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Ministry of Water and Irrigation
Water Authority of Jordan

سلطة المياه
WATER AUTHORITY

Feasibility Study, Environmental and Social Impact Assessment and Detailed Designs and Bidding Documents for Zarqa Governorate Wastewater System Reinforcement and Expansion Project

MILLENNIUM
CHALLENGE CORPORATION
UNITED STATES OF AMERICA

PREPARATORY WORKS TECHNICAL REPORT

MWH
BUILDING A BETTER WORLD

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ACRONYMS AND ABBREVIATIONS

Institutions

GoJ	Government of Jordan
JMD	Jordan Meteorology Department
MWI	Ministry of Water and Irrigation
WAJ	Water Authority of Jordan
MCC	Millennium Challenge Corporation
MCA	Millennium Challenge Account
GTZ	German Technical Cooperation
OMS	Operation and Management Systems Project
MoE	Ministry of Environment
RSCN	Royal Society for the Conservation of Nature
DOS	Department of Statistics
WHO	World Health Organisation

Facilities

AGTP	Ain Ghazal Preliminary Treatment Plant
WZPS	West Zarqa Pumping Station
EZPS	East Zarqa Pumping Station

Technical Terms

BOD	biochemical oxygen demand
cm	centimetre
COD	chemical oxygen demand
D, d	day
Dunum	1000 square metres
EIA	environmental impact assessment
GIS	geographic information system
Ha	hectare (10,000 square metres)
Kg	kilogram
Km	kilometre
L, l	litre
M	metre
MCM/y	million cubic metres per year
mg	milligrams
mm	millimetre
TOR	Terms of reference
TWw	treated wastewater
WwTP	wastewater treatment plant
Y, y	year

1. INTRODUCTION

1.1 General

MWH was retained by the Ministry of Water & Irrigation / Water Authority of Jordan (MWI/WAJ) on November 19th, 2009 to perform consulting services for the preparation of the feasibility study, environmental and social impact assessment and detailed designs and bidding documents for Zarqa Governorate wastewater system reinforcement and expansion. The key objective of this programme is to provide a substantial improvement in the existing levels of service in terms of extending the collection services to as many of the population as possible and to eliminate the spilling of sewage from the collection systems and secure additional fresh volumes of water to Zarqa and Amman Governorates through the substitution of treated wastewater for the fresh water supplied from the Jordan Valley.

The study is divided into two stages: Stage I is the base contract, whereas Stage II is optional, and will start only upon authorization after a compact is signed with the Millennium Challenge Corporation (MCC). Stage I of the study includes preparatory studies that are required to define an investment programme; preliminary environmental and social assessment; preliminary designs; and the assessment of feasibility of the investment program, including economic analysis. Stage II is the preparation of an EIA, detailed design and contract documents; and is dependent upon the successful completion of Stage I.

The study area includes the whole of Zarqa Governorate. However flows from some of Amman catchment areas that flow downstream of Ain Ghazal pre-treatment facility will be considered in the upgrading measures of the existing Zarqa wastewater system as these areas are already connected to the Zarqa wastewater system.

1.2 Background

The Zarqa Governorate extends from Zarqa River in the west to the Saudi border in the east with year 2004 population of 799,000, about 15% of the national population. However, ninety percent of the population is concentrated in the Zarqa, Russeifa and al-Hashemiyah metropolitan area. This urban area is the second largest metropolitan area in Jordan after Amman with year 2004 population of 687,000 and because of its proximity to Amman many urban development projects are planned in the area such as the King Abdullah Bin Abdul Aziz City, with a planned population of 400,300 by year 2035.

The first piped sewerage system was constructed in 1985 serving the central areas of Zarqa and Russeifa cities. Today the total length of the gravity sewer network is about 851 km of diameter 200 – 1000 mm, serving most of Zarqa, Russeifa and al-Hashemiyah areas.

The existing collection systems are supported by three existing pumping stations (West Zarqa, East Zarqa and Hitteen). West Zarqa pumping station serves west Zarqa area that drains towards Zarqa River and Russeifa in addition to flows coming from parts of Amman that drain downstream of Ain Ghazal preliminary treatment plant. East Zarqa pumping station located in al-Hashemiyah serves the eastern parts of Zarqa and al-Hashemiyah. Hitteen pumping station is small lifting station serving a small section of Hitteen camp in Russeifa.

All collected wastewater at West Zarqa and East Zarqa pumping stations is delivered to As Samra WwTP via 1200 mm diameter and two-500 mm diameter pumping mains respectively.

The existing wastewater collection system is designed as a separate collection system, which is not sized for stormwater collection.

Presently, the deficiencies in the sewerage system in Zarqa Governorate are such that they represent a danger to public health. The deficiencies can be outlined as follows:

1. Blocked sewers by sand, silt and grease, causing spills of raw sewage into the street. Some of the sewers have been found to be more than half full with sediments. This can be explained in various ways: low velocities in sewers; poor condition of some pipes and manholes; and poor maintenance of the sewerage system.
2. Several segments of the collection system are overloaded during rain events, causing backup into streets, wadis, and, in some rare cases, into residences. These wet weather problems are largely attributed to unauthorized storm drain connections from many buildings, as well as open manhole covers in flooded streets and wadis.

3. Inadequate pumping (storage) capacity at the pumping stations to cater for rain events. Stormwater collected through the sewer system is allowed to overflow into Zarqa River.

The other major problem with the existing sewer system in Zarqa Governorate is its extent. The last records obtained from WAJ show that the total number of subscribers for water services in 2009 is 130,948, while the number of subscribers for wastewater services is 94,265, which indicates that approximately 72% of households with water connections are sewered.

Future wastewater generation rates are expected to increase to 192,000 m^3/day by the year 2035, which is more than double the present level.. It is urgent to improve, renew and extend the wastewater collection, treatment and disposal systems.

To address these issues, this project will study the extension of the coverage of piped sewerage within Zarqa Governorate to areas that are not presently connected, the expansion of the trunk sewer system to better cope with present and future demand, the reduction of the number of blockages and sewage overflows through the upgrading of trunk sewers, and the increasing of wastewater volumes being collected and treated.

1.3 Objective

Jordan is considered to be one of the 10 poorest countries worldwide in water resources. The available renewable water resources per capita have dropped drastically to an annual per capita share of less than 160 m^3 in recent years, compared to 3600 m^3 per capita in 1946. Thus, the water sector strategy stresses the need for improved resource management, with particular emphasis being placed on the sustainability of the present and future uses. Special care is advocated for protection against pollution, quality degradation and depletion of water resources.

Accordingly, this project aims to plan and prepare urban sanitation improvements in Zarqa Governorate for a project proposal for MCC funding, with the intended purpose to provide collected wastewater, to be later processed and treated, and then used as a substitute for non-domestic purposes (irrigation, industrial, etc), in order to reduce demand on the limited domestic quality water resources.

Fulfilling the objectives of this project will result in a significant general benefit to the entire population of Zarqa due to the decrease or elimination of sewage overflows and the resulting health risks and costs and there will be specific benefit to that part of the population who are presently served only by water and not by sewer when the piped sewerage system is extended.

The project should also be a benefit to people living downstream from Zarqa, near the wadis, due to reduced pollution resulting from the extension of the piped sewerage coverage and the increase in treatment capacity.

Therefore, the objectives of this project are to:

- achieve an overall understanding of the present sanitation conditions and of future requirements;
- determine satisfactory service levels and standards commensurate with affordability and environmental concerns;
- project the long-term needs of physical works and how they should be phased in view of investment requirement and availability of funds and criteria to be set on priorities;
- provide justifications for investments in view of expected impacts;
- ensure that the facilities to be provided are least cost solutions, financially and environmentally sustainable and appropriate to the circumstances;
- arrive at the most feasible alternatives for expansion and upgrading of the wastewater collection systems;
- preparation of feasibility study and detail designs and tender documents for the expansion and upgrading of the sanitation systems in Zarqa Governorate.

In order to achieve these objectives, the following scope of services has been developed. The defined tasks are:

1. **Stage I:** Preliminary Design, ESA, Feasibility Study and Economic analysis

- Task 1: Collection of data and preparatory works
- Task 2: Hydraulic model, analysis of options and Master Plan
- Task 3: Preliminary environmental and social assessment
- Task 4: Feasibility study, preliminary design and work plan

2. **Stage II:** EIA and Detailed Design and Preparation of Contract Documents (optional)

- Option A: Environmental impact assessment
- Option B: Preparation of detailed designs and contract documents

The study will include developing and detailing an investment programme to reinforce and expand the wastewater system of Zarqa Governorate, conducting a feasibility study and undertaking environmental and social assessments, developing reliable and realistic cost estimates for the proposed investments and developing detailed engineering design and bidding documents for construction.

This study will then form the basis to identify the investment project to be potentially funded by MCC, under a compact that is currently under preparation.

1.4 Project Location

Zarqa Governorate is located in the central-northern part of Jordan with an area of 2,451 km^2.The location of the study area for the project is depicted in Figure 1.1.

Zarqa River, the second largest river in Jordan, runs through the cities of Russeifa and Zarqa and drains westward towards the Jordan Valley and the King Talal Reservoir.

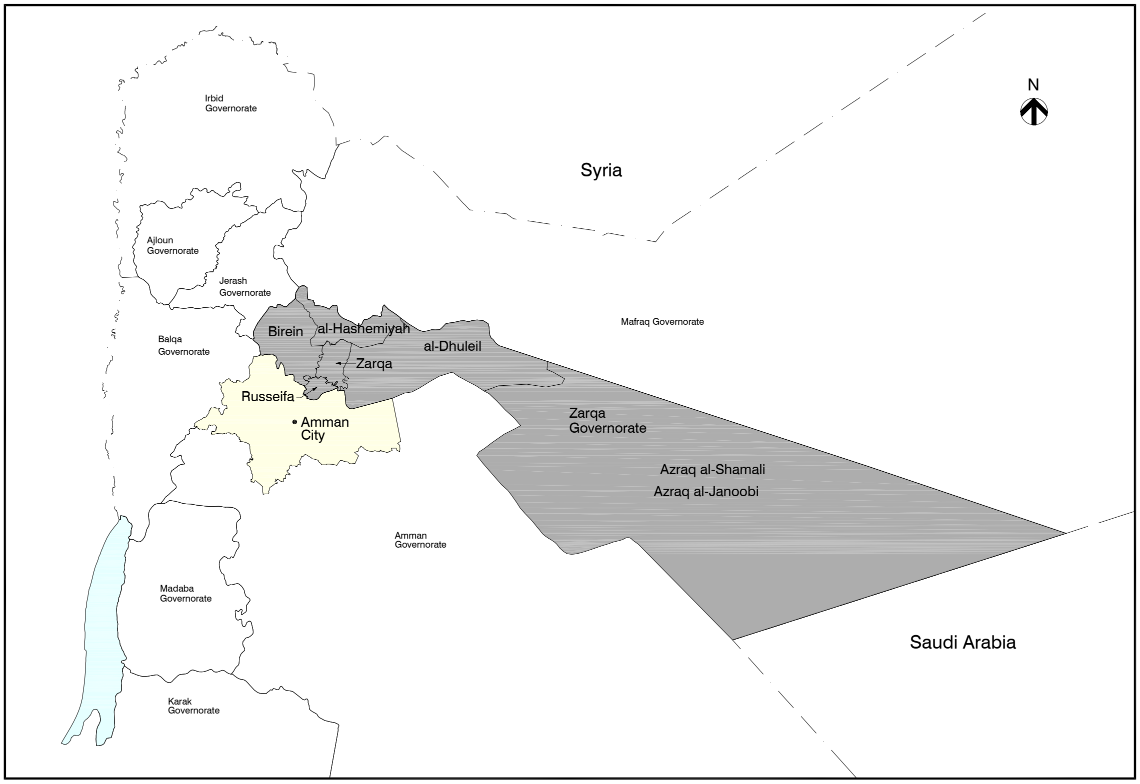

Figure 1.1 Location Map of Study Area

1.5 Preparatory Works Technical Report

The purpose of this Preparatory Works Technical Report is:

- to present the Team's understanding of the exiting situation. The physical characteristics of the project area along with assessment of the existing wastewater facilities are presented in Section 2;
- to present the results of the review of the past reports for the study area;
- to present the planning considerations that will be adopted in developing the master plan. Planning criteria including population, water consumption and wastewater generation projections are presented in Section 4;
- to present the design criteria of the different project components that will be used in the design and costing of the wastewater system expansion and reinforcement programme;
- to present the results of the topographical survey of the main sewer system in the project area;
- to present the results of the flow monitoring survey; and
- to identify the different options for the expansion of the wastewater collection systems that will be evaluated.

2. EXISTING SITUATION

2.1 Introduction

To formulate a realistic Master Plan for the expansion and reinforcement of the Zarqa wastewater system, a thorough understanding of the existing situation within the study area is required. This section presents the team's understanding of the existing situation, covering such topics as a definition of the proposed study area, the physical characteristics of the study area and a description of the existing wastewater systems and their current condition.

2.2 Existing Service Area

The extent of the existing wastewater services within the Zarqa Governorate, which is under the direction of the Zarqa Water Directorate, is shown in Figure 2.1. In general, the existing sewerage system covers only the cities of Zarqa, Russeifa, al-Hashemiyah and the Zarqa Free Zone.

2.3 Physical Characteristics

2.3.1 Topography

The general topography of the project area is rolling to hilly, resulting in the formation of small catchment areas. Each catchment area drains locally into a tributary wadi that drains into a larger wadi and so on until all drain into Wadi Zarqa which represents the collector of the study area.

Wadi Zarqa flows north as it leaves the urban area, but at its confluence with Wadi Dhuleil near Sukhneh it turns west to flow into King Talal Reservoir (KTR). The elevation in the study area ranges from about 500 m to about 800 m.

Wastewater collection areas in the Amman-Zarqa River basin are designed based on topography to allow gravity collection. Based on the surface topography of the study area, the Zarqa wastewater network system could be divided into five major catchment zones:

1. West Zarqa Pumping Station (WZPS) Zone,
2. East Zarqa Pumping Station Zone (EZPS) Zone,
3. Sukhneh Zone, and
4. Wadi Zarqa Zone
5. Wadi Dhuleil Zone

Within each of the above mentioned major catchments, the topography allows sewers to drain by gravity through existing roads or through natural wadis.

The topography of the WZPS zone allows to serve by gravity the unsewered neighbourhoods in west of Zarqa such as Hai al-Falah, Hai al-Dweik, Hai Hai Umm Bayadhah, Hai al-Madadinah al-Munawarah, Hai al-Jneineh, and al-Majd City Also, in Russeifa the neighbourhoods of Hai al-Rasheed al-Shamali and Hai al-Qadissiyah will be served by gravity. All mentioned neighbourhoods within this zone will be served through the existing sewer networks.

The topography of EZPS zone allows to serve the by gravity the unsewered neighbourhoods in eastern of Zarqa such as Hai al-Batrawi and King Abdullah City through the existing sewer network..

The topography of Sukhneh zone allows to serve by gravity the unsewered neighbourhoods in west of Zarqa such as such as Hai Makka al-Mukarramah, Hai Hai al-Ahmad, Hai al-Jabr, Hai Nassar, Hai al-Ameera Haya, Hai Shomar, Hai al-Bustan, Hai al-Hashemi, Salheyah, Abu al-Zeighan, and Sukhneh. All mentioned communities will be served via the proposed Sukhneh Pumping Station.

The topography of Wadi Zarqa Zone is relatively steep and allows to serve remote and isolated communities such as Birein, Umm Rummanah, Maqam Essa, Dogara, etc toward the proposed Wadi Zarqa Wastewater Treatment Plant.

The topography in the east is relatively milder than the west. In that area Dhuleil drains through Wadi Dhuleil until reaching the vicinity of As Samra Treatment Plant where a pumping facility is required to lift the flow up to the inlet.

2.3.2 Climate

The climate in Jordan is predominantly Mediterranean, with hot and dry summers and cool, wet winters with two short transitional periods in the autumn and spring. During those short transitional periods, most convective activity occurs, producing thunderstorms. The precipitation pattern is dependent upon both latitude and altitude. Rainfall decreases from north to south, west to east, and from higher elevations to lower ones (JMD 2003).

Most of the rainfall in Jordan occurs in the winter and spring, from November through April in some years. Historically, the maximum amount of rain occurs during January. The amount and the period of rainfall are highly variable, and they fluctuate widely from year to year. Within the study area, humidity and precipitation decrease rapidly moving from the Amman plateau towards the eastern deserts.

The average annual rainfall varies from less than 200 mm in the northeast to more than 500 mm in the northwest, close to Bal'ama. The average maximum daily rainfall is 61.8 mm/d in January. The average daily temperature is 12.4 °C during the wet season (from November to April) and 23.2 °C during the dry season (from May to October). The average minimum daily temperature in the study area, which occurs in January is about 4.1 °C and the average maximum daily temperature is about 33.1 °C. The prevailing wind direction in the study area is west-southwest in winter, shifting to west-northwest in summer. The average daily wind speed is 2.1 m/s, ranging between 1.9 and 2.3 m/s in winter and 1.6 and 2.4 m/s in summer. The average daily relative humidity varies from 65.2 to 82.6% in winter and from 59.2 to 71% in summer.

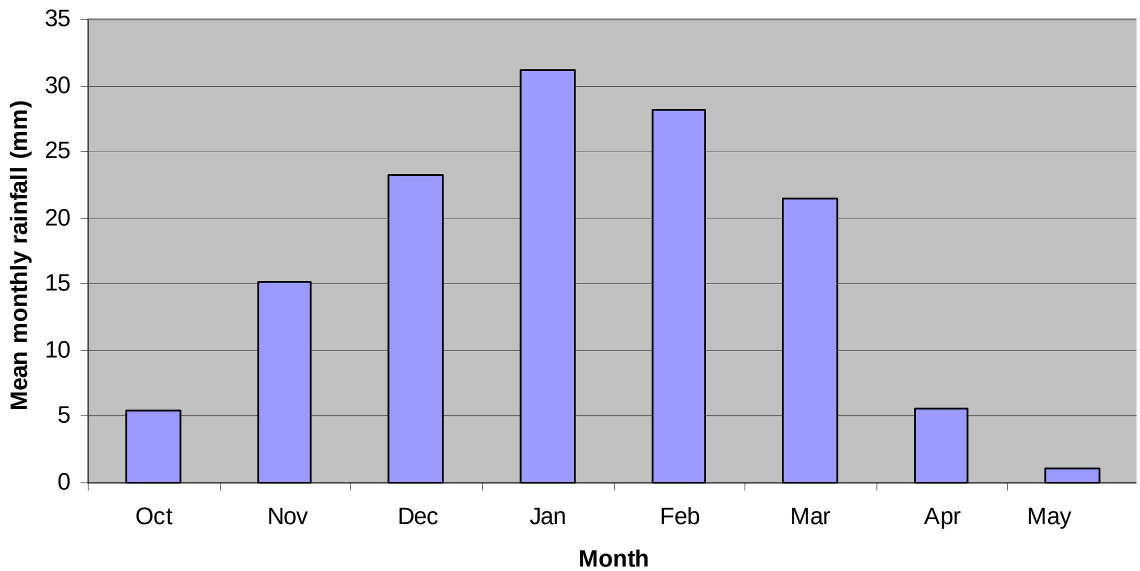

Figure 2.2 Monthly Rainfall at Zarqa Station

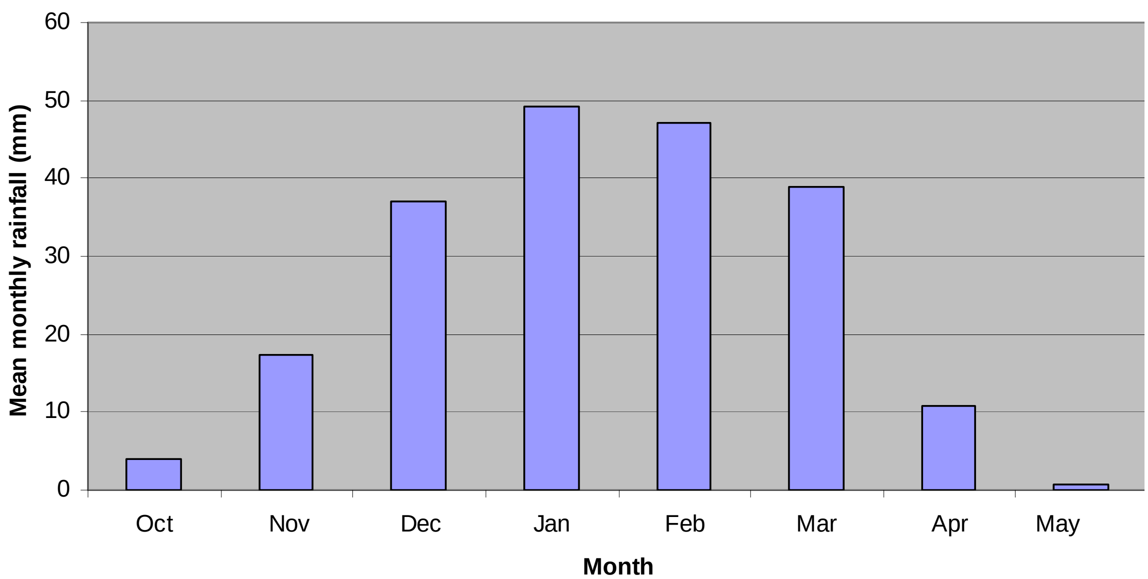

Figure 2.3 Monthly Rainfall at Bala'ama Station

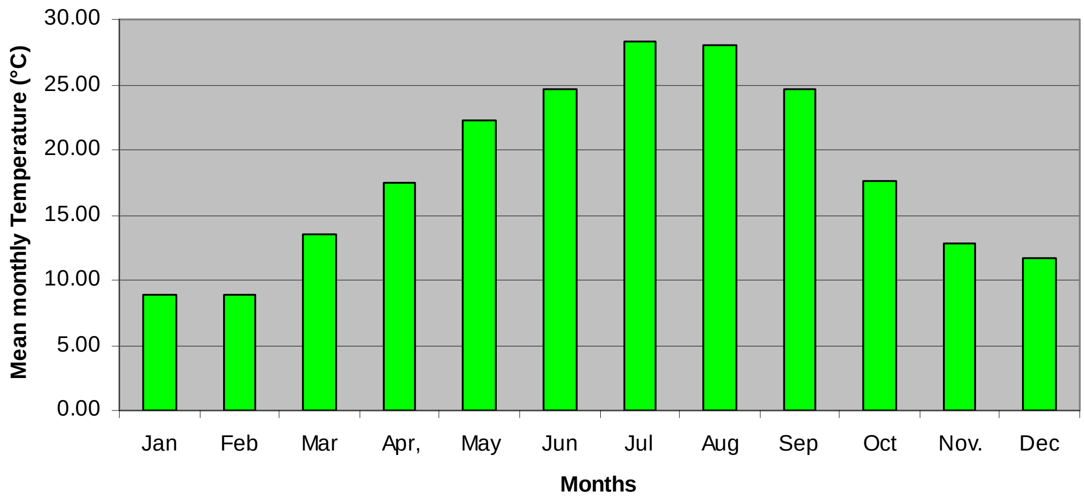

Figure 2.4 Mean Monthly Temperature at Amman Airport Station

2.3.3 Geology and Geotechnical Study

The geology and geotechnical study is required to collect basic data for the establishment of design criteria and for design work within the frame of the Preliminary Study. Accordingly, the study area was selected based on the anticipated new construction works. A key plan showing the area in which a geotechnical study was conducted for the purposes of this project is presented in Figure 2.5.

Soil Units and Land Use of the Geotechnical Study Area

Soil Units of the Geotechnical Study Area

Soil is the uppermost layer of the earth's crust, which develops slowly as a result of weathering processes. Different types of soil develop at distinct sites, depending on the type of exposed rock, as well as parameters such as the amount of rainfall, wind, solar radiation, temperature, vegetation and land use. Generally, four soil groups can be distinguished in Jordan (Bender 1974):

Grey desert soils (Sierosem), formed under arid conditions (<150 mm precipitation/yr);

- Red Mediterranean soils, formed under sub-humid conditions (>600 mm precipitation/year) and semi-arid conditions (precipitation between 300 and 600 mm a year);
- Yellow steppe soils, formed under semi-arid and arid conditions (between 150-300 mm precipitation/yr); and
- Yellow Mediterranean soils (transitional type of soil between the red Mediterranean soils and the yellow steppe soils), formed under semi-arid climatic conditions (250-350 mm precipitation/yr).

In the study area Nisab (NIS) and Abu Salih (ALI) soil types are the dominant soil units as shown in Figure 2.6 and Table 2.1. The Nisab soil unit is a dissected plateau in the Belqa Group limestones producing narrow interfluve crests and long valley slopes with gradients between less than 10 and 20%. It contains silty clay loam and clay loam (very highly calcareous and weakly to moderately saline) at depths of more than 80 cm. On the other hand, it contains very stony silty clay loam (very high calcareous and weakly saline) at depths of less than 50 cm.

The Abu Salih soil unit (ALI) is finely dissected limestone uplands and slopes with gradients ranging between 5-35 %, with some valley sides up to 70 %. It characterized by deep (at depths of more than 80 cm) silty clay that is highly calcareous and non-saline in some parts and very shallow (less than 25 cm) gravely silty clay loam on limestone, highly calcareous and non-saline.

