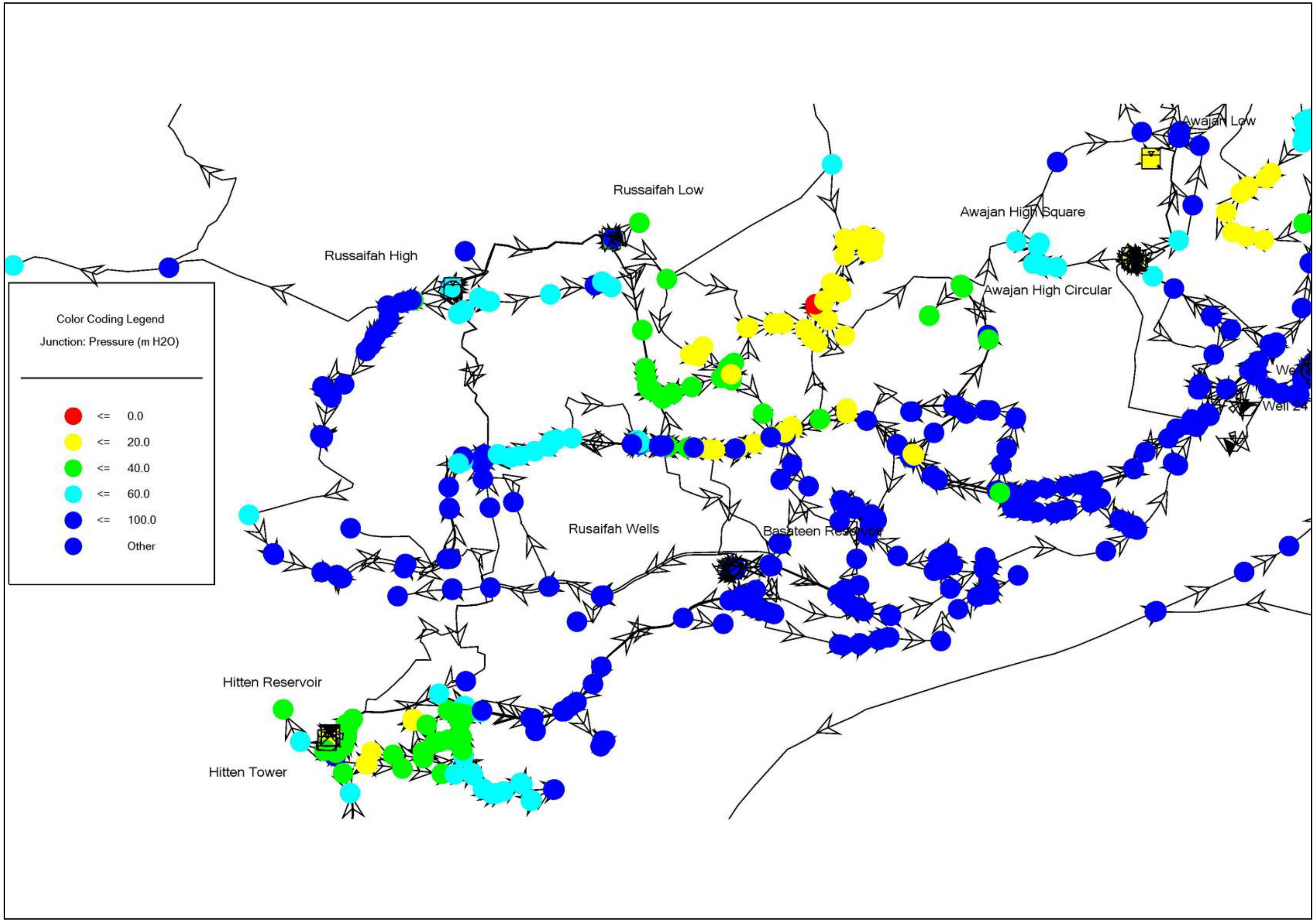


Figure 2-1: Existing model at Average Demand (continuous supply)

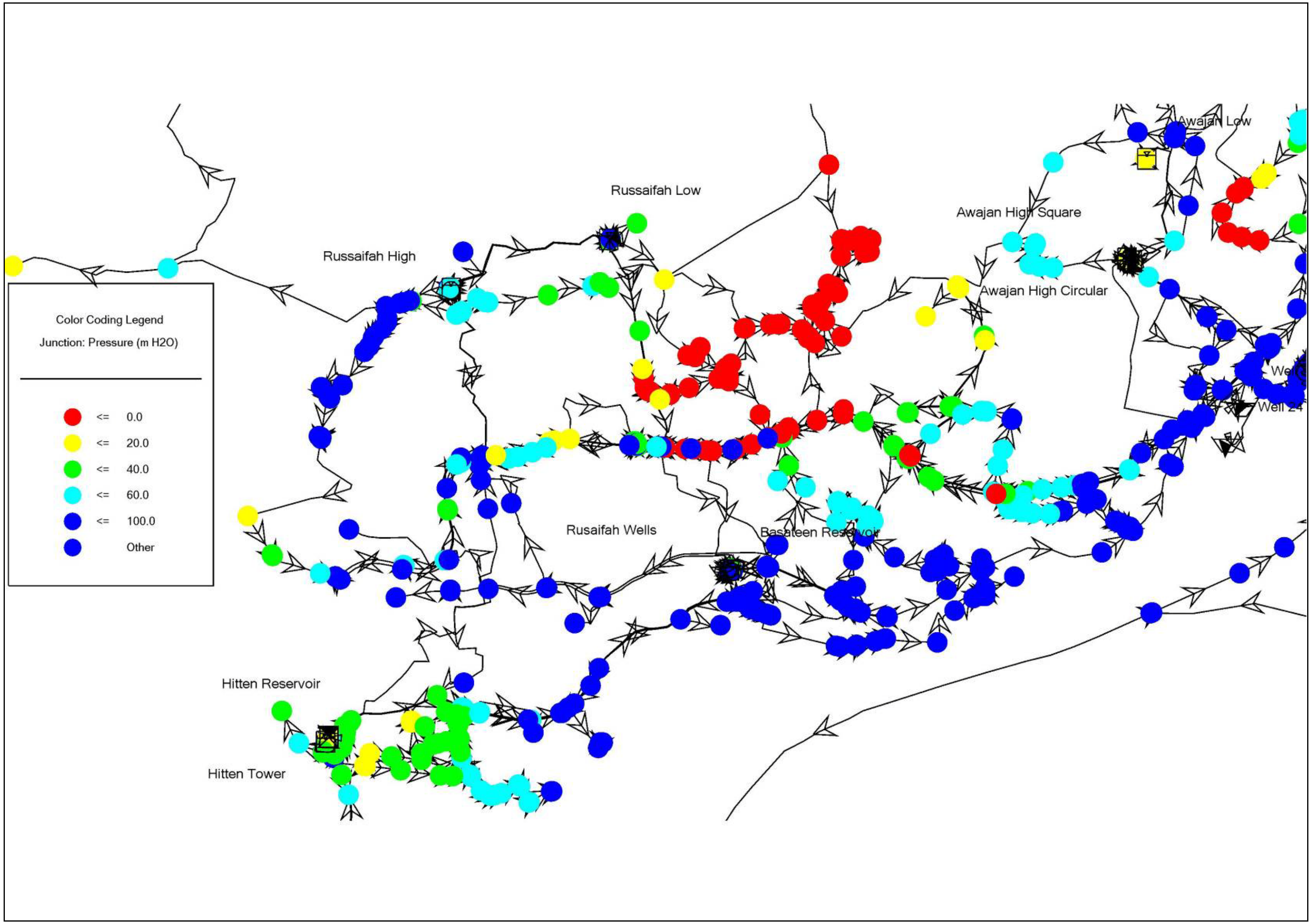


Figure 2-2: Existing model at Russaifah, Peak Demand (continuous supply)

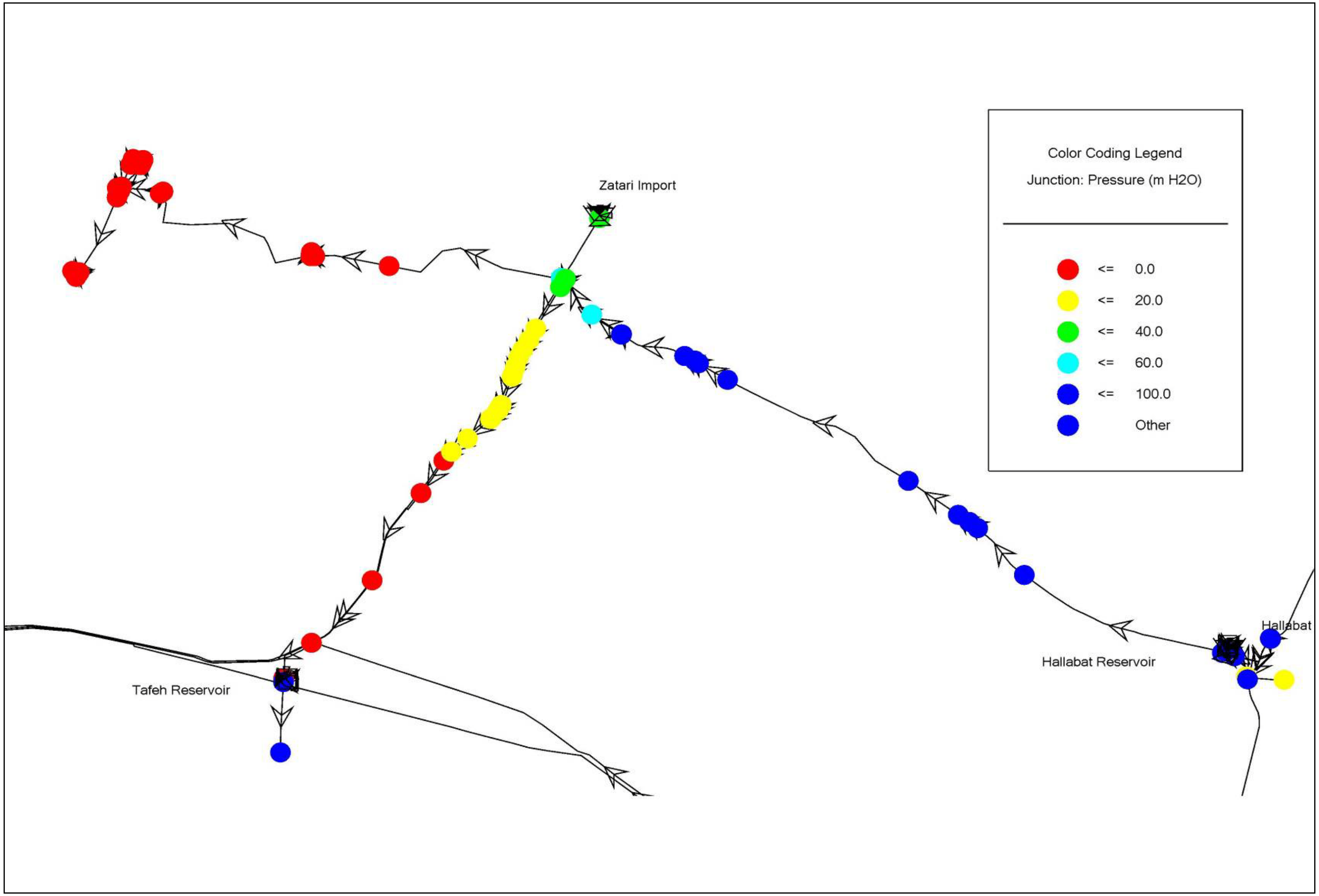


Figure 2-3: Existing model at Dulail, Peak Demand (continuous supply)

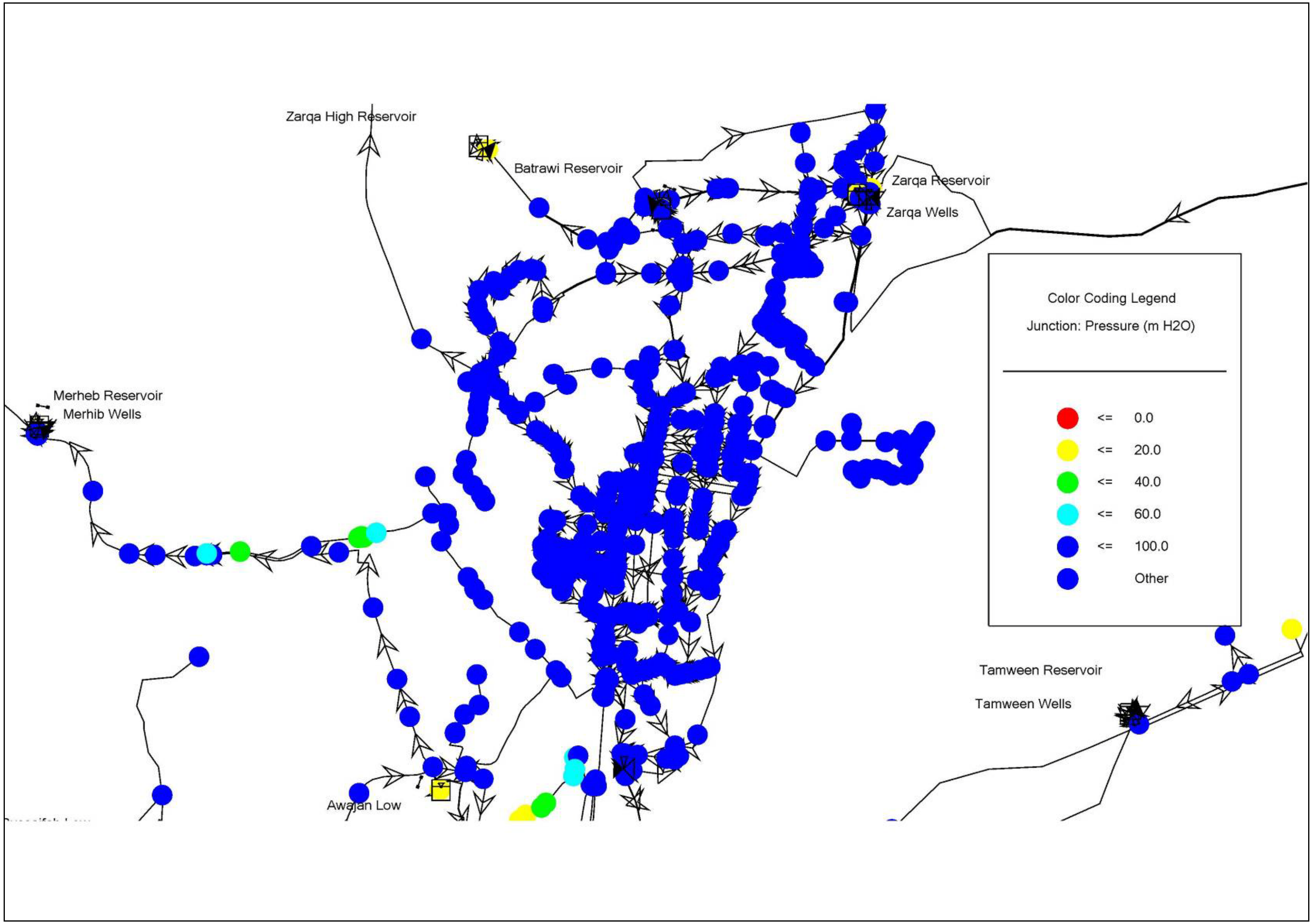


Figure 2-4: Existing Model at Zarqa City, Thursday Morning (Water Rationing)

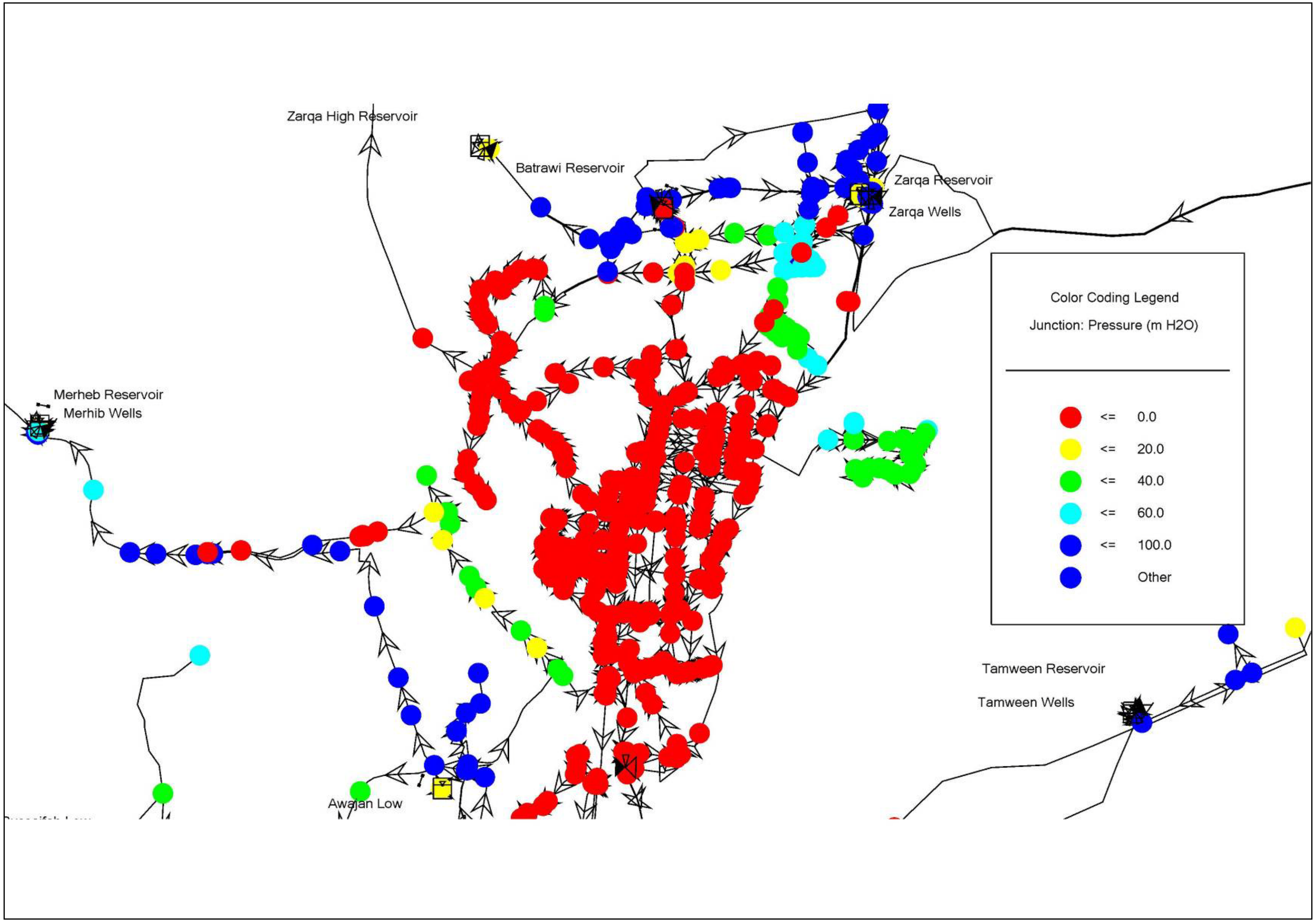


Figure 2-5: Existing Model at Zarqa City, Thursday Evening (Water Rationing)

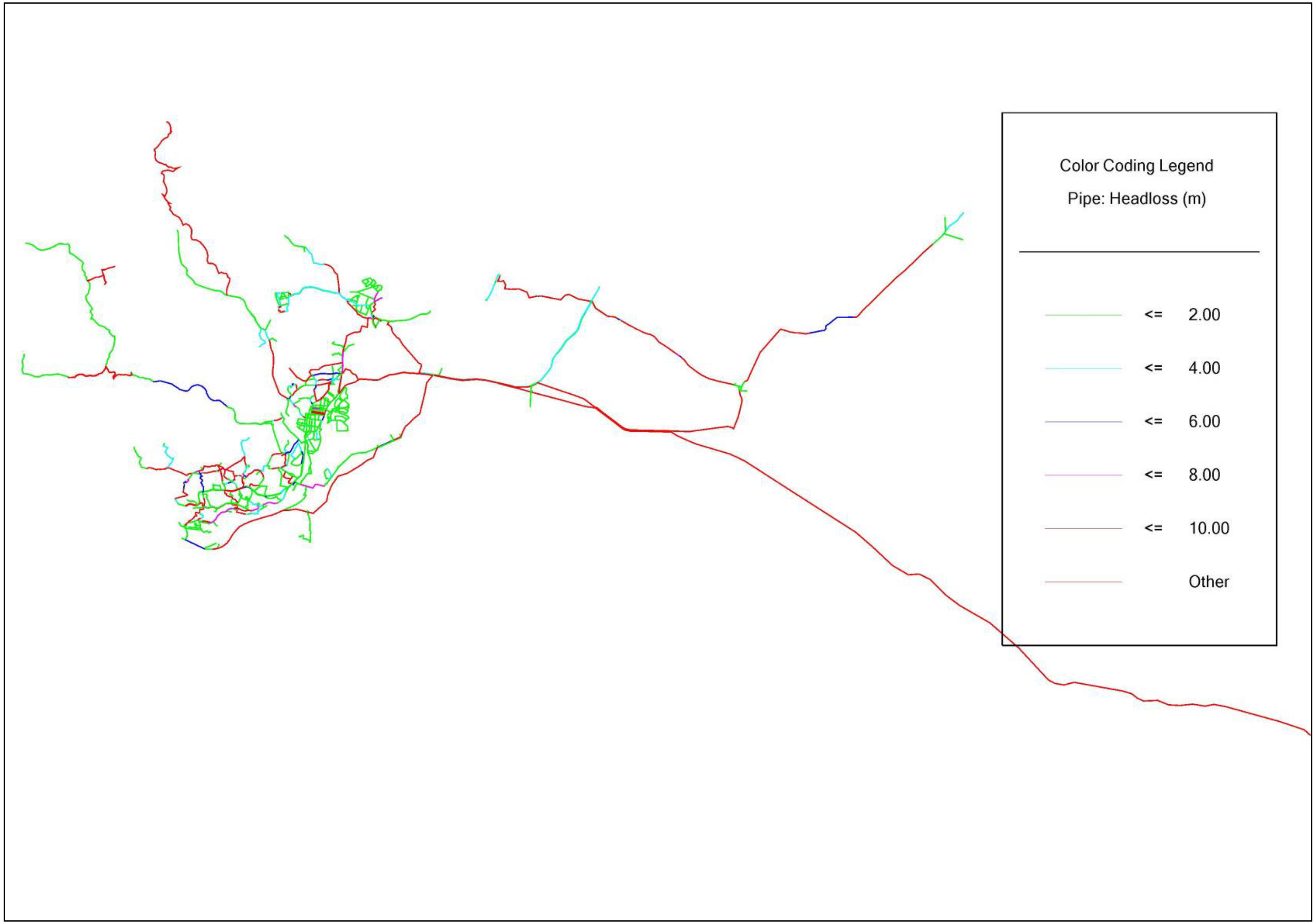


Figure 2-6: Headloss Gradient (m/km) in Existing Network

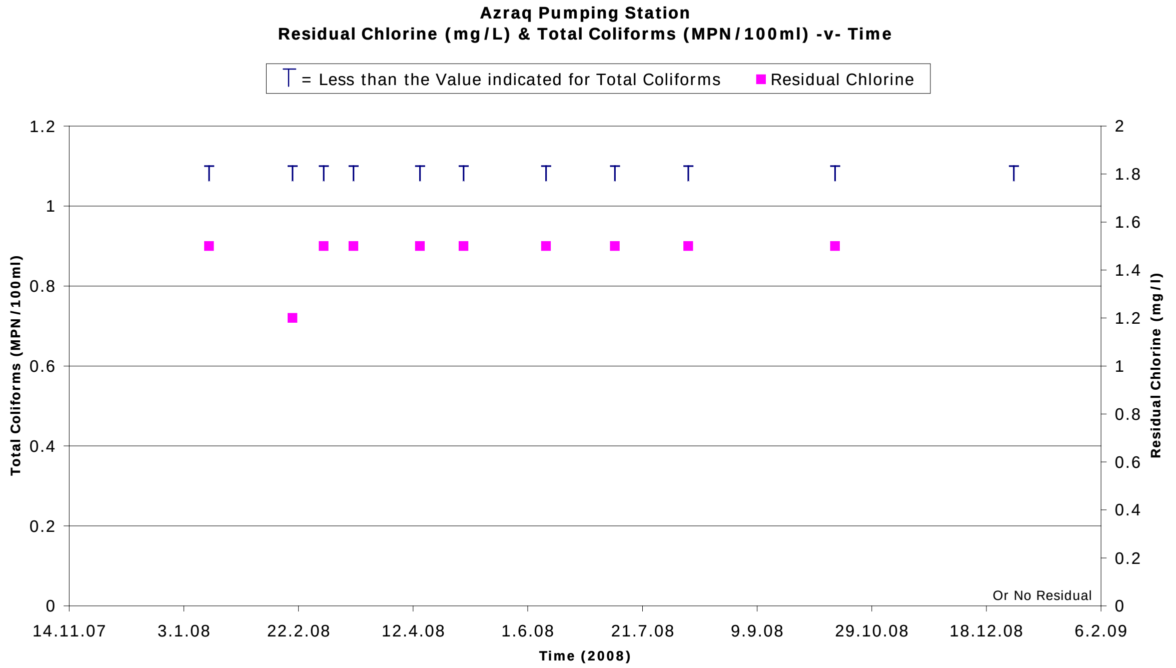
2.10 Water Quality in the Distribution System

As stated earlier, water source development and water quality issues in the Zarqa Governorate are being dealt with under a separate study. However in our investigation of the existing water supply network and its various components such as reservoirs and pumping stations, we have noted the presence of chlorination boosting facilities at a number of sites, in general these facilities are in need of substantial upgrading. We have included a budget for the provision of robust, reliable and safe disinfection boosting facilities at a number of appropriate sites under our restructuring and rehabilitation proposals.

While there are considerable shortcomings associated with the existing chlorination boosting facilities as noted earlier, the water quality data for the supply network for the year 2008 indicates a high level of compliance with key parameters such as presence of coliforms and chlorine residual.

For the samples taken at the pumping station/reservoir sites and at various locations in the supply network, the level of compliance with the coliform standard of less than 1.1 MPN/100ml was over 98%. In addition a chlorine residual was detected at 99% of sampling locations.

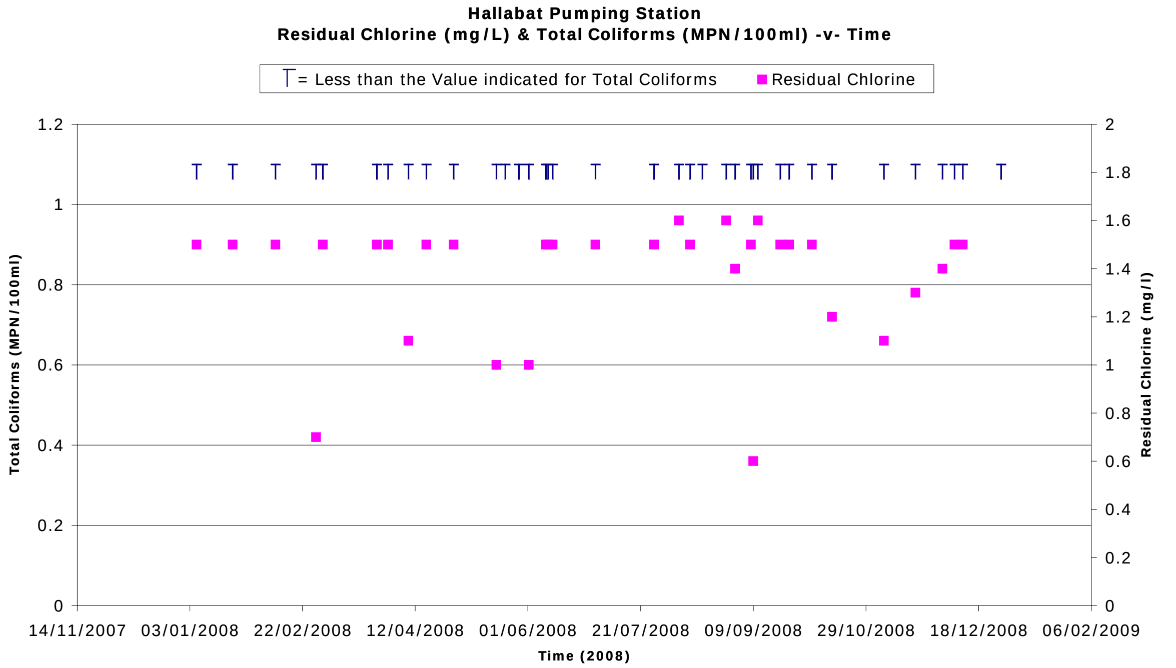
The test results for coliforms and chlorine residuals at eight locations which were monitored regularly for the year 2008 are represented in Figures 2.5 to 2.12 below. The locations include Azraq Pumping Station, Hallabat Pumping Station, Zarqa Pumping Station, Basateen Pumping Station, Batrawi Reservoir, Hashmeya Pumping Station, Zarqa Civil Defence (network) and Russaifah Municipality (network). In each case, the value for the coliforms was less than 1.1 MPN/100ml threshold and a chlorine residual was present in all samples.



Graph 2.1

Figure 2-7: Azraq Pumping Station

Residual Chlorine (mg/l) & Total Coliforms (MPN/100ml) –v- Time.



Graph 2.2

Figure 2-8: Hallabat Pumping Station

Residual Chlorine (mg/l) & Total Coliforms (MPN/100ml) –v- Time.

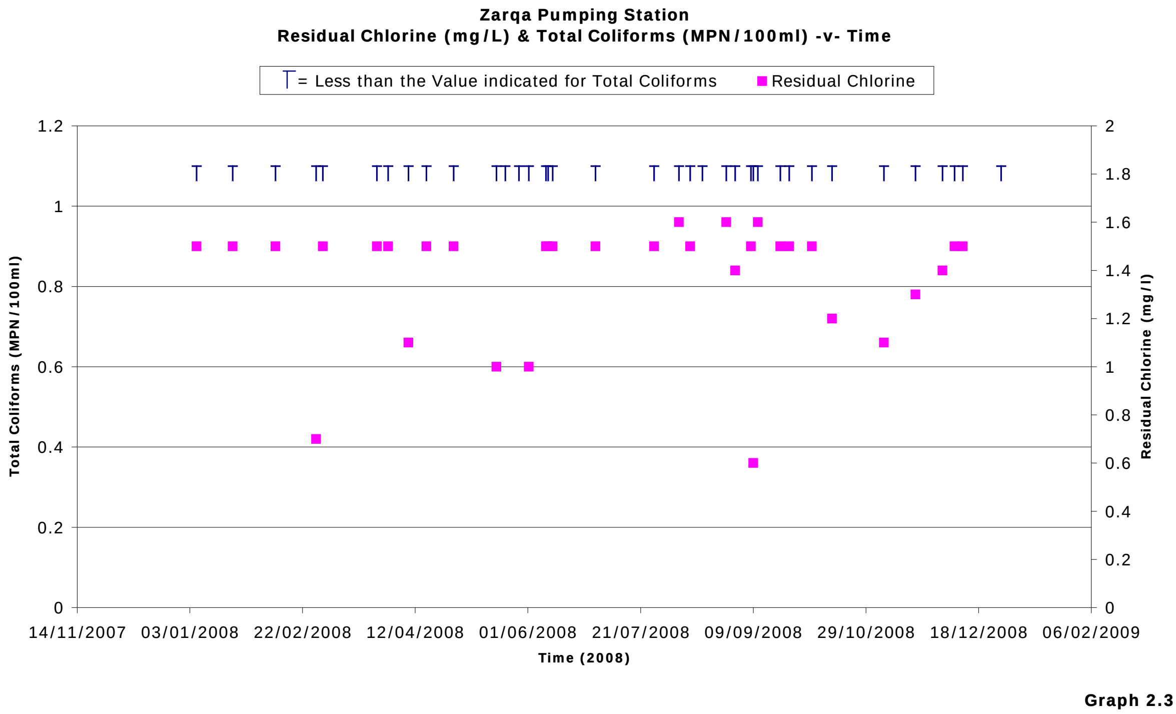


Figure 2-9: Zarqa Pumping Station

Residual Chlorine (mg/l) & Total Coliforms (MPN/100ml) –v- Time.

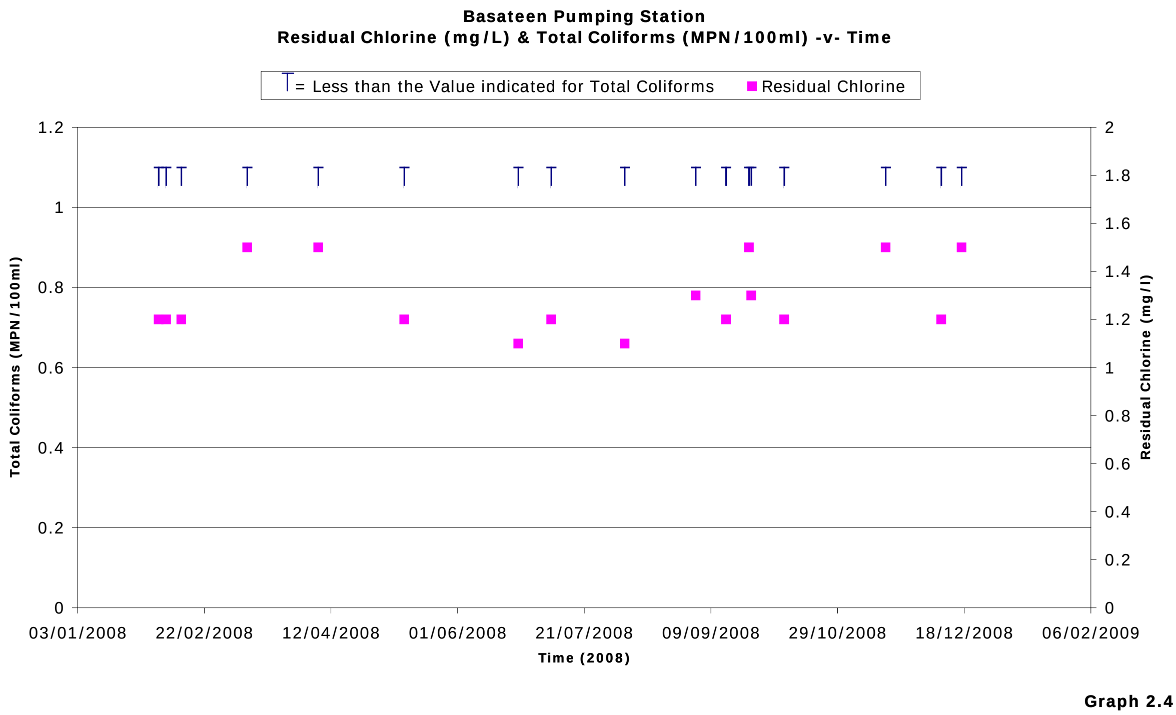


Figure 2-10: Basateen Pumping Station

Residual Chlorine (mg/l) & Total Coliforms (MPN/100ml) –v- Time.

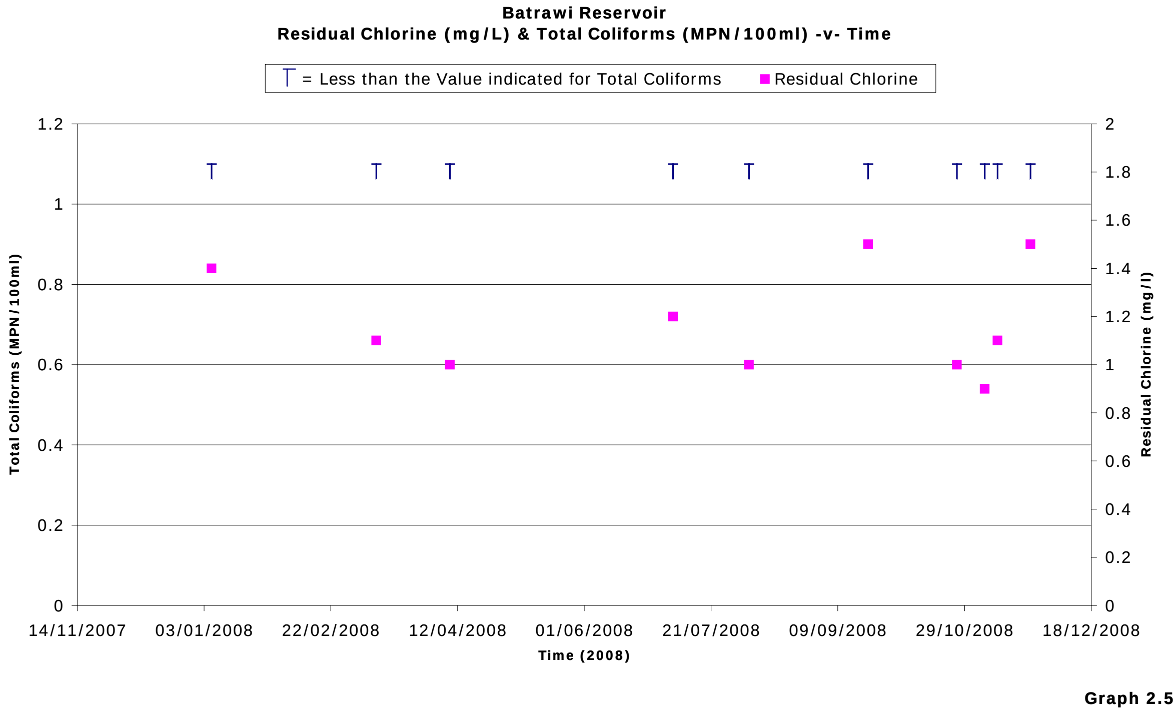


Figure 2-11: Batrawi Reservoir

Residual Chlorine (mg/l) & Total Coliforms (MPN/100ml) –v- Time.

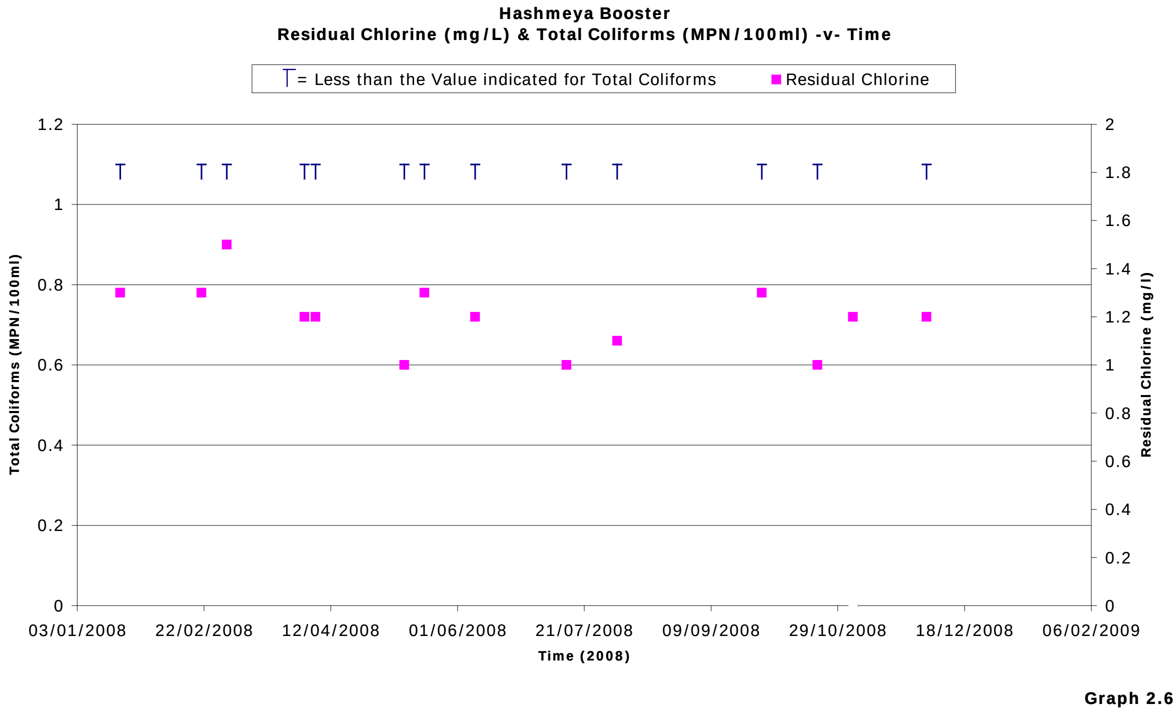


Figure 2-12: Hashmeya Pumping Station

Residual Chlorine (mg/l) & Total Coliforms (MPN/100ml) –v- Time.

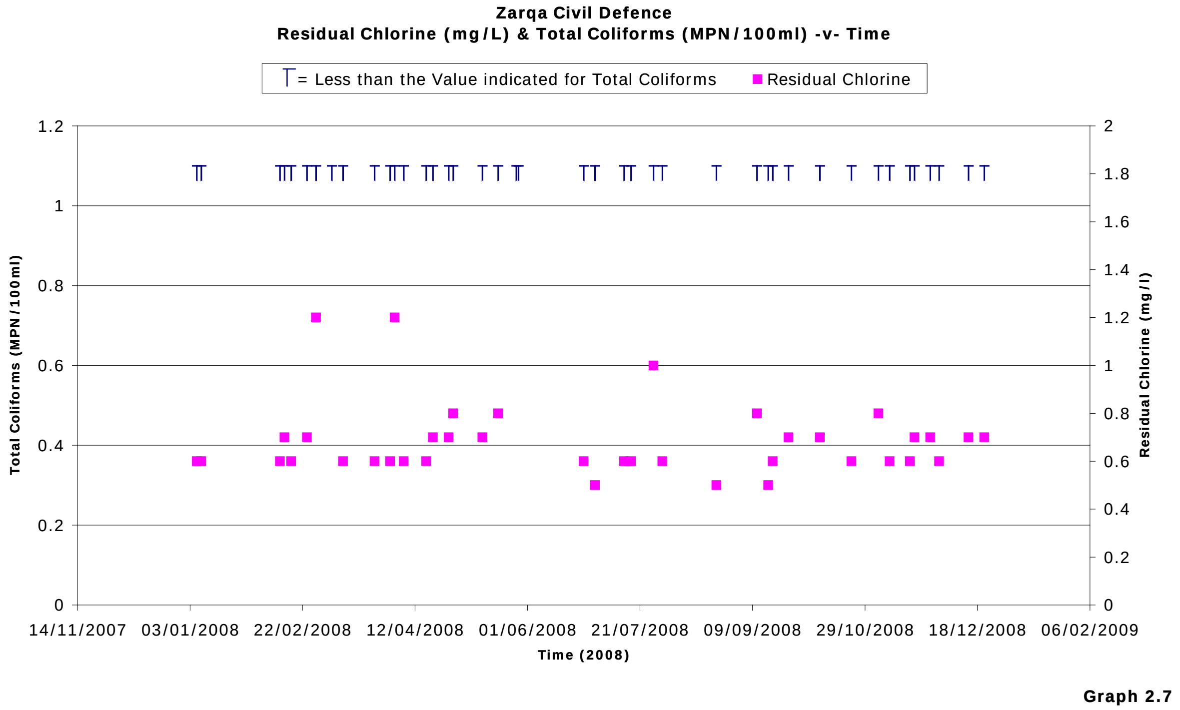


Figure 2-13: Zarqa Civil Defence (Network)
Residual Chlorine (mg/l) & Total Coliforms (MPN/100ml) –v- Time.

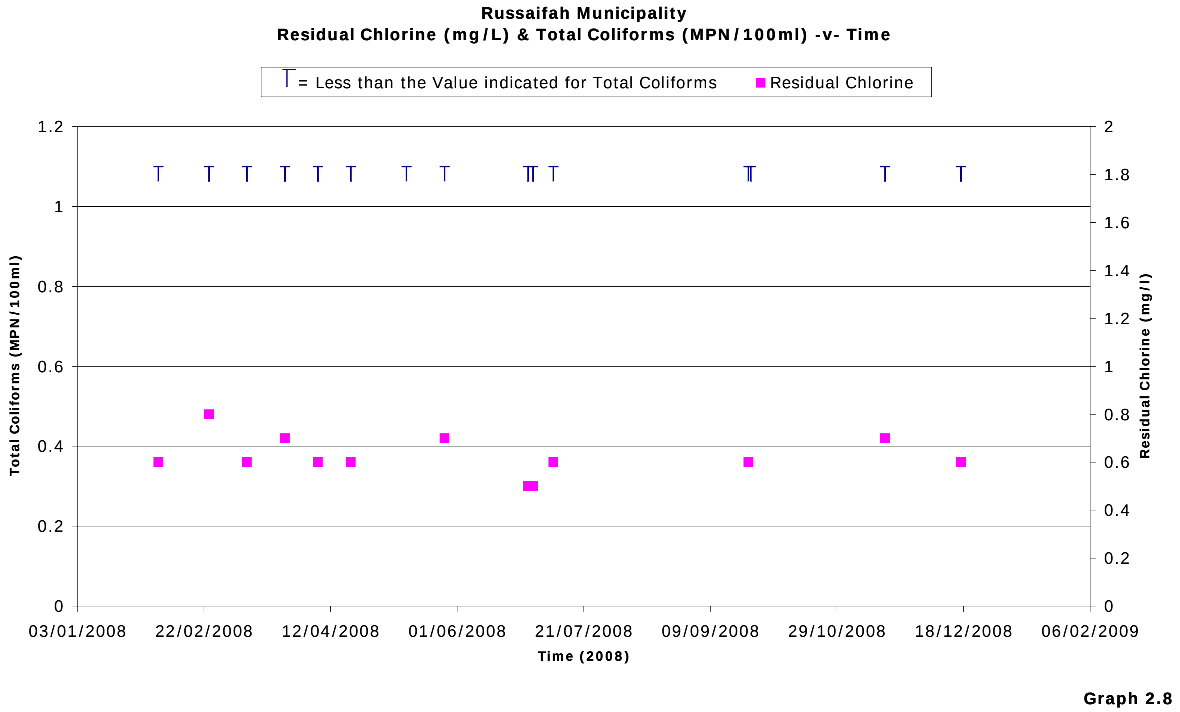


Figure 2-14: Russaifah Municipality (Network)
Residual Chlorine (mg/l) & Total Coliforms (MPN/100ml) –v- Time.

2.11 Summary of Major Shortcomings in Water Transmission and Distribution System

The major shortcomings of the existing transmission and distribution system may be summarized as follows:

1) Due to inadequate water resources and high levels of unaccounted for water, the existing water supply system is incapable of meeting current demand. As a result supply is available to consumers on an intermittent basis only.
2) There are high levels of unaccounted for water (50%) and non revenue water (54%) within the water supply system. There are high levels of leakage particularly in the tertiary pipe network.
3) The modeling of the existing network has shown that there are capacity inadequacies throughout the system.
4) Our investigations indicate that there are serious deficiencies associated with the secondary and tertiary distribution systems and that there are large quantities of galvanized steel and polyethylene pipes laid overground. In addition, corrosion in steel piping is a major cause of leaks in the system.
5) While a number of new reservoirs have been constructed in recent years, there is still a lack of service storage in certain significant areas within the network, which continue to be supplied directly from high pressure pumping mains.
6) Due to inadequacies in the current supply network and supply arrangements, there are supply and water pressure imbalances across the distribution system, with some areas experiencing excessively high pressures while others in the higher areas having minimal a supply due to low pressure.
7) The existing pumping installation and chlorination facilities apart from recently installed plant are generally in poor repair and in need of full replacements. In a number of cases, pumping plant and equipment is not properly accommodated in secure and weatherproof buildings.
8) There is a significant deficit in instrumentation which is operational, such as flowmeters, level monitors, pressure transducers etc.
9) There is no SCADA (Supervisory Control and Data Acquisition) system for a major water supply operation.

These deficiencies have been taken into account in the establishment of the Master Plan proposals in Section 8 of this report.

3. RECENT AND CURRENT CAPITAL PROJECTS

There has been quite an amount of investment in infrastructure in Zarqa Governorate over the past number of years. The main projects are summarised in Appendix 6 – Details of Current and Recent Capital Projects. Most of the capital investment has been to improve the existing water distribution system, and has included transmission pipelines, reservoirs, distribution pipelines and local pipe networks. This has tended to take place in the more densely-populated areas of Russaifah and Zarqa and has been funded by, among others, Japan (through the Japan Overseas Development Agency (ODA) and the Japan International Cooperation Agency (JICA)), the European Union (through the EU Commission Delegation to Jordan), and the People's Republic of China.

The Water Authority of Jordan (WAJ) has also been active in undertaking many water system improvements over the past few years, including water network improvements in Azraq, Zarqa, Russaifah, Um Rumanneh, Dulail and the development and servicing of wells in Hallabat, Corridor and Awajan. WAJ has also undertaken poverty reduction water improvement projects in Al Gareesah, Hashmeya, Sukhna, Arnous and Dhab'aan areas.

It is our understanding that current and future investment by WAJ will be undertaken within the context of this MCC-funded Investment Master Plan, the Priority Investment Program and the Feasibility Study.

Germany's KfW and GTZ is currently active in meter replacement and network rehabilitation in Al Gwaireyeh and has also been involved in a major project, the Operations Maintenance Support to the Middle Governorates, which has been developing detailed geographic information systems (GIS) tools for operations and management of the water systems.

Based on information provided by WAJ, investment in water supply and distribution infrastructure has been of the order of $70M over the past six to seven years.

One of the most important water infrastructure projects, undertaken in the recent past, has been the JICA Project for Improvement of the Water Supply for the Zarqa District. It has set out to restructure the primary and secondary water supply and distribution system in the areas of Zarqa, Russaifah, Hashmeya, Sukhna, Awajan, through the construction of new storage and distribution reservoirs, transmission pipelines, pumping stations and rising mains, and disinfection facilities.

Other projects of note include the China-funded replacement of water networks within the Russaifah Low reservoir distribution zone and the EU-funded water network improvements in Zarqa, Al Gwaireyeh, Awajan, Russaifah, Bani Hashem and Dogara. The locations of the main current and recent projects are illustrated in Appendix 6.

4. THE STUDY OF THE BENEFITS TO THE POOR OF MCC FINANCIAL PROJECTS IN THE WATER SECTOR – ISSUES / FINDINGS RELEVANT TO ZARQA GOVERNORATE WATER SYSTEM RESTRUCTURING AND REHABILITATION

4.1 Introduction

It was originally envisaged that the above titled study and report would be available to the Nicholas O'Dwyer Ltd. / ACEPO Consortium in January 2010 to allow the findings of that study to be taken into account in our reports which were submitted on schedule in late February / early March 2010. We were eventually provided with a copy of the Beneficiary Report in mid-April 2010 (Report Title: The Study of the Benefits to the Poor of Millennium Challenge Corporation Financed Projects in the Water Sector – Second Draft Diagnostic Report, dated 12th April 2010).

Under Sub-Task 2.2 of the Terms of Reference, we were required to take account of the Beneficiary Study in the development of the Investment Master Plan – "Results of a separately funded MCA study will be made available during the consultancy, which will provide guidance on how best to consider and quantify the poverty-impact criterion".

Under Sub-Task 4.1, we were again required to take account of the Beneficiary Study in the preparation of the Priority Investment Program. "The Consultant shall co-ordinate its work with the MCA – Jordan funded "Study on the Benefits to the Poor of the MCC Funded Projects in the Water Sector" and shall take consideration of its results as an integral part of the selection criteria".

In regard to the Feasibility Study, we were required to "review the findings of an earlier MCA financial beneficiary study and update/amend the finding given new information gained from the ERR analysis and estimates" – Sub-Task 5.3.

We confirm that we have taken due account of the Beneficiary Study – Second Draft in the preparation of the current drafts of our Investment Master Plan, Priority Investment Program and Feasibility Study.

4.2 Summary of Issues / Findings Relevant to Zarqa Governorate Water System Restructuring and Rehabilitation

The Second Draft of the Beneficiary Study Report contains 7 sections as follows: 1. Introduction, 2. Study Area Background, 3. Under Consumption Analysis, 4. Benefits Analysis, 5. Priority Investment Zones, 6. Interventions Analysis and 7. Monitoring Plan.

Sections 1 and 2 are consistent with our reports in relation to general and background information on the project. We have adjusted our projected consumption estimates in line with those contained in the Beneficiary Study. The data and finding contained in Sections 4 and 5 has been used to ensure consistency with our Priority Investment Program and Feasibility Studies. The priority investment analysis identified a number of high priority zones within the Zarqa and Russaifah areas which was similar to outcome of our preliminary assessment.

While Section 6, Interventions Analysis, still appears to be a preliminary draft, Interventions Nos. 11 – “Expansion and Rehabilitation of water supply systems to increase water availability and improve water quality” and 13 – “Geographically target network rehabilitation and zoning to serve the poor” would specifically support the investment proposals contained in the Zarqa Governorate Water System. Of these, intervention 13, the geographical targeting of works to support the poor has been included in the proposals short list in the Beneficiary Study document. This specific requirement has further refined our analysis of priority improvements as set out in Section 9 of this Report, and further developed in our separate Priority Investment Programme report.

5. WATER DEMAND ASSESSMENT

5.1 Population of Zarqa Governorate

The population of the Zarqa Governorate area has been steadily increasing over a number of decades. The population record for the Zarqa Governorate area from 1979 to 2008 is set out in Table 5.1 below.