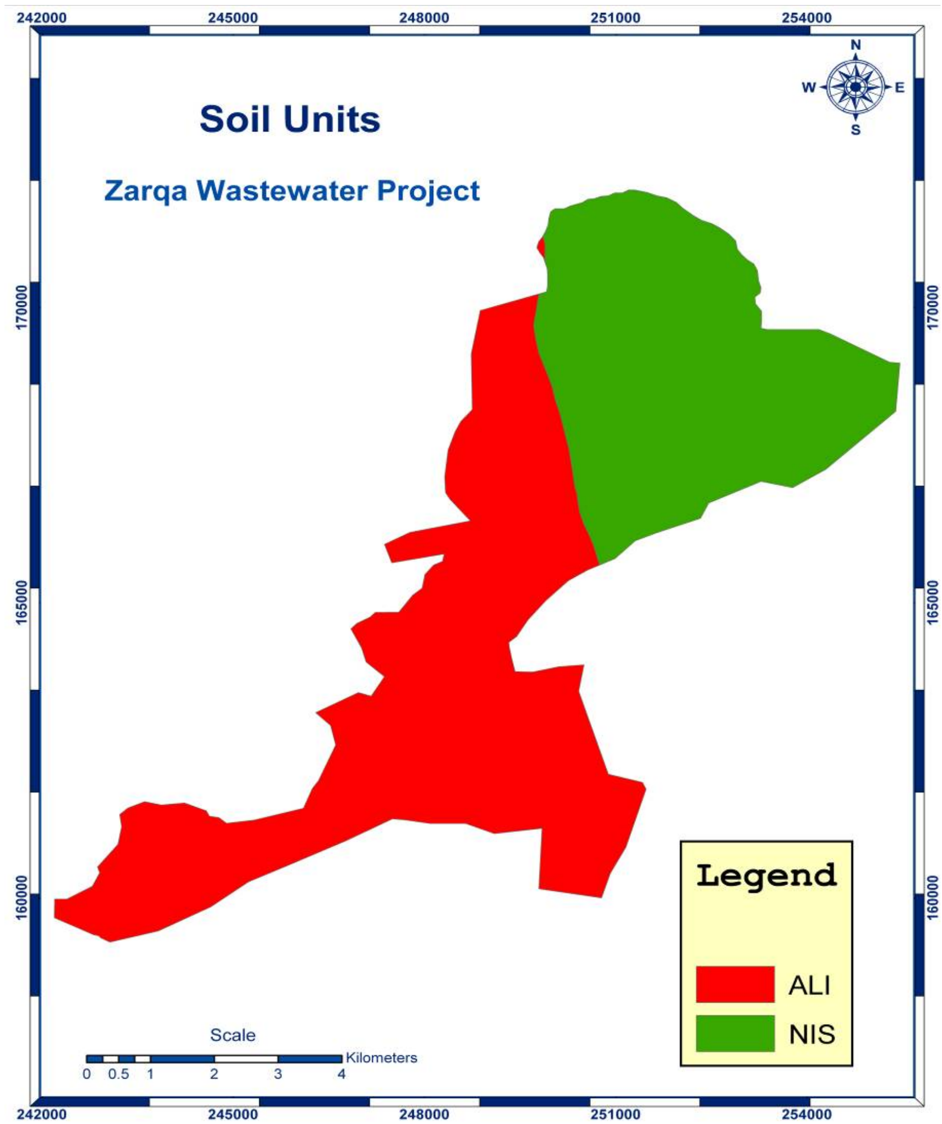

Figure 2.6 Dominant Soil Units in the Geotechnical Study Area

Table 2.1 Description of Soil Units of the Geotechnical Study Area (Ministry of Agriculture (MOA), 1994)

Soil Unit	Description	Soil association	Description
Abu Salih (ALI)	Finely dissected limestone uplands and slopes: moderately dense dendritic drainage: gradients in range 5-35% with some valley sides up to 70%: altitude 500-1000m: relative relief 100-150m.	Typic and Calcixerollic Xerochrept Rock	40%: deep (>80cm) silty clay: highly calcareous and non-saline: occurs in colluvium of middle and lower slopes and in valley bottom alluvium: gradients 2-35%. 20%
Nisab (NIS)	Dissected plateau Belqa Group limestones producing narrow interfluve crests and long valley slopes: colluvials mantle on upper and middle slopes, alluvial fans on lower slopes: altitude 550-750m: relative relief 100m	Xerochreptic Camborthid and Calciorthid Lithic (Xerochreptic) Camborthid Rock	40%: deep (>80cm) silty clay loam and clay loam: very highly calcareous and weakly to moderately saline: formed in loessic gradients <10%. 40%: shallow and very shallow (<25-50cm) very stony silty clay loam: formed in thin loess mantle of upper slopes, crests and valley shoulders: very highly calcareous and weakly saline: gradients 0-50%. 5%.

Land Use Map of the Geotechnical Study Area

The land use map for the Geotechnical Study area is constructed based on the land use map of the Amman-Zarqa basin, and is presented as Figure 2.7. The land use types of the Geotechnical study area comprises 90 % as bare rock, thin soils and urbanization and 10% as natural vegetation, forest, irrigated agriculture (cereals, vegetables, fruit trees, olives, bananas and citrus) and rained agriculture (cereals, vegetables, fruit trees, olives, bananas and citrus). The land use ranges from urban and associated non-agricultural land (built-up areas, quarries and mines), to non-vegetated and sparsely vegetated land (basalt, bare rocks), to open field crops and fallow lands (rain-fed areas with a very low intensity of< 35 % cropping), and finally to ancient villages and archaeological sites.

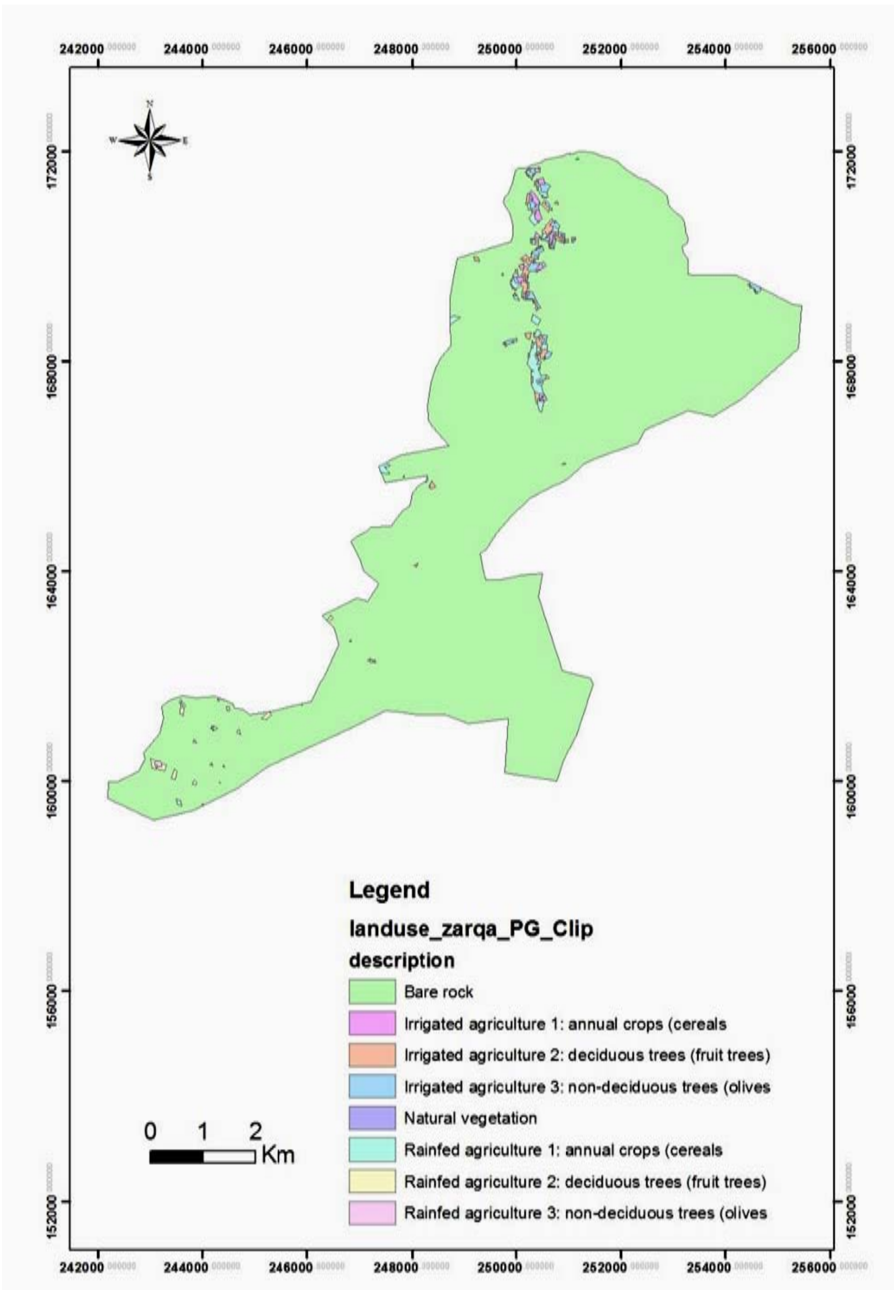

Figure 2.7 Land Use Map of the Geotechnical Study Area

Geology

Geology of the Amman-Zarqa Basin

The geology of the Geotechnical study area falls within the geology of Amman-Zarqa Basin. The outcropping of Amman-Zarqa Basin extends from Lower Cretaceous (except wadi deposits which are Quaternary) to recent age, which is belonging to the Ajlun and Belqa Groups according to Jordanian classification (Table 2.2 and Figure 2.8). However, the Kurnub Group (Lower Cretaceous) is usually found at certain depths except where it outcrops in western parts of the study area (Baq'a Valley) along the axis of Suweileh anticline. In addition, the older Zarqa Group (Jurassic-Triassic age) occurs at considerable depth (Howard Humphreys 1983).

Lithologically, Amman-Zarqa Basin includes the following (from old to young):

1. Zarqa Group: this group consists of sandstone, shale, dolomite and dolomitic limestone, marl, gypsum and intercalation of volcanic ash. Its thickness reached up to 1000 meters as encountered at Wadi Rimam (south of Amman).
2. Kurnub Group: this group is exposed in the western parts of Amman-Zarqa Basin at Baq'a Valley. It mainly consists of white, grey and multicolored sandstone (weakly cemented fine-medium and coarse grained) with red silts, shales and dolomite streaks. The top of this group is known as the Subeihi Formation, which mainly consists of red-brown varicolored sandstone with a large portion of marl, clay and siltstone. On the other hand, the lower part of this group is known as Aarda Formation which consists of yellow-white sandstone with shale partings and dolomite streaks. The thickness of Kurnub Group has been encountered between 200-300 meters (USAID and WAJ 1989). The age of this formation is Lower Cretaceous.
3. The Ajlun Group overlays the Kurnub Group and consist of five formations, namely: the Naur (A1-2); the Fuheis (A3); the Hummar (A4); the Shuayb (A5-6) and the Wadi as Sir (A7).
4. The Belqa Group overlays the Ajlun Group and consists of five formations, namely: Wadi Umm Ghudran (B1); Amman-Al Hisa (B2); Muwaqqar (B3); Umm Rijam (B4) and Wadi Shallala (B5). However, Wadi Shallala formation is not represented in the geology of Amman-Zarqa Basin.

Geology of the Geotechnical Study Area

The outcropping rocks in the study area mainly consist of Ajlun group (A4, A5/6 and A7) and Balqa Group (B1 and B2). Soil cover is generally thin, although local topography has led to accumulation of wind-blow soils in numerous places. Valleys are generally filled with alluvial deposits of gravel, boulders, and pebbles. The Amman Formation B2 (Santonian – Campanian) consists of cyclic deposits of chalk, phosphate, silicified phosphate, limestone and chert. The limestone is occasionally silicified. In the Amman-Ruseifa and Zarqa areas, two members of the formation are recognized:

- Upper chalk-marl and phosphate member (26-27m thick in Russeifa); and
- Lower chert-limestone member (about 90m east of Amman).

Geologic Structures of the Project area

The study area possesses various structural features indicating that Jordan Dead Sea Transform represents the structural control of the region.

The Amman - Hallabat Structure is a major structure in the study area, which extends between the area southwest of Amman and northeast of Qasr Al-Hallabat. The structure was formed as a result of the lateral compression zone beginning from Siyagha at the northeastern comer of the Dead Sea towards Qasr Al-Hallabat, and passing through an echelon arrangement between Madaba and Amman to Tal Al-Sour.

The major element, which determines the configuration of the whole study area, is the Amman-Zarqa syncline structure represented by a syncline and adjoining folded layers. The syncline extends through the area southwest of Amman to northeast of Zarqa. It swings gradually to the north, widens behind Awajan, and plunges towards the east.

A fault zone exists within the Zarqa River Valley as a result of the relative 20° rotation of the block on both sides of the Zarqa River, which has a relationship with the structural history and tectonic factors of the region. The movement of this structure is thought to have taken place in the Quaternary Era.

The geological structures affecting groundwater movement. can be summarized as follows:

1. Sweilih Anticline: The axis of this anticline strikes NE-SW. In its care, erosion has exposed the Kurnub Sandstone Aquifer in Ain el Basha and Baqa north of Sweilih. Modern recharge in this relatively high rainfall area directly and indirectly reaches the Kurnub and the underlying Zarqa aquifers.
2. Amman- Zarqa Syncline: The axis of this syncline strikes NE-SW. It extends from the southwestern side of Greater Amman to a point about 6.60 km southeast of Zarqa. The syncline is about 30 km long by 10-15 km wide. This synclinal zone is the highest potential area in the Hummar aquifer.
3. The Amman- Zarqa Monoclinal Flexure: The axis of this structure is parallel to the Amman-Zarqa syncline. It is to the southeast of the synclinal axis. They are 6.5-19 km apart. This monoclinal flexure and associated faulting form a hydraulic barrier to the eastward movement of water within the Hummar (A4) aquifer.

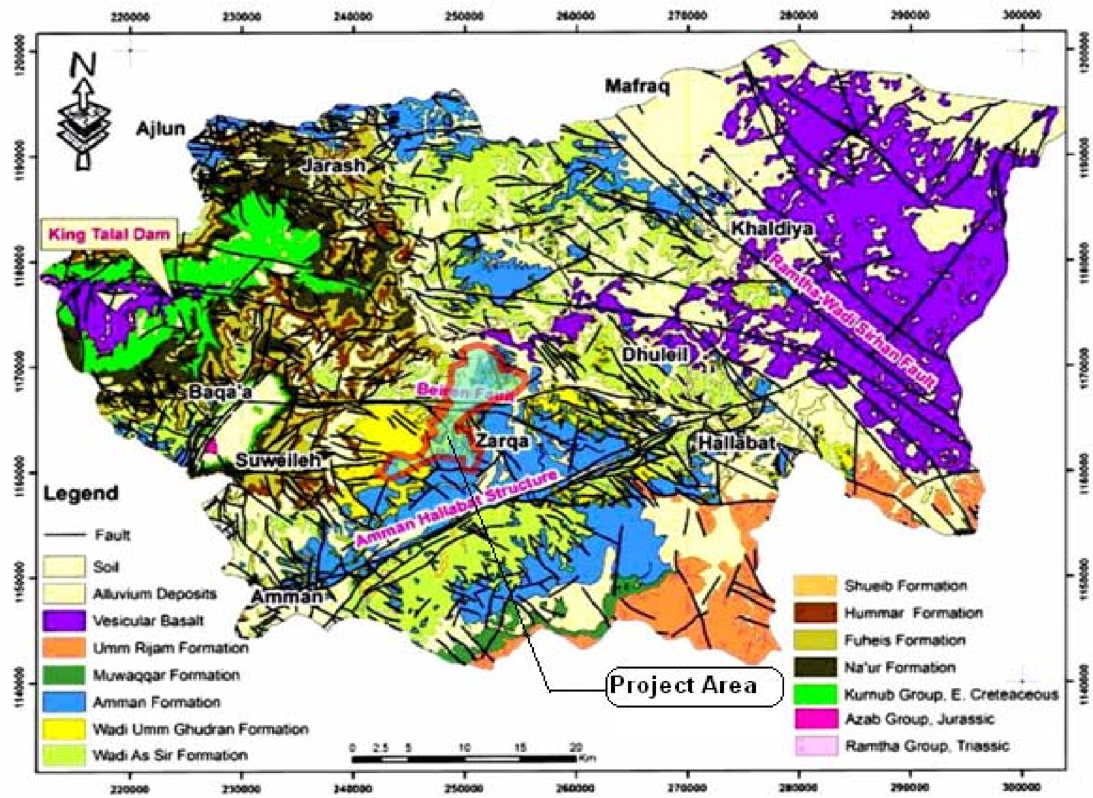

Figure 2.8 Geology of the Amman-Zarqa Basin (AZB), Modified after the Natural Resources Authority (NRA), 2000

Table 2.2 Geological and Hydrogeological Classification of the Rock Unit in Amman-Zarqa Area (Rimawi, 1985)

Epoch	Age	Group	Formation	Symbol	Rock type	Thickness (m)	Aquifer Potentiality	Permeability (m/s)
Tertiary	Holocene	Balqa	Wadi Fill		Soil, Sand and Gravel	Oct-40	Good	2.4 x10^{-7}
	Pleistocene		Basalt	V	Basalt. Clay	0-50	Good	-
Upper Cretaceous	Maestrichtain		Muwaqqar	B3	Chalk, marl and Chalky limestone	60-70	Poor	-
	Campanian		Amman	B2	Chert, limestone with phosphate	80-120	Excellent	10^{-5}- 3 x 10^{-4}
	Santonian		Ghudran	B1	Chalk, Marl and Marly limestone	15-20	Poor	-
	Turonian	Ajlun	Wadi Sir	A7	Hard Crystalline Limestone. Dolomitic and Some Chert	90-110	Excellent	1x10^{-7} - 1x10^{-4}
			Shueib	A5-6	Light Grey limestone interbeded with Marls and Marly Limestone	75-100	Fair to poor	6.3 x10^{-5} -7.2 x10^{-4}
			Hummar	A4	Hard dense limestone and Dolomitic Limestone	40-60	Good	8.1 x 10^{-7} - 7.6 x10^{-4}
	Cenomanian		Fuheis	A3	Gary and Olive Green soft Marl. Marly limestone and limestone	60-80	Poor	5.3 x 10^{-7} - 1.7 x 10^{-5}
			Na'ur	A1-2	Limestone interbeded with a thick sequence of Marl and Marly Limestone	150-220	Poor	2 x 10^{-8} - 3.1 x 10^{-5}
	Albian –Aptian		Kurnub	K	Massive White and Varicolored Sandstone with layers of Reddish Silt and Shale	300	Good	6.9 x 10^{-3}- 5.2 x 10^{-2}

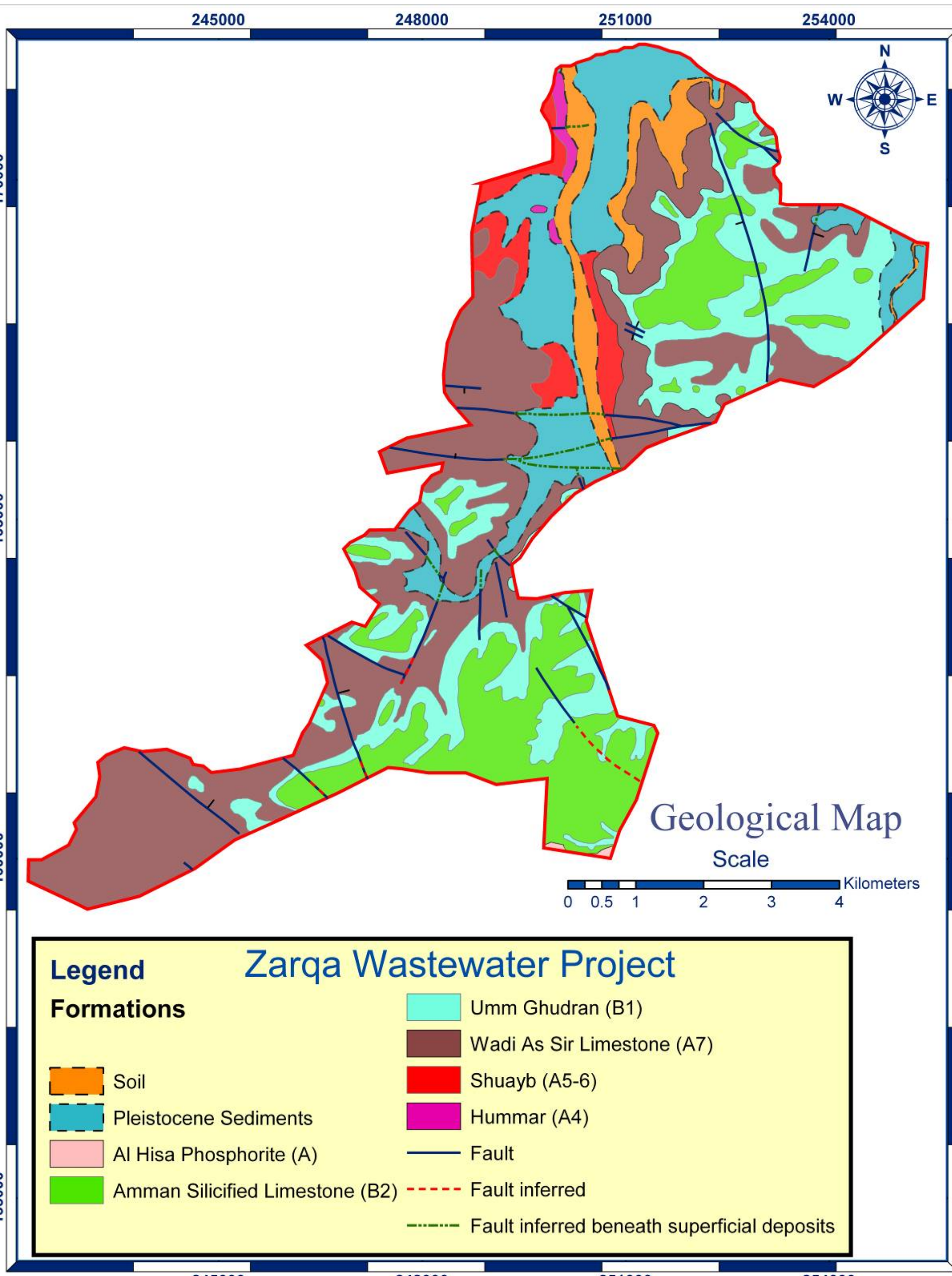

Figure 2.9 Geological Map of the Geotechnical Study Area

Hydro-geology

The Amman-Zarqa Basin is the most important basin in Jordan, because this basin is one of the transitional areas between high lands in the west and desert in the east. The two main aquifers in the Amman-Zarqa basin (the Amman/Wadi Sir formation (B2/A7) and the Hummar (A4) formation) are both exposed in the high rainfall region, where precipitation reaches 400 mm/year, to the west of Amman. In the area, the rainfall does not exceed 150 mm/year. The major aquifer system in the geotechnical study area is (B2/A7), which is known as the Upper Aquifer. These aquifers are well jointed and fissured and on a local scale exhibit solution channels and karstic features. It is believed that the two aquifers are hydraulically connected and in some locations they are separated by an aquiclude (i.e. Ghudran Formation B1), which consists of chalk, marl and marly limestone. The Amman formation (B2), which acts as an aquifer, consists mainly of chert and limestone with phosphate beds. The Wadi Sir Aquifer lies below the Amman Formation and consists mainly of highly-fractured limestone, dolomitic limestone and some chert concretions. Most of the groundwater wells extract water from these aquifers.

Aquifer Systems

According to the potentiality of water bearing, three aquifer systems are available in Amman-Zarqa Basin:

- Upper aquifer system, which includes Basalt and underlying Amman-Wadi As Sir (B2/A7) formation;
- Middle aquifer system, consisting of Hummar (A4) and Naur (A1/2) formations;
- Lower aquifer system (Kurnub Group).

The Amman-Wadi Sir Aquifer System (B2/A7)

The B2/A7 aquifer is the most important aquifer in the geotechnical study area. It has a large and continuous extent, and a relatively high permeability. It receives the highest amount of modern recharge and is considered to be the principal source of fresh water for domestic as well as for irrigated agriculture in the study area. A regional groundwater level map of B2/A7 in Amman-Zarqa Basin is given in Fig. (0.3). Based on the groundwater flow pattern of B2/A7 aquifer, the groundwater flow directions are from south-west of Amman-Zarqa Basin to Wadi Dhuleil and Azraq Basin in central and eastern parts, respectively, and from south-west where recharge occurs into Seil el Zarqa north-west of the study area. In addition, the groundwater is moving from directions through the plateau of basalt into the Yarmouk and Azraq Basins in northwestern and eastern parts of Amman-Zarqa Basin, respectively. The depth to water table varies from 50 m in the southwest (closed to As-Samra wastewater treatm more than 400 m in the north-east and about 100 m at the central parts of the study area. Moreover, the elevation of the water surface varies from more than 750 m the south-west, and more than 675 masl in the south to less than 500 m (towards Yarmouk Basin), east (towards Azraq Basin) and central (towards Seil el Zarqa) of Amman-Zarqa Basin.

Groundwater in B2/A7 is under phreatic conditions over the Amman-Zarqa Basin, which is confirmed by wells drilling, however, in some wells there is indication to confined or semi-confined conditions occurred. The dominant direction of groundwater flow of B2/A7 is from south-west and northeast to the far northwest, east and center (Seil el Zarqa).

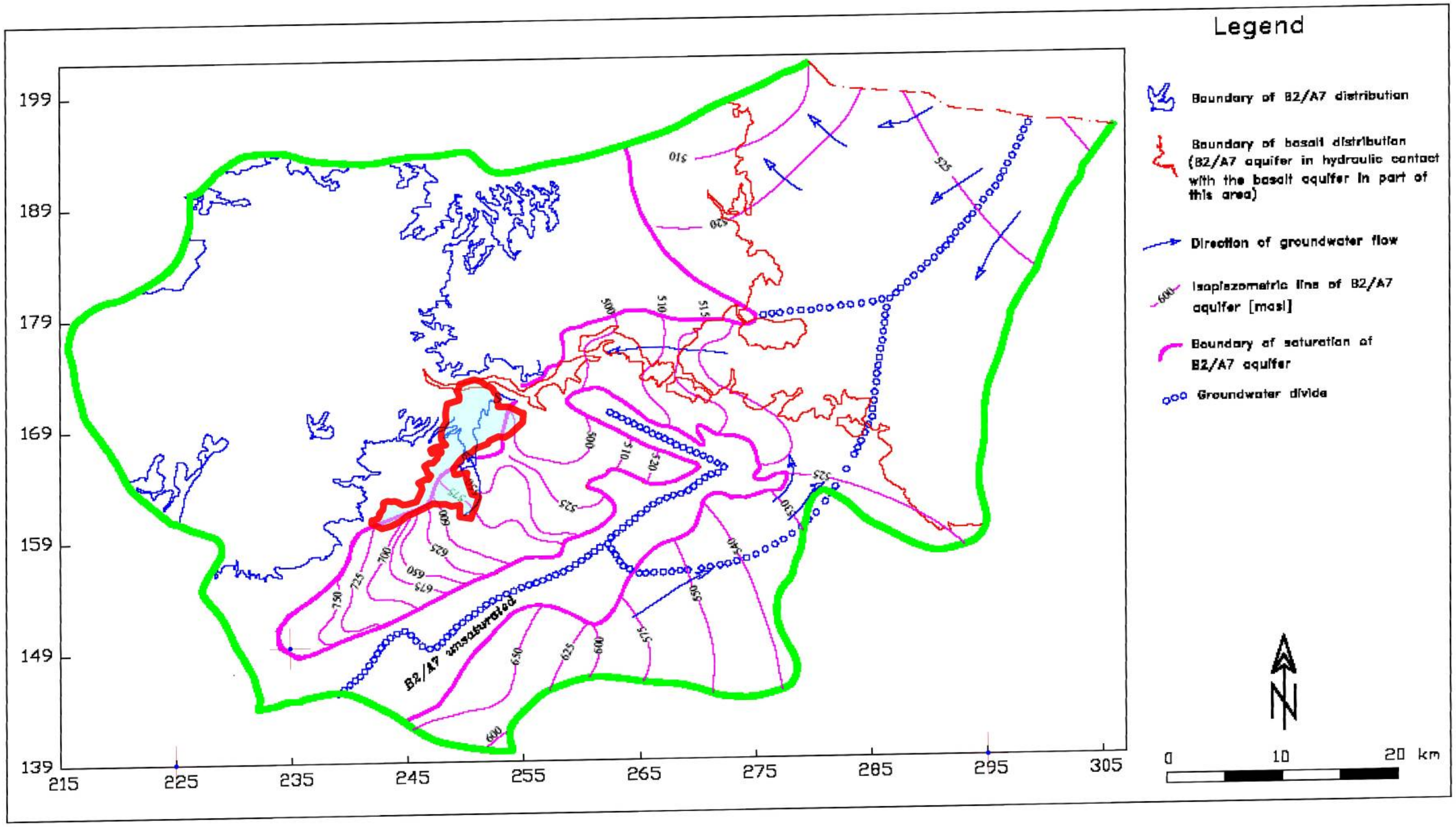

Figure 2.10 Regional Groundwater Contour Map of the Amman – Wadi Sir (B2/A7) Aquifer (BGR and WAJ, 1996)

The local groundwater contour map of the geotechnical study area is constructed based on the available groundwater wells in the vicinity of the geotechnical study area shown in Figure 2.11. The groundwater contour level map in the geotechnical study area is shown in Figure 2.12. The groundwater level varies from approximately 470 m to 690 m above sea level. The groundwater flows in a NE and NW directions, indicating that the groundwater flow is affected by the presence of faults prevailing in the project area. The red arrows in Figure 2.12 show the groundwater flow directions.