Year	1979	1994	2004	2008
Population (persons)	381,962	639,469	774,569	871,600

Table 5-1: Population of Zarqa Governorate area 1979-2008.

The population growth rate for the Zarqa Governorate area for the 4-year period 2004-2008 was 2.99% per annum.

For the purposes of determining a future population for the Zarqa Governorate area, several population growth scenarios were considered for the period 2008-2030. Taking account of the exceptional availability of land for the new King Abdullah bin Aziz City, combined with the apparent significant political and financial support for its development, as demonstrated by the strong rate of construction progress, it is considered likely that the opportunity exists for future population growth to exceed recent and longer term population trends. However, the population for the new King Abdullah bin Aziz City is likely to attract many residents who would otherwise have settled elsewhere in the Zarqa Governorate area. The population growth scenario to 2030 selected for the purpose of planning the requirements for the Water Transfer and Distribution System has a 2030 population of 1,705,876.

This represents an annual growth rate of 3.1% per annum from 2008 to 2030. For the purposes of Water Transfer and Distribution System Planning, this growth rate is applied evenly through the full period 2008-2030, giving the population projections for the Zarqa Governorate as set out in Table 5.2 below.

Year	2008	2010	2015	2020	2025	2030
Population	871,600	926,465	1,079,217	1,257,153	1,464,427	1,705,876

Table 5-2: Population Projection for Zarqa Governorate 2008-2030

5.2 Population – Geographical Distribution

The population within the Zarqa Governorate area, which receives a piped water supply from the municipal water distribution network, is measured at 854,325 (Ecoconsult 2010). This amounts to 98.02% of the total Governorate population, which correlates with the 98% reported by the Jordanian Department of Statistics for 2008. The population without a piped water supply from the municipal water distribution network at 2008 was 17,275. This population is located in scattered rural communities beyond the current extent of the water distribution pipe network. It is anticipated that the extent of the water distribution pipe network will continue to grow at a moderate rate in future years as it has done in the past. One consequence of this network growth will be that the population without a piped water supply will reduce gradually. The projected populations with and without a piped water supply from the municipal water distribution network over the period 2008-2030 is set out in Table 5.3 below.

Year	2008	2010	2015	2020	2025	2030
Population without water supply	**17,275**	**17,148**	**16,830**	**16,512**	**16,194**	**15,876**
Population % with water supply	**98.02%**	**98.16%**	**98.68%**	**98.89%**	**98.98%**	**99.07%**
Population with water supply	**854,325**	**914,916**	**1,253,663**	**1,476,249**	**1,575,279**	**1,690,000**

Table 5-3: Zarqa Governorate Population without/with water supply 2008-2030

For the purposes of planning for the future development of the municipal water distribution network, the Zarqa Governorate is sub-divided into nine Water Supply Areas (WSAs). The WSAs cover those lands which have existing water distribution networks, and also those lands adjacent to existing water distribution networks which have been set out in land maps for future development. The extents of the WSAs are illustrated in Fig 5.1 below, with the exception of Azraq WSA, which is situated c.60km to the East of Dulail WSA.

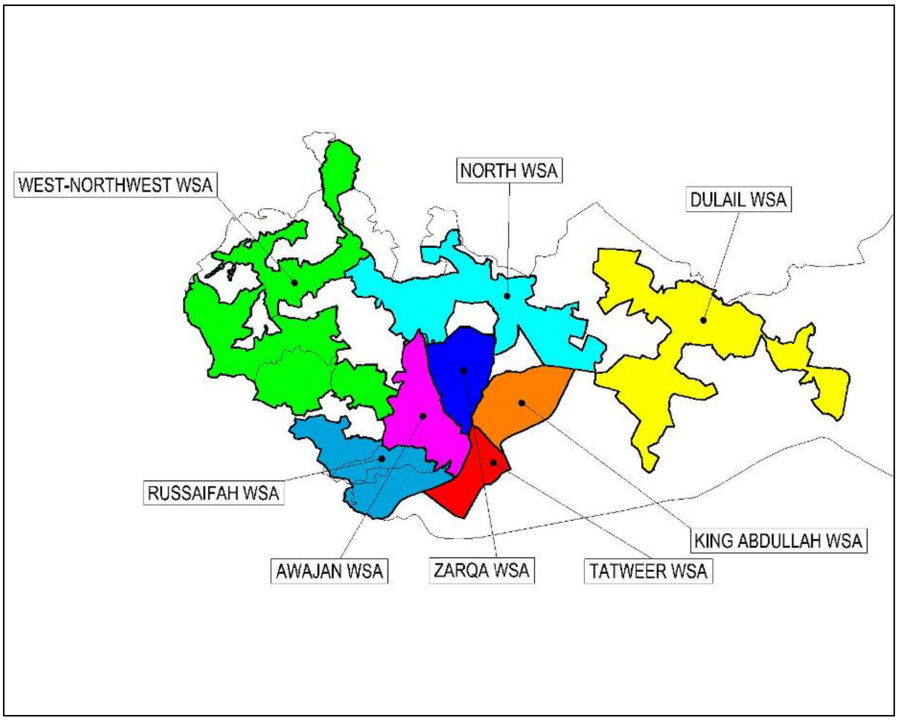


Figure 5-1: Zarqa Governorate WSAs showing Serviceable Lands to 2030

It is anticipated that the future population of the Zarqa Governorate will be distributed across the WSAs in accordance with a number of key drivers, in particular the level of existing local population, the availability of land / space for further development, the proximity of each locality to the main urban centres, and the presence of a pro-active land development plan, as in the case of King Abdullah bin Aziz City.

The 2008 populations, serviced lands and population densities of the nine WSAs and their most densely populated neighbourhoods are set out in Table 5.4 below.

WSA	Population (persons)	Serviced Land (km2)	Pop Density Average (persons/km2)	Pop Density Most Dense Neighbourhood (persons/km2)
Azraq	7,396	5.56	1,329	1,329
Dulail	37,790	9.99	3,781	3,781
King Abdullah	-	-	-	-
Tatweer	8,501	1.97	4,308	14,568
Zarqa	283,526	16.37	17,315	42,827
Awajan	149,171	16.77	8,894	22,753
Russaifah	303,448	18.24	16,640	44,371
North	51,629	10.73	4,814	4,814
West-NorthWest	12,864	17.01	756	756
TOTAL WSAs	**854,325**	**96.65**	**8,839**	**44,371**

Table 5-4: WSAs Populations and densities at 2008

In addition to the existing population, the key factors contributing to the apportionment of the projected Zarqa Governorate population growth across the WSAs for 2008-2030 are set out in Table 5.5 below.

WSA	Additional Servicable Land (km2)	Total Servicable Land (km2)	Proximity to Main Existing Urban Areas (km)	Exceptional Factors
Azraq	13.95	19.51	73	
Dulail	75.81	85.81	15	
King Abdullah	24.83	24.83	0	KABA City Project
Tatweer	13.11	15.08	5	
Zarqa	6.84	23.21	0	
Awajan	13.39	30.16	2	
Russaifah	19.80	38.04	2	
North	55.30	66.03	5	
West-NorthWest	86.58	103.60	15	
TOTAL WSAs	**309.61**	**406.26**		

Table 5-5: Key population growth factors for WSAs for 2008-2030

The projected population is apportioned across the nine WSAs by taking account of the 3 key drivers of (a) existing population, (b) available land for development, and (c) proximity to main urban areas. Various combinations were applied in order to achieve a rational, balanced population apportionment, while also ensuring that population densities do not exceed saturation levels. The projected populations for each WSA at 2030 are set out in Table 5.6 below.

WSA	Additional Population (persons)	Total Population (persons)	Pop Increase 2008-2030 (%)	Average Annual % growth rate	Pop Density Average (persons/km2)	Pop Density Saturation % v 2008 highest
Azraq	2,758	10,154	37%	1.45	520	39%
Dulail	17,539	55,329	46%	1.75	645	17%
King Abdullah	436,008	436,008			17,559	
Tatweer	8,387	16,888	99%	3.17	1,120	8%
Zarqa	116,060	399,586	41%	1.57	17,215	40%
Awajan	76,509	225,680	51%	1.90	7,483	33%
Russaifah	147,024	450,472	48%	1.81	11,842	27%
North	24,379	76,008	47%	1.77	1,151	24%
West-NorthWest	7,010	19,874	54%	2.00	192	25%
TOTAL WSAs	**835,675**	**1,690,000**	**98%**	**3.15**		

Table 5-6: Projected Populations for WSAs at 2030

5.3 Population – Socio-Economic Distribution and Water Poverty

The "Poverty Scores" at 2009 for the neighbourhoods in the three most urban WSAs, Zarqa, Awajan and Russaifah, are illustrated in Fig 5.2 below (ref: Ecoconsult April 2010). The Average customer domestic water use at 2008 for the same neighbourhoods is illustrated in Fig 5.3 below (ref: Ecoconsult April 2010).

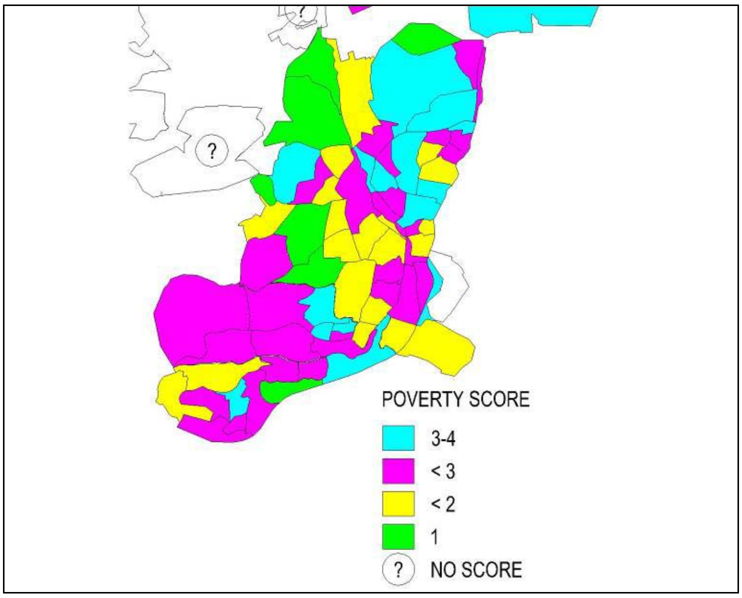


Figure 5-2: Socio-economic "Poverty Scores" at 2009: 1=Poorest, 4=Wealthiest

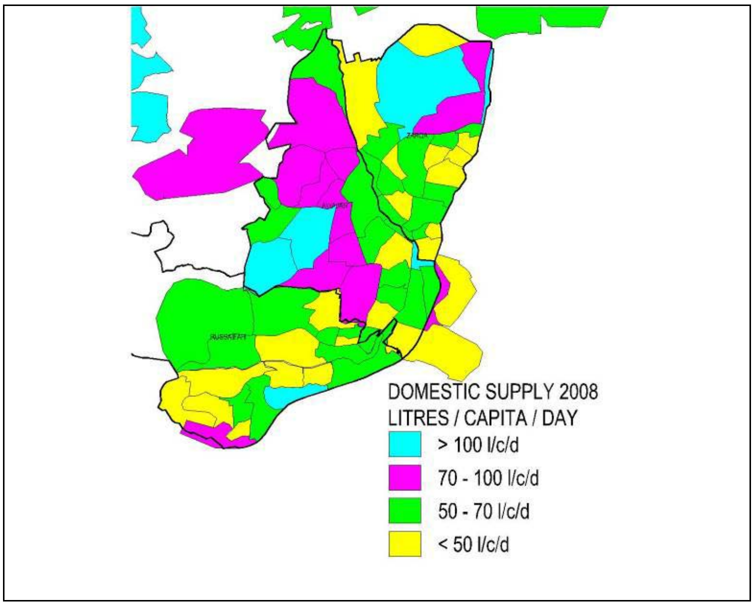


Figure 5-3: Average Domestic Water Usage at 2008

No correlation was established between Socio-economic level and Municipal piped Water Poverty (ref: Ecoconsult April 2010). Consequently average water use is applied across all Socio-economic groups.

5.4 Existing Water Demand

The information on system water inputs, outputs and water use for recent years was reviewed. The most recent full calendar year for which full data was available is 2008. The Water Audit for 2008 is set out in Table 5.7 below.

IWA Water Balance Categories	**Water Audit**		
	Total m3pa	AD m3/d	per capita lcd
System Input - Production	50,408,378	137,728	
System Input - Imports	3,677,248	10,047	
Export - Azraq Conservation Area	727,207	1,987	
Export - to Amman from Khaw	7,047,988	19,257	
Export - to North - Mafraq from Qunaya	124,350	340	
Export - to West - Jerash and Balqa from Um Rumanneh	272,027	743	
Export - to Desert	146,035	399	
System Input Total	**45,768,019**	**125,049**	**146.4**
Domestic Billed Metered Consumption	17,437,114	47,642	55.8
Non-Domestic Billed Metered Consumption	900,440	2,460	2.9
Billed Metered Consumption Total	**18,337,555**	**50,103**	**58.6**
Unbilled Unmetered Consumption - System Backwash / Flushing	931,513	2,545	
Unbilled Metered Consumption - Agriculture *	133,333	364	
Unbilled Metered Consumption - Tankers *	18,969	52	
Unbilled Consumption Total	**1,083,815**	**2,961**	**3.5**
Unaccounted-for Water: UFW	**26,346,649**	**71,985**	**84.3**
UFW %	57.6%		
Non-Revenue Water: NRW = UFW + Unbilled Consumption	**27,430,464**	**74,947**	**87.7**
NRW %	59.9%		

Table 5-7: Water Audit for 2008

The Unaccounted-for Water (UFW) analysis for 2008 is summarised in Table 5.8 below.

Parameter	**Unit**	**Value**	**At Current Supply Continuity (37 hrs/wk)**
Total UFW - Average Day	m3/d		71,985
Total UFW	% of SI		57.6%
System Input Total	m3/d		125,049
Supply Continuity (water pressure in pipes for avg 4 hrs longer duration than water-on duration)	system hrs/wk	=37+4	43
Administrative (Apparent) Losses			
Unknown/unmetered connections	% of known&metered	10%	5,366 m3/d
Meters stopped connections	% of known&metered	2%	1,052 m3/d
Meters avg. under-registration for working customer meters	% underregistration av	5%	2,505 m3/d
Systematic data handling errors	% underrecording av	0%	-
Total Administrative Losses	m3/d		8,923 m3/d
Total Administrative Losses	% of SI		7.1%
Physical (Real) Losses			
Total Physical Losses	m3/d		63,062
Total Physical Losses	% of SI		50.4%
Physical Losses - "Background" @ 100l/conn/d + 1m3/km/d	m3/d		3,993
Physical Losses - "Bursts"	m3/d		59,070
Physical Losses no of "espb"s	no.		15,386
Physical Losses espb/km	no./km		4.4
Infrastructure Leakage Index "ILI" = (Background+Bursts)/Background	Ratio		15.8
Total Physical Losses per connection	l/conn/d	water on	2,039
Total Physical Losses per pipeline length	m3/km/d	water on	70.1

Table 5-8: UFW Analysis for 2008

Administrative losses have been calculated by examining the detailed customer meter-reading and billing records, and by site surveys of customer meters. The level of Administrative Losses are calculated as follows:

- Unknown/unmetered connections:- Estimated at 10% of known and metered connections. There are 120,841 known and metered connections for a population of 854,325, giving an average of 7.07 persons per customer meter. Census data indicates that average household size is 5.3 persons per household. WAJ records and Ecoconsult surveys indicate that many metered supplies cover more than one household within a single building, so for full metering coverage of the population, an average coverage of 7.07 persons per customer meter would be appropriate. Site surveys and leak detection activities indicate that there are few properties which are not metered, but that there are some occasional unmetered pipes (possibly illegal or abandoned connections), often on waste ground or vacant plots. We have provided for the 10% of unknown/unmetered connections to have the same average usage as the known metered connections.

- Meters stopped connections:- Calculated at 2% on the basis of analysis of over 11,000 meter records over a period of 5 years.
- Meters under-registration:- Estimated at 5% on the basis of published international data, which puts overall meter under-registration for European networks at 3%. The meter stock in Zarqa is generally older than the typical meter stock in Europe. However, with the rationing water supply arrangement, most of the through-flow at customer meters would be at high flow rates, as tanks which have been empty are being re-filled. This would provide for the meters to operate at an optimal point with much lower percentage error than if they were operating on a low-flow continuous supply arrangement.
- Systematic data-handling errors:- Estimated at zero, as they would arise generally due to clerical and human errors, which would balance out between over-reading and under-reading. Many of these errors would be subsequently resolved at the subsequent reading date. Although there is potential for large numbers of individual errors, it is estimated that the aggregate error rate is zero.

Continuity of Supply to Customers at present is average 37 hours per week. For the purposes of assessing physical losses, it is estimated that the pipelines are pressurised for a typical duration of 4 hours in excess of the duration of the water being turned on in an area, i.e. for an average duration of 4 hours after the water in an area is turned off, there is sufficient water and pressure in the pipes for fractures in those pipes to continue to leak. Effect of Continuity of Supply on UFW: According as continuity of supply is increased, the volume of physical losses will increase proportionately. The Water Audits and UFW analyses for various design scenarios are set out in Appendix 7.

Other Adverse Effects of low Continuity of Supply include – stagnation of remaining water in pipes, potential contamination of water in pipes to to ingress of ground-water, foul water, drainage water through fractures when pipes are empty, stagnation and ageing of water in customer tanks, diminishing of chlorine disinfectant in customer tanks storage, stresses on network pipes and pipe linings due to de-pressurising and re-pressurising and air entrainment, reduction of network performance stability due to air-locking and excessive customer demands in replenishing empty storage tanks, requirement to put excessive chlorine into water supply as it will have to stay in system over a period of up to one week.

Geographic differences. Analysis of the customer water use statistics indicates that there is variation across different WSAs and different neighbourhoods in customer water use, as illustrated in Fig.5.3 above, and summarised by Water Supply Area (WSA) in Table 5.9 below.

WSA	Metered Connections	Population 2008	Domestic Use (lcd)	Non-Domestic Use (lcd)
Azraq	991	7,396	138.1	19.5
Dulail	3,309	37,790	48.4	9.8
KABA	-	-	-	-
Tatweer	1,613	8,501	64.0	1.4
Zarqa	47,474	283,526	55.5	3.4
Awajan	21,885	149,171	59.7	2.0
Russaifah	35,921	303,448	50.6	1.5
North	7,293	51,629	62.4	2.8
WestNW	2,355	12,864	78.7	4.0
non-WSA				
Total / average	**120,841**	**854,325**	**55.8**	**2.9**

Table 5-9: Customer Water Use for 2008 by WSA

System Input Volume (SIV) varies month by month through the year. In practice this gives rise to more continuous water supply in the distribution networks in summer months than in winter in some areas. Additional information on seasonal SIV trends is set out in Appendix 7.

5.5 Water Supply/Demand Balance

Water production, imports, exports, and SIV were reviewed for the period 2001 – 2010. In order to establish recent and current trends, and to assist with future projections. Additional information on trends in water production, imports, exports and SIV is set out in Appendix 7.

Export to Amman has diminished substantially in recent years, and soon may possibly no longer be needed due to DISI Project providing additional water to

Amman. Water exports to other adjacent Governorates have fluctuated from year to year and month to month. For the purposes of future projections in this report, these other exports are fixed at 2008 levels.

Future projections: Additional water resources will undoubtedly be required in order to provide a water supply to the increasing population. The level of additional resources required will depend on a number of factors, in particular:

- Population
- Unit per capita water use
- Condition of network and associated level of physical losses
- Condition, completeness and security of customer metering systems and meter-reading and billing systems, and associated level of administrative losses
- Duration of supply continuity (no. of hours per week) and associated duration of physical losses
- Long-term security and viability of existing water production and import sources
- Long-term level of exports to adjacent Governorates

In the event that no project were to be undertaken, and that customer use and continuity of supply were to remain at their current levels (domestic 55.8 lcd and continuity 37 hrs/wk) then a total System Input Volume (SIV) of c. 258,000 m3/d would be required by 2030, i.e. more than twice the current SIV. A realistic target SIV for 2030 is discussed at sub-section 5.7 below. If that level of SIV were to be applied to a Do-nothing scenario (where no project were to be undertaken), then the only way to meet such a cap would be to reduce customer water use and to reduce continuity of supply – customer water use at 53.0 lcd and supply continuity at 18 hours/wk. Inevitably such average levels would include effective system failure in some neighbourhoods and would be unsustainable. Consequently the Do-nothing scenario presents a very compelling argument for intervention through restructuring and rehabilitation.

The Water Audits and UFW analyses for various design scenarios and SIV levels are set out in Appendix 7.

The SIV requirement for a Do-nothing scenario, where customer use and continuity of supply were to remain at their current levels, is illustrated in Figs. 5.4 and 5.5 below.

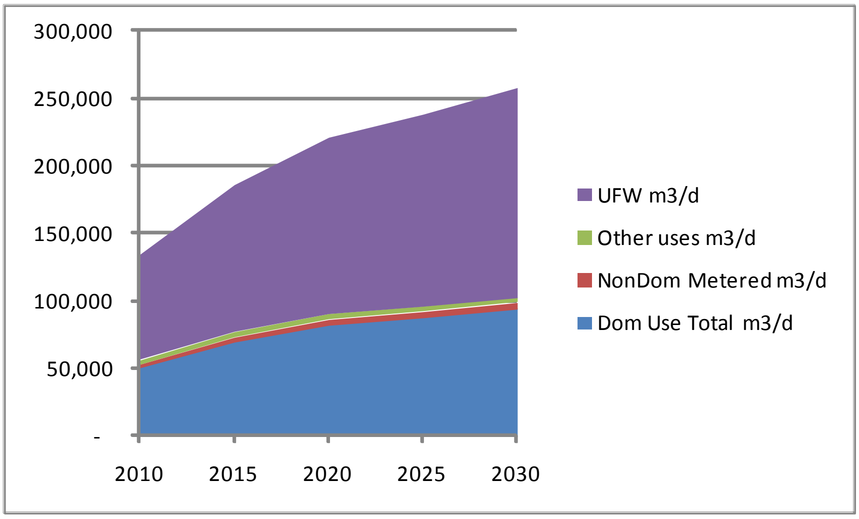


Figure 5-4: Do Nothing Scenario showing increased SI (m3/d) requirement for period 2010-2030

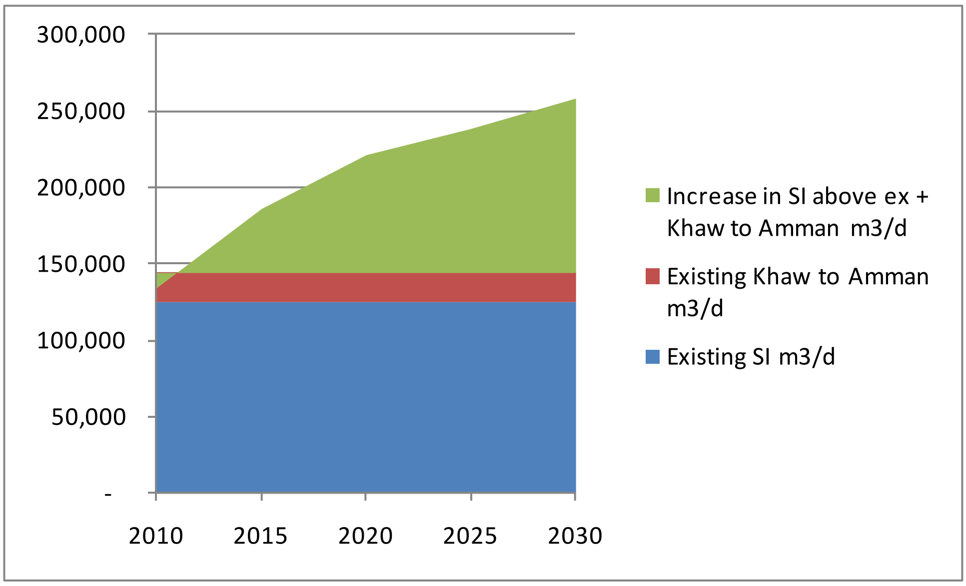


Figure 5-5: Do Nothing Scenario showing increased SI (m3/d) requirement for period 2010-2030

5.6 Projected Future Water Demand

Several scenarios are considered:

- Design Target 100 lcd @ 24/7: 168 hours
- Interim Target 85 lcd @ 84 hrs/wk
- Interim Target 85 lcd @ 70 hrs/wk

The 85 lcd x 70 hours scenario is considered to reflect a realistic situation, consistent with the re-focussing requirements, and is used in developing the

Master Plan infrastructure. The Water Audit for this scenario is set out in Table 5.10 below.

IWA Water Balance Categories	**Water Audit**		
	Total m3pa	AD m3/d	per capita lcd
System Input - Production	50,270,650	137,728	
System Input - Imports	3,667,201	10,047	
Additional Production / Import Requirement	17,033,455	46,667	
Export - Azraq Conservation Area	725,220	1,987	
Export - to Amman from Khaw	-	-	
Export - to North - Mafraq from Qunaya	124,010	340	
Export - to West - Jerash and Balqa	271,284	743	
Export - to Desert	145,636	399	
System Input Total	**69,705,156**	**190,973**	**113.0**
Domestic Billed Metered Consumption	52,432,247	143,650	85.0
Non-Domestic Billed Metered Consumption	2,726,477	7,470	4.4
Billed Metered Consumption Total	**55,158,724**	**151,120**	**89.4**
Unbilled Unmetered - System Backwash	928,968	2,545	
Unbilled Metered - Agriculture	132,969	364	
Unbilled Metered - Tankers	-	-	
Unbilled Consumption Total	**1,061,937**	**2,909**	**1.7**
Unaccounted-for Water: UFW	**13,484,496**	**36,944**	**21.9**
UFW %	19.3%		
Non-Revenue Water: NRW = UFW + Unbilled Consumption	**14,546,432**	**39,853**	**23.6**
NRW %	20.9%		

Table 5-10: Water Audit for 2030 for Design scenario

The Unaccounted-for Water (UFW) analysis for the above scenario is summarised in Table 5.11 below.

Parameter	Unit	Value	At Target Supply Continuity (70 hrs/wk)
Total UFW - Average Day	m3/d		36,944
Total UFW	% of SI		19.3%
System Input Total	m3/d		190,973
Supply Continuity (water pressure in pipes for avg 4 hrs longer duration than water-on duration)	system hrs/wk	=70+4	74
Administrative (Apparent) Losses			
Unknown/unmetered connections	% of known&metered	3%	4,855 m3/d
Meters stopped connections	% of known&metered	2%	3,237 m3/d
Meters avg. under-registration for working customer meters	% underregistration av	3%	5,098 m3/d
Systematic data handling errors	% underrecording av	0%	-
Total Administrative Losses	m3/d		13,191 m3/d
Total Administrative Losses	% of SI		6.9%
Physical (Real) Losses			
Total Physical Losses	m3/d		23,753
Total Physical Losses	% of SI		12.4%
Physical Losses - "Background" @ 100l/conn/d + 1m3/km/d	m3/d		11,877
Physical Losses - "Bursts"	m3/d		11,877
Physical Losses no of "espb"s	no.		1,798
Physical Losses espb/km	no./km		0.34
Infrastructure Leakage Index "ILI" = (Background+Bursts)/Background	Ratio		2.00
Total Physical Losses per connection	l/conn/d	water on	249
Total Physical Losses per pipeline length	m3/km/d	water on	10.1

Table 5-11: UFW Analysis for 2030 with Domestic use at 85 lcd and supply continuity of 70 hrs/week and rehabilitated and restructured network

The Unit per capita SIV requirement for a With-project scenario, where customer use and continuity of supply move from their current levels to the interim target level 85 lcd x 70 hours, is illustrated in Fig. 5.6 below.

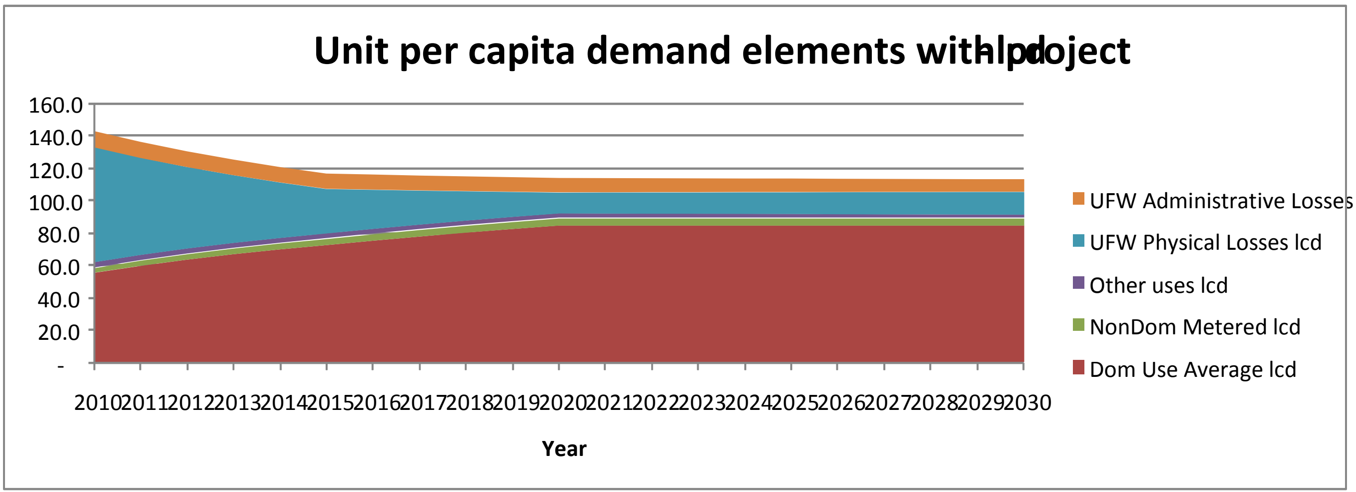


Figure 5-6: With-project Unit per capita SIV (lcd) for period 2010-2030

5.7 Future Water Supply/Demand Balance

Supply/Demand Balance Projection With Project would require that an additional 47,000 m3/day would be required by 2030 in order to satisfy Domestic use at 85 lcd and supply continuity of 70 hrs/week and rehabilitated and restructured network, while allowing for existing levels of water production and import and existing levels of export, with the exception of Amman for which exports would cease. This contrasts with the Do-nothing scenarios described at sub-section 5.5 above. The overall SIV requirement for a With-project scenario, where customer use and continuity of supply move from their current levels to the interim target level 85 lcd x 70 hours, is illustrated in Figs. 5.7 and 5.8 below.

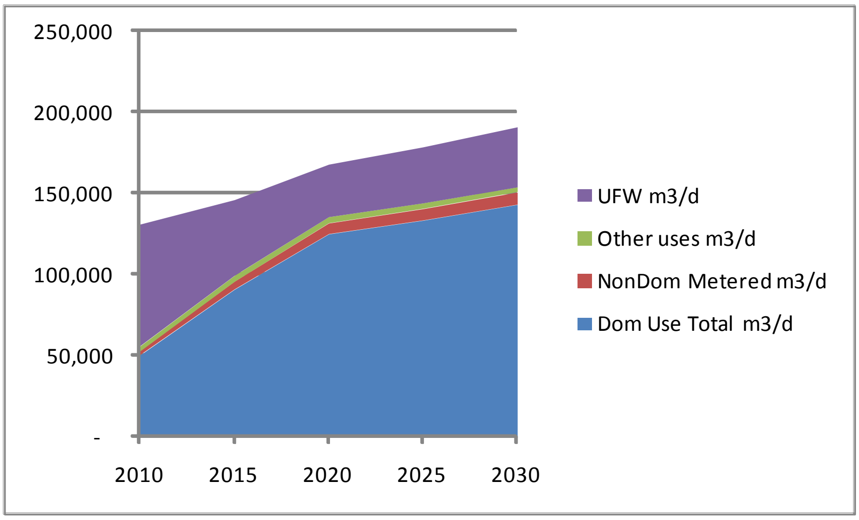


Figure 5-7: With-Project SI (m3/d) for period 2010-2030

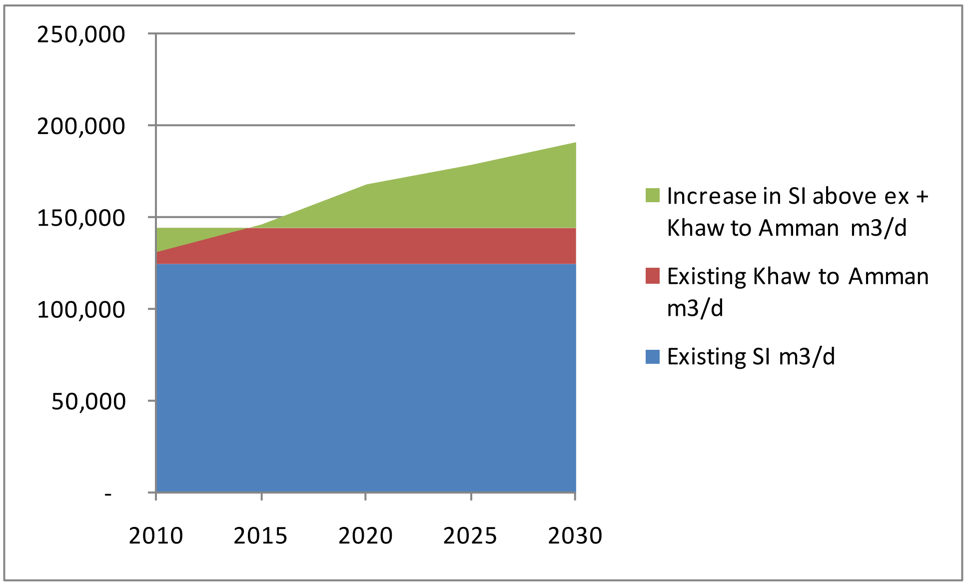


Figure 5-8: With-Project SI (m3/d) for period 2010-2030

5.8 Future Demands by WSA

The 2030 SI requirements by Water Supply Area (WSA) and Distribution Area (DA) will take account of customer water use, level of administrative losses and level of physical losses, which in turn will depend on length of network, number of customer connection points, extent of restructuring and rehabilitation, effectiveness of WAJ operational Active Leakage Control measures and duration of supply continuity in hrs/week. The 2030 customer use requirements are set out in Table 5.12 below.

WSA	Metered Connections	Population	Customer Use – Domestic & Non-Domestic (m3/d)	System Input (SI) (m3/d)
Azraq	1,351	10,154	908	1,147
Dulail	4,722	55,329	4,947	6,252
KABA	43,601	436,008	38,988	49,270
Tatweer	2,896	16,888	1,510	1,908
Zarqa	65,918	399,586	35,731	45,154
Awajan	31,985	225,680	20,180	25,502
Russaifah	51,779	450,472	40,281	50,904
North	10,449	76,008	6,797	8,589
WestNW	3,495	19,874	1,777	2,246
Total	**216,196**	**1,690,000**	**151,120**	**190,973**

Table 5-12: Target customer use and SI requirements by WSA at 2030 with Domestic use at 85 lcd

6. PROPOSED STRUCTURE OF WATER SUPPLY AND DISTRIBUTION NETWORK

6.1 Network Restructuring

The purpose of the restructuring and rehabilitation of the Zarqa Governorate water supply and distribution network is to provide an integrated and robust infrastructure, with the capability to supply all of the water customers over a wide geographical area to an acceptable standard of service over a long period of time. The main changes from the existing system structure to the future structure are set out in the Table 6.1 below.

Existing Structure	Future Structure
1. Pumped System. Water supply is pumped directly into the distribution networks.	1. Gravity System. Water supply will be pumped to high-level storage reservoirs, and then will flow by gravity into the distribution networks.
2. Rationed Water Supply. Water supply is directed to different areas of the distribution networks in turn, with each area having a water supply for a period of between 1 and 3 days per week, with average availability of water to customers at 37 hours per week.	2. Continuous Water Supply. Distribution networks will have capability to provide water supply to all areas on a continuous, 24/7 basis throughout the week. Design Target average availability of water to customers at 70 to 84 hours per week.
3. Low level of Customer Water Usage. Average daily domestic customer usage at 55.8 litres per capita per day (lcd) for 854,325 population.	3. Higher level of Customer Water Usage. Distribution networks will have capability to supply average daily domestic customer usage at 100 litres per capita per day (lcd) for 1,690,000 population. Design Target average daily domestic customer usage at 85 litres per capita per day (lcd).

4. High Levels of UFW and NRW. Physical losses at 70.1 m3/km/day of supply. Administrative losses at 288.5 litres/connection/day of supply.	4. Sustainable Levels of UFW and NRW. Physical losses at 10.1 m3/km/day of supply. Administrative losses at 138.5 litres/connection/day of supply.
5. Open Network Configuration. Substantially open networks, with changing supply boundaries in response to supply, demand and operational circumstances. Primary network supplying across wide areas. Secondary and tertiary networks connected directly to primary at numerous opportunistic locations.	5. Closed Network Configuration. Substantially closed networks, based on hierarchical zoning structure: Discrete, closed Water Supply Areas (WSAs), each containing discrete, closed Distribution Areas (DAs), each containing discrete, closed District Metering Areas (DMAs). Closed boundaries between adjacent WSAs, DAs and DMAs. Separate elements of primary network dedicated to individual DAs. Secondary and tertiary networks connected to primary only at specific controlled DMA connection points.
6. Incomplete Metering. System metering in place at all sources, import and export points and at some key installations. No system metering at primary branch mains. Customer metering in place at most customer connections.	6. Comprehensive Metering. System metering in place at all sources, import and export points and at all key installations and primary branch mains. Customer metering in place at all customer connections.
7. No public-side control at Customer Connection points. At customer connection points, access to the supply connection and meter is above-ground on customer private property.	7. Additional public-side control at Customer Connection points. At customer connection points, additional access to the supply connection and meter will be below-ground on public property.

8. Local manual network facilities monitoring. At network facilities, reading of meters and other instrumentation is generally undertaken locally and recorded by hand.	8. Integrated remote network facilities monitoring. At network facilities, meters and other instrumentation will be linked to a telemetry and SCADA (Supervisory Control and Data Acquisition) system.

Table 6-1: Main changes from existing to future water supply network structure

The change from a rationed supply to a continuous supply, and the increase in customer water use, will require the development of additional sources of water over time, in addition to the restructuring and rehabilitation of the water supply and distribution network. The identification and development of new water sources is outside of the scope of this report.

6.2 Water Supply and Transmission

The water supply and distribution network will comprise the strategic water transmission infrastructure and the water distribution infrastructure.

The strategic water transmission infrastructure will transfer the water from the principal remote water sources to the water distribution networks. The basic configuration of the strategic water transmission infrastructure will remain unchanged from at present, with the principal remote water sources at Azraq, Corridor, Hallabat and Zatari, to the East of the Zarqa Governorate area, being linked by balancing reservoirs, pumping stations and trunk mains to the principal distribution networks in the populated areas to the West of the Zarqa Governorate area. The locations of the water sources and the strategic water transmission pipelines are illustrated in Drawing no. 20445-Fig-3.01.

The transfer of water from the strategic transmission system to the local water distribution networks will take place at a number of hub facilities. The most important hub facility will continue to be at Khaw, which in turn will feed further major hubs at Batrawi Reservoir, King Abdullah City, Awajan and Russaifah, and smaller water transfer points at Hashmeya and Tatweer.

In addition to water from the strategic transmission system, existing local water sources will connect into the local distribution networks at local hubs and water transfer points. In some cases it will be necessary to re-configure the current local source connection arrangements. Where currently water from some local sources is pumped directly into distribution, it will be changed to pump into an existing or new flow-balancing reservoir.

While most of the public water supply networks in the Zarqa Governorate area will be connected to the strategic transmission system, this will not be required in the West-NorthWest portion of the Governorate, due its high elevation, relatively remote location, sparse population and relatively small water demand. This area comprises Merhib, Berein, Um Rumanneh, Sarout, Alouk, Qunaya and the surrounding rural areas. It has several local water sources, which have adequate capacity for the foreseeable demands, subject to restructuring and rehabilitation of the networks.

6.3 Water Distribution

The water distribution networks will be sub-divided based on hierarchical zoning structure: Water Supply Areas (WSAs), Distribution Areas (DAs) and District Metering Areas (DMAs).

Water Supply Areas (WSAs) will be discrete geographical areas, each with their own self-contained supply and distribution networks. They will distribute water incoming from the strategic water transmission infrastructure and also from local sources, where available. The infrastructure within each WSA will have full capacity for water distribution to meet all projected water demands throughout the WSA, without reliance on adjacent WSA infrastructure capacity for support. The pipe networks within each WSA will not be connected with adjacent WSAs for the purposes of day-to-day operation. However, there will be strategic security of supply links, where appropriate, between adjacent WSAs, for use in exceptional emergency and contingency situations. There will be 9 WSAs in the Zarqa Gorvernorate area. Their locations are illustrated in Drawing No. 20445-Fig-3.02.

Distribution Areas (DAs) will be located within each WSA. A DA will comprise all of the distribution network which is supplied by gravity from a single reservoir location. The configuration of the DAs depends substantially on the topography of the WSA and the locations of the existing reservoirs. The network layout will utilise all of the existing reservoirs and other major facilities to their best practical effect. However, several additional reservoirs will be required in order to service areas which are too high in elevation to be serviced by gravity from existing reservoirs. The topography of the 9 WSAs is extremely hilly. It ranges in elevation from about 500 metres over datum (mod) at its lowest points along the Northern Governorate boundary to c. 1000 mod at the Westernmost boundary. Through the most populous areas of Zarqa, Awajan and Russaifah, there are several wadis at c. 600 mod elevation, with large hills rising on each side to above 700 mod within the most urban areas. Along their fringes, the urban areas are continuing to develop outwards, and upwards onto higher and higher ground. The ground elevation topography across the lands covered by the 9 WSAs is illustrated in Drawing No. 20445-Fig-3.03.

Taking account of the topography of the area, and the locations and elevations of the existing reservoirs and other major facilities, it is proposed to arrange the DAs as illustrated in Drawing No. 20445-Fig-3.04. There will be 30 DAs within the 9 WSAs.

District Metering Areas (DMAs). The distribution network within each Distribution Area will be subdivided into DMAs. The typical size of a DMA will be in the range 500 – 1,500 customer properties. Where practical, DMAs will have a maximum difference in elevation of 30 metres between their highest and lowest points. DMAs will generally have a consistent property age and type. The layout of DMAs will be modular, and will take account of a range of operational factors, including provisions for network control, pressure management, sub-zoning, and potential future DMA reconfiguration. By 2030, there will be approximately 150 DMAs within the 30 DAs.

The proposed WSAs and their DAs, together with population and System Input projections for 2030 are set out in Table 6.2 overleaf.

WSA	Distribution Area	Population 2030 (persons)	System Input Volume 2030 (m3/d)
Azraq	Azraq	10,154	1,147
Dulail	Hallabat	4,704	532
	Dulail	46,481	5,252
	Tafeh	4,144	468
King Abdullah City	King Abdullah City	436,008	49,270
Tatweer	Tatweer	16,888	1,908
Zarqa	Zarqa High	31,677	3,580
	Zarqa Mid - Batrawi	313,932	35,475
	Zarqa North	53,977	6,100
Awajan	Awajan High	76,882	8,688
	Awajan Low	47,069	5,319
	Awajan West	46,344	5,237
	Awajan North	55,386	6,259
Russaifah	Russaifah North West	47,676	5,387
	Russaifah High	129,853	14,674
	Russaifah Low	86,039	9,723
	Hitteen Tower	15,753	1,780
	Hitteen Reservoir	171,153	19,341
North	Khaw	5,752	650
	Hashmeya South	1,568	177
	Hashmeya Town	32,974	3,726
	Hashmeya Rural	6,942	784
	Sukhna	28,772	3,251
West-NorthWest	Merhib	2,258	255
	Berein	3,976	449
	Um Rumanneh	5,242	592
	Berein North	1,759	199
	Sarout/Alouk	4,978	562
	Qunaya	1,661	188
Total		**1,690,000**	**190,973**

Table 6-2: WSAs and Distribution Areas statistics for 2030

In the development of the Investment Master Plan, the proposed structure of the water supply and distribution networks is divided into Primary, Secondary and Tertiary levels, which are summarised in Table 6.3 overleaf.

Primary Infrastructure: • Elevated Storage Reservoirs, located at high points within WSAs, in order to provide a gravity water supply to Distribution Areas. • Pumping Balancing Reservoirs, located at strategic hub points, where water from local or distant sources is stored prior to being pumped to Elevated Storage Reservoirs. Some Elevated Storage Reservoirs will also act as Pumping Balancing Reservoirs, as they will facilitate onward pumping to additional reservoirs at higher elevations. • Pumping Stations, located at key network locations, including sources (to pump from source to pump balancing reservoir), strategic hub points (to pump from pump balancing reservoir to elevated reservoir), and local high points (to pump from primary pipeline to local elevated area too high for gravity supply). • Primary Network Pipelines: Pumping mains / force mains from sources to hub points, and from hub points to elevated reservoirs. • Primary Network Pipelines: Gravity mains from elevated reservoirs through Distribution Areas to DMA Connection Points. • Connection Points to DMAs at specific controlled locations along Primary Network Pipelines (Gravity Mains), to facilitate monitoring and control of water supply into Secondary and Tertiary networks.
Secondary Infrastructure: • Secondary Network Pipelines within DMAs. Pipes of diameter > 50mm
Tertiary Infrastructure: • Tertiary Network Pipelines within DMAs. Pipes of diameter up to 50mm • Customer Connection Points. Underground control and monitoring point located on public property at the frontage of each building or land plot serviced by the distribution network. • Customer Meters. Above ground meters, usually housed within cabinets on private property to the front of customer premises.

Table 6-3: Elements of Primary, Secondary and Tertiary Infrastructure

6.4 Water Supply Sources

By 2030, 8 of the 9 WSAs (all with the exception of the West-NorthWest WSA) will receive the majority of their supply from the existing principal remote water sources at Azraq, Corridor, Hallabat and Zatari, to the East of the Zarqa Governorate area, with supplementary water supply being provided from existing local sources, where available. In order to meet the full Design Target System Input requirement, these sources will be augmented by additional future supplies of up to 47 Mld (= 47,000 m3/d), if it is available. This additional System Input will most likely be met either by further supplies from the areas around the existing principal remote water sources or from the Amman direction, possibly via Ein Ghazal Pumping Station, which currently pumps water into Amman from the Khaw-Ein Ghazal pipeline. In the event that additional water is not available for production or importation, then it will be necessary to reduce System Input by reducing customer use, and/or reducing hours of availability of water supply.

The West-NorthWest WSA will continue to receive its System Input from existing local sources, currently supplying c. 6.14 Mld. These sources may need to be augmented by additional local sources over time, according as the population and System Input requirement increase, and the water distribution network is extended into newly developing areas, and if demand for water exports to neighbouring Governorates increases above current levels. The System Input requirement within the West-NorthWest WSA is calculated at 2,246 m3/day by 2030, so it is anticipated that the WSA should be self-sufficient provided that outside demands are not excessive.

The identification and development of additional water sources is outside the scope of this report.

6.5 Construction Projects

The construction of the restructuring and rehabilitation of the Zarqa Governorate water supply and distribution networks can be undertaken as a series of separate construction projects. Works on Primary infrastructure can be readily separated from works on Secondary / Tertiary infrastructure without loss of construction efficiency. However, restructuring and rehabilitation of Secondary and Tertiary infrastructure in any area would be undertaken most efficiently as a single construction project. In order to achieve substantial benefits in system performance and customer levels of service in any WSA or Distribution Area, both the Primary and the Secondary/Tertiary would require restructuring and rehabilitation. If only one or the other is undertaken, then worthwhile benefits will not be realised.

In recent years, very substantial investments have been made in the provision of new and upgraded primary infrastructure in some WSAs, in particular Zarqa, Russaifah, Awajan, North (Hashmeya and Sukhna). In these WSAs, the majority of urgent work remaining is in the secondary and tertiary networks, as substantial portions of the primary infrastructure are up to the required standard.

6.6 Typical Scope of Restructuring and Rehabilitation Construction Works

The typical scope of construction works for the principal components of the restructuring and rehabilitation projects is set out below.

Construction of New Reservoirs will include the following features:

- Site pipework and fittings sized to 2030 design capacity.
- Separate inlet, outlet, scour and overflow pipework.
- By-pass pipework linking inlet to outlet pipework.
- Minimum of two separate reservoir cells at any site.
- Electromagnetic Flow-meters on each inlet and outlet pipe.
- Ultrasonic level recorders within each reservoir cell.
- Flow control valves on inlet and outlet pipework.
- Provision for Chlorination system at reservoir inlet.
- Telemetry outstation connected to central operational monitoring / control site.
- Site-works, including roadway, parking, control building, fencing, gate, landscaping, lighting.

Upgrading and Refurbishment Works at Existing Reservoirs will include the following features:

- Leakage tests on reservoir structure and site pipework.
- Structural inspection and repairs as required to concrete structures.
- Repairs to reservoir joints and internal sealing coating as required.
- Condition and operational inspection of valves and site instrumentation, and repairs / replacement as required.

- Additional site pipework as required, including site pipework and fittings sized to 2030 design capacity.
- New Electromagnetic Flow-meters on each inlet and outlet pipe where required.
- New Ultrasonic level recorders within each reservoir cell where required.
- New Flow control valves on inlet and outlet pipework where required.
- Provision for Chlorination system at reservoir inlet.
- New Telemetry outstation connected to central operational monitoring / control site.
- New Access covers, ladders, protection railings, vent covers.
- Site-works as required, including roadway, parking, control building, fencing, gate, landscaping, lighting.

Construction of New Pumping Stations will include the following features:

- Site pipework and fittings sized to 2030 design capacity.
- Duty and Stand-by pumps sized to modular sizing, taking account of standard sizing, current pumping requirement, projected 2030 design capacity.
- Surge protection measures as appropriate, including surge vessel / variable speed drive
- Electromagnetic Flow-meters on each inlet and outlet pipe.
- Pressure monitors on all pump inlet and outlet points.
- Flow control valves on inlet and outlet pipework.
- Telemetry outstation connected to central operational monitoring / control site.
- Site-works, including roadway, parking, pumping station building, fencing, gate, landscaping, lighting.

Upgrading and Refurbishment Works at Existing Pumping Stations will include the following features:

- Duty and Stand-by pumps sized to modular sizing, taking account of standard sizing, current pumping requirement, projected 2030 design capacity.
- Surge protection measures as appropriate, including surge vessel / variable speed drive
- New Electromagnetic Flow-meters on each inlet and outlet pipe.

- New Pressure monitors on all pump inlet and outlet points.
- New Flow control valves on inlet and outlet pipework.
- New Telemetry outstation connected to central operational monitoring / control site.
- New / Additional site pipework as required, including site pipework and fittings sized to 2030 design capacity.
- Site-works as required, including roadway, parking, pumping station building, fencing, gate, landscaping, lighting.

Construction of New Primary Network Pipelines will include the following features:

- Extensive advance geotechnical site investigations to determine ground corrosiveness, presence of rock, contaminated ground and other relevant ground conditions.
- New underground pipelines with minimum cover of 1.0 metres.
- Use of appropriate pipeline materials, coatings, linings and protection features to protect pipeline integrity against ground and environmental conditions, crossings of highways and wadis, and other physical features of site.
- Isolation valves at maximum 1.0 km intervals.
- Air valves at pipeline high-points and scour valves / washout valves at pipeline low-points.
- Minimum branch main size equal to smaller of main pipe size or 300mm.
- Electromagnetic Flow-meters at selected metering points.
- Pressure monitors at selected monitoring points.
- Telemetry outstations at metering / monitoring points connected to central operational monitoring / control site.
- Temporary-works and reinstatement works as required, including access works, re-location of other services, road reinstatement.

Upgrading and Refurbishment Works of Existing Primary Network Pipelines will include the following features:

- Extensive advance geotechnical site investigations to determine ground corrosivity, contaminated ground and other relevant ground conditions.

- Extensive external and internal investigation of existing pipeline, including temporary metering, leakage survey, CCTV survey, checking of valves and fittings, metallurgical survey, visual and measurement survey of integrity of external coatings.
- New pipeline coatings, linings and protection features to protect pipeline integrity against ground and environmental conditions, and to redress any deterioration discovered.
- Re-laying / burying / armouring of exposed / overground sections of pipelines.
- Installation of additional isolation valves, air valves and scour valves / washout valves as appropriate.
- Installation of New Electromagnetic Flow-meters, Pressure monitors and Telemetry outstations as appropriate.
- Temporary-works and reinstatement works as required, including access works, re-location of other services, road reinstatement.
- In cases where existing pipelines have no worthwhile remaining life expectancy, full structural rehabilitation of pipelines will be required, usually involving construction of new pipelines and disconnection and de-commissioning of existing pipelines.

Works at <u>Connection Points to DMAs</u> will include the following features:

- New branch connection pipe.
- New Electromagnetic Flow-meter.
- New Pressure Reducing Valve (PRV), where required, if upstream pressure at connection point is high.
- New DMA isolation valves and by-pass pipework.
- New Pressure monitor and Telemetry outstation connected to central operational monitoring / control site.
- A typical DMA will have one, or maximum two, Connection Points from the Primary Network Pipeline system, which in turn, will be supplied by gravity from the High-level storage reservoir supplying the Distribution Area.