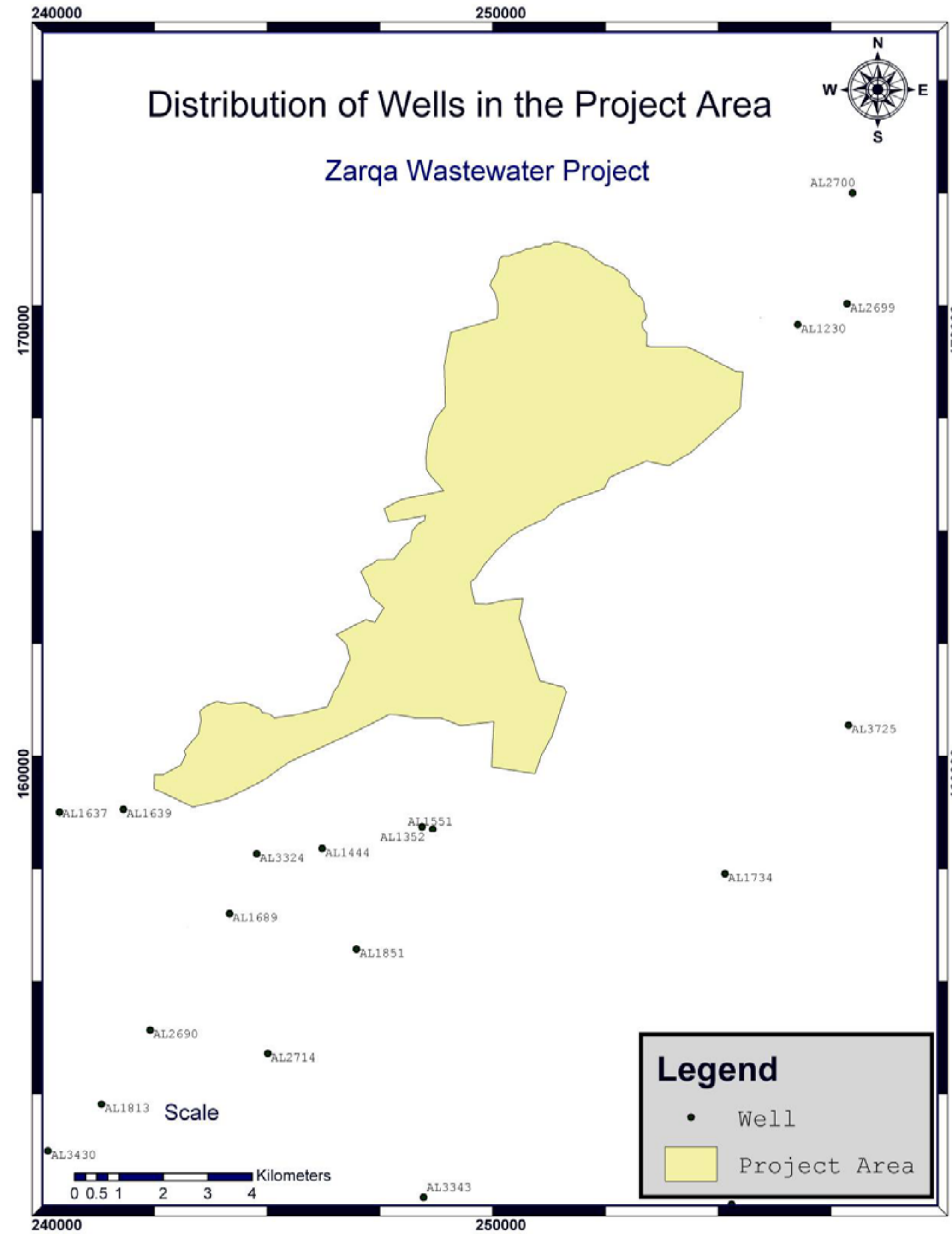

Figure 2.11 Location Map of Groundwater Wells in the Vicinity of the Geotechnical Study Area

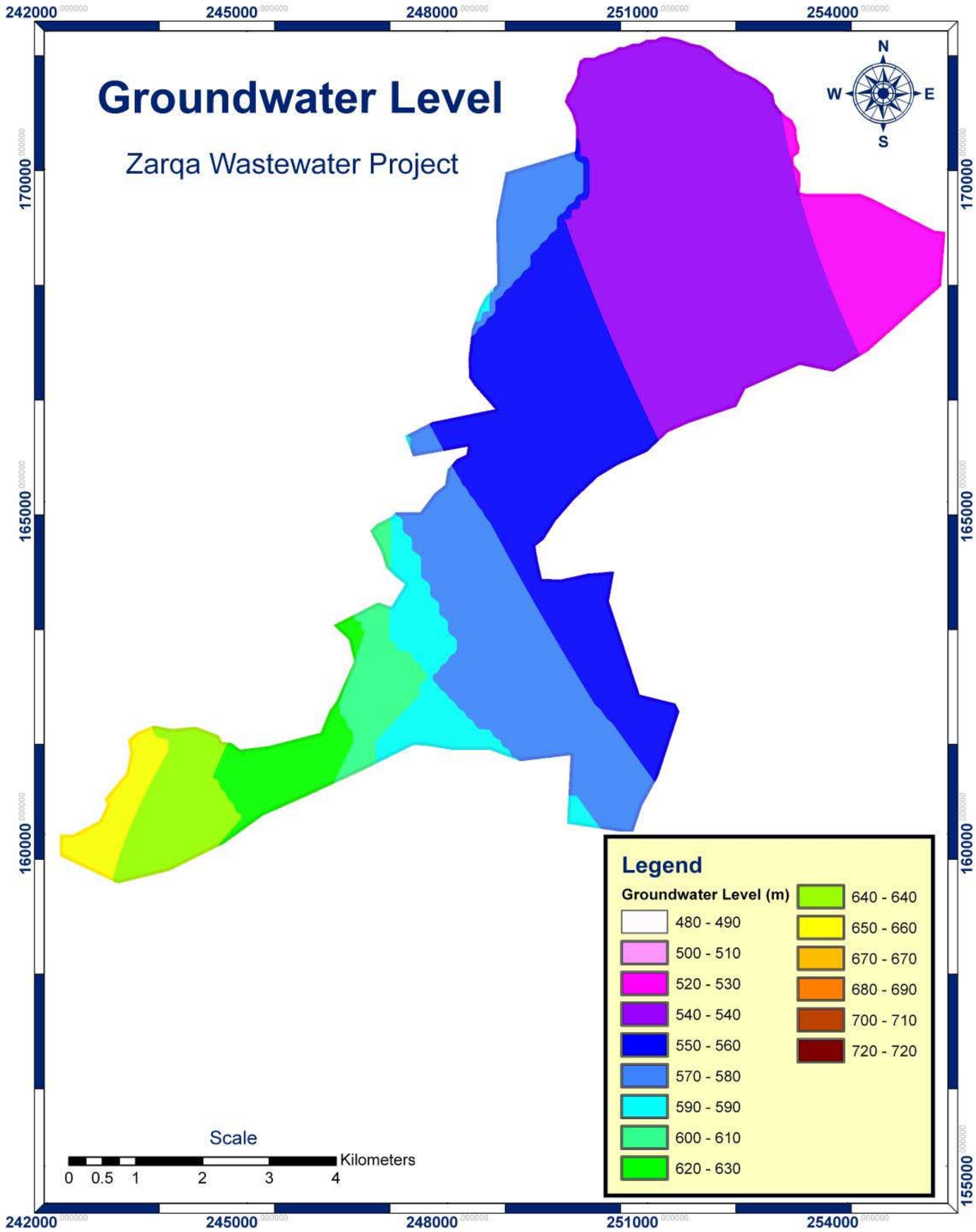

Figure 2.12 Groundwater Contour Map of the B2/A7 Aquifer System in the Geotechnical Study Area (masl)

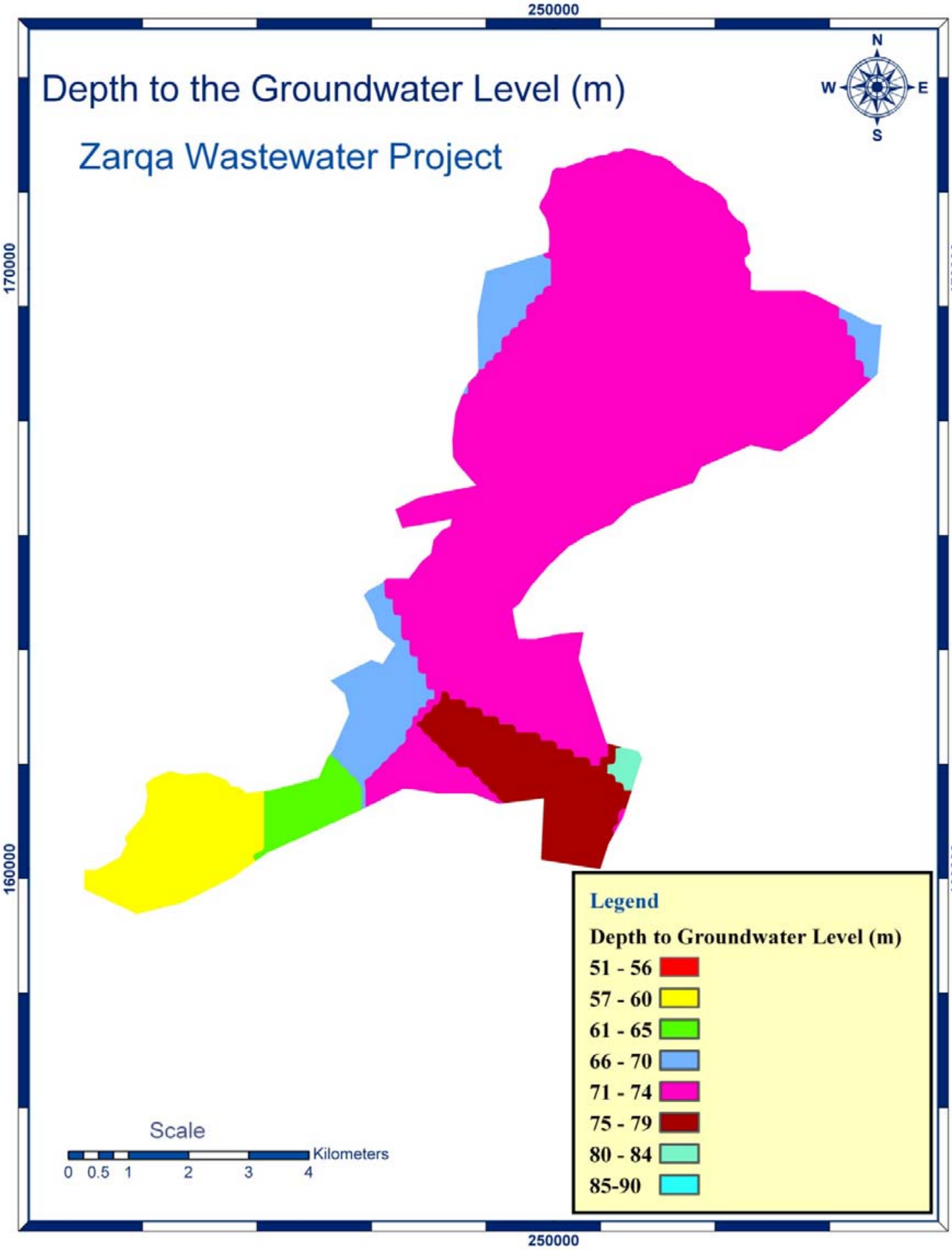

Figure 2.13 Depth of Ground Water From Natural Ground

Most of the springs in vicinity of the project area are emerging from two major aquifers (USAID and WAJ 1989):

- Amman-Wadi As Sir formations and recent alluvium (major springs are: Ras el Ain and Ruseifa); and

- Hummar and Naur aquifers (major springs are: Zarbi, Sukhneh, Fawwar, Suleihi, Maghasil, Nimra, Qunayyah and El Tannour).

The distribution of springs in the vicinity of the geotechnical study area is presented in Figure 2.14. There is one spring within the geotechnical study area (AL0522) which emerges from B2/A7 aquifer. The other springs surrounding the geotechnical study area such as (AL0514, AL0515, AL0517 and AL0518) are emerges from A4 aquifer. The spring discharge has declined over the past 10 years as a result of local or regional overexploitation of the aquifers; a decreased amount of rainfall over the period; and the fact that a portion of the spring discharge has been ‘extracted from upstream wells and used for domestic purposes.

Preliminary Geotechnical Data

Types of Soils

Two main soil association units were recognized in the geotechnical study area. The first soil association unit is the Nisab (NIS) which has an average depth of > 80 cm and composed of silty clay loam and clay loam (very high calcareous and weakly to moderately saline) and on the other hand, it contains very stony silty clay loam (with very high calcareous and weakly saline) with depth less than 50 cm.

The second soil association units is known as Abu Salih (ALI) which characterized by deep (more than 80 cm) silty clay with highly calcareous and non-saline in some parts and very shallow (less than 25 cm) gravely silty clay loam on limestone with highly calcareous and non-saline.

Excavation Method and Slope Cuts

It is expected that most of the excavation will be through the silty clay loam and clay loam. Therefore, conventional excavation equipment such as loaders and bulldozers can be used. Also pneumatic and mechanical equipment such as jack hammers and rock breakers will be required for excavation of the stronger rock materials.

It is recommended to use the following slopes of cuts as summarized in Table 2.3

Table 2.3 Summary of Slopes of Cuts in Soil and Rock Strata

Encountered material type	Cuts height (m)	Slope
Different types of soils	– 3.0m More than 3.0m	1V:2H 1V:1H
Rock strata	– 10.0 10.0 – 20.0m	3V:1H 2V:1H

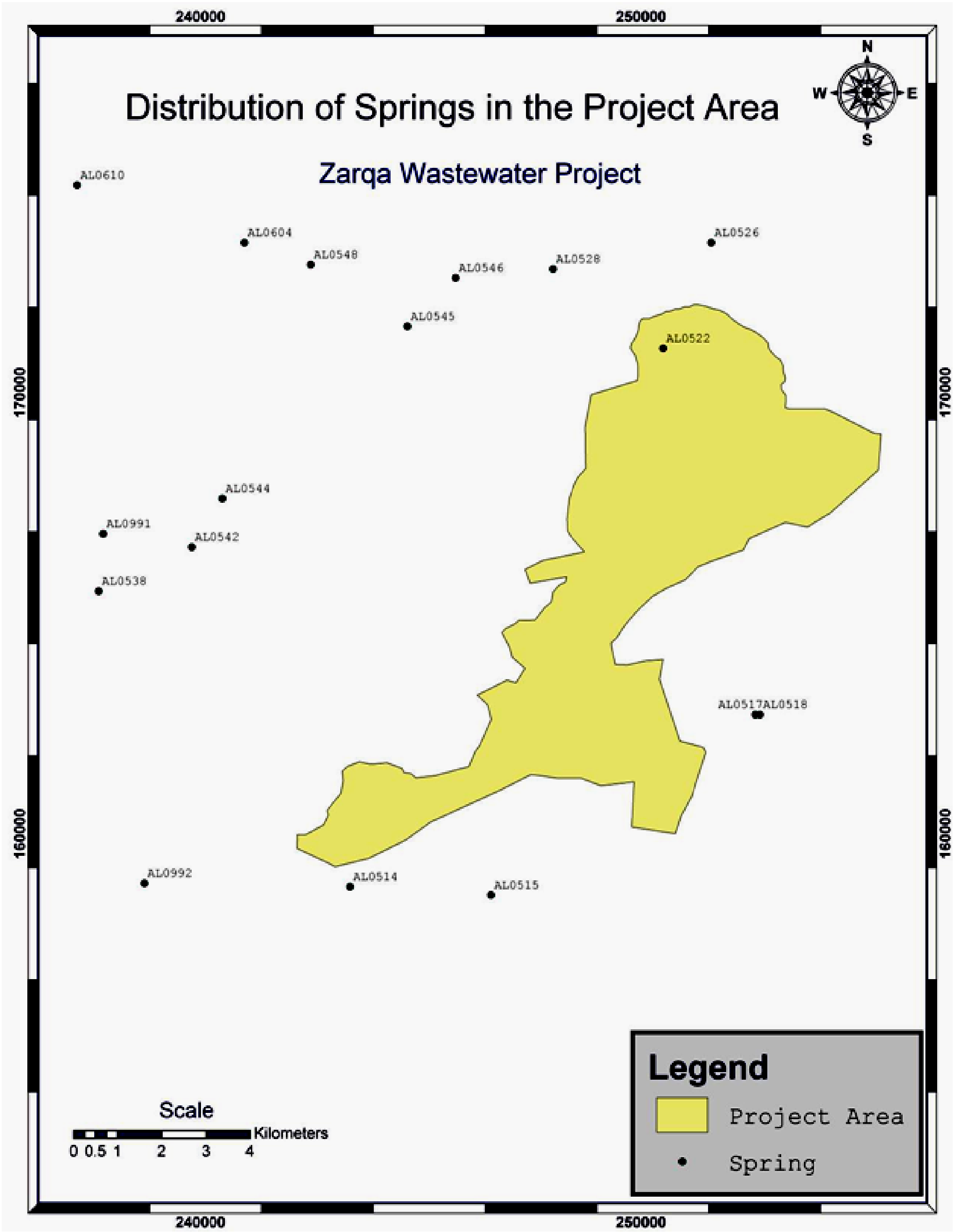

Figure 2.14 Location Map of Springs in the Vicinity of the Geotechnical Study Area

Allowable bearing capacity

The recommended allowable bearing pressure on the foundation ground is summarized in Table 2.4

Table 2.4 Allowable Bearing Capacity for Soil and Rock Material

Type of Material	Allowable bearing capacity (kg/cm^2)
Soil material up to 1.5m depth	1.50
Carbonate Rock strata of 0.5m penetration	> 3.0

Summary and Recommendations

Amman-Zarqa Basin is one of the most important basins in Jordan because this basin is located in the transitional zone between highlands in the west and the desert in the east. The variation in altitude is not only reflected in the climatological changes from wet to dry but also in different land use patterns and also in large changes of habitat

The outcropping formations of the study area are extending from Lower Cretaceous (except wadi fill deposits) to recent age. Kurnub and Zarqa groups are exposed in the south-western (Baq'a Valley) and western parts (surrounding Jarash area) of the study area, respectively. Basalt outcrops in the eastern and northeastern parts of the study area. Belqa and Ajloun groups outcrop in other parts of the study area. The geological formations outcropping in the geotechnical study area mainly consist of Ajlun group (A4, A5/6 and A7) and Balqa Group (B1 and B2). Soil cover is generally thin, although local topography has led to accumulation of wind-blow soils in numerous places. The main geological structures dominating in the study area: Amman Syncline; Zarqa-Fault and Ramtha-Wadi Sirhan Fault.

The preliminary geotechnical data of soil and rock materials in the geotechnical study area which could be considered for a preliminary design criteria are summarized in Table 2.3. The allowable bearing capacity of soil up to 1.5 m depth is estimated to be 1.50 kg/cm^2 and for rock strata of 0.5 m penetration is 3.0 kg/cm^2 respectively.

It is highly recommended to carry out the following:

1. Detailed mapping of geological rock formations and geological structures prevailing in the study area;
2. Drilling of boreholes of a depth of 5 to 8 m;
3. Test pits for a depth not less than 3.0 m with the soil or until reaching the bedrock;
4. Conducting laboratory testing on representative soil samples collected from boreholes and test pits; and
5. Conduction Electrical Imaging Resistivity Tomography (ERT) lines to detect any cavities or subsurface structures affecting the sewer system pipelines.

2.4 Wastewater System

2.4.1 Wastewater Collection System

The existing collection system in the study area serve most of the built up areas in Zarqa, Russeifa and al-Hashemiyah consisting of main sewer trunk lines (generally 300 to 1000 mm in diameter) and a network of 200 mm diameter collector sewers. The collection system is split into two systems draining to West Zarqa and East Zarqa pumping stations. The following is brief description of the two collection systems:

1. Russeifa – West Zarqa Sewer System: The areas served by this system include Russeifa and west Zarqa. Flows from northeast Amman areas of Tariq, Marka and parts of Shafa Badran, Jubaiha and Nasser are also tributaries to the Russeifa/West Zarqa sewer system. This system forms about 70% of the collection systems of the study area. Flow collected by the Russeifa/West Zarqa system drains to the West Zarqa Pumping Station from where it is pumped to As Samra WwTP. Trunk sewers in the Russeifa/West Zarqa system are predominantly 300 to 1000 mm diameter.

2. East Zarqa – al-Hashemiyah Sewer System: This system serves developed areas in East Zarqa and al-Hashemiyah, resulting in a sub-system that accounts for about 30% of the collection system in the study area. Flows collected from the area are conveyed by gravity to the al-Hashemiyah Pumping Station and pumped to As Samra WwTP. Trunk sewers in the sub-system are predominantly 300 to 800 mm diameter.

The total length of the main trunk sewers with diameters equal to or above 300 mm is about 128 km. The secondary collection system is a dense network of 200 mm diameter sewers covering most of the populated areas of Zarqa, Russeifa and al-Hashemiyah with a total length of about 789 km. Most of the sewers are made of concrete, and a few are made of ductile iron and vitrified clay.

Investigations have shown that:

- Most of the low gradient sewers are blocked by sand, silt and grease; and
- Several segments of the collection system are overloaded during rain events, causing backup into streets, wadis, and in some rare cases into residences.

The last records obtained from WAJ show that the total number of subscribers for water services in 2009 is 130,948, while the number of subscribers for wastewater services is 94,265, which indicates that approximately 72% of households with water connections are sewered.

Although stormwater inflow is recognized as a significant source of excess flow into the collection system during rainfall events, the relative infrequency of significant rainfall events does not justify major upsizing of the system to accommodate storm flows. Rather, it is assumed that WAJ will continue efforts to promote compliance with current stormwater regulations that require that roof and area drains not be connected to the wastewater system.

In 2008, WAJ started a programme for cleaning the sewers using specialized bucket cleaning machines. About 23.1 km of sewers were cleaned by WAJ operators during the last two years and the cleaning of another 13.3 km was contracted to a local contractor. The lengths and diameters of the cleaned sewers are shown in Table 2.5. Results of the sewer cleaning operations are very promising as sewers blocked to more than half full have been fully cleared of the sediments. It is thought that such cleaning operations should be continued, as they will increase the expected life of the sewers considerably, and will eliminate the need for upgrading or replacement of many of the sewers.

Table 2.5 Length of Sewers Cleaned During 2008-2009 (m)

Diameter (mm)	Cleaned by WAJ	Cleaned by Contractor
200	17,756	11,507
300	3,873	1,202
400	175	626
500	620	-
800	700	-
Total	**23,124**	**13,335**

The basic layout of the sewer system, obtained from the GTZ/OMS team, was updated by the Team by comparing the GIS maps with the record drawings and through site visits and meetings with Zarqa wastewater operators. Sewer networks for areas such as Hai Ja'far al-Tayyar, Abu Ghalyoon in Russeifa and scattered sewers in al-Hashemiyah and Hai al-Batrawi in Zarqa were added to the OMS maps from the record drawings, and layouts of the main sewer systems in Hai al-Jundi and Hai al-Ameer Ali in Russeifa were added to the maps by field verifications.

The extent of the existing wastewater collection networks is shown in Figure 2.15 and the lengths of the sewers are summarized in Table 2.6.

Table 2.6 Summary of Lengths of Existing Gravity Sewers *

Sewer Diameter (mm)	West Zarqa System	East Zarqa System	Total
200	570,101	219,310	789,411
300	43,944	11,210	55,154
400	8,381	7,287	15,668
500	7,351	12,443	19,794
700	1,422	6,975	8,397
800	20,167	6,996	27,163
1000	2,366		2,366
Total	653,732	264,221	917,953

The sewer networks are operated and maintained by WAJ Zarqa Directorate through two wastewater operation offices: one for the Zarqa and al-Hashemiyah networks and one for the Russeifa networks. The operation and maintenance activities are largely confined to clearing blocked manholes and sewers.

The operation and maintenance activities of the Zarqa and al-Hashemiyah collection networks are carried by a total workforce of 38 staff. This labour force are supported by 6 jet trucks, 1 rodding machine, 1 backhoe excavator, 1 compressor, 1 two-ton dump trucks, 2 portable pumps (which are not operational), 4 pick ups in addition to a bucket machine sewer cleaning.

The operation and maintenance activities of the Russeifa collection networks are carried by a total workforce of 27 staff. This labour force are supported by 6 jet trucks, of which only two are operational and the other four are in bad condition and 3 pickups in addition to various hand tools.

2.4.2 Wastewater Pumping Stations and Pumping Mains

Zarqa sewerage system includes two main pump stations; WZPS and EZPS that deliver wastewater to As Samra WwTP and a small lifting station, Hitteen Camp Pumping Station (HCPS) that serves a small section of the camp and delivers to the Russeifa collection network. WZPS and EZPS are currently operated and maintained by the Samra Plant Operation & Maintenance Co. Ltd., and Hitteen Camp pumping station is operated by WAJ / Russeifa operations department.

West Zarqa Pumping Station

Wastewater collected from Russeifa, west Zarqa and the northern parts of Amman that drain downstream of AGTP is directed to WZPS, which delivers to As Samra WwTP through a 1200 mm pumping main. The 1200 mm pumping main is the downstream end of the siphon that originally was the main wastewater conveyor (siphon) pipeline from AGTP to As Samra treatment plant. After the commissioning of the 1500 mm AGTP - As Samra conveyor, the 1200 mm pipeline is now utilized by WZPS although the siphon is considered as an emergency conveyor for AGTP – As Samra WwTP. In the past when the 1200 mm siphon was used by AGTP, WZPS was operating at a discharge pressure gauge of approximately 110 meters.

According to the pump station daily and hourly logs, the average daily and hourly flows during 2009 were about 52,700 m^3/d, and 2220 m^3/hr respectively.

The pumping station was commissioned in 1985 and was refurbished in 2009 by installation of new pumps and associated electrical works. The firm capacity of the refurbished pumping station is 72,000 m^3/d operating at 65 m head.

The pumping station consists of:

1. Inlet Structure:
   i. 1000 mm diameter inlet pipe
   ii. 2 No. manual coarse screens of 50 mm bar spacing installed 80 cm wide channel,
   iii. 2 No. mechanical fine screens of 12 mm bar spacing installed in 120 cm wide channel
   iv. Emergency overflow facility
   v. Venturi chamber, with ultrasonic flow meter (up to 4,727 m^3/hr)
2. Grit Removal System:
   i. 2 No. aerated grit removal channels
   ii. Blowers
   iii. Classifier
   iv. Mixer

3. Sewage grinder/macerator is installed as an additional pumps protection measure.
4. Wet Wells: Three open top wet wells with 256 m^3 capacity;
5. Pumps: Four centrifugal variable speed pumps each with 1000 m^3/hr flow and 120 m head, each equipped with 500 kW Siemens motor;
6. One discharge flow meter;
7. 10,000 m^3 capacity emergency pond; and
8. 1500 kW emergency power generator.

The emergency pond often acts as additional wet well as the pumping capacity during peak flow hours is insufficient to pump the incoming flows. Thus, creating operation difficulties and odour nuisance.

East Zarqa Pumping Station

Wastewater collected from East Zarqa and al-Hashemiyah is collected at the EZPS, which discharges to As Samra WwTP through one of two 500 mm diameter, 7.2 km long force mains under a pressure head of approximately 74 meters. The pump station includes five pumps (4 duty + 1 standby) each rated to pump a flow of 420 m^3/hr at 88 meters head. However currently at normal operating conditions only one or two pumps are operated. According to the pump station daily and hourly logs, the average daily and hourly flows during 2009 were about 12,000 m^3/d, and 860 m^3/hr respectively. It is noted that the pumping station is not working at full load.