<u>Rehabilitation Works on Secondary and Tertiary Distribution Pipe Network</u> within a DMA will include the following features:

- Extensive advance geotechnical site investigations to determine ground corrosivity, contaminated ground and other relevant ground conditions.
- Extensive advance network performance site investigations to determine distribution network and operational system characteristics, including water rationing details, locations and frequencies of leaks and bursts, pressures and flows during operation, locations susceptible to stagnant water and air entrapment.
- Appraisal of existing pipelines in order to determine the need for rehabilitation and the appropriate method of rehabilitation. Appraisal will include physical location of pipes at intervals and at key locations, in order to inspect, measure and gather information on pipe material, diameter, location, depth, physical condition, type and condition of joints and fittings, residual life expectancy, pipe bedding materials, ground conditions for trenching, surface reinstatement requirements, significant obstacles and other utility service pipes and cables, etc.
- Before and after customer levels of service surveys.
- Selection of appropriate pipeline materials and protection features to protect pipeline integrity against ground and environmental conditions and other physical features of site.
- Replacement of all non-plastic (Polyethylene / uPVC) underground pipes, where their poor condition is confirmed by site investigations.
- Replacement of all overground pipes.
- Disconnection and decommissioning of redundant existing pipes.

<u>Restructuring Works on Secondary and Tertiary Distribution Pipe Network</u> will include the following features:

- Distribution Network Sizing, Layout, Valving and Fittings to ensure breaking up into discrete DMAs, with satisfactory hydraulic capacity within each DMA.
- Additional pipes, cross-connections and sluice valves to ensure looped water circulation through majority of each DMA.
- Additional Air-valves and underground hydrants at key end points and high points in each DMA.

Works at Customer Connection Points from Distribution Pipe Network will include the following features:

- Survey and location of all Customer Connection Pipes and Meters.
- Replacement of Customer Connection Pipes other than polyethylene (PE) pipes.
- Replacement of PE pipes where they are in unsatisfactory condition or location.
- Replacement of all public-side overground pipes.
- Installation of new underground customer-connection control-point on public property at the frontage of each customer property, comprising chamber, stop-valve and housing for check-meter installation.
- Installation of check-meters at c. 10% of new underground customer-connection control-points.
- Replacement of Customer Meters more than 5 years old.
- Replacement of Customer Meters in poor / inoperable condition.
- Provision of new meters on unmetered connections.

Works at Customer Meters will include the following features:

- Survey of properties serviced by metered supply pipes to establish accurate information database, and to check for cross-connections / unmetered connections and anomalies between historical record and site situation.
- Appraisal of existing meters in order to determine the need for replacement and the appropriate method of replacement. Appraisal will include meter age, condition, size, visual condition and performance, suitability for connection to remote monitoring system, suitability for tamper-proofing, ease of replacement, accuracy testing, etc.
- Replacement of meters where they do not satisfy appraisal criteria.
- Re-configuration of customer connection arrangements where they do not satisfy appraisal criteria.

6.7 Additional Features of Restructuring and Rehabilitation Project Works

Aside from the construction works for the principal components of the restructuring and rehabilitation projects, a range of additional features will be incorporated into the projects. The additional features will assist in achieving the maximum performance and operational benefits from the network improvements over a long period of time, and will facilitate the management of the water supply system in a sustainable manner. The additional features will include the following:

- Provision of a comprehensive SCADA (Supervisory Control and Data Acquisition) and Telemetry System for the water supply networks.
- Standardisation and modularity - standardisation of pumps, flow-meters, telemetry outstations, pressure monitors, level recorders and pressure-reducing valves (PRVs).
- Quality control of Materials and Workmanship through rigorous specifications for undertaking and testing of works, and through supervision of construction works.
- Environmental and Archaeological monitoring of construction works and mitigation measures.
- Testing, disinfection and commissioning of new, rehabilitated and upgraded infrastructure.
- Network information encountered during preparatory site investigations and during construction will be gathered and recorded in formats compatible with the WAJ GIS. As-constructed measurements and drawings will be prepared on completion of construction works.
- Clear written procedures and timely arrangements for temporary handover of site areas from WAJ to Contractors.
- Detailed planning, programming and resourcing for interim operation of existing infrastructure during construction.
- Formal procedures, including provision of operations manuals and comprehensive training of WAJ operational staff, for handover of completed works from Contractors to WAJ.
- Pro-active Maintenance and Defects periods, to ensure comprehensive snagging and remedial works by Contractors.
- Preparation of Operations Manuals, including measures for routine maintenance, trouble-shooting and repairs,

incorporating method statements and check-lists for standard activities such as new customer connection, new pipe branch connection, system meter service, PRV service, reservoir inspection and clean-down, pump service, etc.

- Preparation of Leakage Management Plan and equipment for ongoing water conservation in operation of new network elements – Active Leakage Control, appropriate equipment, setting-up of relevant information and measurement parameters, e.g. for each DMA: zero-pressure test, sub-zoning / step-testing plan, water audit template, target night-flow and weekly flow settings, and initial alarm / response level settings.
- Preparation of Asset Management Plan – setting out annual, 5-year and long-term programmes for routine inspection, servicing, preventative maintenance and replacement, including spare parts schedule and budget plan.
- Operation Health and Safety Plan – including appropriate site-specific risk assessments, in particular for hazards such as water, electricity, chlorine, confined spaces, excavations, traffic management, night-time work, working at height.
- Identification of specialist expertise requirements to supplement WAJ staff capabilities, such as specialist maintenance contractors and suppliers, e.g. for servicing of SCADA and telemetry equipment, training, system auditing and review.

In addition to the above features being incorporated into the Restructuring and Rehabilitation works, it is expected that WAJ will continue to develop their current initiatives in relation to staff training and the use of GIS to improve of network information systems. The "Study for the Benefits to the Poor of Millenium Challenge Corporation Financed Projects in the Water Sector", which is discussed in Section 3 of this report, identifies several activities as "Intervention 1", including a SCADA system, Asset Management, Capacity building through staff training, and replacement of customer meters. In order to guard against double-costing of proposed investments, we have not included for the cost of SCADA system, Asset Management or Capacity building through staff training in this report, although we have included for the cost of replacement of customer meters, as it is an integral part of the required physical Restructuring and Rehabilitation works.

7. DESIGN OF RESTRUCTURING AND REHABILITATION WORKS

7.1 Design Standards

The Design Standards set the target performance levels against which the Master Plan infrastructure will be designed and constructed. The key Design Standards for the Master Plan infrastructure are set out in the Table 7.1 below.

Design Parameter	Value
Base Year	2008
Final Design Year	2030
Hydraulic Design Capacity: Average Customer Domestic Use x Continuity of Supply (litres per capita per day x hours per week) (lcd x hrs)	100 lcd x 168 hrs
Hydraulic Design Capacity Check: (lcd x hrs)	85 lcd x 84 hrs
Hydraulic Design Capacity Check: (lcd x hrs)	85 lcd x 70 hrs
Design Day for network hydraulic capacity = Average Day Peak Week (ADPW): Ratio of Customer Demand ADPW: AD	1.35
Primary Network Elevated Storage Reservoirs - Primary System response time (hrs) *	2 hrs
Primary Network Elevated Storage Reservoirs - Capacity (hours x AD throughflow)	12 hrs
Primary Network Pump Balancing Reservoirs - Capacity (hours x AD throughflow)	2 hrs
Primary Network Pumps - Minimum Pumping System Efficiency (at optimal duty point)	70%
Primary Network Pumps - Minimum Pumping System Efficiency (at range of duty points over extended period)	60%
Primary Network Pumps - Max. Pump Hours at optimal duty point required to deliver AD daily throughflow – pumping to reservoir (hrs)	20 hrs
Primary Network Pumps - Booster pumps direct to supply, pumping capacity for maximum hourly demand: Peak Hour Flow Factor	2.5
Primary Network Pipelines - Target Average Flow Velocity (m/s)	1.0 m/s
Primary Network Pipelines - Target Max. Flow Velocity (m/s)	1.5 m/s
Primary Network Pipelines - Max. Primary Main Valve Spacing (km) **	1.0 km
Primary Network Pipelines - Minimum Branch connection size off Primary main (mm)	300 mm
Secondary and Tertiary Networks - Peak Hour Flow Factor = AD x factor	2.5

Secondary and Tertiary Networks - Min. Residual Mains Pressure at Peak Demand – metres head (m)	25 m
Secondary and Tertiary Networks - Max. Residual Mains Pressure at Minimum Demand – m	60 m
Secondary and Tertiary Networks - Max. Unit Headloss in Secondary Pipelines at Peak Design Flow – m per km	3.0 m/km
Minimum Design Life of Civil Assets (years)	60 yrs
Minimum Design Life of M&E Assets (years)	15 yrs

Table 7-1: General Design Standards for Zarqa Restructuring and Rehabilitation Works

* Primary Network Elevated Storage Reservoirs - Primary System response time (hrs): This is the response time that would be required in order to ensure that the primary network operates securely in the event of an emergency, e.g. if a primary pipeline bursts, it should take no more than 2 hours to become aware of the burst, identify its location, activate and mobilise a response team, and isolate the affected area by shutting key valves on the pipeline, in order to prevent against the problem causing excessive knock-on effects over a wide part of the network. In order to achieve this standard of response time on a 24/7 basis over a large geographical area with a complex infrastructure and a rationed operation system, it would be necessary to have comprehensive system metering, an integrated telemetry/SCADA system, a restructured primary network, including improved valving, and stream-lined maintenance and operational resources and procedures.

** Primary Network Pipelines - Max. Primary Main Valve Spacing (km): This refers to isolation valves, i.e. Sluice Valves and Butterfly Valves depending on pipe diameter, location and site factors. The valves would be operated for the purposes of isolation of sections of the network either for routine operation reasons, or in emergency situations, or to facilitate planned works. The maximum spacing of 1 km on primary pipelines is in line with best international practice.

7.2 Design Process

At the detailed design stage, for individual project packages, additional design measures will be considered, as appropriate, for various elements of the network. These will include the following:

- General: Review of Population Projections and Design Demands at the time of detailed design.
- General: Review of System Configuration: WSAs, Distribution Areas and DMAs.
- General: Review of expected availability of additional water sources, e.g. where further water sources are not likely to be available for several years, then additional design measures might be considered, such as larger reservoir size (up to 24 hrs of current demand).
- Construction: Identification and mitigation of potential impacts of construction works on water supply operations, customer water supplies, other utilities and services, vehicular and pedestrian traffic, access to business premises and domestic dwellings, local environment and other factors addressed in the Preliminary Environmental and Social Impact Assessment (PESIA).
- Construction: Identification and mitigation of potential impacts of other major infrastructure projects in the area on proposed construction works.
- Primary Infrastructure: Reservoirs – outflow control valves to restrict max outflow to 2.5 times average through-flow rate, in order to safeguard the stability and consistency of system operation. Reservoirs in operation should be kept full.
- Primary Infrastructure: Pumping Stations - Provision of duty and stand-by pumping capacity, provision of pumping manifold to facilitate modular addition of further pump sets according as through-flow increases over years.
- Primary Infrastructure: Pumping Stations - Provision of standby electricity power supply assessed on a site-by-site basis.
- Primary Infrastructure: Pumping Stations – Surge protection and potential benefit of Variable Speed Drives will be assessed on a site-by-site basis.
- Primary Infrastructure: Pipelines -Security of Supply (SOS) measures: Primary Network Cross-link pipes, and stand-by inter-linkage between adjacent WSAs.
- Primary Infrastructure: Pipelines - Optimal pipe sizes and future cross-connection points will be provided, in order to allow for flexibility and modularity in developing the trunk main network into the future. Allowance for future or staged duplication /

reinforcement. The design life of the primary network is up to 2070, whereas strategic assessment of the water supply requirements has only been undertaken for the period up to 2030. Future-proof / modular design checks will be undertaken to prevent against future “bottle-necks”.

- Primary Infrastructure: Pipelines - Fittings: Swabbing chambers, scour valves, fittings for leak-sounding, and tappings for insertion of inspection probes and cameras will be provided.
- Primary Infrastructure: Pipelines – Surge pressure protection measures including valve closure controls, Pressure-Reducing Valves and Pressure Relief Valves.
- Primary and Secondary Infrastructure: Pressure-Reducing Valves (PRVs) – will be fitted, on primary gravity mains, at DMA Connection Points and on secondary distribution networks where required (i.e. if max pressure > 60m without PRV). By-passes to PRVs will also be fitted.
- Secondary and Tertiary Infrastructure: Pipelines – Optimal pipe sizes will be provided, being the smallest pipe sizes which achieve the target flow velocities at proposed Design Flow-Rates.
- Secondary Infrastructure: Pipelines – Looped network will be provided, generally avoiding dead ends. Network fittings will include flow meters where they may supplement DMA meters, Sluice Valves (SVs) at key pipe junctions, and within the network to isolate areas with a typical maximum of 40 properties, hydrants at strategic operational points for system flushing and pressure monitoring, Air Valves (AVs) at critical high points where air-lock could arise. Minimum pipe size will generally be 100mm on secondary, subject to hydraulic model checking.
- Secondary and Tertiary Infrastructure: Pressure Management – At detailed design stage and in operational practice it will be beneficial to adjust the set-up of elements of the network to suit local situations, e.g. pressure range could be set at 20m – 45m for a relatively flat and low-rise WSA like Azraq.

7.3 Specific Design Measures to deal with UFW and NRW

The reduction of Unaccounted-for Water (UFW) / Non-Revenue Water (NRW) will be facilitated by the following measures:

- Rehabilitation of networks will remove all existing pipes which are old, weak, corroded, overground and/or inadequately protected from damage. The more comprehensive the rehabilitation, the less number of leaks will be present.
- Restructuring of networks will include the setting up of District Metering Areas (DMAs), improved pressure management, the installation of network monitoring instrumentation and telemetry and the installation of extensive network control valving.
- Faulty customer connection pipes and connectors will be replaced and new supply-side customer control and monitoring points will be installed at each customer connection where none exist at present.
- All unmetered supply connection pipes will be metered, and old and faulty customer meters will be replaced. There will be no unmetered or inadequately metered customer supplies.
- Enhanced network operational infrastructure will be provided, and recommendations for improved operational systems will be provided, including: Network Information System – mapping and GIS; Network monitoring system – SCADA / telemetry; Preventative maintenance and improved system house-keeping; Active Leakage Control based on DMA management with improved equipment to replace existing Passive Leakage Control based on customer complaints; Asset Management Plan including planned servicing and replacement of instrumentation and electrical / mechanical equipment, planned cleaning and surveying of reservoirs and trunk mains; Efficient leak repair system; Scope for specialised operational expertise as required to support WAJ in-house capabilities.
- Note that 24/7 supply will increase total UFW / NRW losses above the levels experienced during rationed supply. In general, the level of physical losses from the network will be directly proportionate to the number of hours for which there is a supply into the network. The relationship between UFW and continuity of supply will apply regardless of whether or not the network has been rehabilitated, as the quantity of water lost through each individual leak will be directly proportionate to the length of time for which water is available in that leaking pipe.

7.4 Specific Design Measures to deal with Energy Conservation

At present the pumping systems are operating at very inefficient levels as indicated in Section 2 above. Improved Energy Conservation will be facilitated by the following measures:

- Hydraulic right-sizing of pumps.
- Hydraulic right-sizing of pumping mains.
- Generally fixed-head, steady-state pumping to reservoirs to ensure that pumps are operating at their most efficient flow-pressure duty point.
- Modular pumping systems (i.e. future-proof pumping station and pipework layouts to allow additional pumps to be installed as required when demand increases; standardisation of pump sets insofar as practical at various locations to ensure efficient maintenance and availability of spares and fittings).
- Pumping pipeline routes for shortest distance practical.
- Pumping only required volume of water to highest elevations (e.g. instead of pumping all water for Awajan High and Low areas first to Awajan High Reservoir and then cascade from there as at present, the system would be configured to pump only what is required at Awajan High to be pumped to that level, with the supply for Awajan Low being pumped separately from Awajan Hub to Awajan Low).
- Sufficient flow-balancing storage at low-level reservoirs and peak-demand balancing storage at elevated reservoirs to allow pumps to operate consistently at their optimal duty point.
- Reduction of UFW in network to economically optimal level.
- Location of highest level reservoirs not always at very highest elevations, e.g. at Russaifah North-West, it would be necessary to increase the reservoir elevation by c. 30 metres in order to ensure a gravity supply from the reservoir to the entire Russaifah North-West supply area. By maintaining the reservoir level 30 metres lower, c. 95+% of the Russaifah North-West supply area will have a gravity supply, with the remainder requiring some limited local boosting.

The minimum design target for pumping efficiency is set at 60% over an extended period, i.e. over the range of pumping duties which a pump system would be expected to operate in its 15 year mechanical life. While at particular optimal duty points the pump system would achieve higher efficiencies (70%+), it is important to ensure that when the duty point (flow and pressure) changes that the efficiency of the pumps remains above 60%.

While there will be energy efficiencies achieved by incorporating the measures set out above, there will be additional pumping power required in some locations, e.g. currently, when water is pumped directly into supply, the pumps can pump to a lower pressure, whereas in the future all of the water for a Distribution Area will be pumped to an elevated reservoir at the highest level. Also, according as UFW is decreased, it is likely that the most or all of the water saved will be taken up by customers, so the quantity pumped will not diminish, although less of it will go to waste.

7.5 Specific Design Measures to deal with Water Quality and Public Health

Water Quality in Distribution will be affected primarily by the raw water quality and the treatment processes which are undertaken upstream of the network, and these matters fall within the scope of other projects. Once the water is in distribution there are particular factors which impact on water quality relevant to public health, and other factors which relate to network condition. Public health can be affected by water becoming contaminated in distribution networks and by water quality deteriorating over time.

Improved Water Quality in distribution will be facilitated by the following measures:

- Reduction of pipe leakage. When the network is pressurised, water leaks out through fractures in the pipelines. When the network is unpressurised, during the frequent periods of rationing, contaminated groundwater can seep into the pipelines. If pipe leakage is reduced, through rehabilitation, improved network management and active leakage control, then the numbers of potential contamination locations are reduced.
- Increased continuity of supply reducing the opportunity for contamination. If continuity of supply is increased, then the duration of opportunity for potential contamination is reduced.

- Increased continuity of supply improving the effectiveness of disinfection. If continuity of supply is increased, then the average time from chlorination of the water at network facilities until use of the water by customers is reduced, ensuring that the disinfection measure is more effective.
- Improvement in hydraulic efficiency of networks ensures that water moves rapidly and evenly through the network, providing a balanced level of supply across all customers, and reducing the incidences of sediment accumulation and stagnant water.
- Upgrading and provision of chlorination facilities at key locations, in particular at reservoirs.
- Increased storage capacity which will allow adequate chlorine contact time, opportunities for mixing and blending water from different sources, evening out of spikes in water quality parameters, settling out of suspended solids from the water body, buffering time to protect the distribution network from contamination incidents upstream, and contingency storage to provide emergency supplies in the event of pipe burst or pump failure.
- Customer Storage capacity also can provide some level of water quality protection downstream of the distribution network, although, if not properly protected and maintained, customer storage tanks can become the access point for contamination of customer supplies. Back-flow prevention measures are required and generally in place at customer connection points to ensure that customer storage tanks cannot back-feed into the tertiary supply network.
- Facilitation of operational measures, such as periodic cleaning out of reservoirs and occasional operation of washout valves to flush out portions of the network. The proposed upgraded network will include features to facilitate such operational practice, e.g. twin-cell reservoirs and the provision of washouts/hydrants and scour valves on pipelines.

Aside from public health concerns, water quality can affect network condition, e.g. where chemical composition of the water, low pH or particulates in the water can cause corrosion and scouring on the inside of pipes and fittings. Measures to mitigate the potential impact of water quality on distribution networks will include the following:

- Testing of water quality to identify parameters of concern to particular pipe and facilities materials.
- Specification of robust and durable network materials, linings, joints, etc to ensure that the upgraded network is resistant to attack by the water.
- Correct sizing of the network to ensure that water velocities are kept below scouring levels.

7.6 Modelling of Future Water Supply Network

7.6.1 General

In order to verify the proposed Master Plan solution scheme outlined in Section 8 it was necessary to construct a hydraulic model which would incorporate the future water demand to the year 2030. The model was also used to show the immediate improvements to the supply system as a result of implementing Phase 1 of the proposed schedule of work. As per the existing water supply model described in Section 2, the hydraulic model was constructed using Bentley WaterCAD v8i.

The future network model consists of the strategic supply system to each of the proposed new water supply zones and is based on the same information and physical details of the network used to construct the existing network model.

This section should be read in conjunction with the following figures and tables appended at the end of this section:

- Table 7-2: Strategic Headloss and Flows in Main Transmission Lines
- Figure 7-1: Strategic Future Model at Average Demand – Continuous Supply
- Figure 7-2: Strategic Future Model at Peak Demand – Continuous Supply
- Figure 7-3: Future Model 2030 Russaifah / Awajan Area (Water Rationing 70 hrs of supply per week at average demand)

- Figure 7-4: Future Model 2030 Russaifah / Awajan Area (Water Rationing 70 hrs of supply per week at average demand+ 10%)
- Figure 7-5: Headloss Gradient (m/km) in Future Network

Network model outputs and results are contained in Appendix 5.

7.6.2 Objectives

The objective of the model is to verify that the proposed solution scheme described in the schedule of works is hydraulically capable of delivering the 2030 water demand requirements to the Zarqa supply system and that this supply meets the design standards agreed with WAJ.

7.6.3 Model Construction

The future strategic model consists of the trunk supply links from the existing water supply sources in the Zarqa Governate to the existing and proposed pumping station and storage facilities across the system as outlined in Section 6 including the proposed pipe sizes, reservoir capacities and pumping rates. The model is divided into 9 distinct water supply areas (WSA's) connected only by the Azraq–Khaw-Russaifah strategic supply link with the exception of the West-Northwest Region which is independent of this strategic link. Each WSA includes primary distribution mains from the key storage facilities. The proposed routes and connections for the primary pipelines will be determined at Design stage, in conjunction with the layouts for the future District Metering Areas (DMAs).

The Hazen Williams formula was used for hydraulic analysis and "C" roughness values for pipes were chosen on the basis of new and rehabilitated pipe material and age. The following C values were initially selected for Pipe roughness:

PE Pipes	120
PVC Pipes	120
Ductile Iron	120

Pumps are shown at a constant power rate (kW) with a pump and motor efficiency of 70%.

7.6.4 Model Demands

Section 5 contains details of proposed future demand together with details of the nine Water Supply Areas (WSA): Azraq, Dulail, Zarqa, Awajan, King Abdullah Bin Aziz City, Russiafah, Tatweer, North and West-Northwest.

The major water supply sources in the existing model have also been used for the future model. These include the wellfields at Azraq, Zatari, Hallabat, Corridor, Tamween, Awajan, Russaifah, Hashmeya, Merhib and Sarout. The future proposed model has been run for two scenarios.

In the first scenario it is assumed that the supply required to meet the 2030 demand will be met through the existing sources and that the supply is continuous throughout the system with no areas being rationed. In the second scenario the full 2030 demand is not met with the supply from the existing sources and so a rationing arrangement is applied with areas being fed for up to 70 hours per week. In this scenario the primary infrastructure is required to deliver the full demand in a shorter time increasing the demand by a factor of approximately 2.4 to allow all parts of the network to receive water through the reduced window of supply.

It should be noted that the future model scenarios assume that the existing export to Amman (approximately 19MLD) will be discontinued thus making this demand available to the Zarqa supply system.

7.6.5 Modelling Scenario –Continuous Supply, Demand 2030

The first modelling scenario carried out represents continuous supply assuming that sufficient source water was available. This is an instantaneous picture of flow and average daily demand for the year 2030 in the network assuming that all WSA's are being fed simultaneously and no rationing is being undertaken. The model was run at Average Demand and at peak hourly demand (1.5 times Average Demand for primary pipelines).

Figure 7-1 shows that there is sufficient capacity in the proposed network to supply all parts of the network while maintaining residual pressures above 15m. The strategic supply link from Azraq to Khaw is also strengthened by a duplicate 600mm main which cross connects at Hallabat junction, and at the proposed Tafeh Pumping Station with the existing refurbished 600mm steel main, as well as the 600mm mains from Hallabat, Corridor and Za'atari. From Khaw the supply is pumped to the storage hubs at Batrawi, King Abdulla Bin Aziz City, Awajan and Russaifah.

The proposed Pumped systems in the network now supply high level reservoirs and storage tanks rather than pumping directly into supply which will allow for more controlled delivery pressures in the distribution system. There is, however, a need for some localised booster stations for the high level areas in Hashmeya and Sukhna. These are low density and low demand areas where it would not be economic to provide a storage reservoir.

Figure 7-2 shows the future network supply at peak demand. The primary distribution mains are sized accordingly to facilitate the adequate distribution of peak demand to the local areas.

7.6.6 Modelling Scenario – Rationed Supply, Demand 2030

The second modelling scenario occurs where the supply from the sources cannot meet the future expected demand in the system with all areas receiving supply for 70 hours over each week. To mimic this in the model we increased the average demand by a factor of 2.4 with a further 10% being added to allow for seasonal fluctuations in supply. This scenario proves useful in assessing if the new proposed supply mains can meet short term high flow demand on the primary distribution side as well as determining if any of these mains need to be re-sized as a result.

Figure 7-3 shows the future model at 2.4 times average demand in the Russaifah / Awajan area. Although the residual pressures are reduced the system can cope with the high flows with the exception of a number of high points and extremities where the pressures are negative. Up-sizing of mains at these locations would improve the pressures but likewise the layout of the secondary distribution mains and DMA arrangements, which will be determined at Design Stage, would also improve local supply pressures. Elsewhere in the system the pressures are also reduced but the supply is being adequately met.

Figure 7-4 shows the rationed supply for Russaifah / Awajan area at 2.4 times average demand increased by a further 10% (2.64). As a result the system is further stressed with more areas showing negative or low pressures but as above this could be dealt with through some minor pipe up-sizing and in the setting up the DMAs.

7.6.7 Conclusions from the Modelling Process

Results from the modelling process show that the proposed solution scheme is capable of delivering the estimated future demand to the year 2030. The proposed system has:

- Sufficient capacity in network pipes to deliver a continuous supply
- Sufficient capacity to meet 70hr rationed demand.
- Removed the need for pumping directly into supply except for small localised high level areas where it is not practical to build a storage tank.
- Adequate storage volumes with generally 12hrs available storage.

Table 7-2 below shows the headloss in the primary transmission mains in the proposed solution scheme for the Zarqa system, and with the exception of the 600mm main from Khaw to Russaifah and Russaifah Hub to Hitteen / Russaifah high, the headloss gradient is less than 5m/km. This is shown in Figure 7-5 which shows the headloss gradient for the entire network under average flow conditions where much of the network has a headloss of less than 5m/km.