The pumping station was commissioned in 1988 and was refurbished in 2006 by installation new screen and an additional 500 mm diameter pumping main. The firm capacity of the pumping station is 40,320 m^3/d operating at 82 m head.

The pumping station consists of:

1. Inlet Structure:
   i. 800 mm and 700 mm diameter inlet pipes
   ii. 2 No. manual coarse screens
   iii. 1 No. mechanical fine screen
2. Wet Wells: Two open top wet wells with 240 m3 capacity;
3. Pumps: Five centrifugal pumps (KSB); each with 420 m^3/hr flow at design head of 88 m each, with 315 kW motor;
4. Outlet force main: 600 mm pipe branching into two 500 mm diameter force mains;
5. 1200 kW generator: (Mitsubishi).

Hitteen Camp Pumping Station

Wastewater collected from the lower elevations in Hitteen Camp and nearby areas is collected and lifted by the pump station to the nearby sewage collection system. The pump station is in a bad operational condition mainly attributed to inefficient screen, where it is not holding the relatively high quantities of screenings specially rugs that are clogging the pumps. Also, the station is lacking general equipment maintenance. There is a lack of records about the pump station details to give accurate information. The following are the general details of the pump station:

1. Pumping building including:
   - Inlet chamber with a screening basket
   - Wet well with three submersible pumps of 100 mm outlet but with unknown capacity
   - lifting crane;
   - None operational flow measurement device;
2. Guard room
3. Generator and transformer rooms

3. REVIEW AND COMMENTS ON PREVIOUS STUDIES

3.1 Introduction

The following main studies and reports were reviewed:

- The wastewater Master Plan, Feasibility Study and Preliminary Engineering Design for the Rehabilitation, Expansion and Development of the Wastewater Systems of the Municipalities and Communities within the Watershed of the Amman-Zarqa River Basin, by Harza, 1997;
- The Technical and Economic Review and Update Study of the Wastewater Studies Prepared for the Greater Amman Area, by MWH, 2006;
- The National Water Master Plan, by the Ministry of Water and Irrigation, the Hashemite Kingdom of Jordan and the German Technical Cooperation (GTZ), 2005;
- The Feasibility Study and Design of the Wastewater Collection, Treatment and Effluent Reuse for the West Jerash and al-Sukhneh Area, by C. Lotti & Associati and Engicon, 2004;
- Design of Sewer Networks in Zarqa (Fallah, Ma'asoum, Princess Haya areas), 2007and
- Conceptual Design Report for the Construction of a Closed Wastewater Canal of Wadi Zarqa, by CEC, 2009.

3.2 Summary of Previous Studies

Wastewater Master Plan, 1997

The study was prepared by Harza, with the primary objective of planning for adequate treatment facilities and collection and conveyance systems for the population of the Amman-Zarqa Basin through the year 2025.

The population projections in this study were based on the 1994 census. For the study area, the future population growth rates were estimated to decline from 4.4% per annum in 1995 to 3.7% per annum by the year 2025.

For Zarqa Governorate, "adjusted consumption" (water supplied minus physical leakage in transmission and distribution) was estimated at 85 and 116 l/c/d in 1994 and 2025 respectively. Wastewater flows were taken to be about 87% of adjusted consumption, estimated from measurements at AGTP and the pumping stations at West Zarqa and al-Hashemiyah.

The 1997 Master Plan recommended that flow from areas tributary to the Zarqa pump stations and al-Sukhneh should be conveyed by gravity to a new treatment facility along Wadi Zarqa. As part of this strategy, the 1997 Master Plan recommended implementation of the conveyance and treatment systems in two phases.

The conveyance will include mainly the construction of approximately 31 km of a new gravity sewer conveyance pipeline to accommodate peak sewer flow through the year 2025 from areas downstream of the existing AGTP to the new Wadi Zarqa WWTP. This pipeline plus the new Wadi Zarqa WWTP will eliminate the need for the existing West Zarqa and al-Hashemiyah (East Zarqa) Pumping Stations.

Preliminary treatment processes have been proposed at Sukhneh that will include coarse screening, manually and mechanically cleaned bar screens and aerated grit removal.

Wastewater Master Plan Update, 2006

In this revised master plan, the population projections were based on both the 1994 and 2004 census data. Therefore, the revised growth rates were estimated to decline from 2.6% in 2004 to 2.3% in 2025 for the whole Amman-Zarqa area.

The water consumption rates for Amman-Zarqa area were projected at 118 and 125 l/c/d in 2010 and 2025 respectively. The wastewater flow generation rate was kept at 87%, the same value used by the 1997 master plan.

The revised Amman-Zarqa Wastewater Master Plan has identified the following five alternatives when considering options for conveying the flows to treatment locations:

1. A new treatment facility along Wadi Zarqa to treat flows from Zarqa area (as proposed in the 1997 Master Plan);
2. A new treatment facility adjacent to the new As Samra Plant to treat flows from the Zarqa area, with a pre-treatment facility/pumping station at Sukhneh;
3. A new treatment facility adjacent to the new As Samra Plant to treat flows from Zarqa area, with existing pumping stations online;
4. Expansion of the new As Samra Plant, with a pre-treatment facility/pumping station at Sukhneh to treat projected flows from the entire study area; and
5. Expansion of the new As Samra Plant to treat projected flows from the entire study area, with existing pumping stations online.

Using the derived scoring mechanism, the Updated Master Plan considered Alternative 1 as the most preferred alternative.

National Water Master Plan, 2004

Population growth is considered the major parameter influencing future water demand development in this report. Although Jordan is striving to reduce population growth, it is likely to remain high. Up to the year 2020, Jordan's population is expected to grow between 7 and 9 million.

The National Water Master Plan has expected that the municipal per capita demands will rise significantly owing to increasing income and changes in the way of life. Higher per capita demands are particularly expected in the urban development areas of Greater Amman, Irbid and Aqaba, whereas per capita demands in other areas are expected to remain at a lower level.

Of interest is the water allocation in Urban Amman and Zarqa, where it is expected to rise from 136 to 150 l/c/d and from 108 to 132 l/c/d between 2005 and 2020 for Amman and Zarqa respectively.

West Jerash and Sukhneh Feasibility Study, 2004

The study has considered population projections for Sukhneh to the design horizon year 2015, based on 1994 census data. The growth rate for Sukhneh town was taken to decline from 2.6% in 2005 to 2.3% in 2015, while the growth rate for Sukhneh Camp was taken to be constant at 3.3% up to 2015.

The water consumption for Sukhneh town was projected to rise from 93 l/c/d in 2002 to about 141 l/c/d in 2015, while the water consumption of the camp was considered constant at 80 l/c/d. The wastewater generation percentage was assumed at 85% of the water consumption.

This study is concerned with the design of a new wastewater collection network in the al-Sukhneh area, which falls in the catchment area of Seil Al-Zarqa. The refugee camp has been designed separately by the Community Infrastructure Program. The study is also concerned with the design of a new pumping station that carries the flow generated from al-Sukhneh and its refugee camp to the existing West Zarqa Pumping Station through a 350 mm diameter, 6.5 km long force main.

The proposed Sukhneh pumping station was designed for the 2015 flows, considering a peaking factor of 3.09. This results in a total flow of 234.7 m^3/hr.

Design of Sewer Networks in Zarqa, 2007

The study area comprises of the following areas in Zarqa:

1. Princess Haya Housing Area;
2. Part of Hay al-Jabr;
3. Hay al-Hamad; and
4. Hay al-Madina al-Monawara.

The population of the selected areas is estimated by defining the number of inhabited plots with an assumption that each inhabited plot within residential areas in Zarqa consists of one building with an average of three floors, two apartments on each floor and six inhabitants per apartment. Forecasting up to the year 2032 is done using an annual growth rate of 2.5%.

Water consumption in Zarqa Governorate, as derived from the Water Administration in the year 2003 is 110 l/c/d and the recent data for the year 2006 is 122 l/c/d. According to that, the study estimated a consumption of 124 l/c/d in the year 2007 increasing up to 140 l/c/d in the year 2032. Wastewater flow is assumed to be 80% of the forecasted consumption.

Closed Canal Conceptual Design Report, 2009

The proposed closed canal will be tributary by gravity and collect all wastewater flows from the Amman-Zarqa basin, including the summer base flow. The proposed canal has been divided into two parts:

1. The first part will collect flows from most of Amman and discharge them at Ain Ghazal pre-treatment plant to the existing 1500 mm pipeline to As Samra WwTP;
2. The second part, which is relevant to our study, will start from Ain Ghazal pre-treatment plant along Seil al-Zarqa to the proposed Wadi Zarqa Treatment Plant. This part will collect all flows that currently go through West Zarqa Pumping Station (generated from Amman areas downstream of Ain Ghazal pre-treatment plant), as well as Russeifa and West Zarqa.

The overall objective of the project is to prevent pollution of surface and groundwater, through the construction of a new wastewater closed canal with enough capacity until the year 2060.

For the population projections, a model prepared by the Department of Statistics for the study area has been used. From the derived projected population growth it can be noted that one growth rate of 2.43% up to the year 2025 was used for both Amman and Zarqa areas.

However, two different growth rates of 1.6% and 2.1% up to the year 2060 were used for Amman and Zarqa, respectively.

3.3 Comments on Previous Studies

Wastewater Master Plan, 1997

The population growth rates used by the 1997 master plan for the Amman-Zarqa Basin were relatively high (4.4% and 3.7% for the years 1995 and 2025), compared to the actual growth rates of 2.1% and 1.9% for Amman and Zarqa respectively in the inter-censal period 1994 and 2004.

The water consumption rate of 116 l/c/d for 2025 used in the study is much lower than the rate suggested by the National Water Master Plan (150 l/c/d for Amman and 132 l/c/d for Zarqa in 2020).

The study considered only the populated areas within the study area, and therefore planning, analysis, and preliminary engineering design were made without considering any possible future development areas such as those that happened in west Zarqa and is now happening in east Zarqa.

The study recommended implementation of its study actions regarding sewer networks, conveyance system, and treatment facilities to meet the needs by growth of population as foreseen by the study. The study suggested to implement its recommendations into two phases; phase 1 up to 2015 and phase 2 up to the end of the study period in 2025.

The 1997 Master Plan recommended the construction of a new Wadi Zarqa Wastewater Treatment Plant to eliminate the need for pumping facilities in Zarqa.

In general, the recommended implementation programmes of the study concerning the population of Zarqa were not materialised until now. However, an update of the study was conducted in 2006.

Wastewater Master Plan Update, 2006

Although the revised master plan has updated the estimated population growth rates based on the actual rates between 1994 and 2004 census data, it still used one combined rate of 2.3% for both Amman and Zarqa population projections until 2025. This contradicts actual growth rates for Zarqa, which was lower than that of Amman rates.

The water consumption rate proposed by the revised master plan is still lower than the rate suggested by the National Water Master Plan (125 l/c/d in 2025 compared to 150 l/c/d in 2020).

The revised master plan considered the same populated areas as proposed by the original 1997 master without considering the new development areas in east and west of Zarqa. As a result, population and flow projections of the report need to revised to take account of the new available information regarding the growth rates and development plans.

The revised master plan supported the original 1997 master plan with the proposal to construct a new wastewater treatment plant in Wadi Zarqa, after evaluating several alternatives. The proposed Wadi Zarqa Treatment Plant of 145,000 m^3/d capacity using activated sludge with nitrification/denitrification process is to be located along Wadi Zarqa to treat flows from the Zarqa area by year 2016.

The study also proposed that West Zarqa Pump Station and East Zarqa Pump Station to continue to operate until 2016. By 2016, with the proposed Wadi Zarqa WWTP online, these pump stations along with their force mains will be decommissioned.

The existing 1200mm siphon will be designated exclusively as the standby conveyor from AGTP to As Samra after 2016 or when WZPS is decommissioned.

Although the study has proposed to decommission the West Zarqa Pump Station but it proposed that the new pump station at Sukhneh, being planned as part of the Irbid-Jerash Treatment Contract, will be online to collect flows from the Sukhneh area and convey it to the WZPS. Which could be understood that this will be done until 2016 only.

West Jerash and Sukhneh Feasibility Study, 2004

We believe the project design period (through the year 2015) is too short. Additionally, the design of al-Sukhneh pumping station took into consideration al-Sukhneh town and the camp within the town, without considering any future connections from populated areas that drain towards the same site. Our study of the boundaries of the Zarqa catchments shows that al-Sukhneh pumping station can cover several additional populated neighbourhoods in Zarqa and along Wadi Zarqa, such as Hai al-Bustan, Hai al-Jabr, Hai Nassar, Hai al-Ahmad, Hai Makka al-Mukarramah and Abu Zeighan.

The location and sizing of the pumping station and sewers will need to be reviewed to bring the design horizon in line with the current study and also to enable the pumping station to serve all the communities that could drain into it.

Design of Sewer Networks in Zarqa, 2007

The design of this project includes the design of a gravity trunk sewer to collect the flow generated from the concerned neighbourhoods towards al-Sukhneh pumping station. This trunk sewer line has been designed without giving consideration to any future connections from areas within its catchment.

Also, the flows from the service areas are drained to the proposed Sukhneh pumping station under the West Jerash and Sukhneh Feasibility Study. without studying the capacity of the pumping station. As mentioned before, the design of the proposed al-Sukhneh pumping station should be reviewed to cope with these flows or with other future flows in the catchment area.

Closed Canal Conceptual Design Report, 2009

This study assumed an overall constant population growth rate for Zarqa at 2.2% until year 2060, which the MWH Team believes to be high when compared with the historical growth rate for the governorate.

Relevant to our study is the second part of the proposed canal, which will collect all generated wastewater from contributing catchment areas of West Zarqa WWPS (WZPS), in addition to al-Sukhneh catchment area (with a design horizon through the year 2060). The implementation of this canal will eliminate the need for the West and East Zarqa pumping stations and the need for many of the existing or proposed sewer trunks along Wadi Zarqa.

4. PLANNING CONSIDERATIONS AND PROJECTIONS

4.1 Introduction

The establishment of basic planning criteria and the subsequent projection of wastewater services requirements using these criteria are crucial to the formation of a proper Wastewater Development Plan for Zarqa. The following criteria and projections have been established and will be used by the Project Team in its formation of the Master Plan.

For the most part, the criteria and projections summarised herein are based on the experiences of WAJ and on the past studies conducted within the planning area supplemented with additional data and information collected by the Team under this current study.

4.2 Planning Criteria

The planning and design criteria defined and reported herein include:

- General planning criteria:
    - Planning period;
    - Geographical service area;
    - Population projections
    - Level of service to be provided;
    - Income levels and its spatial distribution;
    - Planned economic and industrial activities; and
- Water consumption:
- Wastewater systems:
    - Wastewater generation factors;
    - Wastewater flow quantities

4.2.1 General Criteria

The following general planning criteria covers the key basic planning considerations.

4.2.2 Planning Period

The planning period for this project was established to be the period through year 2035. Therefore, key planning parameters, such as population, water consumption and wastewater production projections, have been defined in five-year increments, with the first being 2010.

4.2.3 Service Area

In accordance with the Terms of Reference all villages and towns in the Governorate of Zarqa shall be included in the study.

After discussions with WAJ it was understood that a feasibility study and final design and preparation of bidding documents project for the wastewater collection, treatment and reuse for Azraq, in the eastern parts of the governorate, is currently underway. Therefore this area will be excluded from this Study.

The proposed area, shown in Figure 4.1 consists of the existing wastewater service area plus approximately 3,222 hectares within the current municipality boundaries encircling the existing service from west and north directions in addition to the proposed development areas in the King Abdullah Bin Abdul Aziz City and al-Majd City and the towns and villages in Birein, al-Hashemiyah and al-Dhuleil districts. This area has been developed in conjunction with WAJ and is also consistent with the planning boundaries of the municipalities of Zarqa, Russeifa and al-Hashemiyah.

4.2.4 Level of Service – Sewer Coverage

The initial focus of the reinforcement and expansion program will be on bringing sewers to areas that are currently only served by water and to areas that have inadequate wastewater collection systems. These areas will be given high priority under the evaluation of areas to be included in the MCC funded Investment Program. As future areas develop, the plan will be formulated on the basis that both water and sewerage services will be provided to each new development at the same time.

All of Zarqa Governorate communities, except for the Azraq district, have been studied for coverage by the proposed collection networks. However, sewers will be provided for areas and towns with paved roads.

The currently unserved communities and new expansion areas within Zarqa, Russeifa, and al-Hashemiyah municipalities will be served by the existing Zarqa systems (WZPS System and EZPS System). The Zarqa Free Zone, al-Hashemiyah University, and the new King Abdullah Bin Abdul Aziz City will be served through the EZPS System, while the new al-Majd City will be served through the WZPS system.

The new service areas within the catchments of the existing networks consist mainly of the newly developed neighbourhoods of Zarqa and Russeifa west of the Zarqa River and some parts of Hai al-Batrawi in north Zarqa.

A new pumping station is proposed at Sukhneh to convey the flows from areas that drain downstream of WZPS. This catchment zones includes the western neighbourhoods of Zarqa such as Hai al-Bustan; Hai Shomar; Hai al-Hashemi; Hai al-Jneineh; Hai al-Ameera Haya; Hai Nassar; Hai al-Jabr; Hai al-Ahmad; Hai Makka al-Mukarramah; and part of Hai al-Madinah al-Munawwarah. Also, the Sukhneh PS Zone system covers the communities north of Zarqa such as Sukhneh; Salheyah; Abu al-Zeighan; Ghareisa; and Umm Suleih.

Flows from eastern parts of al-Hashemiyah district could be collected at the proposed Sukhneh pumping station, which lies at the confluence of Zarqa River and Wadi Dhuleil.

Most areas of Birein district drain to Zarqa River downstream of Sukhneh. Therefore a separate system will be required to collect the flows from these areas at pumping stations in Wadi Zarqa to deliver their flows to the proposed Sukhneh pumping station. This system will be serving the towns and villages of Birein, Umm Rummaneh, Maqam Eissa, al-Alouk, Sarrout, etc.

The town of al-Dhuleil and nearby villages drain to Wadi Dhuleil which passes near As Samra WwTP. This system could also in future serve more communities within Zarqa Governorate such as Hallabat communities and outside Zarqa Governorate such as Khalediyah and Khirbet al-Samra communities in Mafraq Governorate.

Other remaining scattered communities with less than 1,000 population that could not be served by gravity neither by the existing systems nor by the above proposed new systems due to their remote distances from the networks such as Kamshah, Umm al-Makman, Rujm al-Shoak, Tafeh, Hallabat, Dhaythem, etc. will remain on private on-site disposal systems using cesspools or septic tanks.

4.3 Population

The results of the 2004 Census revealed that the resident population of Zarqa Governorate for that year was approximately 799,000, about 15% of the national population. This indicated a growth rate for the governorate of 2.2% per annum between the 1994 and 2004 inter-censal period. The national and Amman Governorate growth rates were 2.6% and 2.8% respectively for the same period. It is considered that migration to Amman skews the population growth rates below the average for Amman Governorate.

4.3.1 Projections

The population projections are based on the Department of Statistics (DOS) projections and the planning considerations of the major urban development areas. The DOS projected population of the Zarqa Governorate is presented in Table 4.1.

Table 4.1 Department of Statistics Zarqa Governorate Projected Population

Year	Population	Growth rate
2004	799,000	
2010	921,451	2.40%
2015	1,033,404	2.32%
2020	1,133,368	1.86%
2025	1,231,580	1.68%
2030	1,329,048	1.53%
2035	1,426,229	1.42%

Source: Department of Statistics

In discussions with DOS officials it was understood that the above projections do not consider the effects of the two major urban development projects of King Abdullah Bin Abdul Aziz City and al-Majd City in east Zarqa. The planned population of these two areas at year 2035, as collected from the developers, are shown in Table 4.2.

Table 4.2 Populations Projections of Major Development Areas

Year	King Abdullah Bin Abdul Aziz City	Al-Majd City	Total
2010		-	-
2015	50,000	31,800	81,800
2020	135,000	42,400	177,400
2025	230,000	42,400	272,400
2030	340,000	42,400	382,400
2035	450,400	42,400	492,800

It can be seen from the above two tables that the expected population of the two development areas at year 2035 will be about 35 percent of the total projected population of Zarqa Governorate and that these two areas could contain almost all the natural population increase of Zarqa Governorate until year 2035.

There is currently no information available at DOS or other governmental departments nor the developers about the nature of the future inhabitants of the two development areas and whether they would entirely be from Zarqa Governorate or will be incomers from other parts of Jordan.

Therefore, to arrive at a reasonable population projection for the project area in the absence of any official studies about the nature of the future inhabitants of the two developments, it is considered that half of the population of the new developments would come from outside Zarqa Governorate.

This means that the DOS projected population for Zarqa Governorate would need to be adjusted to allow for the increase in population that would migrate to the governorate attracted by the new development areas. If no such assumption is made then it would mean that population in other parts of the governorate will not start to increase until year 2035 as all the increase in population until then would be accommodated in the two development areas.

The population projection at five year intervals up to year 2035 based on the above criterion and the resulting growth rates are shown in Table 4.3.

Table 4.3 Proposed Zarqa Governorate Population Projection

Year	Migration from other governorates	DOS population projection	Proposed projected population	Overall growth rate
2010		921,451	921,451	
2015	40,900	1,033,404	1,074,304	3.12%
2020	88,700	1,133,368	1,222,068	2.61%
2025	136,200	1,231,580	1,367,780	2.28%
2030	191,200	1,329,048	1,521,518	2.15%
2035	246,400	1,426,229	1,672,629	1.91%

4.3.2 Spatial Distribution

The spatial distribution of the projected total population of Zarqa Governorate over the municipal planned areas and in towns and villages is required for the proper planning of the wastewater collection and conveyance systems.

The population distribution projection in the towns and villages outside the municipality planning boundaries of Zarqa, Russeifa and al-Hashemiyah is based on the growth rates projected by DOS.

The projected population distribution within the municipal planning boundaries of Zarqa, Russeifa and al-Hashemiyah is based on assuming different growth rates for each Hai (neighbourhood) depending on the degree of current saturation levels in these neighbourhoods. For population distribution purposes the neighbourhoods within the town planning boundaries were classified in three categories by judgement of the present saturation levels determined from examination of the satellite images and observations made by the Team during reconnaissance trips. The three categories are as follows:

- Neighbourhoods with current saturation levels more than 60%;
- Neighbourhoods with current saturation levels between 40 to 60%;
- Neighbourhoods with current saturation levels less than 40%;

For areas judged to be currently built up more than 60% of saturation levels an annual growth rate of 1% was adopted for the period from 2004 to 2015 and a constant growth rate of 0.5% thereafter until 2035 or until the area reached saturation levels.

For areas judged to be to currently saturated between 40% and 60% of saturation levels an growth rates of 1.5%, 1.0% and 0.5% were adopted for the periods from 2004 to 2015, 2016 to 2025 and 2026 to 2035 respectively or until the area reached saturation levels.

After calculation of the population projections at each five year interval for the towns and villages outside the municipal planning boundaries and for the first two neighbourhood categories within the planned municipality boundaries using the above mentioned growth rates the remaining population were distributed over the third neighbourhood category by applying a different growth rate for each five year interval for this category to make up the total population for each five year interval.

The applied growth rates for each neighbourhood category at each five year interval are shown in Table 4.4.

Table 4.4 Population Growth Rates in Project Areas

Period	Towns and villages outside Zarqa, Russeifa and al-Hashemiyah	Zarqa, Russeifa and al-Hashemiyah areas		
		Current saturation level more than 60%	Current saturation level between 40-60%	Current saturation level less than 40%
2004-2010	2.40%	1.0%	1.5%	20.5%
2010-2015	2.32%	1.0%	1.5%	4.8%
2015-2020	1.86%	0.5%	1.0%	3.5%
2020-2025	1.68%	0.5%	1.0%	2.8%
2025-2030	1.53%	0.5%	0.5%	1.8%
2030-2035	1.42%	0.5%	0.5%	1.6%

Detailed population distribution projections in the neighbourhoods and towns and villages are presented in Appendix 1 and are summarized in Table 4.5.

Table 4.5 Projected Zarqa Governorate Population

District / Community	Year						
	2004	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
Zarqa District *	1,410	1,626	1,823	1,999	2,173	2,345	2,516
Zarqa Municipality	412,982	505,704	550,560	584,514	617,013	642,749	666,320
Birein District	12,434	14,339	16,081	17,637	19,165	20,682	22,194
Dhuleil District	34,071	39,292	44,066	48,329	52,517	56,673	60,817
Russeifa District	280,287	296,254	309,924	317,487	325,206	332,770	339,479
al-Hashemiyah Municipality	26,619	28,257	29,698	30,448	31,217	32,005	32,814
al-Hashemiyah District *	21,772	25,109	28,159	30,883	33,559	36,215	38,863
Azraq District	9,426	10,871	12,192	13,371	14,530	15,680	16,826
King Abdullah Bin Abdul Aziz City			50,000	135,000	230,000	340,000	450,400
al-Majd City			31,800	42,400	42,400	42,400	42,400
Total	799,000	921,451	1,074,304	1,222,068	1,367,780	1,521,518	1,672,629

Note: * Population of towns and villages outside planned municipality boundaries

4.3.3 Population Projections of Tributaries from Amman Areas

As mentioned previously flows from the north eastern parts of Amman that drain downstream of AGTP flow into the Zarqa wastewater system. The areas of Amman that contribute flows to the system are Shafa Badran (partly), Jbaiha (partly), Tareq, Marka (partly), al-Nasr (partly) and Basman (partly).

The 2004 population of the contributing areas of these five areas estimated as a percentage of the contributing area delineated around the layout of the existing sewer systems of the total land area of each of these areas was 260,818.

The population projection of the Amman contributing areas over the project horizon over 5-year periods is shown in Table 4.6.

Table 4.6 Population Projections of Tributary Areas of Amman

Year	**2004**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
Growth rate		2.4%	2.3%	1.9%	1.7%	1.5%	1.4%
Area							
Shafa Badran	12,115	13,972	15,670	17,185	18,674	20,152	21,626
Jbaiha	15,567	17,953	20,134	22,082	23,995	25,894	27,788
Tareq	47,629	54,928	61,601	67,560	73,415	79,225	85,018
Marka	89,218	102,891	115,392	126,554	137,521	148,404	159,256
Al Nasr	63,531	73,267	82,169	90,118	97,927	105,677	113,404
Basman	3,695	4,262	4,780	5,242	5,696	6,147	6,596
Total	**231,755**	**267,273**	**299,746**	**328,741**	**357,228**	**385,499**	**413,687**

4.4 Wastewater Flow

4.4.1 Water Consumption

Current Consumption

Based on a review of the water billing data for the period between 2006 and 2009, the average per capita billed amount was 64.6 L/d. The reported average unaccounted-for water during the same period was 46%, with the administrative losses being 80% of the physical losses (25.5% for physical losses and 20.5% for administrative losses). Consequently, the average water consumption during this period was about 90 lpcd, assuming all of the administrative losses were consumed by the population.