Pipe ID	Route	Diameter (mm)	Hazen-Williams C	Material	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/km)
5281	Khaw to Tamween / Awajan	600	120	Ductile Iron	402.75	1.42	3.36
6059	Khaw to Awajan / Russaifah	600	120	Refurbished	520.17	1.84	5.39
5982	Khaw to Zarqa	400	120	Refurbished	128.08	1.02	2.90
5198	Azraq to Khaw	600	120	Refurbished	268.40	0.95	1.59
5975	Khaw to Batrawi	700	120	Ductile Iron	600.00	1.56	3.32
5839	Khaw to King Abdullah BA city	800	120	Ductile Iron	669.78	1.33	2.12

5917	Corridor to Khaw	600	120	Refurbished	457.36	1.62	4.25
5356	Russaifah Hub to Hitteen / Russaifah	600	120	Ductile Iron/ Refurbished	503.62	1.78	5.09

Table 7-2: Strategic Headloss and Flows in Main Transmission lines

The network model of the proposed solution scheme verifies that the strategic infrastructural improvements required to improve the current water network are capable of meeting the future water demand to the year 2030.

Additional details on the network model inputs and outputs are set out in Appendix 5.

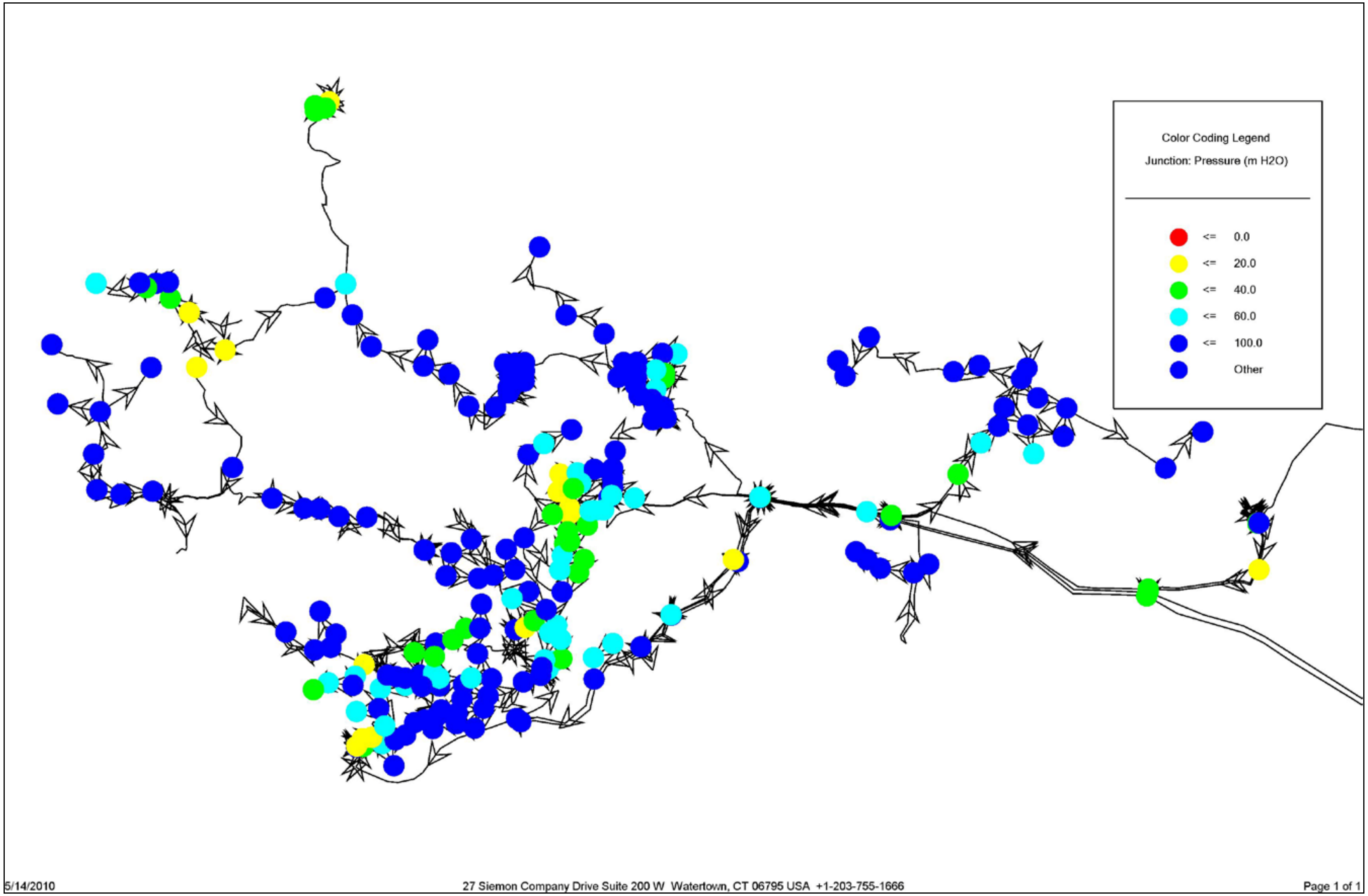


Figure 7-1 Future model 2030 at Average Demand (continuous supply)

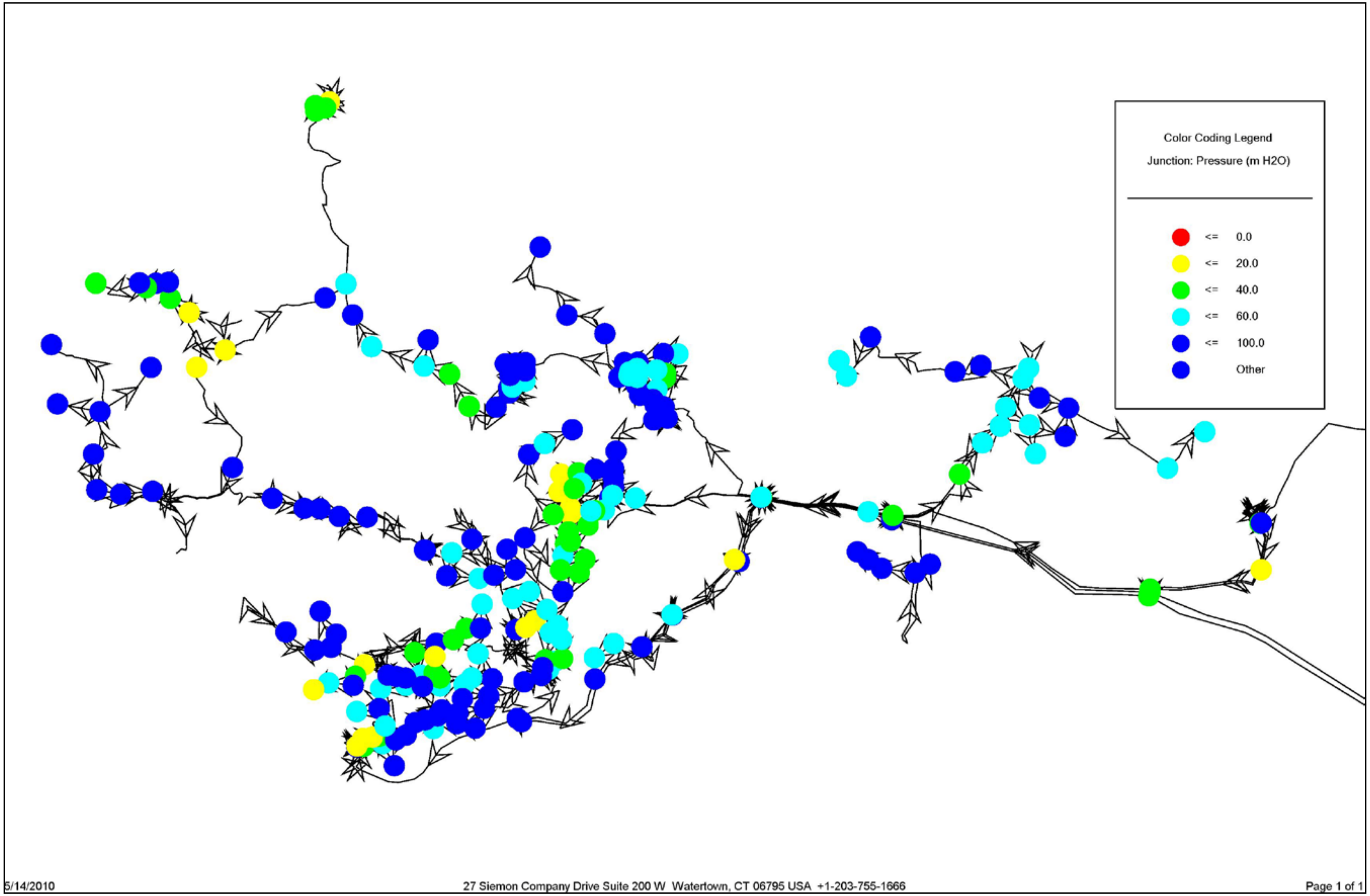


Figure 7-2 Future model 2030 at Peak Demand (continuous supply)

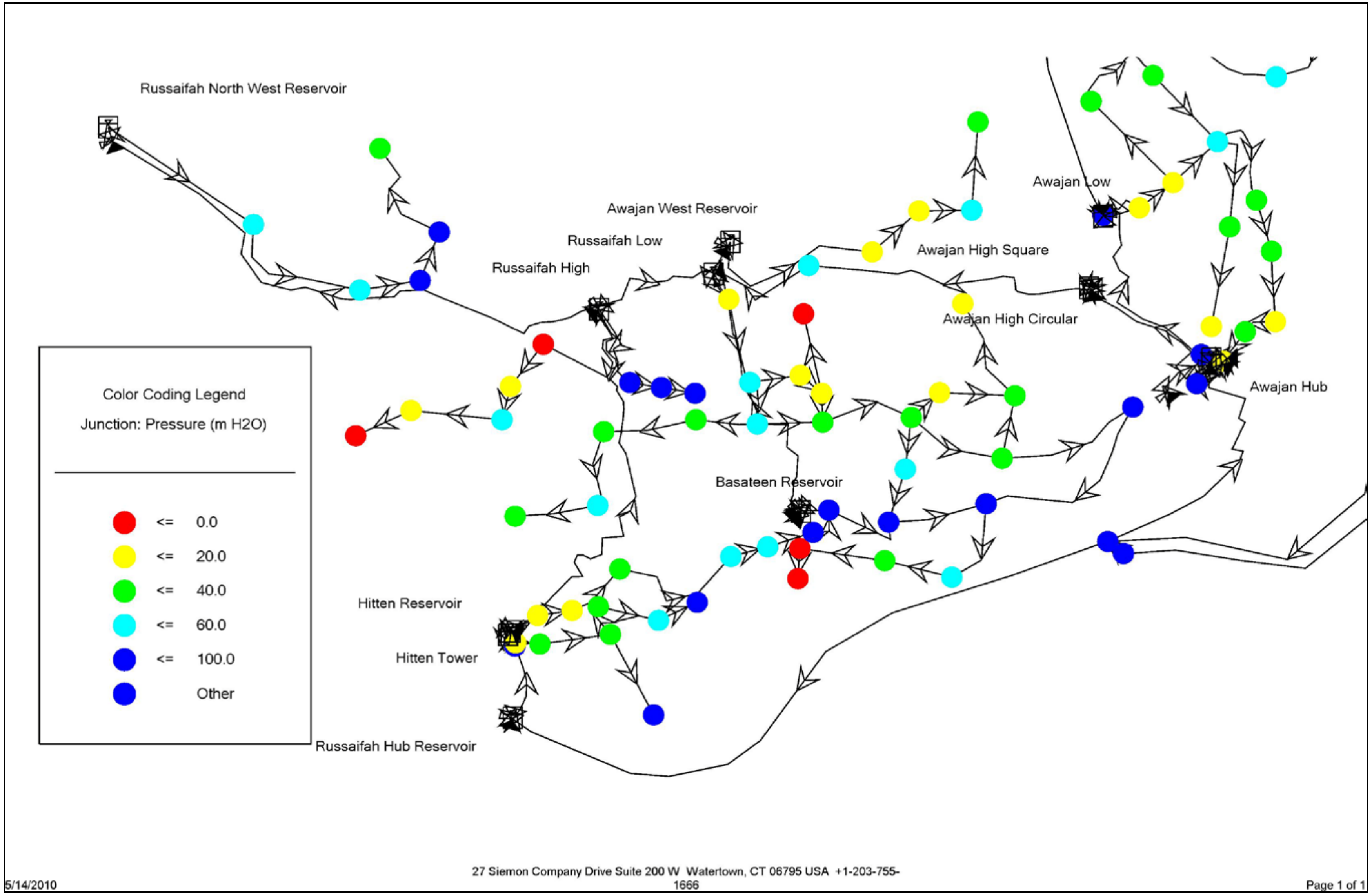


Figure 7-3 Future Model 2030 Russaifah / Awajan Area (Water Rationing 70hrs supply / week)

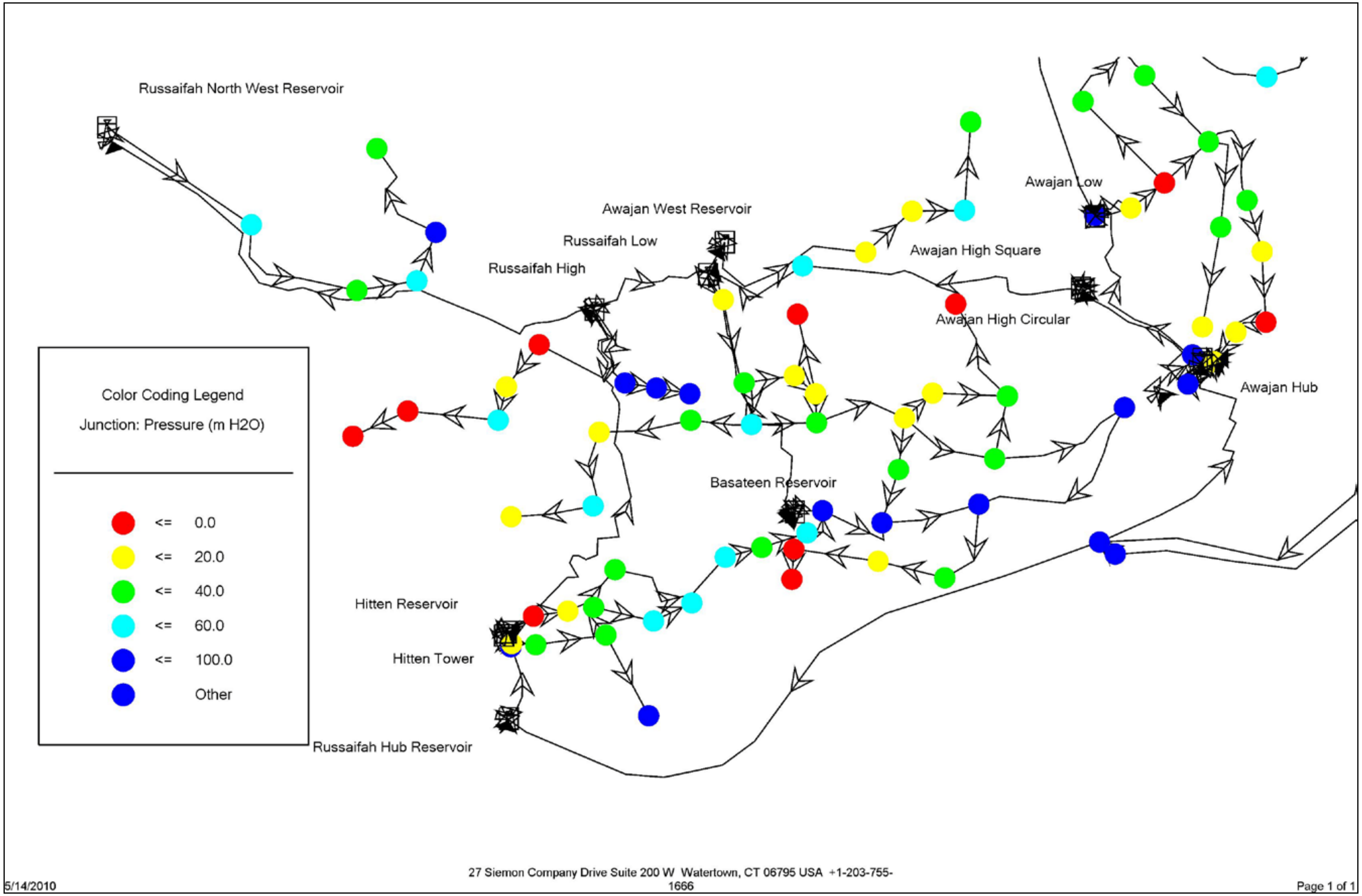


Figure 7-4 Future Model 2030 Russaifah / Awajan Area (Water Rationing 70hrs supply/week, AD+10%)

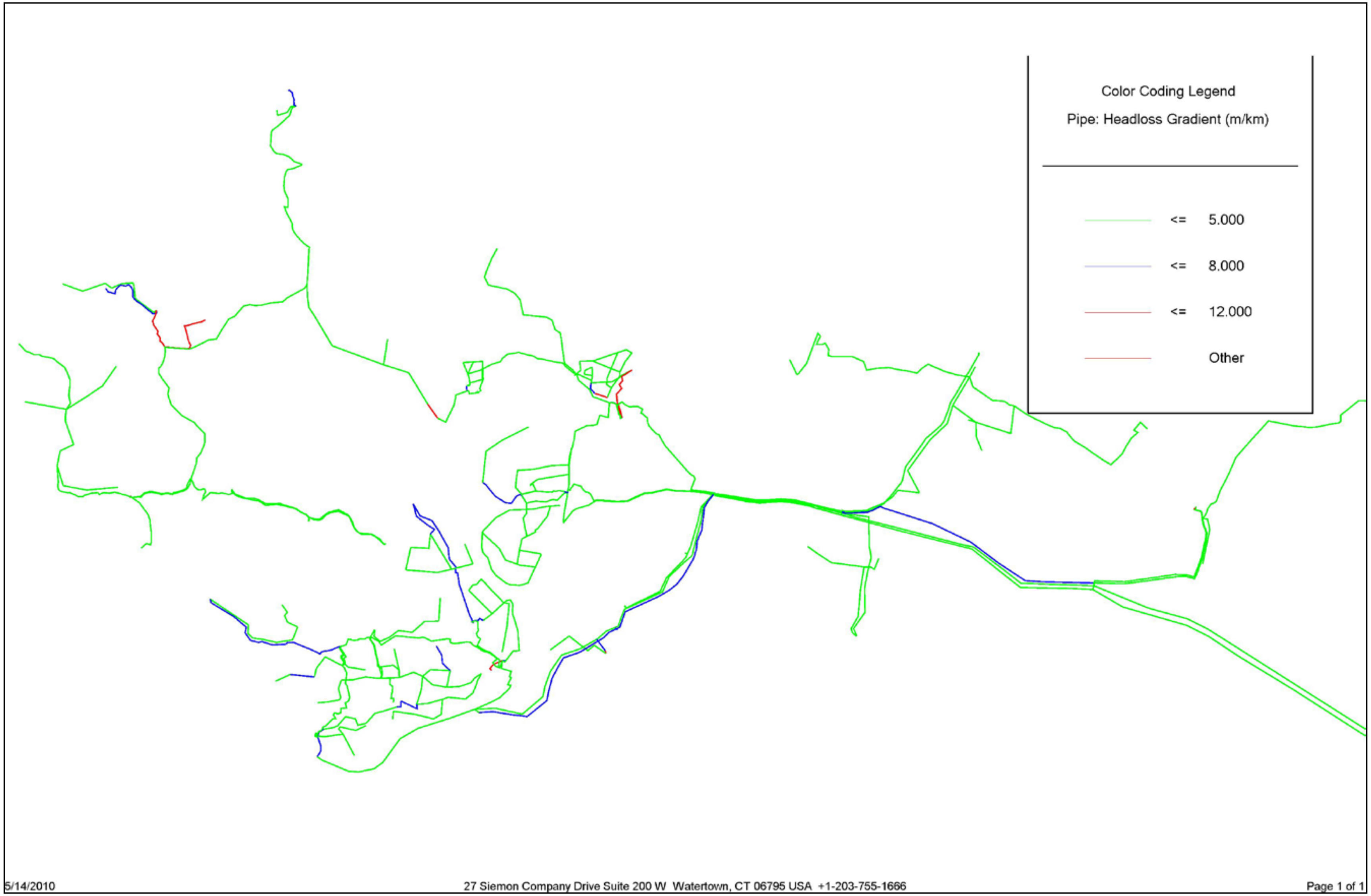


Figure 7-5 Headloss Gradient (m/km) in Future Network

8. STRATEGIC MASTER PLAN

8.1 Master Plan Objectives

The key objectives of the Strategic Master Plan are as follows:

- To meet the 2030 demands as set out in Section 5 of this report.
- To meet the system structure requirements as set out in Section 6 of this report.
- To meet the design standards as set out in Section 7 of this report.

8.2 Scale and Scope of Works in Master Plan

Primary Network Facilities. The requirement for and size of new and additional facilities is based on the additional facility requirements identified by the hydraulic modelling exercise. The requirement for upgrading of existing facilities and primary pipelines is based on site inspections of existing facilities as described in Section 2 and Appendix 3 of the IMP, and on information received from WAJ on particular vulnerable sections of strategic pipelines, and also on a general assessment of the pipe material factors as described for Secondary and Tertiary networks rehabilitation below. The entire pipe network requires re-structuring, i.e. the addition of control valves, air valves, cross-connections, etc to ensure efficient hydraulic performance and operational control capability. A comprehensive SCADA system is required, together with extensive additional network monitoring instrumentation, in particular the provision of system meters at key network points. On the primary network, DMA connection and control points are required as described in Section 6 above. These DMA control points will provide for independent valve control, metering and pressure management for each DMA, with telemetry linkage to a central SCADA system.

Secondary and Tertiary Networks. The pipe network has a current length of c.3,515 km, including 3,054 km of secondary and tertiary pipes. Approximately 2,380 km of the pipe network is currently mapped on the GIS, and the available GIS information has been analysed, in addition to the information from extensive site surveys and meetings with WAJ personnel across all parts of the network. Pipe material information is provided for c.2,102 km length of pipeline. There is a further c.278 km of pipeline which is shown on the mapping, for which pipe material is not currently known. The majority of the c.1,135 km of pipeline which is not shown on the mapping is small diameter tertiary network. The summary network pipe material and length statistics are shown in Table 8.1 below.

WSA	Secondary and Tertiary Pipes: up to 150mm diameter (m)	Primary Network Pipes: 200mm+ diameter (m)	Total Length of Network Pipes (m)
Azraq	42,675	6,081	48,756
Dulail	179,126	52,111	231,237
KABA	42,187	21,382	63,568
Tatweer	70,137	11,619	81,755
Zarqa	797,516	61,580	859,095
Awajan	581,972	35,107	617,079
Russaifah	850,446	70,369	920,815
North	268,502	27,062	295,564
WestNW	221,455	20,990	242,445
non-WSA	-	154,529	154,529
Total	**3,054,016**	**460,828**	**3,514,844**

Table 8-1: Summary Existing Pipe Network Statistics

More detailed Network Statistics by pipe diameter, pipe material and Distribution Area (DA) are provided in Appendix 8.

Detailed information reviews and site inspections were undertaken in order to assess the general condition, performance and likely remaining life-time of different pipe materials. In addition to the current physical/structural condition of pipes, there is a significant proportion of pipes which are laid above ground (average 17.5% from sample survey – details included in Appendix 8), and there are significant secondary and tertiary pipes which are laid at very shallow depths, and which suffer from excessive leakage due to inadequate cover. Arising from the reviews and inspections, different pipe rehabilitation percentages have been derived for different pipe materials, for the purposes of providing quantity estimates. These rehabilitation percentages are set out in Table 8.2 below.

Pipe Material	Rehabilitation Ratios
Steel	50%
Galvanised Metal	100%
Ductile Iron	20%
PE/PVC	50%
Other/Unknown	80%
Non-GIS	80%

Table 8-2: Pipe Rehabilitation Percentages for different pipe materials

We have applied the rehabilitation percentages in Table 8.2 to the pipe network statistics in Table 8.1, and taken account of the works currently underway as described in Section 3 above. This calculation yields the pipe rehabilitation quantities for the WSA networks set out in Table 8.3 below.

WSA	Tertiary Network up to 50mm diam (m)	Secondary Network 60-90mm diam (m)	Secondary Network 100-150mm diam (m)	Primary Network 200-300mm diam (m)
Azraq	-	-	-	-
Dulail	118,975	11,400	18,675	7,422
KABA	-	-	-	-
Tatweer	18,687	14,457	7,115	796
Zarqa	277,733	101,372	21,135	11,636
Awajan	229,942	111,936	24,293	7,794
Russaifah	382,346	232,928	76,829	8,669
North	73,829	80,424	47,011	5,236
WestNW	93,491	7,796	51,360	12,166
Total	**1,195,003**	**560,312**	**246,418**	**53,718**

Table 8-3: Pipe Rehabilitation Quantities for WSA networks

Network re-structuring will be required for 100% of the secondary and tertiary networks with the exceptions of Azraq and King Abdullah WSAs, where networks are new. The pipe network restructuring quantities for the WSA networks are set out in Table 8.4 below.
below.

WSA	Tertiary Network up to 50mm diam (m)	Secondary Network 60-90mm diam (m)	Secondary Network 100-150mm diam (m)	Primary Network 200-300mm diam (m)
Azraq	-	-	-	-
Dulail	118,975	22,800.53	37,351	14,843
KABA	-	-	-	-
Tatweer	24,286	30,446	15,405	3,732
Zarqa	348,808	217,946	43,976	32,391
Awajan	290,786	230,642	60,544	20,821
Russaifah	427,775	291,931	130,741	41,709
North	87,634	102,045	78,824	22,780
WestNW	116,864	14,228	90,363	20,907
Total	**1,415,126**	**910,038**	**457,204**	**157,183**

Table 8-4: Network Restructuring Quantities for WSA networks

DMA connection points from the Primary networks are required in order to separate the network into DMAs, each with typically 500-1500 properties. For some DMAs it will be possible to service them via a single DMA connection point, for others 2 or more points may be required. New Customer Control Points will be required at all customer service connections will be provided on public property, as described in Section 6 of the IMP. Provision is made for replacement of 50% of existing Customer Meters. The pipe quantities of DMA connection points, Customer Control Points and Customer Meters for replacement are set out in Table 8.5 below.