Projected Consumption

The recommendations of the MWI Policy Note, issued on 21 April 2010, on water allocation for municipal water use is adopted to estimate the water consumption for the project area. The MWI Policy Note municipal water consumptions are presented in Table 4.7. These consumption figures will be used for the design and sizing of wastewater system facilities and they include all municipal uses such as residential, commercial, institutional and light industrial

Table 4.7 Water Consumption Projections as per MWI Policy Note

Location	Water consumption (lpcd)
Amman	120
Other cities	100
Villages	80
Suburbs	80

4.4.2 Wastewater Generation Factors

In the 1997 Master Plan, wastewater flows were calculated to be about 87% of water consumption based on wastewater flows measured at AGTP and the WZPS and EZPS. This same proportion was used as the basis of projecting wastewater flow in the1997 master plan. The 2006 update of the 1997 master plan also recommended the use of this percentage, so for the purpose of this study it is also assumed that 87% of the water consumed results in wastewater generation.

4.4.3 Wastewater Projection

Future wastewater generation rates estimated based on population forecasts, water consumption rates and the wastewater return value are presented in Appendix 2 and are summarised in Table 4.8.

Table 4.8 Wastewater Generation Projections of Zarqa Governorate (m^3/d)

District	2010	2015	2020	2025	2030	2035
Zarqa District *	113	127	139	151	163	175
Zarqa Municipality	43,996	47,899	50,853	53,680	55,919	57,970
Birein District	998	1,119	1,228	1,334	1,439	1,545
Dhuleil District	2,735	3,067	3,364	3,655	3,944	4,233
Russeifa District	25,732	26,916	27,570	28,237	28,890	29,470
al-Hashemiyah Municipality	2,458	2,584	2,649	2,716	2,784	2,855
al-Hashemiyah District *	2,014	2,258	2,477	2,691	2,904	3,117
Azraq District	757	849	931	1,011	1,091	1,171
King Abdullah Bin Abdul Aziz City		4,350	11,745	20,010	29,580	39,185
al-Majd City		2,767	3,689	3,689	3,689	3,689
Total	**78,803**	**91,935**	**104,643**	**117,175**	**130,406**	**143,408**

Note: * Population of towns and villages outside planned municipality boundaries

4.4.4 Wastewater Flow Projections from Amman Tributaries

Applying the water consumption rates recommended by the MWI Policy Note and the same return factor of 87% as used for Zarqa areas, the projected wastewater flow quantities from the Amman Tributaries are as summarised in Table 4.9.

Table 4.9 Wastewater Flow Projections from Tributaries of Amman (m^3/d)

Area	2010	2015	2020	2025	2030	2035
Shafa Badran	1,459	1,636	1,794	1,950	2,104	2,258
Jbaiha	1,874	2,102	2,305	2,505	2,703	2,901
Tareq	5,734	6,431	7,053	7,664	8,271	8,876
Marka	10,742	12,047	13,212	14,357	15,493	16,626
Al Nasr	7,649	8,578	9,408	10,224	11,033	11,839
Basman	445	499	547	595	642	689
Total	**27,903**	**31,293**	**34,321**	**37,295**	**40,246**	**43,189**

5. DESIGN CRITERIA

5.1 Introduction

The establishment of basic design criteria is critical to the formation of a proper wastewater system reinforcement and expansion plan for Zarqa. The following criteria have been established for use in the formation of the Master Plan.

These design criteria are consistent with best engineering practice and the Consultant's experience in similar regions, and they incorporate the comments made by WAJ on the design criteria presented in the Draft Preparatory Works Technical Report.

5.2 General Criteria

5.2.1 Design Horizon

The design horizon follows the planning period for the master plan as outlined in the previous section. The design horizon for all wastewater facilities is year 2035. Construction of facilities such as electromechanical equipment of pumping stations will be phased out in two phases with the first phase being year 2020.

In circumstances where the pumping station is planned for interim use the planning period for establishing flow rate can be shorter. For all pumping stations, consideration shall be given to future upgrading flexibility necessary to accommodate flows beyond the planning horizon. This is especially important for the larger sewage pumping stations.

5.2.2 Design Life

Design life is defined as the period of time that the asset (a structure or element) is designed to operate for under a normal maintenance regime, without detriment to its function and without major deterioration. After the design life has expired major renovation or refurbishment may be necessary to further extend the asset life beyond its original design life.

The design life for the project facilities is presented in Table 5.1.

Table 5.1 Design Life

Facility	Design Life (Year)
Civil works	50
Sewers and pumping mains	50
Power cables	40
Mechanical equipment	15
Electrical equipment	25
Instrumentation and control	10

5.3 Collection Network Design Criteria

5.3.1 Hydraulic Design of Gravity Sewers

Gravity sewers should flow freely and with a velocity which prevents the deposition of solids within them. This is accomplished by providing sufficient slope to achieve a velocity of 0.9 m/s when flowing half full.

Flow Equations

For the purposes of this study, the Manning formula is used for gravity pipelines.

The Manning equation is as follows:

$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

Where *Q = flow rate (m^3/s)*

A = cross sectional area of flow (m^2)

R = hydraulic radius of flow area in (m) [flow area/wetted perimeter]

S = hydraulic gradient (m/m)

n = Manning roughness coefficient

Friction Factor

It is common to relate friction factors to the materials involved, particularly in the design of systems handling clean water. Polyvinyl Chloride (PVC) and Glass Reinforced Plastic (GRP) have a very smooth surface when fabricated and their laboratory friction factor is small. In a sewer environment, however, the pipe quickly becomes coated with slime, grease and sediments that are deposited during low flow conditions. The sediments, once deposited, are rarely removed at low flow velocities, because they are combined with grease and thus become cemented. For these reasons, it is considered good practice to correlate the friction factors to flow velocities in addition to pipe material properties in the hydraulic design of sewers and to use conservative friction factors to compensate for the loss of capacity due to slime, grease and sediment build-up.

The roughness coefficients for different pipe material and velocities for sewers slimed to half depth will be as follows:

Velocity when flowing half full	Manning's n value [s/m$^{1/3}$]
Up to 0.75 m/s	
Concrete	0.015
DI (cement lined)	0.014
Clayware	0.013
Plastic	0.012
Greater than 1.2 m/s	
Concrete	0.013
DI (cement lined)	0.012
Clayware	0.011
Plastic	0.010

The above values are recommended following review and experimental work undertaken at HR Wallingford during 1995 to 1996. The value of n should be interpolated for velocities between 0.75 and 1.2 m/s.

Design Flow Depth

The design depth of a sewer is always less than 100 percent of the diameter to accommodate deviations from the design slope and flow rates, to ensure adequate ventilation and to protect against the possibility of choking. Recommended design depths given in various literature and design guidelines vary between 30% to 85% of sewer diameter.

The variation in design depth with diameter used in past projects in Jordan is as shown in Table 5.2. These flow depths allow for adequate ventilation in small diameter sewers and also allow for additional capacity to carry some of the stormwater flows that are illegally connected to the sewer system.

Table 5.2 Design Flow Depth vs. Diameter

Diameter [mm]	Maximum design flow depth [as % of diameter]
200	50
250	50
300	67
400	67
500 & larger	75

Minimum Velocity

The minimum flushing velocity of flow in a sewer is taken to be 0.75 m/sec for the calculated hourly peak flow, achieved at least once per day, to prevent the deposition of mineral matter, such as sand and gravel.

All main sewers are designed to achieve this velocity during the early years of the operation of the system, while secondary sewers are designed to achieve this velocity at the design horizon flows because the design flow quantities in these sewers will not be achieved during the early years of the operation of the system.

Minimum Gradient

Table 5.3 presents the minimum slopes needed to achieve a velocity of 0.9 m/s at half full flow for concrete pipe against different pipe diameters. These minimum slopes will be adopted when designing new sewers.

For diameters of 700 mm and larger, an absolute minimum slope 0.2 % is taken, because lower slopes will be influenced too much by the uncertainty due to the construction.

It is important to note that for the smallest pipe diameter of 200 mm at upstream ends of sewers and until the connection of 900 persons, the above mentioned minimum gradients will not achieve the required minimum velocities because of the low flows and flow depths.

Table 5.3 Minimum Gradients of Sewers vs. Pipe Diameters

Pipe Diameter (mm)	Minimum slope to achieve a velocity of 0.9 m/s when flowing full (mm/m)
200	9.9
300	5.8
400	3.9
500	2.9
600	2.3
700 and larger	2.0

The minimum gradients for the 200 mm diameter sewers for self cleansing pipes (calculated based on internal diameters) that would achieve a sheer stress of 3 N/m^2 for the assumed per capita flow generation rates of 79.1 lpcd in winter season at 2010 flow conditions are shown in Table 5.4.

Table 5.4 Minimum Gradients of 200 mm Sewers for Self Cleansing as a Function of Connected Population

Connected population	Minimum Gradient for Self Cleansing (mm/m)
10	20.0
200	20.0
250	19.0
300	17.0
350	16.0
400	15.0
450	14.0
500	13.0
700	12.0
800	11.0
900	10.0

The gradients of the pipes should be chosen in such a way that the velocity in all pipes is maximized. This means that along a sewer stretch with the same diameter, the sewer gradients should be as equal as possible, certainly where they are near the minimum gradients.

In order to maximize the benefit of the terrain slope for the self-cleansing behaviour, the pipes will follow as much as possible the shortest path to the main sewers. This will minimize deep excavations and also residence times.

Maximum Velocity

The maximum velocity at design flow depth in concrete and plastic pipe sewers shall be limited to 4.0 m/sec to prevent damage to sewers from the erosive action of the materials suspended in the wastewater.

At velocities higher than 4 m/s ductile iron pipe sewers shall be used.

Flow Pattern and Peaking Factor

Since wastewater flows vary substantially throughout the day, peaking factors for sewers are applied to the average design flow as a function of the connected population. The smaller the population, the larger the peaking factor.

An applicable formula for calculating the daily peaking factor (PF) for populations of 1,000 to 80,000 is the Babbitt formula, which is as follows:

$$PF = \frac{5}{\left(P/1000\right)^{1/6}}$$

And the applicable formula for calculating the daily peaking factor (PF) for populations exceeding 80,000 is the Bauman formula, which is as follows:

$$PF = \frac{18 + \sqrt{P/1000}}{4 + \sqrt{P/1000}}$$

Where PF = Peak Factor

P = Population

The derivation of the peaking factors (PF) for sewer design based on the above is summarised in Table 5.5.

Table 5.5 Peaking Factors for Design of Sewers

Population	Daily peaking factor
1,000	5.0
2,000	4.5
3,000	4.2
4,000	4.0
5,000	3.8
10,000	3.4
20,000	3.0
40,000	2.7
50,000	2.6
60,000	2.5
80,000	2.08
100,000	2.0
150,000	1.86

Population	Daily peaking factor
200,000	1.77
300,000	1.66
400,000	1.58
500,000	1.53

For the design of the extensions of Zarqa wastewater system more representative peaking factors derived from the analysis of the results of the flow measuring programme conducted under this study will be used.

5.3.2 Sewer Design and Installation Considerations

Size of Sewers

The minimum size of sewer pipe, to prevent clogging shall be:

Minimum service connection diameter: 150 mm

Minimum sewer diameter: 200 mm

Installation and Connection Details

The local details in the connections, junctions, etc are very important for the minimizing of the head losses and the prevention of flow disturbance that leads to deposits.

For this reason, the flowing aspects should be taken into account:

- All house connections should be made using the proper fittings of a Y-junction and a 45 degree bend;
- Connections at angles of 90 degrees should be avoided;
- Manhole floors should have proper benching for a fluent flow through them; and
- Sudden flattening of gradients after steep gradient sections should be avoided.

Depth of Sewers

The minimum depth of sewers shall be 1.50 m to allow house connections to be made and to reduce the crossing probabilities with other utilities such as water, electricity and telephone.

The minimum cover of the sewer pipe shall be 1.0 m to protect the pipe from traffic loads. If this protection is not achieved then the sewers shall be encased in concrete.

The maximum depth depends on the slope, topography, ground conditions and other factors, but typically should be limited to 6 m.

Separation Distance between Sewers and Water Mains

The horizontal separation distance between sewers and water mains shall not be less than 3.0 m. The vertical separation distance at crossings between inverts of water lines and crown of sewers shall not be less than 0.5 m. Where this vertical separation distance in not secured, both lines shall be concrete encased for at least 3.0 m from both sides of the crossings.

Width of Trenches

Width of trenches shall be limited to outside pipe diameter plus 600 mm. Minimum working space around the sides of the pipe shall be 200 mm.

Pipe Bedding

Pipe bedding is the prepared layer of granular or concrete material acting as a support under a pipe, and determined by calculating external loads in conjunction with pipe strength and engineering requirements. Type and class of bedding for concrete pipes shall be determined by the following formula:

$$BeddingFactor = \frac{ExternalLoad * SafetyFactor}{PipeStrength}$$

Where: *External Load is the total soil and traffic load on the pipe (KN/m)*

Pipe strength is defined as the line load that a pipe can sustain without the development of cracks of width greater than 0.25 mm over a distance greater than 300 mm in a two or three edge bearing test (KN/m)

Safety factor is usually taken as 1.0 and 1.3 for reinforced and non-reinforced pipes, respectively

The type of bedding used with respect to bedding factor shall be as given in Table 5.6

Table 5.6 Bedding Factor for Concrete Pipes

Bedding details			Bedding factor
Class	**Material**	**Bedding angle**	
A	Reinforced concrete	180°	3.4
B	Granular	180°	2.0
B	Shaped sub-grade	120°	1.9
C	Granular	60°	1.5
D	Granular	0°	1.1

Notes:

1. The bedding angle refers to the width of bedding support under the pipe
2. Class D bedding should only be used when suitable bedding material is not available.
3. Class A concrete bedding should not be used unless there are special requirements for shall sewers installed under heavily trafficked roadway.

The minimum thickness of the pipe bedding under pipe barrel shall be 25 percent of the outside pipe diameter or 100 mm whichever is more.

5.3.3 House Connections

House connections, usually 150 mm in diameter, shall preferably be connected to the main sewers at manholes or at Y-junctions if distances to manholes are long. These shall be installed at a minimum gradient of 2 percent and at 90 degrees to the centreline of the sewer.

House connections shall end with plug end half meter outside the property wall to permit house connection to be made.

All house connections inside the properties shall be provided with ventilation pipes.

5.3.4 Manholes

Manholes are provided on sewers as a means of access for inspection, testing and clearance of obstructions. Except for very shallow sewers of less than one metre depth to invert, all manholes should be of adequate dimensions to facilitate entry and for the operation of cleaning apparatus while wearing full safety equipment.

Manholes shall be provided at the head of a sewer, at every junction of two or more sewers and wherever there is a change in its alignment, gradient, diameter or material. Otherwise maximum spacing should be as listed in Table 5.7.

Table 5.7 Maximum Spacing between Manholes

Sewer diameter	Maximum spacing
200 mm	50 m
300 & 400 mm	60 m
500 mm and larger	90 m

Standard manholes for sewers shall be of cast-in-situ or precast reinforced concrete circular rings. Manhole size selection is a function of main sewer diameter, number of pipe entries together with depth of the manhole but, to avoid individually designing every chamber, standardization has been introduced. The sizes of the manholes shall be as shown in Table 5.8:

Table 5.8 Manhole Internal Diameters

Maximum pipe diameter (mm)	Depth to soffit of main inlet sewer less than 3 m			Depth to soffit of main inlet sewer more than 3 m		
	Number of incoming pipes			Number of incoming pipes		
	1	2	3	1	2	3
200	900	900	1000	1000	1000	1200
300	900	1000	1200	1000	1200	1500
400	1000	1200	1500	1200	1500	1500
500	1200	1500	1500	1500	1500	1800
600	1500	1500	1800	1500	1800	1800
700	1500	1800	Special	1800	1800	Special
800	1800	Special	Special	1800	Special	Special
900	1800	Special	Special	1800	Special	Special
1000	2100	Special	Special	2100	Special	Special
1200	2100	Special	Special	2100	Special	Special

When two sewers are connected at a manhole or special structure, the crowns of the two sewers should be at the same elevation.

Materials used in the construction of manholes will be resistant to or protected from attack by the aggressive environment which exists in sewers. Sulphate resisting concrete will be used for all concrete works coming in contact with sewers.

Manhole covers and frames are to be circular and manufactured from ductile iron. A minimum clear opening of 660-700 mm shall be specified to facilitate man entry to the sewer with breathing equipment. Heavy duty (40 ton bearing capacity) covers and frames shall be specified for all manholes in roads and streets. Medium duty (25 ton bearing capacity) are specified for footpaths.

Drop manholes are used to connect two sewers where the incoming sewer is shallow and the other sewer is deep or to permit the use of flatter slopes when a sewer is descending a steep slope. When the difference between the elevations of the crowns of the two sewers is greater than 600 mm, a drop manhole shall be used for sewers up to 300 mm diameter.

Vertical drops in sewers larger than 300 mm should be avoided to minimize sewage turbulence inside the manhole and hence minimize the release of H_2S. The higher sewer shall be deepened and, if necessary, a special junction structure shall be provided.

5.3.5 Pipe Material for Gravity Sewers

The various elements of sewerage systems; pipelines, manholes, pumping stations etc., should be constructed from materials which enable them to be readily constructed, and then to be operated with a minimum of maintenance for the required service lifetime, so as to achieve the optimum economic benefits.

Fundamental to the achievement of the above objective is the need to employ materials, which will give a long service life in the environmental conditions to which they will be exposed. Inspection of the existing sewerage system in Zarqa shows that concrete pipes installed from the mid 1980s are still in good condition.

Biological oxidation of hydrogen sulphide (H_2S) by bacteria of the genus thiobacillus on the moist surfaces of the sewer will produce free sulphuric acid. This acid will attack concrete, asbestos cement, and metal appurtenances unless washed off and made harmless by dilution. The generation of hydrogen sulphide (H_2S) increases with high air temperatures, high strength sewage and low velocities in the sewer. The acid attacks concrete and ferrous materials rapidly so it is critical to select pipe materials that are corrosion resistant and will not suffer from the generation of sulphuric acid in it.

Because Zarqa has moderate air temperatures with steep topography generating high velocities and low retention times, it is considered that generation of hydrogen sulphide (H_2S) in the sewers will not be a problem.

Two types of material capable of resisting sulphuric acid attack are available for use in sewer pipes: vitrified clay and polymeric materials (plastics).

Metal pipes, though suitable for sewer construction, are only likely to be preferred to other materials in circumstances where their extremely high strength is needed to sustain abnormally high loadings or where high velocities are expected. They are therefore not considered suitable for general use in sewers.

The most commonly accepted pipe materials currently used worldwide for sanitary sewer application include:

- Polyethylene (PE)
- Unplasticised Polyvinyl Chloride (uPVC)
- Glass Reinforced Plastic (GRP)

- Vitrified Clay Pipe (VC)
- Concrete Pipe (unreinforced)
- Reinforced Concrete Pipe (RCP)

It is believed that, except for concrete pipe and small diameter uPVC pipe, none of the abovementioned pipes is manufactured in Jordan.

Following is a brief discussion of the above mentioned pipe material:

PE Pipe

PE pipe is used for both gravity and force main sewers. Jointing is primarily accomplished by butt fusion or flanged adapters.

Advantages of PE pipe include:

1. Long laying lengths
2. Light weight
3. Ease in field cutting

Disadvantages include:

1. Relatively low tensile strength and pipe stiffness.
2. Requires high quality workmanship for placing bedding and backfilling otherwise pipe will fail by excessive deflections.
3. Requires special tool for jointing (fusion welding machines).
4. Possible leakage at connection point with manholes if not properly installed.
5. Limited range of size.

uPVC Pipe

uPCV is used for both gravity and force main sewers. Jointing is primarily accomplished with elastomeric seal gasket joint, although solvent cement joints for small diameters are available.

Potential advantages of uPVC pipes include:

1. Light weight
2. High impact strength.
3. Easy to install and cut.

Disadvantages include:

1. Subject to excessive deflection when improperly bedded and backfilled.
2. Limited range of sizes
3. Can be affected by UV.

GRP Pipe

GRP pipe is used for both gravity and force main sewers. Advantages and disadvantages of GRP pipe are similar to uPVC except that large diameter GRP pipe is available.

GRP is specified by nominal diameter, pipe stiffness and pipe class. Standard pipes utilize couplings for jointing to each other and also spigotted fittings.

VC Pipe

VC pipe is used for gravity sewers only. The product is manufactured from clay and shales.

VC pipe is manufactured in standard and extra strength classifications. VC pipe is specified by nominal pipe diameter, strength and type of joint.

Main advantages include:

1. High resistance to chemical corrosion
2. High resistance to abrasion.

Disadvantages include:

1. Heavy pipe
2. Subject to shear and beam breakage if improperly bedded.
3. More expensive than GRP or uPVC pipe.

Concrete Pipe

Reinforced (RCP) and non reinforced concrete are used for gravity sewers. Reinforced concrete pressure pipe is used for pressure as well as gravity sewers.

Standard specification, advantages, disadvantages of concrete pipes are well known as they are the most common pipe material used in Jordan.

Recommended Pipe Materials

Based on the above, it is recommended that the technical specifications for the construction of gravity sewers in Zarqa permit only the pipe materials shown in Table 5.9.

Table 5.9 Recommended Pipe Material

Pipe diameter	Pipe material
Up to 200 mm	Concrete, uPVC
300 mm to 1000 mm	RCP
Over 1000 mm	RCP, GRP, profiled PE

5.4 Pumping Station Design Criteria

5.4.1 General

Pumping stations are provided in a sewerage system generally to either avoid the construction of uneconomically deep gravity sewers or to transfer sewage flows from isolated communities which cannot be connected to the treatment works or point of disposal by a gravity pipeline.

The pumping station must be located so that neither noise nor odours are potential causes of nuisance. The location of all pumping stations should be such as to permit reasonable vehicular access for the purposes of repair and maintenance.

5.4.2 Pumping Station

Submersible wastewater non-clog pumps shall be used for wastewater pump stations. Pumping stations shall be designed to pump the peak flow with minimum two pumps (1 duty + 1 standby) with consideration for future expansion.

Ductile Iron pipework will be used in the pump station and for inter-connecting pipework.

All main pumping station sumps should be constructed in reinforced concrete.

A single manhole outside the station sump shall be provided at all pumping stations into which all incoming sewers are collected so that there is only one inlet to the sump itself. This simplifies the problem of sewage diversion in the event of a major failure of the pumping station.

Sluice valves and non-return valves are fitted to each pump outlet, and a sluice valve at the suction pipe when pumps are installed in a dry well. Further valves are often not necessary unless it is intended to be able to isolate the rising main for washing out purposes or for the addition of further pumping units in the station at some future date.

If twin rising mains are installed, an emergency by-pass should be provided between the two pipelines, and sufficient sluice valves must then be fitted immediately outside the station, so that either main can operate as the duty main or both pipelines can operate either separately or together.

Although the sumps are entirely closed there is the possibility of odour problem at most main pumping stations. De-odourisation equipment may therefore need to be provided.

Flow metering is to be provided as standard in all pumping stations. Ultrasonic flow measurement installed in a venturi flume will be designed for the measurement of incoming flow. Whereas, electromagnetic flow meters will be utilised for outlet flow measurement.

Sewage composition can vary widely, adequate consideration and necessary provisions shall be taken to ensure that sewage pumping station equipment and materials are suitable for the anticipated composition of sewage. Mechanical screens and in some cases grit removal systems should be provided to protect pumps and prevent the pumps being clogged by large objects.

Also, consideration should be given to providing main pumping stations with emergency storage facilities sized according to design requirements, should space permit.

Sewerage systems normally incorporate two types of pumping stations:

1. Submersible stations
2. Wet well / dry well stations.

Submersible Pumping Stations

Could be used to serve average wastewater flows up to 100 L/s at maximum 80 m head, the submersible station basically comprises a wet well with two or more submersible pump sets.

Submersible pumps must be provided with corrosion resistant guide rails, chains and special automatic coupling flanges to permit routine withdrawal and replacement of the pumps without undue difficulty and without entry into the well.

Access covers must have a clear opening of at least 600 mm; one or more covers being provided so as to enable each pump to be withdrawn vertically. The covers must be lockable, of adequate strength for vehicular traffic as may be appropriate, and capable of being lifted by not more than two operators.

Access ladders must be provided and bolted in place in order to facilitate future renewal.

Wet Well / Dry Well Stations

Wet well / dry well pumping stations are designed essentially to be able to isolate the pumping equipment from the sewage without moving the equipment, for ease of maintenance. Large pumps can therefore be installed to handle the major flows. These main pumping stations normally operate on trunk sewers.

In addition to most of the characteristics listed for the submersible stations, the pumps of wet well / dry well pumping stations should be able to handle solids of minimum size of 60 mm and the pumping stations also include a superstructure to house control and switchgear to accommodate full time attendance, all within a walled enclosure.

5.4.3 Pump Station Components

Wet Wells

Wet wells should preferably be reinforced concrete structure. The design of wet wells must be such as to ensure satisfactory flow conditions to the pumps, and in particular to avoid the formation of vortices. There must be a minimum capacity between first start and cut-out level controls to give between ten and fifteen starts per hour. The inlets must each be provided with a sluice valve or penstock.

Pump start/stop sensors should be spaced to suit a pumping regime which produces the best compromise between stop/start and “continuous” flow. The minimum live volume in the sump per pump is:

$$V = \frac{QT}{4}$$

Where *V = live volume of wet well (m^3)*

Q = pump capacity (m^3/min)

T = minimum on/off cycle time offered by pump manufacturer (min)

In addition to the minimum live volumes the size of the wet well is to allow for the required minimum submergence of the pumps and minimum floor clearance which are given by the following formulas:

Minimum submergence (m) = 0.04 X (pump capacity)$^{1/2}$ + 0.2

Minimum floor clearance (m) = 0.5 X pump suction diameter (m)

For an installation with several identical duty pumps, the start and stop levels of all pumps differ by a constant value determined by the characteristics of the control system. The difference in levels should be large enough to eliminate pump starts and is normally in the range of 200 – 300 mm.

Side slopes to wet well benching should be a minimum of 40 to 45^{o} to the horizontal.

Pumps

Pumps are to be of a submersible type with a minimum of two sets provided (one duty and one stand-by). However, it might be necessary to use overhung impeller pumps for the large capacity high head pumps.

The following criteria are to apply to pumps:

- The pump station total pumping capacity must be able to pump the peak design flow. In other words, the single pump capacity must be equal to peak design flow divided by the total number of operational pumps with the head required for pumping at peak flow.
- Pumps must be heavy duty, non-clog type with double machined shaft seals.
- Impeller design and motor selection should preferably be such that the unit is of the non-overloading type.
- Pump motors must be designed to provide for 30% overload to the working load.
- Impeller speeds must not exceed 1500 rpm. However, for cases of low flows against high heads impeller speeds of 3000 rpm shall be acceptable.
- Impellers must be of cast construction capable of passing solids. Impeller passages shall be smooth so that rags and stringy matter will not adhere to them and shall be capable of passing a sphere of 60 mm dia. without choking.
- Screw-on impellers are not acceptable.
- Impellers must be keyed or pinned to the drive shaft or fixed by other approved methods.
- Under normal operating conditions the pump should run close to its best efficiency point.

5.4.4 Pre-treatment Facilities

Screens

The following criteria are to apply to screens:

Coarse Screens

Screen Type	Travelling band, rake type bar screens, multiple rake type bar screens
Screen Operation	Automatic
Bar spacing	40-50 mm
Bar width	3-6mm (depends on the manufacturer)
Min velocity u/s screens	0.5 m/s
Velocity through screens	1.0-1.2 m/s
Slope	0-90^{o} (depends on the type)
Blinding factor for max headloss	50%
Maximum allowable headloss	400 mm
Material	AISI 316 (L)

Fine Screens

Screen Type	Drum screens , multi rake climber type screens
Screen Operation	Automatic

Screen surface for drum screens:	Perforated or bi-directional
Design philosophy	can be operated under (n-1) conditions or standby to be provided
Bar spacing	15-20 mm
Bar width	3-6mm
Min velocity u/s screens	0.5 m/s
Velocity through screens	1.0-1.2 m/s
Slope	0-40^{o} (depends on the type)
Blinding factor for max headloss	50%
Maximum allowable headloss	400 mm
Material	AISI 316 (L)

General Consideration for design of the Screening Facilities

- Screen channels must be equipped with ON/OFF actuated penstocks.
- Each screen channel must be covered with closed fitting removable covers (preferably GRP)
- Sufficient lifting equipment must be installed to lift the screening skips for removal.
- Service water must be provided for each screen and sluice trough with the required pressure (usually 4-6 bars)
- The screens should be able to handle flows when one unit is out of service so the design must be based on (n-1) conditions or a standby channel must be provided
- Hydraulic jumps must be avoided in the water surface profile which will create turbulence and release excessive H2S.
- Air inlet and extraction dampers must be provided on the covers
- It is advisable to have a sump in the screening channel for complete emptying of the channel during maintenance.
- Inlet and outlet arrangement of the screens must be carefully designed to avoid dead spots and hence settlements.
- Connection from the washpactors back to the screen channel must be provided for organics discharge.
- Wash water feed should be arranged using solenoid valves.

Aerated Grit and Grease Removal

The following criteria are to apply to grit and grease removal facilities:

Grit and Grease Removal

Type	Aerated combined grit and grease removal
Number	Sufficient number of multiple units must be provided to allow cleaning , service and repair
Detention time	5 mins @ Peak flow (excluding grease compartment)
Aeration Requirt.	0.4-0.6 Nm3/min-m tank length
Blowers	1 per channel + standby , to be designed according to site conditions

Aeration Type	Coarse bubble diffusers
Grit Scraping Mech.	Traveling bridge or screw conveyor
Grit removal Mech.	Via centrifugal or submersible wear resistant pumps
Velocity in pipe	1.4-2 m/s in grit transfer pipe
Tank Width	2.5-7 m
Tank Length	7.5-20 m
Width : Depth Ratio	1:1 to 5:1 (Typical value 1.5:1)
Length : Width Ratio	3:1 to 5:1 (Typical value 4:1)
Surface Loading	16.6 – 35.6 m3/m2-h
Removal Efficiency	95% removal of grit particles having 20 microns size
Grit Quantity	0.004 – 0.2 m3 / 1000 m3 influent wastewater
Grit SG	2.65
Inlet Grit conc.	30-80 mg/L
Settled grit conc.	3000-1000 mg/L
Bulk density of grit	500 kg/m3 (grit-water mixture)
Bottom cone slope	35-45o

Grease removal

Mechanism	Flotation effect created by the spiral roll pattern with aeration Followed by surface skimming

Grease chamber

Surface loading	25 -35 m3/m2-h @ maximum flow
Grease chamber length	Equal to grit tank length
Grease chamber width	Determined by the surface loading rate and length of grit tank
Detention time with grease removal	max 10 minutes @ Peak flow
W_{grease}:W_{grit}	: 0.8-1.2

Typical cross section of aerated grit removal chamber is shown in Figure 5.1.

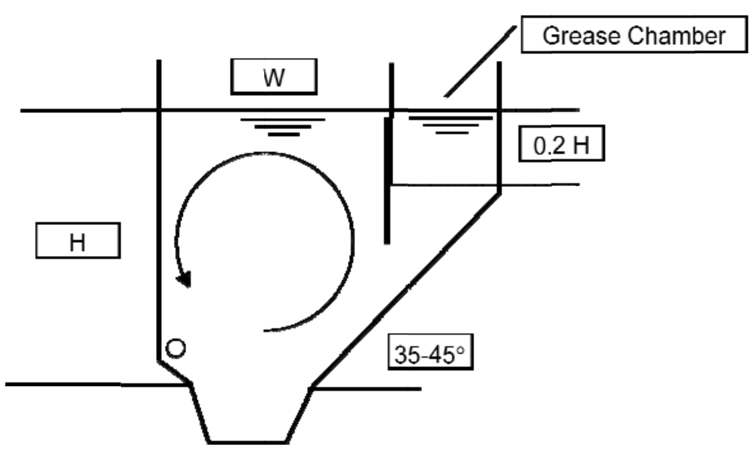

Figure 5.1 Typical Cross Section of Aerated Grit and Grease Removal Chamber

General Consideration for design of the Grit/Grease Removal Facilities

- Inlet to the grit tanks must be equipped with ON/OFF actuated penstocks.
- Each grit tank and the connecting channels must be covered with closed fitting removable covers (preferably GRP)
- Air inlet and extraction dampers must be provided on the covers
- Sufficient lifting equipment must be installed to lift the skips for removal.
- Service water must be provided for grit fluidization , flushing and for the grit classifier
- Grit fluidization must be done prior to pumping grit
- Grit classifier operation must be interlocked to the operation of the grit pumps.
- Discharge piping with nominal diameters of min 100mm must be used to avoid high pressure and scouring velocities that will result in wear
- Length of grit suction pipe must be minimized
- A connection must be provided from the grit classifier to the inlet of the screens to allow organics discharge
- Wash water feed should be arranged using solenoid valves.
- Tank inlet and outlet should be positioned so that the flow through the tank is perpendicular to the spiral roll pattern.
- The concentration of fats, oil and grease (FOG) must be analyzed during the detailed design stage.

5.4.5 Odour Control Works Design Criteria

Odour control

To ensure adequate odour control system performance, all of the pre-treatment works including the coarse screens, fine screens, grit removal tanks, the connecting channels in between and the wet well of the pumping station must be covered with closed fitting removable GRP or other type of covers which will be resistant to heavy corrosion.

Extraction Rates

The headspace under the covers must be connected to an odour control system where the foul air will be treated to the required standards. The air extraction shall be sufficient to maintain a negative pressure under the covers and to avoid elevated levels of H_2S. The criteria given Table 5.10 will be followed for extraction rates:

Table 5.10 Design Criteria for Air Extraction Rates at Pumping Station Facilities

Process unit	Air changes per hour (ACPH)*
Coarse Screens	6-12
Fine Screens	6-12
Grit Removal Tanks	1.2 x $Q_{process}$ air
Connecting Channels	6-12
Wet Well	12

**: to be finalized during detailed design*

The covers must be fitted with sufficient number of air inlet and extraction dampers over each process unit. Then the combined foul air will be fed to the odour control system.

Inlet Pollutant Concentrations and Load to the Odour Control System

The inlet pollutant concentrations are a key to the selection and design of the odour control system. The major odour pollutants generated from the pumping stations and the sewage treatment plants can be listed as H_2S, mercaptans (R-SH), dimethyl sulfide (DMS), dimethyldisulfide (DMDS) and volatile organic compounds (VOCs).

The H_2S concentration depends on a number of factors including sewage age, sewage temperature, load and the degree of aeration in the network. The length of the sewers feeding the pumping stations has a direct effect on the age of sewage. Measurement of the inlet pollutants and odour levels is required prior to determining appropriate odour control measures.

The design criteria for the inlet pollutant concentrations will have to be finalized during detailed design supported by actual measurement at East and West Zarqa pumping stations.

Performance Criteria for Odour Control Systems

The required stack discharge quality shall be as shown in Table 5.11:

Table 5.11 Stack Discharge Quality

Contaminant	Expected Design % removal at peak inlet design load	Maximum discharge concentration at peak load (ppm)	Maximum discharge concentration at peak load
Hydrogen sulphide (H2S)	99.95	0.05	Total including all contaminants not to exceed 500 OU/m3
Dimethyl sulphide (DMS)	99.9	0.01	
Mercaptans (R-SH)	99.9	0.003	
VOC (average Mol. Wt 120)	There shall be sufficient removal of VOCs to achieve stack discharge max. concentration specified (at peak load)		

General Design Considerations for Odour Control Systems

- The odour control system must be designed, operated, maintained, and managed under Good Industry Practice.
- All components of the OCU(s) must be compatible with the conditions and chemicals to which they will be subjected to during normal operation. Compounds with which the materials of construction must be compatible with are Hydrogen Sulphide, Sulphuric Acid, Ammonia, Dimethyl Sulphide, Mercaptans , and any other corrosive gases that may be present.
- Odour control system must provide redundancy (level of redundancy to be confirmed during detailed design stage) in its design concept to eliminate any possibility of odorous discharge. This may be achieved by redundancy of equipment of the same kind or by a combination of odour control technologies. (details to be finalized during detailed design)
- Prevent odour complaints from the public by reducing concentrations of hydrogen sulfide, mercaptans, other sulfur-containing compounds and Volatile Organic Carbons

(VOCs) such that those from the site are undetectable at the site boundaries. The odour level at the site's boundary must not be above 5 ppb on an one hourly average basis based on the AS4323.2 standard odour measurement method.

- The discharge of odorous air at the odour control system stack under no circumstances must ever exceed 0.1 PPM of H_2S for more than one day. The odour control system design must stipulate for sufficient redundancy and robustness to guaranty this level of performance under all circumstances.
- The discharge of Hydrogen Sulphide at the odour control system stack must remain below 0.05 ppm under normal operating condition at expected peak loads.
- The stack must be sized tall enough (not less than 3 meter taller than the nearest interfering structure) to disperse the discharge with a minimum discharge velocity of 15 m/s.

Acceptable Technologies for Odour Control

1. Wet chemical scrubber utilizing sodium hydroxide and sodium hypochlorite as the scrubbing liquor for removal of odorous compounds and neutralizing the scrubbing solutions salts to a stable condition. The chemical scrubber may be followed by an Activated Carbon (AC) filter as a polishing stage to remove the remaining VOC's. The disadvantage of Wet Chemical Scrubber is the continuous use of chemical solutions, which requires continuous monitioring and adds high operational costs.
2. Bio-scrubbers and AC filter. The biological system must remove the bulk of odorous compounds followed by a polishing AC system. Bio-scrubber design and specification must be per guidelines to be provided in the detailed design stage.
3. Biofilters or biotrickling filters. These are reliable and proven technologies that has been used in many plants. The operating cost of these systems are low as they do not require any chemicals however it cannot handle high and variable H2S loads. It requires a high footprint.
4. Combination of bioscrubbers and wet chemical scrubbers can also be used to substantially lower the chemical costs.

According to the above description, it is recommended to consider the Bioscrubber followed by activated carbon filter.

Design Criteria for Bioscrubber followed by Activated Carbon Polishing Filter

Bioscrubbers

The bio-scrubber treatment stage will contain biologically active synthetic media layers to facilitate the growth of bacteria necessary for biological oxidation of odorous compounds. The media must have the following properties:

1. It should be a dual-density structured media made entirely of a synthetic, non-reactive material. Organic and/or non-synthetic inorganic media materials or any random-packed media shall not be allowed.
2. The media is to facilitate efficient mass transfer of odour compounds and growth of bacteria used to oxidize odour compounds.
3. Media must be designed to be compatible with all process contaminants and their by-products; and;
4. It must be suitable for use at pH levels as low as 1.0.

The bio-scrubber design criteria must be selected to fulfil the following requirements:

1. The system must utilize an intermittent irrigation system consisting of a single spray nozzle per media layer to maintain a wetted surface on the media and provide chemical nutrients to the bacteria on the media.
2. The system must be designed to allow the formation of a pH gradient within the media bed, to allow the growth of autotrophic bacteria for hydrogen sulphide oxidation, and heterotrophic bacteria for the oxidation of other Reduced Sulphur Compounds (RSC's).
3. The reactor(s) must be configured with one fluid injection spray nozzle for each treatment layer.
4. The spray nozzle must be located above the treatment layer and must disperse the fluid evenly over the entire treatment layer.
5. Systems using multiple spray nozzles and/or a spray header will not be acceptable.

The design criteria for the Biofilter is summarized as follows:

No of Biofilters	two (as minimum)
Media loading rate	50-850 m/hr 0.014-0.25 m/s
Packing depth range	150-3000 mm
Main media size	6-8 mm
Support media material	Wood chips or equivalnet
Support media size	25-75 mm
Support media depth	150 mm
Underdrain system	Perforated PVC pipe
Perforation size	15 mm
Air distribution system	Solid supply header with air manifold and perforated PVC laterals
Other components	Spray Nozzle FRP Fans Irrigation system (sprinklers) to moisturize the biofilter media Alkalinity media make up Media moisture control system

Activated Carbon

Carbon adsorption system may be utilized as a polishing stage to the chemical or bio-scrubbers. Activated carbon is to remove residual sulphur based compounds or any other non-soluble VOCs. The performance of the carbon adsorption system as a standalone unit must meet the minimum requirement of the specification namely 0.1 ppm of H2S concentration if the bio-scrubbers for any reason are by-passed. The carbon must be a Virgin, granular activated carbon derived from bituminous coal suitable for the vapor phase adsorption and catalytic oxidation of odour causing substances. The carbon must be suitable for regeneration of its adsorptive capacity by washing with water with no other chemical added or required. No more than one regeneration per six month is permitted. Carbon must have a minimum operative capacity of 3 years. A system of continuous monitoring of smell in the stream of air leaving the odour control facility must indicate the required regeneration of the carbon unit. The carbon must be of acceptable quality standards in industry and have equal or similar properties shown in Table 5.12:

Table 5.12 Activated Carbon Quality Standards

Property	Value
Apparent density (kg/m^3)	>560
Mesh size (U.S. sieve) greater than 4 mesh	<15%
Mesh size less than 7 mesh	<8%
Hardness number (min.)	>97
Moisture (w/w max.)	2% max.
Minimum H_2S saturation capacity	0.16 g H_2S removed /1 g carbon
H_2S breakthrough capacity (g H_2S removed / cc carbon)	>0.09
Ash (%w)	<8
Iodine Number (mg/g)	>800
Butane Activity (%w)	>16

Chemically impregnated carbon is not acceptable.

Adsorber vessels with single or double activated carbon bed must be designed to prevent bed fluidization. The minimum contact time for the foul air passing through the carbon bed is 2.5 seconds(empty bed contact time, EBCT). The units must be complete with bed(s) supports, nozzles, piping, valves, instrumentation and controls. The design must provide 33% standing-by capacity to be used when any of the duty vessels undergoes regeneration.

5.4.6 Pumping Mains

Hydraulic Design

Pumping mains, must be designed to withstand the total manometric head on the pumps (static head plus friction loss). An additional allowance should be made for surge in cases of high pumping velocity, or in very long rising mains.

Materials commonly used for rising mains include steel, ductile iron, uPVC, PE and GRP. Welded steel pipe or ductile iron pipe shall be used for pumping mains due to relative large diameters involved.

The diameter of pumping mains should be such that the flow velocity will be in the range 0.75 to 1.8 m/sec.

Single pump vertical discharge pipes should be sized such that the discharge velocities in these pipes will be in the range of 1.8 to 3.5 m/s and collector headers should be sized to achieve a discharge velocity in the range of 1.2 to 2.4 m/s.

Of the numerous formulae used for pressure mains, Colebrook-White and Hazen Williams gives a good degree of accuracy. In metric terms, the Colebrook-White formula is:

$$V = -2\sqrt{(2gDi)}\ \log\left(\frac{Ks}{3.7D} + \frac{2.51\nu}{D\sqrt{(2gDi)}}\right)$$

Where V = velocity (m/s)

g = gravitational acceleration (m/s^2)

i = hydraulic gradient (m/m)

ν = kinematic viscosity of fluid (m^2/s)

K_s = effective roughness (mm)

D = internal pipe diameter (m)

Experimental results have shown that pipe roughness coefficients for sewage pumping mains are more related to flow velocities rather than to pipe material or condition of pipe because of the effects of build up of slime and grease on the inner walls of pipe. Recent experiments have shown that the roughness values are determined by the following relationship:

$$Ks = \alpha V^{-2.34}$$

Where Ks = roughness value (mm)

α = factor usually taken as 2.053 for upper bound design

V = mean velocity (averaged across the pipe cross section) for the actual flow through the pipe (m/s)

In metric terms, Hazen Williams' formula is given below:

$$V = 0.849\, C\, r^{0.63}\, s^{0.54}$$

Where V = velocity in meters/sec

C = Hazen Williams C-value

r = hydraulic radius in meters

s = hydraulic slope, in meters/meter

Typical C-values used for design are tabulated in Table 5.13.

Table 5.13 Friction Coefficients (C values)

Material	New pipes	Old pipes
Ductile Iron (lined)	130	90 - 110
Cast Iron	130	80 - 100
Steel (lined)	130	80 - 100

Valves and Fittings

A pumping main is a pressure pipeline, and its design differs in many respects from the design of a gravity sewer. The basic principles of structural design will equally apply, and to some extent the hydraulic design is similar, but in addition, as the pipeline will normally be laid to follow the ground contours (minimum cover generally about 1.0 m), provision must be made for the release of trapped air at high points, and for washing out at low points. Air valves suitable for use with sewage must be provided at all high points on the line, and may also be required at intermediate positions along long lengths of even gradient, activated carbon odour control units should be installed at the air valve chamber outlet.

A washout should take the form of a tee-junction and valve, and should discharge into a gravity sewer if possible. Valves and connecting pipelines should be at least 80 mm diameter. Where no suitable sewer is available, the washout may have to discharge to a specially constructed sump, which must then be emptied after use. The section of the rising main near the pumping station can sometimes be arranged so that a washout can discharge to the wet well of the pumping station; if so, the wet well must be of adequate capacity, or alternatively, if a second rising main is installed the pumps can be used to control the level in the well during the period of washing out.

Thrust Blocks and Anchorage

Thrust blocking should be provided on the pumping mains as necessary to prevent movement of pipe or appurtenances in response to thrust. Thrust blocking is required whenever the pipeline:

- Changes direction (for example, tees, bends, elbows, and crosses),
- Changes size such as at reducers,
- Stops such as at dead ends, or
- Connects to valves, at which thrust develops when closed.

Size and type of thrust blocking depends on:

- Maximum system operating pressure or test pressure,
- Pipe size,
- Appurtenance size,
- Type of fitting or appurtenance,
- Line profile (for example, horizontal or vertical bends), and
- Soil strength.

Forces due to expansion and contraction should not be allowed to reach valves, pumps, or other appurtenances that might be damaged by these forces. Appurtenances can be protected by making the connection between pipe and appurtenance with an expansion joint or sleeve coupling, or by providing anchor rings and thrust blocks of sufficient size and weight to prevent the forces from reaching the appurtenance to be protected.

Thrust blocks shall be made of grade 30 reinforced concrete.

5.4.7 Water Hammer

Water hammer is a series of pressure surges or waves resulting when a fluid in motion is forced to stop or change direction suddenly which may be heard emanating from pipe work.

The noise is caused mainly by shock waves which occur at the sonic velocity of sound when water flowing at high velocity is suddenly arrested by rapid closure of online valve(s), check valve(s) in normal operating condition and in common power failure case(s)

In many instances although audible sound is not present, water hammer effect could be observed by pressure gauge reading. Some of water hammer effects are:

- premature failure of valves,
- leakage at joints,
- loosening of supports, and
- burst of pipe.

The rigid pipes experience higher surge pressure than flexible pipes.

Surge Control Criteria

The sum of the operating pressure and the maximum positive pressure surge should not exceed the pipe's allowable pressure class. The following procedure should be followed:

1. Calculation of the theoretical pressure surge: Initially, this shall be carried out using the theoretical water hammer calculation. The surge is a function of elasticity of pipe, thickness, pipeline installation and the critical time closing period of valves.
2. For small diameters, choose pipelines with pressure class that can withstand the surge pressure.
3. For large diameters, if the theoretical surge is higher than the standard pipeline nominal pressure classes, surge suppression equipment must be used.

   In case of large pumps, inertia of pumping unit has an effect in minimizing surge pressure.
4. Check for the formation of negative pressures in the pipeline during surge events. Provide surge suppression or ensure that the pipeline can withstand the negative surge pressures.
5. Control measurements carried out at the installation at the time of commencement of operation should be compared with the values calculated previously. If the pressure surge is observed at an early stage, the risk of failure can be reduced by the installation of pressure surge reduction equipment.
6. The maximum negative pressure that the pipe can handle before buckling depends on the surrounding material, the pipe material and wall thickness. Pipes laid in well-compacted bedding will have a higher permitted negative pressure.

5.4.8 Electrical Design Criteria

All electrical works shall be carried out in accordance with the regulations and guidelines laid down by the Electricity Authority.

Standby generators will be included for in the design of pumping stations.

Duty and standby pumping cycles will be set up to ensure alternate pump operation takes place as standard.

Facilities will also be provided for the installation of a SCADA control system.

Standards

The electrical works will be designed in accordance to the following standards:

- General Technical Specification for Buildings, Electrical Installation, Part 3, 1996, Ministry of Public Works & Housing – Jordan
- Jordan Standards Specifications (JSS) – Jordan
- Requirements for Electrical Installations for Buildings (IEE Wiring Regulations), published by the Institute of Electrical Engineers – London (UK).
- International Electro-technical Commission (IEC) Standards as applicable
- American National Standard Institute (ANSI)
- Insulated Cable Engineers Association (ICEA)
- National Electrical Code (NEC)

- National Electrical Manufacturers Association (NEMA)
- Underwrites' Laboratories (UL)

Electrical Components

Power Transformer

Power transformer will be designed in accordance with ANSI or IEC Publication 726. The power transformer will operate at (11/0.4) KV or (33/0.4) KV and the capacity of the transformer will be determined after the detailed design of the plant. The transformer will be of outdoor type. The transformer will be supplied and erected by Jordan electric power company (JEPCO).

Stand-By Power Diesel Generator Set

In case of failure of the utility power source, the source of power is automatically transferred by auto transfer switch, and the emergency diesel generator will provide emergency power so as to keep continuous operation.

The Stand-by diesel generator will be designed, rated, assembled and installed in accordance with all applicable standards of ANSI, NEC, U.K. and NEMA.

The generator will be a complete integrated emergency generator system. The system consists of a diesel generator set with related component accessories and automatic transfer switch.

The capacity of the generator will be determined after the design and calculation the load of the pumping station. The generator set will be housed inside a generator room.

Automatic Transfer Switch (ATS)

Separate (ATS) panel will be designed and will comprise of:

- Two contactors, 4 pole with electrical and mechanical interlock
- Status lights indicate which contactor is ON
- Set of control terminals
- Set of load terminals
- Set of protecting fuse
- Front access hinged door with key lock

The (ATS) will be located at the electrical room near the main distribution board.

Main Distribution Board

Main Distribution Board (MDB) will be designed to feed power to the Motor Control Centres (MCC) and secondary distribution board. The MDB will be 3 phase, 400V, 50 Hz. This MDB will be fed by power from both the transformer and the diesel generator through the ATS. Power cable of appropriate size shall be designed to feed the MDB from the ATS.

The MDB will be designed to have a main circuit breaker (MCCB), main busbar, number of outgoing moulded case circuit breakers, in addition to all instruments and accessories needed for the board.

The MDB will be located inside the electric room. The dimensions of the MDB will be determined based upon the plant equipment power.

Secondary Distribution Board

3 phase, 400/230 volt, 50 Hz secondary distribution board will be designed to serve the loads of lighting, power, socket outlets, and power for mechanical equipments.

This distribution board will have a (100) A, 3 pole main isolator and a number of single or 3 pole outgoing breakers, to meet the requirements of lighting and power circuits.

The secondary distribution board will be supplied by power from the MDB through PVC/PVC, or XLPE/PVC cable with size suitable to the load and current designed.

This distribution boards will comply the BS 5486-part 13-1984 requirements or IEC-439 part 1 and 3.

Motor Control Centre (MCC)

Motor Control Centre (MCC) 3 phase, 400 volt, 50Hz will be designed to feed power and control the pumps motors. This MCC will have its own cabinet, main incoming breaker, outgoing breakers, bus bars, starters, protection and monitoring relays, instruments…. Etc. Power cables of appropriate size will feed these MCCs from the (MDB).

System Power Factor

The overall system power factor, including reactive power losses in transformers and other distribution equipment, will not be allowed to fall below 0.92 for the entire plant.

The location of power factor correction facilities will be such as to minimize distribution system power losses.

Cabling and Wires

Wherever possible, underground cabling will be used for inherent protection against fire and mechanical damage. All power, lighting, control and earthing cables will have copper conductors. Cables shall comply with ANSI or IEC 228, 287, 502 and wires will comply with ANSI or IEC 227, 502, 540.

Cables will be sized taking into account the following:

- System voltage and type of system (3-phase or 1 phase)
- Expected short circuit capacity
- Voltage drop
- Current rating
- Conditions of installations

The short circuit rating of cables will correspond to the clearing time of the associated protective device.

The voltage drop in cables will not be more than 4% based on continuous maximum current loading and rated voltage.

Fire Alarm System

The pumping stations will be provided by conventional or addressable type fire alarm system, in order to protect the operators and pumping station contents from fire hazards. The system will include alarm initiating, and signalling devices such as smoke and heat detectors, alarm bells, pull stations. The main control panel of the system will be installed in the administration building.

The fire alarm system design will be based on one of the following standards:

- BS 5839 Fire Defection and alarm Systems in Buildings
- BS 3116 Automatic Fire Alarm Systems in Building
- BS 5445 Specification for components of automatic fire detection System.
- (NFPA-72E) USA
- (IEC 839-1-4)

Earthing System

Earthing of electrical systems, equipment and structures in the installation will be designed to the relative standards.

Instrumentation Control and Automation System

The pumping stations will be provided with instrumentation control and automation system (ICA) to enable the control of the operation of the pumping station facilities, such as operational status equipment, water levels, flow rates, etc., by using central monitoring control system in the administration building. The system will consist of PLC. I/O cards, modems, instrumentation wiring…etc.

6. TOPOGRAPHICAL SURVEY OF MAIN SEWER SYSTEM

6.1 Introduction

The field survey works started at an early stage of this project. The survey works included a topographic survey of 250 km of main and sub-main sewer systems (all sewers with diameters equal to or greater than 300 mm, in addition to the collector pipes with diameters 200 mm).

The survey works were conducted to collect the data required for building the hydraulic model, since the identified 250 km of main and sub-main sewers are the ones that were ultimately represented in the hydraulic models.

The field survey works also included surveying of approximately 50 km of proposed trunk sewer mains route. Work under this activity included taking levels at 20 meter intervals and documenting the landmarks (streets, wadis, etc) that the proposed lines pass through, within a width of 30 meters.

6.2 Benchmarks and Triangle Points

The field surveying works were started by obtaining bench marks from the Royal Geographic Center. These benchmarks were used to define all elevations within the study area and are shown in Table 6.1.

Table 6.1 List of Benchmarks Obtained from the Royal Geographic Center

Benchmark	Elevation
JZ 21	578.17
JZ 16	539.584
ZW 4	604.389
ZW 5	582.811
ZW 7	674.621
ZW 2	528.43

Additionally, Survey Triangulation Points that fall within the required survey area were obtained from the Land and Survey Department to connect the project with the national Jordanian coordinates. The obtained triangulation points are listed in Table 6.2

Table 6.2 List of Triangulation Points Obtained from the Land and Survey Department

Triangulation Point	Northing	Easting
ZR-74	168,165.334	256,194.694
ZR-43	169,910.470	249,852.550
ZR-11	173,086.491	256,813.540
ZR-203	158,353.340	247,866.370
ZR-79	167,774.940	261,088.610

Triangulation Point	Northing	Easting
ZR-209	185,107.398	254,243.673
ZR-6	173,856.560	253,858.190
ZR-204	157,833.300	249,093.330
ZR-11	173,086.490	256,813.540
TR-950	178,664.820	260,944.560
FA-215	171,146.770	271,441.580
AC-1705	166,819.222	267,501.464

6.3 Surveying Works

The field surveying works consisted of the following main activities:

1. The survey of existing manholes on the identified 250 km. Works under this activity included defining the location of each manhole (x, y and z coordinates), opening the manhole cover, measuring the invert levels of inlet and outlet pipes and describing the situation of each manhole including cover, steps, sediments, etc. The identified 250 km are shown in Figure 6.1.
2. The survey of about 50 km of the route of proposed trunk sewer mains. Work under this activity included taking levels at 20 meter intervals and documenting the landmarks (streets, wadis, etc) that the proposed lines pass through, within a width of 30 meters.