WSA	DMA Connection Points (No)	Customer Connection Points (No)	Customer Meters for Replacement (No)
Azraq	-	-	-
Dulail	7	2,545	1,654
KABA	-	-	-
Tatweer	3	1,241	807
Zarqa	63	24,010	15,608
Awajan	29	16,835	10,943
Russaifah	48	27,632	17,961
North	15	5,610	3,647
WestNW	5	1,812	1,178
Total	**170**	**79,683**	**51,796**

Table 8-5: Connection/Control/Metering Quantities for WSA networks

At a Strategic Infrastructure level, there are some additional particular infrastructure requirements, including the following:

- Strategic Metering – Locations illustrated in Drawing No. 20445-FIG-3.12
- Mapping / GIS
- Strategic Pipeline Condition Assessments
- SCADA System
- Asset Management – Spares, Contingencies

Ten Individual Schedules of restructuring and rehabilitation works are set out in Section 8.4 below for the Strategic Transmission Infrastructure and for each of the 9 individual WSAs. Work-packages will be selected across the schedules of works in order to achieve economies of scale and synergies for procurement, construction and commissioning.

Additional details on the Scale and Scope of the Master Plan works are set out in Appendix 8.

8.3 Phasing

The Schedules of restructuring and rehabilitation works are set out over 3 phases, according to their urgency, and likely time-scale for achieving long-term benefits.

Phase 1 works are considered likely to achieve immediate permanent solutions to current network performance problems. They would be required at 2010 for immediate upgrading of the network to target design levels. They will have immediate benefit, and will also have adequate structure and capacity for 2030 demand levels.

Phase 2 works are required in order to provide permanent solutions to definite future requirements. They would be ideal at 2010 for improvement of network, but would have a lower urgency than Phase 1 works. They could be deferred for a period until demand levels reach a tipping point.

Phase 3 works are required in order to provide permanent solutions to potential additional future requirements. They incorporate the additional works over and above Phase 2 which would be required to meet 2030 demands. They will become critical as population and network demand grows. They will be required to provide network capacity for additional flows of water to satisfy full 2030 design demand.

8.4 Descriptions of Capital Projects and Schedules of works

Descriptions of Capital Projects and Schedules of works are set out in Sub-sections 8.4.1 to 8.4.10 below.

8.4.1 Strategic Infrastructure Schedule of Works (refer to Drawing 20445-FIG-3.10.A Rev B for details)

Phase 1.

- Upgrade/refurbish existing pumping station at Azraq (Pumping Rate 2,400 m3/hr)
- Install Strategic Metering Infrastructure – 65 System meters at 32 locations
- Mapping / GIS / Condition Assessments
- SCADA System – As part of "Intervention 1" under "Benefits Study by Ecoconsult"
- Asset Management – As part of "Intervention 1" under "Benefits Study"

Phase 2.

- Upgrade existing reservoir at Azraq (Pump Flow-balancing Reservoir 12,000 m3)
- Upgrade existing reservoir at Hallabat (Pump Flow-balancing Reservoir 1,000 m3)
- Upgrade existing reservoir at Khaw (Pump Flow-balancing Reservoir 12,000 m3)
- Upgrade/refurbish existing pumping station at Hallabat (Pumping Rate 900 m3/hr)
- Upgrade/refurbish existing pumping station at Khaw (Pumping Rate 4,400 m3/hr)
- Construct new trunk main pipeline Hallabat-Hallabat junction (600mm diameter, 6.9km length)
- Construct new trunk main pipeline Khaw-Awajan (600mm diameter, 16.3 km length)
- Upgrade existing primary network pipeline Azraq-Khaw-Russaifah (600mm diameter, 83.0 km length)
- Upgrade existing primary network pipeline Corridor-Khaw (600mm diameter, 46.2 km length)
- Upgrade existing primary network pipeline Zatari-Khaw (600mm diameter, 11.8 km length) (Governorate Boundary)
- Rehabilitate existing primary network pipeline Vulnerable sections of Azraq/ Corridor/ Zatari-Khaw-Russaifah (26.0 km length)

Phase 3.

- Upgrade existing reservoir at Zatari (Pump Flow-balancing Reservoir 2,000 m3)
- Upgrade existing reservoir at Corridor (Pump Flow-balancing Reservoir 1,000 m3)
- Upgrade/refurbish existing pumping station at Corridor (Pumping Rate 1,300 m3/hr)
- Construct new trunk main pipeline along Azraq-Khaw (600mm diameter, 64.0 km length)
- Upgrade/refurbish existing pumping station at Zatari (Pumping Rate 300 m3/hr)

8.4.2 Azraq WSA Schedule of Works (refer to Drawing 20445-FIG-3.10.B for details)

<u>Phase 1.</u> None
<u>Phase 2.</u> • Construct new water tower at Azraq Water Tower (Distribution Storage Reservoir 600m3) • Construct new pumping station at Azraq Water Tower (Pumping Rate 60m3/hr) • Install new DMA connection points (2 No.)
<u>Phase 3.</u> None

8.4.3 Dulail WSA Schedule of Works (refer to Drawing 20445-FIG-3.10.C for details)

Phase 1.

None

Phase 2.

- Construct new reservoir at Dulail (Distribution Storage Reservoir 3,000 m3)
- Construct new reservoir at Tafeh (Distribution Storage Reservoir 500 m3)
- Construct new water tower at Hallabat Water Tower (Distribution Storage Reservoir 300 m3)
- Construct new pumping station at Tafeh (to Dulail and Tafeh Distribution Storage Reservoirs - Target Pumping Rate 300 m3/hr)
- Construct new primary network pipeline Tafeh PS to Dulail Reservoir (400mm diameter, 2.9 km length)
- Construct new primary network pipelines Dulail Reservoir to Dulail Distribution Area (300mm and 400mm diameters, 11.0 km length)
- Construct new primary network pipeline Tafeh PS to Tafeh Reservoir (200mm diameter, 5.6 km length)
- Construct new primary network pipeline Tafeh Reservoir to Tafeh Distribution Area (300mm diameter, 6.0 km length)
- Rehabilitate existing unsuitable primary network pipelines (200-300mm diameter, 7.422 km length)
- Restructure existing and rehabilitated Primary network pipelines (200-300mm diameter, 14.843 km length)
- Install new DMA connection points (7 No.)
- Rehabilitate existing unsuitable secondary and tertiary network pipelines (149.05km length)
- Restructure existing and rehabilitated secondary and tertiary network pipelines (179.13km length)
- Restructure existing Customer Connection Points (2,545 No.)
- Replace Customer Meters (1,654 No.)

Phase 3.

- Construct new pumping station at Dulail Highest Levels Boosters (Target Pumping Rate 35 m3/hr)
- Construct new pumping station at Tafeh Highest Levels Boosters (Target Pumping Rate 12 m3/hr)

8.4.4 King Abdullah Bin Aziz City WSA Schedule of Works (refer to Drawing 20445-FIG-3.10.D for details)

Phase 1.

None

Phase 2.

- Construct new reservoir King Abdullah Bin Aziz City Strategic Reservoir (Distribution Storage Reservoir 5,000 m3)
- Construct new trunk main pipeline Khaw to New King Abdullah Reservoir (800mm diameter 2.2 km length)
- Construct new trunk main pipeline Tamween to New King Abdullah Reservoir (400mm diameter, 3.4 km length)

Phase 3.

None

8.4.5 Tatweer WSA Schedule of Works (refer to Drawing 20445-FIG-3.10.E for details)

Phase 1.

- Construct new reservoir at Tatweer (Distribution Storage Reservoir 1,000 m3)
- Construct new pumping station at Tatweer (to Tatweer Distribution Storage Reservoir - Target Pumping Rate 100 m3/hr)
- Construct new primary network pipeline Tatweer PS to Tatweer Reservoir (200mm diameter, 3.6 km length)
- Construct new primary network pipeline Tatweer Reservoir to Tatweer Distribution Area (300mm diameter, 2.0 km length)
- Rehabilitate existing unsuitable primary network pipelines (200-300mm diameter, 0.796 km length)
- Restructure existing and rehabilitated primary network pipelines (200-300mm diameter, 3.732 km length)
- Install new DMA connection points (3 No.)
- Rehabilitate existing unsuitable secondary and tertiary network pipelines (40.26km length)
- Restructure existing and rehabilitated secondary and tertiary network pipelines (70.14km length)
- Restructure existing Customer Connection Points (1,241 No.)
- Replace Customer Meters (807 No.)

Phase 2.

- Construct new pumping station Tatweer (High level booster PS - Target Pumping Rate 10 m3/hr)

Phase 3.

None

8.4.6 Zarqa WSA Schedule of Works (refer to Drawing 20445-FIG-3.10.F for details)

Phase 1 – (Note: excludes works currently underway in Al Gweireyeh neighbourhood).

- Upgrade existing reservoir at Zarqa PS Reservoir (Pump Flow-balancing Reservoir 4,500 m3)
- Upgrade existing pumping station at Zarqa PS (to Batrawi Distribution Storage Reservoir - Target Pumping Rate 500 m3/hr)
- Construct new primary network pipeline Batrawi and Zarqa High Reservoirs to Distribution Areas (300mm & 600mm diameter, 17.0 km length)
- Upgrade primary network pipeline Zarqa PS to Batrawi Reservoir (400mm diameter, 2.0 km length)
- Upgrade primary network pipeline Khaw PS to Batrawi Reservoir (400mm diameter, 9.0 km length)
- Rehabilitate existing unsuitable primary network pipelines (200-300mm diameter, 11.636 km length)
- Restructure existing and rehabilitated primary network pipelines (200-300mm diameter, 32.391 km length)
- Install new DMA connection points (63 No.)
- Rehabilitate existing unsuitable secondary and tertiary network pipelines (400.24km length)
- Restructure existing and rehabilitated secondary and tertiary network pipelines (610.73km length)
- Restructure existing Customer Connection Points (24,010 No.)
- Replace Customer Meters (15,608 No.)

Phase 2.

- Upgrade primary network pipeline Khaw PS to Batrawi Reservoir (700mm diameter, 9.0 km length)

Phase 3.

- Construct new reservoir: Additional Batrawi-level reservoir (Distribution Storage Reservoir 3,000 m3)
- Construct new pumping station at Zarqa High - Highest Levels Boosters (Target Pumping Rate 10 m3/hr)

8.4.7 Awajan WSA Schedule of Works (refer to Drawing 20445-FIG-3.10.G for details)

Phase 1.

- Construct new reservoir at Awajan West Reservoir (Distribution Storage Reservoir 3,000 m3)
- Construct new reservoir at Awajan North Reservoir (Distribution Storage Reservoir 3,000 m3)
- Construct new pumping station at Awajan High Reservoir PS (to Awajan West Distribution Storage Reservoir - Target Pumping Rate 270 m3/hr)
- Construct new pumping station at Awajan Low Reservoir PS (to Awajan North Distribution Storage Reservoir - Target Pumping Rate 300 m3/hr)
- Construct new primary network pipelines Awajan West Reservoir to Distribution (300mm diameter, 12.5 km length)
- Construct new primary network pipeline Awajan High Reservoir to new Awajan West Reservoir (300mm diameter, 4.5 km length)
- Construct new primary network pipeline Awajan North Reservoir to Distribution (300mm diameter, 6.0 km length)
- Construct new primary network pipeline Awajan Low Reservoir to new Awajan North Reservoir part length (300mm diameter, 2.4 km length)
- Upgrade primary network pipelines Awajan High Reservoir to Distribution (250mm & 300mm diameters, 3.4 km length)
- Upgrade primary network pipeline Awajan Low Reservoir to new Awajan North Reservoir part length (300mm diameter, 3.2 km length)
- Rehabilitate existing unsuitable Primary network pipelines (200-300mm diameter, 7.794 km length)
- Restructure existing and rehabilitated primary network pipelines (200-300mm diameter, 20.821 km length)
- Install new DMA connection point (16 No.)
- Rehabilitate existing unsuitable secondary and tertiary network pipelines (366.17km length)
- Restructure existing and rehabilitated secondary and tertiary network pipelines (581.97km length)
- Restructure existing Customer Connection Points (16,835 No.)
- Replace Customer Meters (10,943 No.)

Phase 2.

- Construct new reservoir at Awajan Low Additional Reservoir (Distribution Storage Reservoir 2,000 m3)

- Construct new reservoir at Awajan Hub Reservoir (Pump Flow-balancing Reservoir 2,500 m3)
- Construct new pumping station at Awajan West Highest Levels Boosters (Target Pumping Rate 30 m3/hr)
- Construct new pumping station at Awajan North Highest Levels Boosters (Target Pumping Rate 30 m3/hr)
- Construct new pumping station at Awajan Hub PS (to Awajan High and Awajan Low Distribution Storage Reservoirs - Target Pumping Rate 1,300 m3/hr)
- Construct new primary network pipeline Awajan North Reservoir to Distribution (300mm diameter, 6.5 km length)
- Construct new primary network pipelines Interim point to new Awajan Hub Reservoir / PS (600mm diameter, 0.6 km length)
- Awajan Hub Pumping Station to Awajan Low Reservoir (500mm diameter, 4.0 km length)
- Construct new primary network pipeline Awajan High Reservoir to Distribution (300mm diameter, 11.6 km length)
- Construct new primary network pipeline Awajan Low Reservoir to Distribution (300mm diameter, 2.1 km length)
- Upgrade primary network pipeline Strategic Ring Main connection point to interim point (600mm diameter, 3.6 km length)
- Upgrade primary network pipeline Interim point to Awajan High Reservoir (600mm diameter, 2.1 km length)
- Upgrade primary network pipeline Awajan Low Reservoir to Distribution (400mm diameter, 8.0 km length)

Phase 3.

None

8.4.8 Russaifah WSA Schedule of Works (refer to Drawing 20445-FIG-3.10H for details)

Phase 1.

- Upgrade existing reservoir at Basateen Reservoir (Flow-balancing Reservoir 500 m3)
- Construct new pumping station at Basateen PS (to Russaifah Low Storage Reservoir - Target Pumping Rate 560 m3/hr)
- Construct new primary network pipeline Russaifah High Reservoir to Russaifah High Distribution part (600mm diameter, 2.0 km length)
- Construct new primary network pipeline Russaifah Low Reservoir to Russaifah Low Distribution part (400mm diameter, 4.0 km length)
- Upgrade primary network pipeline Basateen PS to Russaifah Low Reservoir (400mm, 500mm diameters, 9.0 km length)
- Upgrade primary network pipeline Russaifah Low Reservoir to Russaifah Low Distribution (500mm diameter, 2.0 km length)
- Rehabilitate existing unsuitable primary network pipelines (200-300mm diameter, 8.669 km length)
- Restructure existing and rehabilitated primary network pipelines (200-300mm diameter, 41.709 km length)
- Install new DMA connection point (22 No.)
- Rehabilitate existing unsuitable secondary and tertiary network pipelines (692.10km length)
- Restructure existing and rehabilitated secondary and tertiary network pipelines (850.45km length)
- Restructure existing Customer Connection Points (27,632 No.)
- Replace Customer Meters (17,961 No.)

Phase 2.

- Construct new reservoir at New Russaifah Hub Reservoir (Flow-Balancing Reservoir 4,000 m3)
- Construct new reservoir at Hitteen Reservoir Additional (Distribution Storage Reservoir 5,000 m3)
- Construct new reservoir at Hitteen Water Tower Additional (Distribution Storage Reservoir 600 m3)
- Construct new reservoir at Russaifah High Reservoir Additional (Distribution Storage Reservoir 6,000 m3)
- Construct new reservoir at Basateen Reservoir Additional (Distribution Storage Reservoir 700 m3)

- Construct new reservoir at Russaifah North-West (Distribution Storage Reservoir 1,500 m3)
- Upgrade existing reservoir at Hitteen Reservoir (Distribution Storage Reservoir 4,000 m3)
- Upgrade existing reservoir at Hitteen Water Tower (Distribution Storage Reservoir 300 m3)
- Construct new pumping station at Russaifah North-West Highest Levels Boosters (Target Pumping Rate 15 m3/hr)
- Construct new pumping station at New Russaifah Hub PS (to Hitteen and Russaifah High Distribution Storage Reservoirs - Target Pumping Rate 2,000 m3/hr)
- Construct new pumping station at Russaifah High Reservoir PS (to Russaifah North-West Storage Reservoir - Target Pumping Rate 62 m3/hr)
- Upgrade existing pumping station at Hitteen Reservoir PS (to Hitteen Water Tower Storage Reservoir - Target Pumping Rate 52 m3/hr)
- Construct new primary network pipeline Strategic Ring Main connection point to new Russaifah Hub Res/PS (800mm diameter, 1.0 km length)
- Construct new primary network pipeline Russaifah High Reservoir to Russaifah High Distribution part (400mm diameter, 6.0 km length)
- Construct new primary network pipeline Russaifah Low Reservoir to Russaifah Low Distribution part (300mm diameter, 4.0 km length)
- Construct new primary network pipeline Hitteen Reservoir to Hitteen Res Distribution Area part (700mm diameter, 1.0 km length)
- Construct new primary network pipeline New Russaifah Hub PS to Russaifah High Reservoir additional pipe (400mm diameter, 5.8 km length)
- Construct new primary network pipeline Russaifah High Reservoir to New Russaifah NorthWest Reservoir (200mm diameter, 5.5 km length)
- Construct new primary network pipeline Russaifah Hub PS to Hitteen Reservoir (600mm diameter, 0.5 km length)
- Construct new primary network pipeline Hitteen Reservoir to Hitteen WT environs pipework (200mm diameter, 0.5 km length)
- Construct new primary network pipeline Hitteen Water Tower to Hitteen WT Distribution Area (200mm diameter, 0.1 km length)
- Upgrade primary network pipeline New Russaifah Hub PS to Russaifah High Reservoir (400mm diameter, 4.8 km length)
- Upgrade primary network pipeline Russaifah High Reservoir to Russaifah Low Reservoir (300mm diameter, 1.4 km length)
- Upgrade primary network pipeline Hitteen Reservoir to Hitteen Res Distribution

Area part (300mm diameter, 7.0 km length)
Phase 3. None

8.4.9 North WSA Schedule of Works (refer to Drawing 20445-FIG-3.10.I for details)

Phase 1.

None

Phase 2.

- Construct new reservoir at Khaw North Water Tower (Distribution Storage Reservoir 2,000 m3)
- Upgrade existing Hashmeya PS - Target Pumping Rate 425 m3/hr)
- Construct new primary network pipeline Khaw North WT Khaw Distribution Area (400mm diameter, 1.0 km length)
- Upgrade existing primary network pipeline at Hashmeya PS to Zarqa PS (400mm diameter, 5.4 km length)
- Rehabilitate existing unsuitable primary network pipelines (200-300mm diameter, 5.236 km length)
- Restructure existing and rehabilitated primary network pipelines (200-300mm diameter, 22.780 km length)
- Install new DMA connection points (15 No.)
- Rehabilitate existing unsuitable secondary and tertiary network pipelines (201.26km length)
- Restructure existing and rehabilitated secondary and tertiary network pipelines (268.50km length)
- Restructure existing Customer Connection Points (5,610 No.)
- Replace Customer Meters (3,647 No.)

Phase 3.

- Construct new reservoir at Hashmeya Additional reservoir (Distribution Storage Reservoir 1,500 m3)
- Construct new reservoir at Sukhna Additional reservoir (Distribution Storage Reservoir 1,000 m3)
- Construct new pumping station at Hashmeya Rural Highest Levels Boosters (Target Pumping Rate 7 m3/hr)
- Construct new pumping station at Sukhna Highest Levels Boosters (Target Pumping Rate 7 m3/hr)
- Construct new primary network pipeline Hashmeya Reservoir additional to Hashmeya Distribution Area (300mm diameter, 3.0 km length)

8.4.10 West North-West WSA Schedule of Works (refer to Drawing 20445-FIG-3.10.J for details)

Phase 1.

None

Phase 2.

- Construct new reservoir at Berein High Reservoir (Distribution Storage Reservoir 300 m3)
- Upgrade existing reservoir at Merhib Reservoir (Flow-Balancing Storage Reservoir 1,000 m3)
- Upgrade existing reservoir at Berein Reservoir (Distribution and Flow-Balancing Reservoir 1,000 m3)
- Upgrade existing reservoir at Um Rumanneh Reservoir (Flow-Balancing Storage Reservoir 500 m3)
- Upgrade existing reservoir at Sarout Reservoir (Distribution and Flow-Balancing Storage Reservoir 400 m3)
- Construct new pumping station at Um Rumanneh PS (to new Berein High Reservoir and new Um Rumanneh High Reservoir - Target Pumping Rate 90 m3/hr)
- Construct new pumping station at Alouk PS (to new Alouk High Reservoir - Target Pumping Rate 5 m3/hr)
- Upgrade existing pumping station at Merhib PS (to new Merhib High Reservoir - Target Pumping Rate 105 m3/hr)
- Construct new primary network pipeline Berein Reservoir to Um Rumanneh Reservoir/PS (200mm diameter, 3.7 km length)
- Construct new primary network pipeline Um Rumanneh PS to new Berein High Reservoir (200mm diameter, 2.5 km length)
- Construct new primary network pipeline Um Rumanneh PS to new Um Rumanneh High Reservoir (200mm diameter, 2.1 km length)
- Construct new primary network pipeline Berein High Reservoir to Berein South Distribution (200mm diameter, 2.0 km length)
- Construct new primary network pipeline Berein High Reservoir to Berein North Distribution (150mm diameter, 2.0 km length)
- Construct new primary network pipeline Alouk PS to Alouk High Reservoir (100mm diameter, 2.5 km length)
- Construct new primary network pipeline Sarout Reservoir to Alouk High Reservoir (150mm diameter, 3.0 km length)
- Upgrade primary network pipeline Merhib PS to new Merhib High Reservoir (300mm diameter, 3.7 km length)
- Upgrade primary network pipeline Berein Reservoir to Berein East Distribution (150mm diameter, 2.0 km length)

- Rehabilitate existing unsuitable primary network pipelines (200-300mm diameter, 12.166 km length)
- Restructure existing and rehabilitated primary network pipelines (200-300mm diameter, 20.907 km length)
- Install new DMA connection point (2 No.)
- Rehabilitate existing unsuitable secondary and tertiary network pipelines (152.647km length)
- Restructure existing and rehabilitated secondary and tertiary network pipelines (221.46km length)
- Restructure existing Customer Connection Points (1,812 No.)
- Replace Customer Meters (1,178 No.)

Phase 3.

- Construct new reservoir at Merhib High Reservoir (Distribution and Flow-Balancing Storage Reservoir 300 m3)
- Construct new reservoir at Um Rumanneh High Reservoir (Distribution Storage Reservoir 300 m3)
- Construct new reservoir at Alouk High Reservoir (Distribution Storage Reservoir 300 m3)
- Construct new pumping station at Berein Highest Levels Boosters (Target Pumping Rate 5 m3/hr)
- Construct new pumping station at Um Rumanneh Highest Levels Boosters (Target Pumping Rate 5 m3/hr)
- Construct new pumping station at Merhib High Reservoir PS (to existing Berein Reservoir - Target Pumping Rate 90 m3/hr)
- Construct new primary network pipeline Inlet-Outlet branch pipework to new Merhib High Reservoir (300mm diameter, 1.0 km length)
- Construct new primary network pipeline Merhib High Reservoir to Merhib Distribution (200mm diameter, 2.0 km length)
- Construct new primary network pipeline Um Rumanneh High Reservoir to Um Rumanneh Distribution (200mm diameter, 2.0 km length)
- Construct new primary network pipeline Alouk High Reservoir Alouk Distribution (150mm diameter, 2.3 km length)
- Upgrade primary network pipeline New Merhib High Reservoir/PS to Berein Reservoir (300mm diameter, 2.9 km length)

9. PROJECT PACKAGES

9.1 Factors related to Project Packaging

The selection of project packages / contracts for procurement will take account of a range of factors, in particular the following:

- Phasing of Works.
- Priority Areas for Works
- Procurement Methods
- Additional factors such as economies of scale, synergies between potential project elements in different WSAs, co-ordination of different projects funded under different programmes and/or by different funding agencies.

Individual project packages will be implemented through the stages of:

- Detailed scoping and design.
- Tendering.
- Construction.
- Commissioning and handover.

9.2 Phasing of Works

The capital works are set out over 3 phases.

Phase 1 works are required for immediate upgrading of the network. They include all of the rehabilitation works required to bring the present infrastructure into satisfactory condition.

Phase 2 works are required for improvement of network, but can be deferred for a period without significant effect on customers on a day-to-day basis. They include all of the additional works required to address re-structuring and hydraulic optimisation of the network.

Phase 3 works are required to meet 2030 demands, according as demand grows with increasing population, and also to provide network capacity for additional flows of water to satisfy full 2030 design demand. They would not be required to improve the short-term population and demand requirements, but which will become critical according as population and demand increase towards 2030 levels.

9.3 Priority Areas for Works

The Strategic Master Plan works, as described in Section 8 above, comprise all of the works considered necessary to bring the entire public water distribution network up to the target standard appropriate for System Inputs up to the levels projected for 2030. The proposed phasing of works described in Sub-section 9.2 above set out the sequencing of works within 3 phases over a period of approximately 15 years. For the Phase 1 proposed works, some of the works can be considered to be more urgent than others. The Priority Investment Programme (PIP) Report and the Ecoconsult Beneficiaries Study Report consider the prioritisation of the areas in need of works, with the intention of identifying those areas with greatest need for investment, and where it is expected that the level of benefits achieved would be the greatest. The criteria which have been used in the prioritisation of areas are as follows:

- The relative socio-economic poverty levels in different areas.
- The relative "water poverty" levels in different areas, i.e. average customer water use.
- The relative population levels and densities.
- The relative condition of the distribution networks, as reflected in frequencies of reported leaks, bursts and customer complaints.
- The relative costs of the proposed works.

The Ecoconsult report of April 2010 has analysed these factors across the different neighbourhood areas in the Zarqa Governorate, particularly in the urban areas of Zarqa, Awajan, Russaifah and the nearby areas. The PIP report has analysed these factors across the different Water Supply Areas (WSAs) and Distribution Areas (DAs) in the Zarqa Governorate, and has taken account of the expected levels of improvements which could be achieved by the implementation of the Strategic Master Plan works.

The Recommendations on Priority Investment areas as set out in the Ecoconsult report of April 2010, are illustrated in Fig 9.1 below.