Based on obtained benchmarks and triangulation points, secondary bench marks and traverse have been created to cover the entire project area.

Each surveyed sewer line was categorized according to diameter and numbered within the category of its diameter, in order to obtain a unique number for each sewer line. Additionally, manholes were given numbers based on their line number and an additional serial number allocated per line.

The coordinates of each manhole were computed from the base map, and the tentative locations were identified in the field using GPS differential instruments. Once a manhole was located the cover was opened and invert levels and other required information were recorded.

The manhole survey works required significant time and effort than anticipated at site to find, identify and open the required manholes to collect the required data. Nevertheless, with all the efforts and attempts including; several site visits, as built drawings verification and WAJ/Zarqa assistance, there was a considerable number of manholes that could not be opened or not found. However, most of the important required manholes have been found and recorded. The remaining manholes, as built drawings have been used to complete the data and where as built drawings are not available, interpolation between the surveyed manholes was used.

The manholes that could not be found can be attributed to one or more of the following reasons:

1. Some sewer lines were buried deep below high constructed fill, embankment, streets, etc;

2. Some sewer lines were constructed within private boundaries, and as such no access was allowed to even search for the required manholes; and
3. Some sewer lines have been re-aligned and moved from their original location without updated record drawings that show the new location.

Additionally, there was a number of manholes which were found but could not be opened for several reason, as follows:

1. Some manholes have not been opened for decades and they will require covers to be broken in order to access them
2. Some had flipped over covers and they will require covers to be broken in order to access them
3. Some were covered by a large concrete block or a pile of stones or concrete to prevent cover removal.
4. Some were covered by street asphalt.

For these manholes, coordinates and levels of the covers (x, y and z) were surveyed, but the invert levels of inlet and outlet pipes could not be taken.

Furthermore, the important unopened manholes with a diameter above 200 mm were identified (Approximately 76 manholes). With a representative from WAJ / Zarqa, these manholes were revisited and the reasons for not being opened have been identified. Table 1 in Appendix 6 is a summary of the findings of these manholes.

The summary of the number of surveyed, could not be opened and not found manholes is shown in Table 6.3.

Table 6.3 Manhole Survey Summary

Zone	Surveyed (No.)	Could Not Be Opened (No.)	Not Found (No.)	Total (No.)
EAST ZARQA	1302	342	311	1955
WEST ZARQA	2169	510	944	3623
Total (No.)	3471	852	1255	5578

The layout of the main surveyed sewer system manhole locations and status are shown in Figure 6.2.

Survey Benchmarks and surveyed trunk mains are shown in Figure 6.3.

6.4 Surveying Data

The data obtained from the surveying works includes the following:

1. An AutoCAD file containing:
    - Network layout with coordinates;
    - Pipeline numbers with diameters; and
    - Manhole numbers.
2. An excel sheet for the manholes for each pipeline containing:

- Manhole numbers;
- Easting and Northing for each manhole;
- Elevation of each manhole;
- Inlet and outlet invert levels at each manhole, and
- Invert level of pipes connected to the manhole.

3. An excel sheet for each manhole containing:
    - Manhole number;
    - Diameters of connecting pipes;
    - Condition of cover and frame;
    - Condition of iron steps; and
    - Sediments in the manhole.

As previously mentioned, a field survey was conducted along the proposed alignment of the new proposed trunk main sewers. Profiles were made for about 50 km of proposed trunk lines, with levels taken at 20 meter intervals. All land marks within a 30 m width at each interval were documented. Profiles were produced for the proposed mains of new served areas such as Hai al-Batrawi, Hai al-Ahmad, Hai Nassar, Dhuleil, Ghareisa and Umm Sulleih. The summary of surveyed main trunks line routes are shown in Table 6.4

Table 6.4 Summary of Proposed Main Trunk Line Land Survey

Trunk Line Route	distance (km)
Wadi Aldlial	18.956
AlKherbeh AlSamra	1.963
Wadi Garesa - AlSokhna	15.463
Wadi al Sokna	5.088
Wadi al Batrawi	5.053
Wadi Shnelar	1.401
Wadi Berin 1	1.543
Wadi Berin 2	0.646
Wadi Berin 3	2.282
Total Surveyed (km)	**52.395**

Detail survey data are attached in a CD in Appendix 6.

7. FLOW MONITORING

7.1 Introduction

As per the Terms of Reference (TOR) for this Project, the Consultant was required to monitor flow in 10 stations using Flo-Dar flow measurement equipment and data loggers for the calibration of the hydraulic model. However ,the MWH Team has deemed it more useful to have 12 monitored stations instead of the proposed 10. Further, owing to tight schedule of works, 4 flow meters were provided instead of the required 2, in order to accelerate measurements. The flow monitoring data from these 12 stations will be used to calibrate the hydraulic model during the hydraulic analysis stage of works.

7.2 Flow Monitoring Location Selection and Preparation

The locations of the measurement stations were determined in agreement with WAJ and the local operators in Zarqa. The two main criteria upon which the decisions relied were the monitoring of critical flow sections and problematic sections of pipes. The locations of the 12 flow monitoring stations are shown in Figure 7.1.

- MH-2: The location of this monitoring station is south-east of WZPS on 400mm diameter sewer that serves Hai Ma;asoum.
- MH-3: The location of this monitoring station is south of WZPS on 240mm diameter sewer that serves Hai al-Basateen.
- MH-4: The location of this monitoring station is at Msheirfah-Russeifa on 800mm diameter sewer that serves Hutteen Camp and surrounding areas, in addition to part of Marka-Amman.
- MH-5: The location of this monitoring station is near Zarqa-Russeifa main road on 800mm diameter sewer that serves Russeifa and parts of Amman that drain through Zarqa wastewater system.
- MH-6: The location of this monitoring station is at Amman-Zarqa Highway on 700mm diameter sewer that serves parts of Marka and Nasr in Amman.
- MH-7: The location of this monitoring station is between Amman and Russeifa on 800mm diameter sewer that serves parts in Tareq and Basman in Amman.
- MH-8: The location of this monitoring station is between Amman and Russeifa on 700mm diameter sewer that serves parts in Shafa Badran and Jubaiha in Amman.
- MH-9: The location of this monitoring station is near EZPS on 300mm diameter sewer that serves Hashemiyah.
- MH-10: The location of this monitoring station is at EZPS on 800mm diameter sewer that serves east parts of Zarqa.
- MH-11: The location of this monitoring station is at Hashemiyah on 500mm diameter sewer that serves Zarqa Free Zone and Hashemiyah University.
- MH-12: The location of this monitoring station is at main Jaish Street in Zarqa on 700mm diameter sewer that serves central commercial part of Zarqa city.

- WZPS: The location of this monitoring station is at WZPS that serves Russeifa, west parts of Zarqa, in addition to north-west parts of Amman that drain within Zarqa wastewater system.

WAJ operators were instrumental in the fulfilment of this task, as they provided assistance in cleaning the manholes that contained large amounts of sediments using water Jet Cleaning equipment. This procedure was necessary to ensure the accurate measurement of flow, since it depended on the shape of the pipe as well as the free discharge of flow.

Some of the initially assigned manholes were flooded, and as such it was not possible to monitor flows passing through them. In these situations, other representative manholes were selected to carry out the flow measurement.

7.3 Flow Monitoring

Flows at each of the selected stations were measured continuously over a period of 7 days (at 5-minute intervals), ensuring that the water supply period in areas where water distribution is rationed (such that water from the municipality is only available for a day or two each week) is covered. Data loggers were checked regularly during the monitoring period to ensure correct functioning and were moved if problems were encountered.

Average daily flows and diurnal peak and minimum flows were estimated using the continuously monitored flows to enable the MWH Team to estimate the actual daily peak and minimum flow factors. Additionally, measurements of flows during rainy periods were conducted to monitor the amount of inflows into the sewer networks.

7.4 Flow Monitoring Data

The measurement data was received for each monitoring station once the monitoring was completed. The received data shows the manhole reference number, pipe ID, location and flow data at 5 minute intervals for the full seven monitoring days. The flow data obtained includes velocity, water level, battery voltage, and flow.

A summary of the daily flow averages over the one-week monitoring period at each of the monitored manhole is shown in Table 7.1. All manholes were monitored for 7 days, but flow data for MH-3 was recorded for three days only due to flow monitor fault. More details about flow monitoring data are shown in Appendix 7.

Table 7.1 Summary of Daily Flow Averages Over 1 Week Monitoring Period

Manhole ID	Min Daily Flow (m^3/hr)	Max Daily Flow (m^3/hr)	Avg. Daily Flow (m^3/hr)	Avg total daily flow (m^3/day)
MH-2	48.02	413.64	161.58	3,877.98
MH-3	22.31	82.62	45.48	1,091.56
MH-4	42.79	655.17	217.83	5,227.90
MH-5	237.99	5,583.89	1,926.23	46,229.50
MH-6	26.65	534.99	191.66	4,599.76

Manhole ID	Min Daily Flow (m^3/hr)	Max Daily Flow (m^3/hr)	Avg. Daily Flow (m^3/hr)	Avg total daily flow (m^3/day)
MH-7	0.00	633.75	89.41	2,145.78
MH-8	143.92	493.35	238.37	5,720.81
MH-9	11.45	154.53	58.31	1,399.34
MH-10	188.42	980.49	505.98	12,143.49
MH-11	33.89	305.01	119.49	2,867.72
MH-12	61.73	347.26	164.70	3,952.88
Inlet to WZPS	891.77	3,824.14	2,445.55	58,693.20

Flow monitoring data analysis will be presented in the Hydraulic Analysis Report.

8. WASTEWATER MANAGEMENT STRATEGY

8.1 Introduction

To meet the needs of the Zarqa wastewater system over the proposed project area through the year 2035, improvements to the existing systems will be required. In this section, alternatives to improve and extend these utility systems are identified to be subjected to later evaluation. The resulting information will be used to select a recommended long-term plan for the expansion and reinforcement of the wastewater systems over the planning horizon.

8.2 Main Wastewater Collection Zones

Based on an investigation of the existing drainage pattern, the topography, the existing wastewater facilities and planned growth of the service area over the planning period, the study area is divided into five main wastewater collection zones each draining into an existing or a proposed pumping station as illustrated in Figure 8.1.The five zones are:

1. West Zarqa Pumping Station Zone: This zone includes the areas that drain to the existing WZPS. The main service areas of this zone are the old developed parts of west Zarqa, new extension areas of Zarqa (such as Hai Umm Bayadhah, Hai al-Duwaik, Hai al-Falah and parts of Hai al-Madinah al-Munawwarah), Russeifa and the northeast areas of Amman (parts of Marka, Tareq, parts of Shafa Badran, parts of Jubaiha and parts of Nasser) that currently drain to this pumping station;
2. East Zarqa Pumping Station Zone: This zone includes the areas that drain towards the existing EZPS. The main areas of this zone are the currently served areas of east Zarqa and al-Hashemiyah and new extension areas of Hai al-Batrawi in Zarqa in addition to the new development area of King Abdullah Bin Abdul Aziz City;
3. Al-Sukhneh Pumping Station Zone: This zone includes the areas that drain towards the confluence of Zarqa River and Wadi Dhuleil. A proposed pumping station at the confluence of the two wadis would be able to serve the town of Sukhneh, new developed neighbourhoods west of Zarqa (such as Hai al-Ameera Haya, Hai al-Hashemi, Hai al-Bustan, Hai Shomar, Hai al-Jabr, Hai Nassar, Hai al-Ahmad, Hai Makka al-Mukarramah and parts of Hai al-Madinah al-Munawwara). It also includes communities along Wadi Zarqa and upstream of Sukhneh such as Abu Zeighan, Salheyah, Ghareisa and Umm Suleih;
4. Wadi Zarqa Zone: This zone includes the areas in Birein and al-Hashemiyah districts that drain downstream of the proposed al-Sukhneh Pumping Station. This zone includes mainly the staggered communities located in the northwestern part of Zarqa Governorate, such as Birein, Umm Rummaneh, Maqam Eisa, al-Khillah, Sarout, al-Alouk and Dogara.
5. Wadi Dhuleil Pumping Station Zone: This zone includes the eastern communities that drain into Wadi Dhuleil. The main communities that could be served in this zone by a proposed pumping station near the As Samra WwTP include Dhuleil, Khirbet al-Samra, Hallabat in addition to the town of khalediyah in the Mafraq governorate.

8.3 Extension Areas

The ToR asked that all communities within Zarqa Governorate be included in the study for extension of wastewater collection services.

Accordingly, and based on our findings regarding the extent of the existing wastewater network, a layout of the proposed wastewater network extensions was prepared that covers the unserved areas within the main Zarqa zones described above, as shown on Figure 8.2. The proposed networks were first delineated on the most updated topographical maps (scale 1:25,000) and then verified on site.

The extension service areas can be classified into two main categories:

8.3.1 Extension Areas that Drain into Existing System

This category includes all the neighbourhoods in Zarqa, Russeifa and al-Hashemiyah municipalities that drain into the existing systems. The main service extension areas within this category are:

a. Hai Batrawi;
b. Hai al-Madinah al-Munawwarah (partially);
c. Hai Umm Bayadhah;
d. Hai al-Duwaik;
e. Hai al-Falah;
f. Hai al-Rasheed al-Shamali;
g. Hai al-Tatweer al-Hadari;
h. Hai al-Jraiba;
i. Abu Sayyah area;
j. King Abdullah Bin Abdul Aziz City;
k. Al-Majd City; and
l. Networks to fill gaps (scattered in various areas).

8.3.2 Extension Areas that Drain into New Pumping Stations / WwTP

This category includes all the communities in Project Study area that will need new pumping stations to connect to the existing system or that drain into new treatment facilities. The communities of this category are further classified by areas that drain into a pumping station as follows:

1) Central communities that drain into the proposed Sukhneh pumping station. These include:

a. Hai al-Bustan;
b. Hai Shomar;
c. Hai al-Hashemi;
d. Hai al-Jneineh;
e. Hai al-Ameera Haya;
f. Hai Nassar;
g. Hai al-Jabr;
h. Hai al-Ahmad;
i. Hai Makka al-Mukarramah;

j. Al-Sukhneh town;

k. Salheyah;

l. Abu al-Zeighan;

m. Hai al-Madinah al-Munawwarah (partially);

The Sukhneh pumping station will only be required in the event that all treatment is carried out at As Samra WWTP. In this even the pumping station would deliver either to WZPS or EZPS.

2) West communities that could be served either by gravity to the proposed Wadi Zarqa Treatment Plant, or by sewage force main from a proposed Wadi Zarqa pumping station back to the proposed Sukhneh Pumping Station. These communities include:

- Maqam Eisa;
- Umm Rummaneh;
- Birein;
- al-Khillah;
- al-Alouk;
- Sarout;
- Ghareisa;
- Umm Suleih; and
- Dogara.

Another pumping station will be required to deliver the flows from the small community of al-Alouk to the Wadi Zarqa pumping station or to Wadi Zarqa treatment plant.

3) East communities that could be served by a sewer trunk line along Wadi Dhuleil and force main from a proposed pumping station north of As Samra WWTP up to the as-Samra Wastewater Treatment Plant. The communities are:

- Dhuleil; and
- Khirbet al-Samra.

8.4 Main Wastewater Options

Based on an investigation of the existing drainage pattern, the topography and planned growth of the service area over the planning period, the following alternative wastewater collection and pumping scenarios have been identified:

- **Option 1** - Treatment at New Wadi Zarqa WwTP
- **Option 2** - Treatment at As Samra WwTP - Conveyance of Sukhneh & Wadi Zarqa Zones to WZPS
- **Option 3** - Treatment at As Samra WwTP - Conveyance of Sukhneh & Wadi Zarqa Zones to EZPS
- **Option 4** - Treatment at As Samra WwTP, Local Treatment for Birein Communities, Conveyance of Sukhneh Zone to EZPS

- **Option 4a** - Treatment at As Samra WwTP, Local Treatment for Birein Communities, Conveyance of Sukhneh Zone to EZPS, Colection of Hai Ameera Haya at Sukhneh PS

- **Option 5 -** Treatment at As Samra WWTP, Local Treatment for Birein Communities, New WZPS in Sukhneh & New ZPS

These options are illustrated in Figure 8.3 through Figure 8.8

Several other secondary options such as using more than one pumping station to subdivide the identified main collection zone will be evaluated later under these four main options.

APPENDIX 1 LIST OF COLLECTED DATA

Table 1 Data Collected by MWH Team to Date

Type	No	Name/Title
Documents	1	WAJ Network Operation Report
	2	GTD WW Prices Analysis
	3	Amman-Zarqa Wastewater Master Plan Update, Final Report, 2006 (by MWH)
	4	Construction of WW Collection and Treatment Plant for Five Municipalities in Jerash area and Pumping Station and Force Main in Sukhna Area, Package 1 Tender Documents (by Engicon)
	5	Wastewater Collection, Treatment and Effluent Reuse for Jerash and Sukhna Areas, Package 2 Tender Documents (Sukhna Collection Network)
	6	Feasibility Study, Detailed Design and Preparation of Tender Documents for Wastewater Network Mains and Sub-mains and House Connections in Zarqa Governorate, Variation Order No. 1, Final Report (Tender M/14/2003/Special works, prepared by ACE)
	7	Zarqa River Problem Analysis Report by OPTIMA
	8	Spacial Distribution and Environmental Implications of Lead and Zinc in Urban Soils and Street Dusts Samples in al-Hashimeyeh Municipality.
	9	Hydrological Modelling of Ungauged Wadis and Arid Environments Using GIS: a Case Study of Wadi Madoneh in Jordan
	10	GIS-based Evaluation of the Groundwater Vulnerability in the Russeifa Area, Jordan.
	11	National Water Master Plan, Amman, 2004.
	12	Conceptual Design Report for the Construction of a Closed Wastewater Canal of Wadi Zarqa, by CEC, 2009.
	13	The Wastewater Master Plan, Feasibility Study and Preliminary Engineering Design for the Rehabilitation, Expansion and Development of the Wastewater Systems of the Municipalities and Communities within the Watershed of the Amman-Zarqa River Basin, by Harza, 1997.
	14	Zarqa Billing Data
	15	Country Concept Paper, by MCA-Jordan, 2008
	16	The National Water Master Plan, by the Ministry of Water and Irrigation, the Hashemite Kingdom of Jordan and German Technical Cooperation (GTZ), 2005.

	17	The Feasibility Study and Design for the Wastewater Collection, Treatment and Effluent Reuse for the West Jerash and Sukhnah Area, by C. Lotte & Associati and Engicon, 2007.
	18	WZPS year 2009 flow and operation data
	19	EZPS year 2009 flow data
	20	Zarqa Governorate Water Billing Data (years 2006 – 2009)
	21	Operation Issues and Problems for Networks and Facilities
	22	Biological Baseline Assessment for the JOSCO Oil Shale Concession Area. This report was prepared in 2009 for a number of governorates within the kingdom, including the Zarqa Governorate.
	23	Social and Health Impact Assessment (ESHIA), Social Impact Assessment (SIA). This report was issued in 2009 covering a number of governorates within the kingdom including the Zarqa Governorate.
	24	Archaeological & Cultural Heritage Study of Exploration and Drilling in Jordan. This report was issued in 2009, covering a number of governorates within the kingdom including the Zarqa Governorate.
	25	Detailed climate data (monthly averages of the past 5 years: 2004 – 2008) concerning the project area has been obtained from the Jordanian Department of Meteorology. Data was obtained from a total of two meteorological stations falling within the Zarqa Governorate.
	26	Population and employment data.
	27	Construction of WW Collection Networks for Mazar Area, Two Force Mains and Two Pumping Stations, February 2009, Cost Data.
	28	Construction of Sewerage Pumping Station, Force Main and Wastewater Collection Networks for Mu’ta Area, Cost Data.
	29	Construction of Wastewater Collection Networks for Adnaniyyeh, Merwed and Median Areas, Two force mains and two pumping stations, February 2009, Cost Data.
	30	GTD Yearly Report, 2008
	31	The Integrated Environmental Management of the Zarqa River: A Proposal for the Restoration of the Zarqa River.
	32	Zarqa River Basin Wastewater and Solid Waste Treatment Project.

	33	Environment Profile of Jordan, 2006
	34	Demographic and Socioeconomic Information from DoS.
Drawings	1	Schneller Camp, Project No SH-S2 by Habib & Associates (1982) – plans & profiles
	2	Jabal El Shamali, Project No 129/91 by ACE (1991) - plans
	3	Schneller Camp, Project No 72/85 SHN-1 by Habib & Associates (1985) - profiles
	4	Schneller Camp 2, Project No 85/99 by Habib & Associates (1987)- plans and profiles
	5	Jabal El Shamali (ZQ-III), Project No 130/91 by ACE (1993) – plans & profiles
	6	Jabal El Shamali (IIA), Project No 129/91 by ACE - profiles
	7	Al Hashimiya, Project No ZQ 73/89 by Jardaneh (1990) - plans
	8	Jabal El Shamali (ZQ-III), Project No 130/91 by ACE (1993) - plans
	9	Jabal Al-Bayan (ZQ-III), Project No ZQ-III, by Habib & Associates (1988) - plans
	10	Zarqa-Rusiefa, Project No 6A, by Jouzy & Partners (1986) - plans
	11	Zarqa-Rusiefa, Project No 7C, by Jouzy & Partners (1986) – plans & profiles
	12	Zarqa-Rusiefa, Project No 7A, by Jouzy & Partners (1987) – plans & profiles
	13	Zarqa-Rusiefa, Project No 7B, by Jouzy & Partners (1985) – plans
	14	Zarqa-Rusiefa, Project No ZQII by Habib & Associates - plans
	15	Zarqa-Rusiefa, Project No 3A by Jouzy & Partners (1984) – plans
	16	Al-Hashimiya Housing & North Hashimiya, Project No 60/90, by Jardaneh (1990) – plans & profiles
	17	Zarqa-Rusiefa, Project No 6B, by Jouzy & Partners (1988) – plans & profiles
	18	Awajan, Project ZQ-II, by Habib & Associates - profiles
	19	Al Batrawi I, Project 126/91, by Arabtech Jardaneh (1991) – plans & profiles
	20	North Rusiefa, Project S.C4-1, by Arabtech Jardaneh (1994) –

Drawings		plans & profiles
	21	Zarqa Free Zone, Project 131/94, by Arabtech Jardaneh (1995) – plans & profiles
	22	Zarqa-Rusiefa, Project 10/205, by Jouzy & Partners (1987) – plans
	23	Zarqa - Rusiefa, Project No 10, by Jouzy & Partners (1987) – plans
	24	Zarqa - Rusiefa, Project No 3B, by Jouzy & Partners (1987) - profiles
	25	Jabal Faisal, Project No 131/91, by ACE (1994) – plans & profiles
	26	Project No 132/94, by Arabtech Jardaneh (1994) - profiles
	27	Zarqa-Rusiefa, Project No 3A by ACE (1990) - plans
	28	Wadi Al-Hajar, Project ZQ-1, by Habib and Associates (1988) – plans & profiles
	29	Al Hashimiya LS, Project 4G/88/694/4 (1988) - plans
	30	Al Hashimiya PS, Project 131/96 (1987) - plans
	31	Al Batrawi ZQ VI, Project 127/9, by Arabtech Jardaneh (1992) – plans & profiles
	32	Al Zahrawi, Project No 74/89, by Jardaneh (1990) – plans & profiles
	33	Al Batrawi, Project No 128/91, by Arabtech Jardaneh (1991) – plans & profiles
	34	Birin Rehabilitation Center, Project No 68/92, by Arabtic Jardaneh (1992) - plans
	35	Zarqa Rusiefa, Project No 4-B, by ACE – plans & profiles
	36	Zarqa-Rusiefa (Al Jabal Al-Abyad), Project No ZQ-III, by Habib & Associates - plans
	37	Zarqa-Rusiefa, Project 4A, by ACE - plans
	38	Zarqa-Rusiefa (Wadi Al Hajar), Project No ZQ-I, by Habib & Associates - plans
	29	Zarqa-Rusiefa, Project ZQ-I, by Habib & Associates - plans
	30	Zarqa-Rusiefa, Project S-C4-5 by Arabtech Jardaneh - plans
	31	Zarqa-Rusiefa (Al Hashmiyeh Housing), Project ZQ-IX, by Arabtech Jardaneh - plans

Drawings	32	Zarqa-Rusiefa (Al Zawahri), Project ZQ-IV, by Jardaneh – plans
	33	Zarqa-Rusiefa (North Ruseifa), Project 7B - plans
	34	Al Batrawi II, Project s-c5-12, by Arabtech Jardaneh - plans
	35	Al Batrawi III by Arabtech Jardaneh - plans
	36	Zarqa-Rusiefa, Project 4B, by ACE - plans
	37	Al Batrawi Housing, Project 4/90, by Jardaneh (1990) - plans
	38	Zarqa-Rusiefa, Project 5, by Jouzy & Partners (1987) – plans & profiles
	39	Zarqa-Rusiefa, Project 7B, by Jouzy & Partners (1987) – plans
	40	Al-Batrawi Housing, Project 4/sh/90, by Jardaneh (1990) – plans & profiles
	41	Yajuz / Jafar Tayyar Wastewater Collection Networks, Project JF, by Engicon (2004) - plans
	42	Sukhnah Collection Network Package II Drawings
	43	Jerash Package 1, Aprile 05: Part I (WWTP Final Drawings); Part II (PS + Force Mains + Final Drawings)
	44	Zarqa Sewer Network
	45	Zarqa Water Network
	46	King Abdullah City Drawings
	47	Topographic Maps of scale 25,000
	48	Land and Survey Maps
	49	Planning (land use) maps for the municipalities of Zarqa, Russeifa, al-Hashemiyah and Sukhneh
	50	Sukhnea Collection System and Pumping Station by Engicon, 2006 (proposed design drawings)
	51	Miscellaneous Wastewater Networks in Zarqa (Hshemiyah, Russeifeh, Massoum, etc) by Engicon – Proposed Design Drawings.
	52	Conceptual Design of Closed Wastewater Canal of Wadi Zarqa by CEC, 2009 – Proposed Design Drawings.
GIS Data	1	Jerash GIS Data
	2	Zarqa GIS Data, Basemap and Sewer Merge.