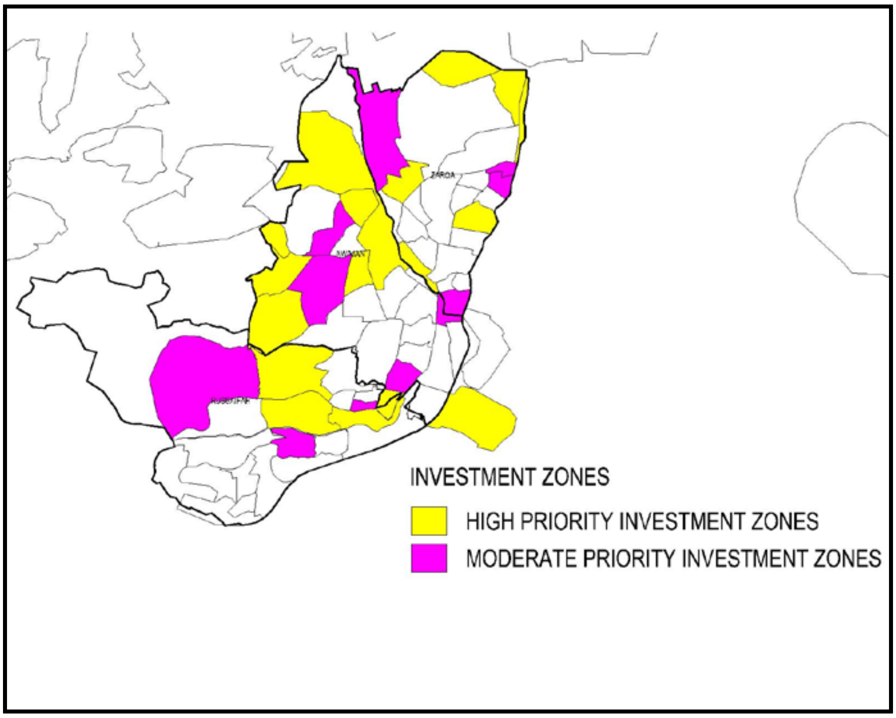


Figure 9-1 Priority Investment Neighbourhood Zones (Ecoconsult April 2010)

The priority investment zones recommended by Ecoconsult are all within the WSAs of Zarqa, Awajan, Russaifah and Tatweer. For the purposes of rational investment packages for network restructuring and rehabilitation, it is proposed to undertake the MCC-funded works generally across full Distribution Areas within these WSAs.

The locations of the Distribution Areas where the priority works will be undertaken are illustrated in Figure 9.2 below.

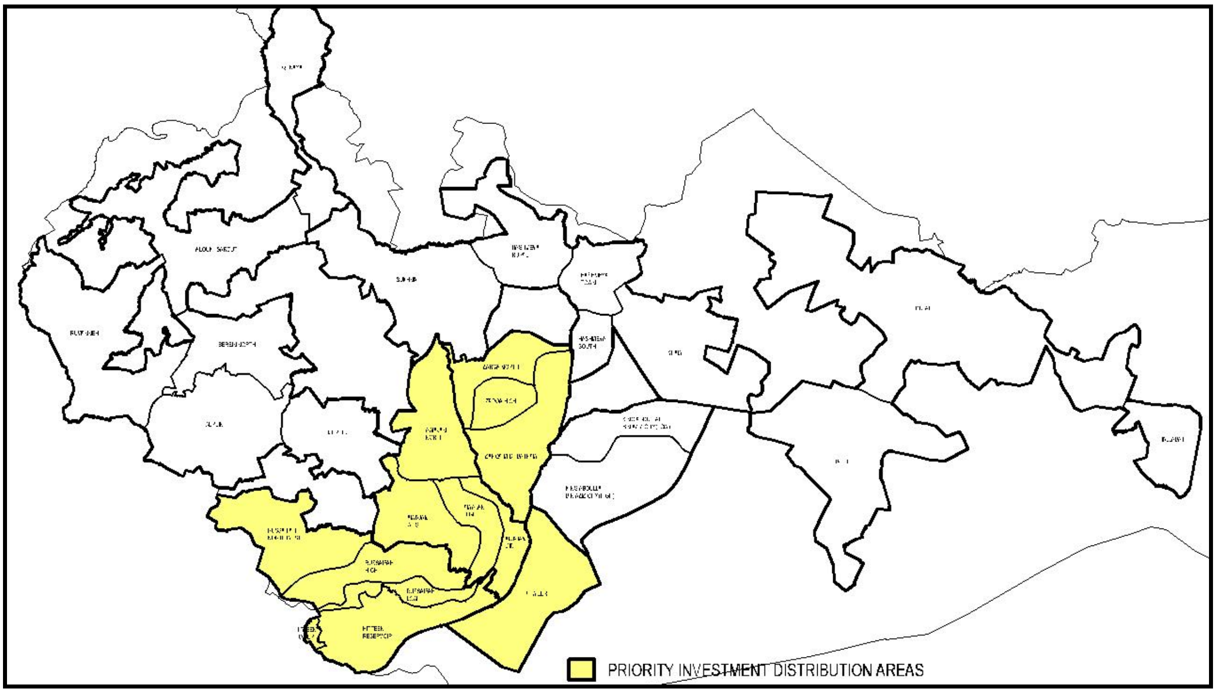


Figure 9-2 Priority Investment Distribution Areas (PIP May 2010)

In order to clarify the scope of works requirements within the priority investment DAs, a review was undertaken of projects in the Zarqa, Awajan, Russaifah and Tatweer WSAs which have recently been completed or which are currently committed or currently underway.

The recent projects include the construction of new reservoirs at Batrawi, Zarqa High, Awajan Low, Awajan High, Russaifah Low and Russaifah High, new pumping stations at Batrawi, Awajan High and Russaifah High, and some local network rehabilitation, including in the Hitteen Tower DA. Most of these projects were funded by the Japanese Government Agency, JICA.

The current and imminent projects include a network rehabilitation and metering project within the Zarqa Mid-Batrawi DA (Al Gweireyeh area) and funded by German Government Agency, a network rehabilitation project in the Russaifah High and Low DAs funded by Chinese Government Agency, and the construction of a new/replacement pumping station at Zarqa Pumping Station funded by Japanese Government Agency.

9.4 Procurement of Works

The anticipated procurement programme for the MCC Package of First Phase Priority Works envisages a construction programme from end 2010-end 2015. The major part of the works would comprise the rehabilitation and restructuring of secondary and tertiary networks, including the installation of customer connection control points and replacement of unsuitable customer meters. The minor part of the works would comprise the construction and upgrading / rehabilitation of key primary network facilities and pipeline, including works on the Strategic Infrastructure network and some works within the priority WSAs.

It is proposed that the rehabilitation and restructuring of secondary and tertiary networks, including the installation of customer connection control points and replacement of unsuitable customer meters, would be undertaken as Design-Build (DB) contracts, which would include an appraisal and a construction stage. The appraisal stage would include the contractor undertaking a pipe-by-pipe verification and assessment investigation prior to finalising and presenting his design for acceptance by the Employer’s Representative, before commencing with construction. A certain level of site information will be gathered for the target areas during the Design stage prior to tendering, which will assist in preparation of outline designs. However, the extent of site information necessary to undertake a full pipe-by-pipe appraisal and design would only be practical from a time and logistics viewpoint by including it within the DB contract. Clear criteria will be set out in the Contract Documents for the locations and nature of the appraisal investigations, and for retention or replacement of the existing pipe arising from those investigations. Contractors would not have scope to manipulate the scale of construction works determined by the appraisal investigations as they would have to comply with the criteria set out in the Contract Documents. By including the investigations within the DB contracts, a very substantial risk is removed from the Client, as the scope for claims arising from unforeseen site conditions would effectively be eliminated. As with all contracts, it will be essential to have effective supervision of the Contract to protect the Client’s interests.

It is likely that the construction and upgrading / rehabilitation of key primary network facilities and pipeline, including works on the Strategic Infrastructure network would be undertaken as traditional Client-Design contracts, which would require advance Site Investigations Contracts as part of the detailed design stage.

The most appropriate procurement routes for these contracts would be determined at detailed scoping stage.

9.5 Proposed MCC Priority Contract Packages

In the Priority Investment Programme (PIP) report, the Phase 1 works are sub-divided into the works which are proposed for financing by MCC and those which might be financed by other agencies. The proposed MCC priority contract packages are summarised in table 9.1 below.

Contract Package	Outline Scope of Works	Distribution Areas Covered by Contract package
1. Strategic Infrastructure	• Strategic Metering • Mapping/GIS/Condition Assessments	All DAs supplied by Strategic Infrastructure
2. Primary WSA Infrastructure	• Strategic Metering • Mapping/GIS/Condition Assessments	• All DAs in Zarqa WSA • All DAs in Awajan WSA • Tatweer DA • Russaifah High DA • Russaifah Low DA
3. Zarqa WSA Secondary and Tertiary Infrastructure	• Secondary / Tertiary Network Restructuring and Rehabilitation • New Customer Control Points • Replacement Customer Meters	• Zarqa High • Zarqa Mid-Batrawi with Exception of Al Gweireyeh area • Zarqa North
4. Awajan WSA Secondary and Tertiary Infrastructure	• Secondary / Tertiary Network Restructuring and Rehabilitation • New Customer Control Points • Replacement Customer Meters	• Awajan High • Awajan Low • Awajan West • Awajan North
5. Tatweer WSA Secondary and Tertiary Infrastructure	• Secondary / Tertiary Network Restructuring and Rehabilitation • New Customer Control Points • Replacement Customer Meters	• Tatweer
6. Russaifah WSA Secondary and Tertiary Infrastructure	• Secondary / Tertiary Network Restructuring and Rehabilitation • New Customer Control Points • Replacement Customer Meters	C. 30% of Russaifah WSA, predominantly in: • Russaifah High DA • Russaifah Low DA

Table 9-1: Proposed MCC Phase 1 Contract Packages

The proposed locations of the MCC Priority Projects in the WSAs are illustrated in Drawing No. 20445-FIG-11. The proposed Phase 1 scope of works for each of the four WSAs is illustrated in Drawings Nos. 20445-FIG-11D to 11D. The proposed locations for the Strategic Infrastructure system meters and telemetry outstations are illustrated in Drawing No. 20445-FIG-12.

9.6 Co-ordination of Project Works

It will be important to ensure that there is no overlap in project commitments between different projects, nor gaps of incomplete work in areas located between different project areas. At the project scoping stage, clear and precise interfaces will be established between MCC-funded projects and other areas of the networks. The most appropriate interfaces to use will be the Distribution Area (DA) boundaries, which will be suitable for use in most cases. Where separate projects are proposed within the same DA, then it will be necessary to determine locations and sequences of works and responsibilities for each interface point on a site by site basis.

10. COST ESTIMATES

10.1 Unit Cost Estimates

Unit Costs for various network elements were built up by NOD/ACEPO Quantity Surveying staff from a review of recent and current market rates for various construction activities in Jordan, and applying them to a series of standard schedules of works. The schedules of works for reservoir and pumping station construction cost calculations are provided with the revised IMP.

Standard schedules were priced for a range of reservoir sizes and pumping station sizes. These individual prices were then plotted on graphs in order to allow intermediate sized reservoirs and pumping stations to be priced. The pricing graphs for reservoirs and pumping stations are shown in Figs 10.1 and 10.2 below.

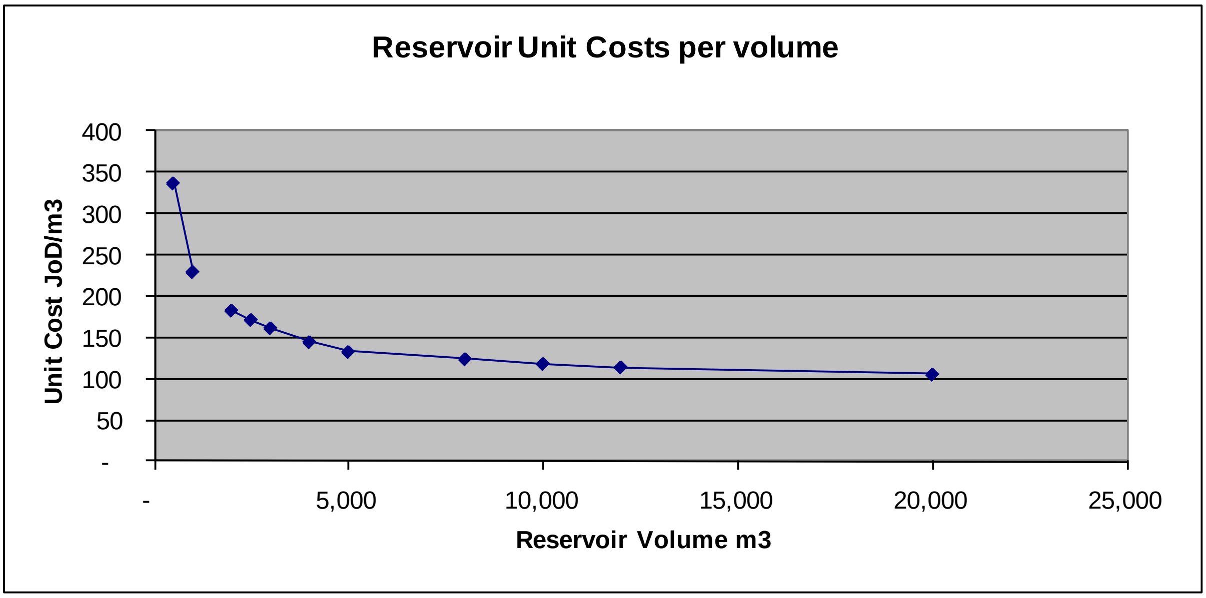


Figure 10-1 Construction Cost Graph for Reservoirs

There are 2 relatively small water-towers proposed for future construction, at Azraq and Hallabat. They are priced at twice the price of equivalent sized reservoirs.

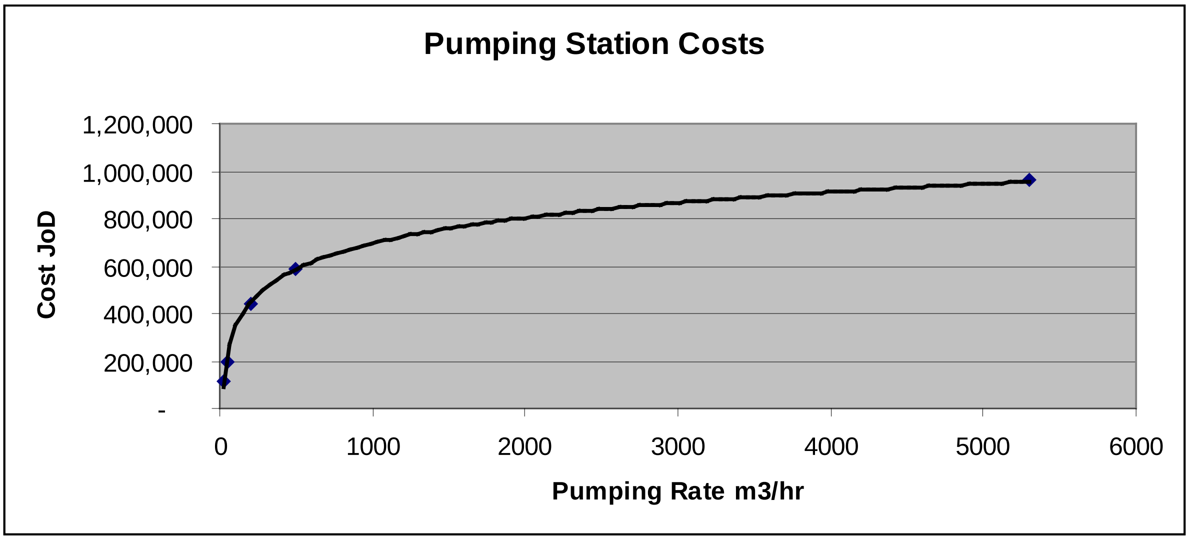


Figure 10-2 Construction Cost Graph for Pumping Stations

An additional 10% was applied to construction costs to cover land costs and outside-site enabling, preparation and services provision works.

From a review of the site surveys of the existing facilities, it was determined that refurbishment/rehabilitation requirements for different facilities would vary significantly. For the purposes of determining average unit costs for these activities, the aggregate condition of existing facilities (excluding relatively new facilities) was assessed and the ratios to new construction cost was determined as set out in Tables 10.1 and 10.2 below.

Reservoir Volume (m3)	New Construction Cost (JD)	Refurbish/Rehabilitate Construction Cost (JD) 20% of new cost for smallest reducing to 10% for largest
500	184,800	36,960
1,000	251,900	47,861
2,000	401,500	72,270
2,500	470,800	80,036
3,000	532,400	85,184
4,000	635,800	95,370
5,000	729,300	102,102
8,000	1,090,100	141,713
10,000	1,300,200	156,024
12,000	1,504,800	165,528
20,000	2,318,800	231,880

Table 10-1: Reservoir Unit Refurbishment / Rehabilitation Costs

Pumping Station Duty Flow-rate (m3/hr)	New Construction Cost (JD)	Refurbish/Rehabilitate Construction Cost (JD) 90% of new cost
10	64,900	58,410
15	96,800	87,120
20	129,800	116,820
25	161,700	145,530
45	217,800	196,020
200	481,800	433,620
240	513,700	462,330
250	521,400	469,260
370	590,700	531,630
380	595,100	535,590
500	644,600	580,140
900	748,000	673,200
1,300	812,900	731,610
1,800	871,200	784,080
2,400	921,800	829,620
2,600	936,100	842,490
4,000	1,012,000	910,800
20,000	2,318,800	231,880

Table 10-2: Pumping Station Unit Refurbishment / Rehabilitation Costs

Construction costs for new and rehabilitated pipelines were calculated directly for standard pipe sizes. Unit costs for restructuring and refurbishment were derived from a general review of the overall restructuring and refurbishment requirements, and their relationship to the works involved in equivalent new construction. Pipeline construction costs are set out in Table 10.3 below.

Pipe Diameter (mm)	New Construction Cost (JD)	Refurbish/Restructure Construction Cost (JD) 20% of new cost for smallest reducing to 10% for largest
50-90	28.60	5.72
100	58.50	8.78
150	71.50	10.73
200	97.50	11.70
250	110.50	12.16
300	130.00	13.00
400	195.00	19.50
500	325.00	32.50
600	390.00	39.00
700	455.00	45.50
800	520.00	52.00

Table 10-3: Pipe Construction / Rehabilitation Costs Unit Costs

Unit costs for DMA connection points, customer connection points and customer meter replacement were calculated on the basis of time and materials inputs at typical sites, and are shown in Table 10.4 below.

Item	Unit Construction Cost (JD)
DMA connection point	10,000
Customer connection point	100
Customer meter replacement	50

Table 10-4: Unit Construction Costs for DMA connection points, customer connection points and customer meter replacement

The construction of a DMA connection point will be a substantial operation, involving the fitting of branch main (typical 200 – 300mm diameter) on a primary distribution pipeline (typical 300 – 600mm diameter), together with electromagnetic flow-meter, sluice valves on the branch pipeline and possibly on the main pipeline, a Pressure-Reducing Valve (PRV), a washout/hydrant, a telemetry outstation linked to a central SCADA system, pressure monitoring points upstream and downstream, and associated pipework, underground chambers, overground kiosk, marker posts, civil works, and power (possibly battery / solar) and communications (possibly GSM / Radio) arrangements.

Other costs are derived for construction of strategic metering locations, site investyigations along strategic pipeline routes, land purchase, and ancillary items, and are shown in Appendix 8.

In addition to construction costs, an additional 24% is added to cover ancillary costs, which are broken down as follows:

- 2% mitigation cost for environmental and social impacts.
- 2% cost for physical / site contingencies.
- 5% cost for price fluctuation contingencies.
- 5% cost for MCC/Client project management costs.
- 10% cost for engineering design, procurement, supervision and project management costs.

10.2 Overall Cost Estimate

The cost estimate for the works set out in the Master Plan Schedules of Works described in Section 8 of this report is summarised in Table 10.5 below. The total cost estimate is **JD 252,738,240**.

WSA	Phase 1 MCC funded works (JD)	Phase 1 funded by others (JD)	Phase 2 (JD)	Phase 3 (JD)	Total Cost Estimate (JD)
Strategic Infrastructure (non-WSA)	1,984,000	5,120,729	29,811,513	32,725,932	69,642,174
Azraq		125,121	876,516		1,001,637
Dulail		7,894,980	6,862,552	334,476	15,092,008
KABA			3,145,012		3,145,012
Tatweer	4,115,150		80,476		4,195,626
Zarqa	27,037,567	813,676	5,319,600	740,652	33,911,495
Awajan	29,191,452	12,142,533	8,622,030		37,813,482
Russaifah	13,152,026	30,688,060	11,926,148		55,766,234
North		12,004,898	3,028,248	1,337,972	16,371,118
WestNW		9,527,815	4,427,274	1,844,364	15,799,454
Total	**75,480,195**	**66,175,279**	**74,099,369**	**36,983,397**	**252,738,240**

Table 10-5: Summary Cost Estimate Investment Master Plan

The cost estimates for the 3 Phases of works are as follows:

- Phase 1. JD 141,655,474
- Phase 2. JD 74,099,369
- Phase 3. JD 36,983,397

The cost estimates include the capital construction contract costs, and ancillary costs.

A more detailed breakdown of the cost estimate is set out in Table 10.6 overleaf, with further detail set out in Appendix 8.

	Strategic Infra.	Water Supply Area (WSA)									Total Cost
		Azraq	Dulail	King Abdullah City	Tatweer	Zarqa	Awajan	Russaifah	North	West-NW	
Phase 1 (MCC)											
Primary Network	1,984,000	-	-	-	1,664,031	3,616,787	8,182,192	1,614,147	-	-	**17,061,156**
Secondary Network	-	-	-	-	1,412,292	7,152,275	8,026,195	5,197,827	-	-	**21,788,589**
Tertiary Network	-	-	-	-	1,038,827	16,268,506	12,983,065	6,340,053	-	-	**36,630,451**
Sum	**1,984,000**	**-**	**-**	**-**	**4,115,150**	**27,037,567**	**29,191,452**	**13,152,026**	**-**	**-**	**75,480,195**
Phase 1 (TBD)											
Primary Network	5,120,729	-	86,800	-	-	813,676	-	3,766,342	-	-	**9,787,546**
Secondary Network	-	-	2,326,919	-	-	-	-	12,128,262	7,843,329	5,085,722	**27,384,232**
Tertiary Network	-	125,121	5,481,260	-	-	-	-	14,793,456	4,161,569	4,442,093	**29,003,500**
Sum	**5,120,729**	**125,121**	**7,894,980**	**-**	**-**	**813,676**	**-**	**30,688,060**	**12,004,898**	**9,527,815**	**66,175,279**
Phase 2.											
Primary Network	29,811,513	876,516	6,862,552	3,145,012	-	5,319,600	8,622,030	11,926,148	3,028,248	4,427,274	**74,018,893**
Secondary Network	-	-	-	-	80,476	-	-	-	-	-	**80,476**
Tertiary Network	-	-	-	-	-	-	-	-	-	-	**-**
Sum	**29,811,513**	**876,516**	**6,862,552**	**3,145,012**	**80,476**	**5,319,600**	**8,622,030**	**11,926,148**	**3,028,248**	**4,427,274**	**74,099,369**
Phase 3.											
Primary Network	32,725,932	-	334,476	-	-	740,652	-	-	1,337,972	1,844,364	**36,983,397**
Secondary Network	-	-	-	-	-	-	-	-	-	-	**-**
Tertiary Network	-	-	-	-	-	-	-	-	-	-	**-**
Sum	**32,725,932**	**-**	**334,476**	**-**	**-**	**740,652**	**-**	**-**	**1,337,972**	**1,844,364**	**36,983,397**
Total											
Primary Network	69,642,174	876,516	7,283,829	3,145,012	1,664,031	10,490,714	16,804,222	17,306,636	4,366,220	6,271,638	**137,850,992**
Secondary Network	-	-	2,326,919	-	1,492,768	7,152,275	8,026,195	17,326,089	7,843,329	5,085,722	**49,253,297**
Tertiary Network	-	125,121	5,481,260	-	1,038,827	16,268,506	12,983,065	21,133,509	4,161,569	4,442,093	**65,633,951**
Sum	**69,642,174**	**1,001,637**	**15,092,008**	**3,145,012**	**4,195,626**	**33,911,495**	**37,813,482**	**55,766,234**	**16,371,118**	**15,799,454**	**252,738,240**

Phase 1 Works: Required for immediate upgrading of network. Will have immediate benefit, and will have structure and capacity for 2030 demand levels

Phase 2 Works: Required for improvement of network, Will be necessary for secure long term operation of the system with structure and capacity to 2030 demand levels even without additional inflows of water to the system.

Phase 3 Works: Additional works required to meet 2030 demands, as demand and flows grow with increasing population.

Table 10-6: Summary Master Plan Cost Estimate

11. CONCLUSIONS AND RECOMMENDATIONS

11.1 This Water Supply Investment Master Plan for the Zarqa Governorate sets out a comprehensive strategy for the restructuring and rehabilitation of the existing water transmission and distribution network to the year 2030. The Master Plan will provide WAJ and the Zarqa Water Directorate with a water supply planning framework for future investment in the Zarqa water supply delivery system on a phased and prioritized basis. A further important consideration of the Master Plan approach is that works undertaken under the earlier phases will still be capable of accommodating the longer term requirements, as they form part of an overall strategy.

This development of the strategy initially involved a detailed study of the existing water supply system serving Zarqa and the development of a hydraulic model of the existing water supply distribution network. The investigation of the existing system also identified the major deficiencies associated with the current supply arrangements.

Our investigations also identified recent and current proposals for the upgrading of the Zarqa Water Supply System.

A detailed water demand projection was then undertaken to determine the likely future water use and System Input requirements for existing and future development areas.

11.2 These investigations together with the water demand projection formed the basis for the development of the comprehensive strategy or Master Plan for water supply in the Zarqa Governorate to the year 2030.

Detailed phasing proposals have been established along with capital cost estimates for each element of the proposals.

In addition, a Preliminary Environmental and Social Impact Assessment of the proposed project has been prepared.

The total value of the master plan proposals amounts to JD 252,738,240. This includes JD 137,850,992 for the restructuring and rehabilitation of the primary facilities and pipelines and JD 114,887,248 for the secondary and tertiary networks.

11.3 It is the recommendation of this report that proposed project packages are now evaluated for prioritisation in accordance with the criteria agreed with WAJ and MCC for the Priority Investment Programme (PIP). This document will be submitted as a separate report.

Furthermore, on identification of the priority projects, it is recommended that the economic feasibility of these projects is assessed in accordance with the MCC requirements. The feasibility report will be submitted as a separate document.

After completion of the Priority Investment Program (PIP) by NOD-ACEPO JV, MCC engaged a Due Diligence Consultant (DDC), Mr Terry Krause of CH2M Hill, to review the NOD-ACEPO JV PIP cost estimate. The DDC made changes to the NOD-ACEPO JV cost estimate, mainly to quantities and unit costs, resulting in a different overall cost estimate. Further detail on the DDC cost estimate is provided in the Priority Investment Program.

11.4 Based on our investigations, it is clear that the existing water supply system is in a poor condition and that a number of projects are required as a matter of urgency as set out under the proposed Phase 1. Accordingly, we recommend the earliest intervention possible to ensure that the priority projects in Phase 1 are implemented as soon as possible.

The proposed Phase 1 works would be undertaken over a 5-year period, from end-2010 to end-2015. The total value of the Phase 1 proposals amounts to JD 141,655,474, including works to be funded by MCC and works to be funded by others. The Phase 1 works are concentrated on the secondary and tertiary networks, with JD 26,848,702 provided for the restructuring and rehabilitation of the primary facilities and pipelines and JD 114,806,772 for the secondary and tertiary networks.