APPENDIX 2 WZPS YEAR 2009 OPERATIONAL DATA

Table 1 West Zarqa Pumping Station Hourly Pumping Log, Summer 2009 (Flows are given in m^3/hour)

Time (Hour)	01/06/2009	02/06/2009	03/06/2009	04/06/2009	05/06/2009	06/06/2009	07/06/2009
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0	3008	2540	2715	2918	2882	2690	2193
1	3070	2246	1934	2708	2774	1767	2053
2	2444	1069	1561	916	1687	1797	2000
3	1339	1795	1574	1201	901	2169	1206
4	1299	1020	1633	1013	1270	1277	1161
5	1081	0	1040	1220	1155	1250	967
6	481	503	1131	1226	1213	1125	963
7	1217	1171	1034	1139	1199	1020	1318
8	1221	1167	1500	1101	1162	1001	1312
9	1596	1619	1504	2125	898	2298	1108
10	2484	2400	1508	2102	1984	2210	2430
11	2078	2070	2504	2041	1839	2044	3324
12	2737	2466	2426	2990	2855	2314	2044
13	2400	2908	2058	2933	3281	2101	3128
14	2983	2441	2966	2827	3016	2420	2284
15	2695	2899	2946	2777	2812	3222	3080
16	2732	2959	2933	2715	2876	2952	2922
17	2198	2893	2819	2700	2865	2984	2875
18	2905	2843	2824	3041	3111	3069	2792
19	2796	2797	2843	3210	3066	3028	1976
20	2777	2735	2777	3011	2999	2998	3004
21	0	2741	2765	3189	2821	2969	2265
22	0	2650	2682	2881	2983	2870	2097
23	3171	2559	2636	2793	2778	2998	2225
Average	**2030**	**2104**	**2180**	**2282**	**2268**	**2274**	**2114**

Table 2 West Zarqa Pumping Station Hourly Pumping Log, Winter 2009 (Flows are given in m^3/hour)

Time (Hour)	07/12/2009 Monday	08/12/2009 Tuesday	09/12/2009 Wednesday	10/12/2009 Thursday	11/12/2009 Friday	12/12/2009 Saturday	13/12/2009 Sunday
0	2466	1075	1955	2002	2991	2013	2031
1	3064	1860	2132	1967	2866	2071	1959
2	2665	875	1135	1104	2789	2005	2126
3	2656	1070	1062	2091	1023	2029	1132
4	947	1075	1090	1119	984	2061	2110
5	1913	1080	1005	1079	1002	1028	1101
6	2001	1159	1011	1101	977	1004	1062
7	1102	999	1156	1117	1090	2102	1968
8	1937	1829	1950	2203	1156	1135	2115
9	2010	1809	1985	2084	2165	2177	2055
10	1995	2064	2074	2060	2123	1003	2105
11	2033	2070	0	2065	1975	2130	3078
12	2030	2020	2155	2053	3036	3101	2130
13	2902	2722	2948	2211	3052	3035	3080
14	2850	2650	3017	2954	2892	2955	3750
15	2900	2636	2950	3006	2806	2860	3015
16	2890	2773	2915	2975	2927	2811	2974
17	2950	2716	2911	2920	2923	2933	2979
18	3060	2663	2879	2911	2910	2910	2855
19	2895	2613	2899	3037	2943	2983	2872
20	2820	2784	2017	3001	2889	2922	2847
21	2678	2772	1941	2898	2855	2957	1994
22	2438	2009	2005	1959	2931	3041	2978
23	2498	1980	2021	1991	2842	2919	2041
Average	**2404**	**1971**	**1967**	**2163**	**2339**	**2341**	**2348**

Table 3 West Zarqa Pumping Station Daily Log for the Year 2009

Part I							
Date	m^3/day	Date	m^3/day	Date	m^3/day	Date	m^3/day
01/01/2009	46870	17/02/2009	45745	05/04/2009	52726	22/05/2009	55404
02/01/2009	45494	18/02/2009	47952	06/04/2009	49028	23/05/2009	56490
03/01/2009	45222	19/02/2009	50566	07/04/2009	52103	24/05/2009	51971
04/01/2009	42173	20/02/2009	53594	08/04/2009	55711	25/05/2009	50224
05/01/2009	43705	21/02/2009	47271	09/04/2009	56394	26/05/2009	52481
06/01/2009	46443	22/02/2009	46073	10/04/2009	59000	27/05/2009	51026
07/01/2009	47806	23/02/2009	46619	11/04/2009	59642	28/05/2009	53398
08/01/2009	50188	24/02/2009	45399	12/04/2009	55952	29/05/2009	54030
09/01/2009	52020	25/02/2009	44659	13/04/2009	53685	30/05/2009	56465
10/01/2009	50317	26/02/2009	48121	14/04/2009	55023	31/05/2009	52531
11/01/2009	48583	27/02/2009	46339	15/04/2009	54306	01/06/2009	49990
12/01/2009	47813	28/02/2009	49061	16/04/2009	54499	02/06/2009	52440
13/01/2009	47159	01/03/2009	16721	17/04/2009	56354	03/06/2009	51820
14/01/2009	46477	02/03/2009		18/04/2009	59487	04/06/2009	54807
15/01/2009	50256	03/03/2009	35955	19/04/2009	56394	05/06/2009	54242
16/01/2009	49519	04/03/2009	51248	20/04/2009	59200	06/06/2009	53460
17/01/2009	50109	05/03/2009	56290	21/04/2009	59642	07/06/2009	50549
18/01/2009	46743	06/03/2009	54881	22/04/2009	55902	08/06/2009	50212
19/01/2009	44429	07/03/2009	54210	23/04/2009	53685	09/06/2009	51307
20/01/2009	45947	08/03/2009	51536	24/04/2009	55023	10/06/2009	51381
21/01/2009	46113	09/03/2009	45885	25/04/2009	54306	11/06/2009	52122
22/01/2009	50338	10/03/2009	48768	26/04/2009	52726	12/06/2009	55449
23/01/2009	46551	11/03/2009	52416	27/04/2009	50088	13/06/2009	52557
24/01/2009	47225	12/03/2009	55741	28/04/2009	52217	14/06/2009	54803
25/01/2009	46477	13/03/2009	54364	29/04/2009	56711	15/06/2009	52492
26/01/2009	45285	14/03/2009	51365	30/04/2009	54108	16/06/2009	52372
27/01/2009	45151	15/03/2009	49933	01/05/2009	56003	17/06/2009	52570
28/01/2009	46458	16/03/2009	52583	02/05/2009	56407	18/06/2009	57580
29/01/2009	48338	17/03/2009	53062	03/05/2009	58630	19/06/2009	57060
30/01/2009	47698	18/03/2009	53260	04/05/2009	52621	20/06/2009	56255
31/01/2009	57704	19/03/2009	55160	05/05/2009	56349	21/06/2009	51987
01/02/2009	40940	20/03/2009	54255	06/05/2009	51324	22/06/2009	52655
02/02/2009	43302	21/03/2009	55395	07/05/2009	54917	23/06/2009	54327
03/02/2009	45395	22/03/2009	50660	08/05/2009	58698	24/06/2009	55451
04/02/2009	48348	23/03/2009	47696	09/05/2009	56114	25/06/2009	58984
05/02/2009	48285	24/03/2009	54286	10/05/2009	52117	26/06/2009	57736
06/02/2009	49802	25/03/2009	49238	11/05/2009	50741	27/06/2009	57396
07/02/2009	49722	26/03/2009	55881	12/05/2009	53861	28/06/2009	56181
08/02/2009	46314	27/03/2009	57498	13/05/2009	54283	29/06/2009	56896
09/02/2009	46201	28/03/2009	56566	14/05/2009	56748	30/06/2009	56098
10/02/2009	52156	29/03/2009	54364	15/05/2009	57174	01/07/2009	58184

11/02/2009	46286	30/03/2009	51365	16/05/2009	56902	02/07/2009	59640
12/02/2009	50901	31/03/2009	49933	17/05/2009	54905	03/07/2009	58985
13/02/2009	52834	01/04/2009	54046	18/05/2009	56369	04/07/2009	59246
14/02/2009	50633	02/04/2009	58500	19/05/2009	53948	05/07/2009	57945
15/02/2009	46074	03/04/2009	55708	20/05/2009	53366	06/07/2009	56021
16/02/2009	44451	04/04/2009	57702	21/05/2009	54591	07/07/2009	57143
Part II							
Date	**m^3/day**	**Date**	**m^3/day**	**Date**	**m^3/day**	**Date**	**m^3/day**
08/07/2009	55920	24/08/2009	54099	10/10/2009	56505	26/11/2009	59283
09/07/2009	58046	25/08/2009	52654	11/10/2009	51269	27/11/2009	51139
10/07/2009	57665	26/08/2009	53073	12/10/2009	50798	28/11/2009	50756
11/07/2009	57670	27/08/2009	53961	13/10/2009	51404	29/11/2009	46704
12/07/2009	55539	28/08/2009	55907	14/10/2009	53057	30/11/2009	48009
13/07/2009	54086	29/08/2009	56407	15/10/2009	57151	01/12/2009	50432
14/07/2009	56581	30/08/2009	52193	16/10/2009	55786	02/12/2009	49815
15/07/2009	55083	31/08/2009	50444	17/10/2009	52201	03/12/2009	52150
16/07/2009	58199	01/09/2009	50246	18/10/2009	51471	04/12/2009	54806
17/07/2009	56651	02/09/2009	50062	19/10/2009	48020	05/12/2009	55988
18/07/2009	57910	03/09/2009	53999	20/10/2009	48684	06/12/2009	48730
19/07/2009	55871	04/09/2009	56000	21/10/2009	45852	07/12/2009	54622
20/07/2009	55061	05/09/2009	56271	22/10/2009	51193	08/12/2009	47386
21/07/2009	54293	06/09/2009	50216	23/10/2009	55024	09/12/2009	48055
22/07/2009	55060	07/09/2009	49396	24/10/2009	54506	10/12/2009	52333
23/07/2009	57734	08/09/2009	50068	25/10/2009	49358	11/12/2009	55197
24/07/2009	57854	09/09/2009	48380	26/10/2009	48373	12/12/2009	55208
25/07/2009	57618	10/09/2009	52411	27/10/2009	47953	13/12/2009	52615
26/07/2009	55655	11/09/2009	53440	28/10/2009	49917	14/12/2009	49508
27/07/2009	54760	12/09/2009	55386	29/10/2009	53048	15/12/2009	51849
28/07/2009	56810	13/09/2009	47230	30/10/2009	59372	16/12/2009	52982
29/07/2009	54906	14/09/2009	50122	31/10/2009	56594	17/12/2009	59999
30/07/2009	57612	15/09/2009	49708	01/11/2009	51529	18/12/2009	53711
31/07/2009	59439	16/09/2009	52686	02/11/2009	57326	19/12/2009	54667
01/08/2009	58296	17/09/2009	55018	03/11/2009	60901	20/12/2009	43719
02/08/2009	54683	18/09/2009	56385	04/11/2009	51546	21/12/2009	54450
03/08/2009	53181	19/09/2009	60138	05/11/2009	53135	22/12/2009	54972
04/08/2009	53349	20/09/2009	50503	06/11/2009	52946	23/12/2009	55804
05/08/2009	53167	21/09/2009	44676	07/11/2009	53919	24/12/2009	60774
06/08/2009	57406	22/09/2009	45385	08/11/2009	54192	25/12/2009	61135
07/08/2009	56453	23/09/2009	47942	09/11/2009	54943	26/12/2009	61374
08/08/2009	57436	24/09/2009	49483	10/11/2009	55898	27/12/2009	50047
09/08/2009	54935	25/09/2009	54008	11/11/2009	53404	28/12/2009	57370
10/08/2009	53748	26/09/2009	55870	12/11/2009	56446	29/12/2009	45190
11/08/2009	53576	27/09/2009	50160	13/11/2009	53960	30/12/2009	56837
12/08/2009	52875	28/09/2009	45634	14/11/2009	58271	31/12/2009	61311
13/08/2009	57954	29/09/2009	46279	15/11/2009	52089	01/01/2010	60100

14/08/2009	58188	30/09/2009	48182	16/11/2009	48519	-	-
15/08/2009	58391	01/10/2009	51115	17/11/2009	54452	-	-
16/08/2009	54933	02/10/2009	55190	18/11/2009	48482	-	-
17/08/2009	51867	03/10/2009	55392	19/11/2009	53685	-	-
18/08/2009	52702	04/10/2009	46313	20/11/2009	53959	-	-
19/08/2009	53234	05/10/2009	44681	21/11/2009	57238	-	-
20/08/2009	57076	06/10/2009	46391	22/11/2009	49509	-	-
21/08/2009	57162	07/10/2009	48023	23/11/2009	50944	-	-
22/08/2009	55479	08/10/2009	54760	24/11/2009	57227	-	-
23/08/2009	53854	09/10/2009	55978	25/11/2009	50620	-	-

Average Daily Flow: 52,701 m^3/day

Maximum Daily Flow: 61,374 m^3/day

Minimum Daily Flow: 16,721 m^3/day

APPENDIX 3 EZPS YEAR 2009 OPERATIONAL DATA

Table 1 East Zarqa Pumping Station Hourly Pumping Log, Summer 2009 (Flows are given in m^3/hour)

Time	06/06/2009	07/06/2009	08/06/2009	09/06/2009	10/06/2009	11/06/2009	12/06/2009
	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
0	820	880	820	830	850	810	820
1	880	820	830	870	810	830	870
2	870	810	820	870	820	840	860
3	870	820	820	860	810	830	880
4	860	830	810	830	810	830	860
5	870	820	810	870	800	820	860
6	870	810	830	870	810	830	870
7	870	820	830	880	820	830	880
8	880	820	820	870	810	830	880
9	880	830	820	870	820	830	880
10	880	820	810	860	810	830	880
11	880	820	830	870	810	830	860
12	880	810	820	870	800	830	860
13	1250	1300	1290	820	830	860	1280
14	1250	1100	1300	1250	840	1270	1250
15	1280	820	1290	1260	830	1280	1210
16	1260	830	870	1250	1280	1270	1240
17	1280	820	860	1260	1290	1290	1240
18	830	810	870	1250	1280	1270	1230
19	810	840	830	830	1270	840	830
20	820	870	820	810	1300	820	820
21	810	860	830	810	860	810	840
22	820	880	820	820	840	820	810
23	830	860	830	810	860	820	810
Average	**940**	**863**	**887**	**933**	**919**	**922**	**951**

Table 2 East Zarqa Pumping Station Hourly Pumping Log, Winter 2009 (Flows are given in m^3/hour)

Time	05/12/2009	06/12/2009	07/12/2009	08/12/2009	09/12/2009	10/12/2009	11/12/2009
	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
0	900	860	800	860	800	830	830
1	830	860	860	790	850	810	800
2	820	930	850	800	850	810	790
3	820	920	850	790	840	820	790
4	810	920	860	790	840	800	800
5	810	910	860	800	840	820	810
6	820	910	860	790	840	810	800
7	820	840	810	860	860	820	800
8	830	850	800	840	860	830	800
9	830	860	790	850	850	820	810
10	830	880	810	840	850	820	820
11	830	890	800	830	840	820	810
12	830	900	810	850	850	810	830
13	1250	900	840	800	820	800	830
14	850	910	850	800	830	800	820
15	1270	800	860	830	810	790	820
16	860	790	850	810	820	790	830
17	860	810	870	790	840	780	850
18	850	800	860	800	850	790	860
19	900	850	1500	840	800	830	840
20	900	840	1490	860	800	840	840
21	890	850	1460	850	790	830	850
22	880	860	1280	860	810	850	830
23	900	850	790	850	790	850	830
Average:	**883**	**866**	**934**	**824**	**830**	**815**	**820**

Table 3 East Zarqa Pumping Station

Part I							
Date	m^3/day	Date	m^3/day	Date	m^3/day	Date	m^3/day
01/01/2009	14460	17/02/2009	13240	05/04/2009	12710	22/05/2009	14930
02/01/2009	14170	18/02/2009	13320	06/04/2009	15310	23/05/2009	15420
03/01/2009	14670	19/02/2009	14220	07/04/2009	14080	24/05/2009	15640
04/01/2009	13000	20/02/2009	16290	08/04/2009	14440	25/05/2009	14200
05/01/2009	13210	21/02/2009	18770	09/04/2009	15020	26/05/2009	15090
06/01/2009	13050	22/02/2009	12970	10/04/2009	15240	27/05/2009	14450
07/01/2009	13570	23/02/2009	12760	11/04/2009	12210	28/05/2009	15400
08/01/2009	13960	24/02/2009	13760	12/04/2009	13400	29/05/2009	15470
09/01/2009	14400	25/02/2009	13340	13/04/2009	12550	30/05/2009	15130
10/01/2009	15430	26/02/2009	15170	14/04/2009	12560	31/05/2009	14960
11/01/2009	13920	27/02/2009	18960	15/04/2009	12250	01/06/2009	14720
12/01/2009	13320	28/02/2009	20560	16/04/2009	13700	02/06/2009	13970
13/01/2009	13000	01/03/2009	15510	17/04/2009	15150	03/06/2009	14750
14/01/2009	13270	02/03/2009	13140	18/04/2009	14870	04/06/2009	16650
15/01/2009	13800	03/03/2009	14000	19/04/2009	13470	05/06/2009	16020
16/01/2009	14220	04/03/2009	15120	20/04/2009	12660	06/06/2009	16450
17/01/2009	14710	05/03/2009	15170	21/04/2009	14400	07/06/2009	15470
18/01/2009	12660	06/03/2009	15340	22/04/2009	12840	08/06/2009	15040
19/01/2009	12290	07/03/2009	16790	23/04/2009	14140	09/06/2009	15460
20/01/2009	12330	08/03/2009	14750	24/04/2009	14110	10/06/2009	15630
21/01/2009	12460	09/03/2009	13420	25/04/2009	13540	11/06/2009	16270
22/01/2009	13400	10/03/2009	13680	26/04/2009	13550	12/06/2009	16320
23/01/2009	13210	11/03/2009	13240	27/04/2009	13860	13/06/2009	15520
24/01/2009	13540	12/03/2009	14390	28/04/2009	12900	14/06/2009	15690
25/01/2009	12550	13/03/2009	14420	29/04/2009	13650	15/06/2009	15660
26/01/2009	13460	14/03/2009	15140	30/04/2009	13850	16/06/2009	15930
27/01/2009	13050	15/03/2009	14390	01/05/2009	14620	17/06/2009	15380
28/01/2009	13080	16/03/2009	15490	02/05/2009	15540	18/06/2009	16080
29/01/2009	13560	17/03/2009	14130	03/05/2009	11900	19/06/2009	16430
30/01/2009	14070	18/03/2009	14300	04/05/2009	12990	20/06/2009	16400
31/01/2009	15580	19/03/2009	14560	05/05/2009	13150	21/06/2009	14660
01/02/2009	11850	20/03/2009	15070	06/05/2009	12700	22/06/2009	14220
02/02/2009	12100	21/03/2009	15850	07/05/2009	13820	23/06/2009	14600
03/02/2009	12830	22/03/2009	14000	08/05/2009	14190	24/06/2009	15010
04/02/2009	12450	23/03/2009	16470	09/05/2009	13780	25/06/2009	16420
05/02/2009	12560	24/03/2009	12350	10/05/2009	14510	26/06/2009	16190
06/02/2009	11930	25/03/2009	11650	11/05/2009	14370	27/06/2009	16180
07/02/2009	13890	26/03/2009	13270	12/05/2009	13150	28/06/2009	15540
08/02/2009	12320	27/03/2009	14960	13/05/2009	14460	29/06/2009	14350
09/02/2009	12200	28/03/2009	15070	14/05/2009	15010	30/06/2009	14410
10/02/2009	15010	29/03/2009	14410	15/05/2009	15750	01/07/2009	15430

11/02/2009	12150	30/03/2009	13810	16/05/2009	16020	02/07/2009	14970
12/02/2009	14010	31/03/2009	14230	17/05/2009	14880	03/07/2009	16200
13/02/2009	14230	01/04/2009	13510	18/05/2009	16680	04/07/2009	15510
14/02/2009	15620	02/04/2009	14610	19/05/2009	14910	05/07/2009	14480
15/02/2009	13530	03/04/2009	14270	20/05/2009	15210	06/07/2009	14220
16/02/2009	12980	04/04/2009	15260	21/05/2009	15040	07/07/2009	13670
Part II							
Date	**m^3/day**	**Date**	**m^3/day**	**Date**	**m^3/day**	**Date**	**m^3/day**
08/07/2009	14360	24/08/2009	14590	10/10/2009	16050	26/11/2009	15700
09/07/2009	17430	25/08/2009	15100	11/10/2009	14860	27/11/2009	11330
10/07/2009	16200	26/08/2009	15690	12/10/2009	13990	28/11/2009	11270
11/07/2009	15520	27/08/2009	16420	13/10/2009	14120	29/11/2009	10710
12/07/2009	13940	28/08/2009	16650	14/10/2009	14360	30/11/2009	10920
13/07/2009	14740	29/08/2009	16420	15/10/2009	15370	01/12/2009	10780
14/07/2009	13760	30/08/2009	16520	16/10/2009	16160	02/12/2009	10290
15/07/2009	14150	31/08/2009	14560	17/10/2009	16530	03/12/2009	11390
16/07/2009	15840	01/09/2009	14680	18/10/2009	13970	04/12/2009	12770
17/07/2009	15060	02/09/2009	15780	19/10/2009	14270	05/12/2009	12880
18/07/2009	16260	03/09/2009	16590	20/10/2009	14100	06/12/2009	10940
19/07/2009	14600	04/09/2009	16620	21/10/2009	14140	07/12/2009	12920
20/07/2009	13530	05/09/2009	16660	22/10/2009	14580	08/12/2009	10600
21/07/2009	14040	06/09/2009	14680	23/10/2009	15330	09/12/2009	11320
22/07/2009	14800	07/09/2009	14120	24/10/2009	14830	10/12/2009	12380
23/07/2009	15530	08/09/2009	15030	25/10/2009	14300	11/12/2009	13280
24/07/2009	15250	09/09/2009	14650	26/10/2009	14600	12/12/2009	12960
25/07/2009	15920	10/09/2009	15570	27/10/2009	13040	13/12/2009	11810
26/07/2009	15010	11/09/2009	17220	28/10/2009	13470	14/12/2009	10920
27/07/2009	14580	12/09/2009	16550	29/10/2009	14140	15/12/2009	11540
28/07/2009	15200	13/09/2009	14960	30/10/2009	14200	16/12/2009	11700
29/07/2009	14730	14/09/2009	14730	31/10/2009	14270	17/12/2009	16560
30/07/2009	15730	15/09/2009	14740	01/11/2009	13050	18/12/2009	16350
31/07/2009	15170	16/09/2009	15480	02/11/2009	13400	19/12/2009	12840
01/08/2009	15040	17/09/2009	16380	03/11/2009	12670	20/12/2009	10990
02/08/2009	15350	18/09/2009	16470	04/11/2009	13520	21/12/2009	10610
03/08/2009	14310	19/09/2009	17350	05/11/2009	14310	22/12/2009	10180
04/08/2009	14400	20/09/2009	13730	06/11/2009	14960	23/12/2009	11960
05/08/2009	14830	21/09/2009	13000	07/11/2009	14370	24/12/2009	13470
06/08/2009	15620	22/09/2009	13400	08/11/2009	12350	25/12/2009	13140
07/08/2009	15500	23/09/2009	14970	09/11/2009	12500	26/12/2009	13170
08/08/2009	15230	24/09/2009	15320	10/11/2009	12300	27/12/2009	10700
09/08/2009	14190	25/09/2009	16100	11/11/2009	12750	28/12/2009	11490
10/08/2009	13830	26/09/2009	16570	12/11/2009	13560	29/12/2009	10460
11/08/2009	14230	27/09/2009	14820	13/11/2009	14070	30/12/2009	11160
12/08/2009	15160	28/09/2009	15210	14/11/2009	13730	31/12/2009	12490
13/08/2009	16570	29/09/2009	14800	15/11/2009	11930	01/01/2010	12880

14/08/2009	16650	30/09/2009	15400	16/11/2009	11620	-	-
15/08/2009	16250	01/10/2009	16050	17/11/2009	13560	-	-
16/08/2009	16500	02/10/2009	17280	18/11/2009	12820	-	-
17/08/2009	15030	03/10/2009	17280	19/11/2009	12870	-	-
18/08/2009	15590	04/10/2009	14780	20/11/2009	12900	-	-
19/08/2009	15210	05/10/2009	14800	21/11/2009	13110	-	-
20/08/2009	16300	06/10/2009	14650	22/11/2009	11240	-	-
21/08/2009	16710	07/10/2009	14860	23/11/2009	11720		-
22/08/2009	16630	08/10/2009	15850	24/11/2009	13360	-	-
23/08/2009	16130	09/10/2009	15220	25/11/2009	12460	-	-

Average Daily Flow: 14,310 m^3/day

Maximum Daily Flow: 20,560 m^3/day

Minimum Daily Flow: 10,180 m^3/day

APPENDIX 4 POPULATION PROJECTIONS

Table 1: Population Distribution Projections

	Neighbourhood	2010	2015	2020	2025	2030	2035
Zarqa District	al-Tafeh	835	937	1,027	1,116	1,205	1,293
	al-Rukban	213	239	262	285	308	330
	Khaw	445	499	547	594	641	688
	al-Farwaniyeh	133	149	163	177	191	205
Zarqa Municipality	Hai al-Hadiqa	4,080	4,183	4,288	4,397	4,508	4,621
	Hai al-Nuzha	6,521	6,853	7,203	7,570	7,956	8,362
	Hai al-Hussein	20,098	20,098	20,098	20,098	20,098	20,098
	Hai al-Wasat al-Tijary	16,848	17,273	17,709	18,157	18,615	19,067
	Hai al-Nasr	13,272	13,272	13,272	13,272	13,272	13,272
	Hai Ramzi	31,230	32,018	32,827	33,656	34,506	35,181
	Hai Shaker	12,451	12,765	13,088	13,418	13,757	14,104
	Hai al-Basateen	5,373	7,451	9,716	10,934	11,509	12,823
	Hai Ma'soum	24,477	25,095	25,729	26,378	27,044	27,727
	Hai al-Hashemi	5,178	7,182	9,364	10,538	11,092	12,359
	Hai al-Ghweireyeh	29,689	29,689	29,689	29,689	29,689	29,689
	Hai al-Ameer Mohammad	15,727	16,125	16,532	16,949	17,377	17,816
	Hai al-Shyoukh	9,092	9,322	9,557	9,798	10,046	10,300
	Hai Barakh	7,688	7,882	8,081	8,285	8,494	8,709
	Hai Ibn Sina	6,691	6,860	7,033	7,210	7,393	7,579
	Hai al-Iskan	4,052	4,154	4,259	4,367	4,477	4,590
	Hai al-Dhubbat	4,399	4,510	4,624	4,741	4,861	4,983
	Hai al-Janna'a	21,237	21,773	22,323	22,887	23,465	24,057
	Hai al-Thawra al-Arabiyah al-Kubrah	22,063	22,620	23,192	23,777	24,378	24,993
	Hai al-Jundi	5,610	5,752	5,897	6,046	6,199	6,355
	Hai al-Masane'e	7,558	10,483	13,669	15,382	16,191	18,040
	Hai Tarwq Bin Zeyad	6,547	6,712	6,881	7,055	7,233	7,416
	Hai Tarwq Bin Zeyad	6,837	6,441	6,441	6,441	6,441	6,441
	Hai al-Ameer Hamzah	12,546	12,863	13,188	13,521	13,862	14,212
	Hai al-Jabal al-Abyad	16,189	16,598	17,017	17,446	17,887	18,339
	Hai al-Ameera Rahmah	10,157	10,413	10,676	10,946	11,222	11,506
	Hai al-Ameer Hassan	11,561	11,853	12,153	12,459	12,774	13,097
	Hai al-Malek Talal	14,125	14,481	14,847	15,222	15,606	16,000
	Hai Awajan	1,672	1,757	1,846	1,941	2,040	2,144

Table 1: Population Distribution Projections

	Neighbourhood	2010	2015	2020	2025	2030	2035
	Hai al-Falah	9,051	9,513	9,998	10,508	11,044	11,608
	Hai Umm Bayadhah	3,820	3,917	4,015	4,117	4,221	4,327
Zarqa Municipality	Hai al-Dweik	1,706	1,793	1,884	1,980	2,081	2,188
	Hai al-Madina al-Munawara	3,709	5,144	6,707	7,548	7,945	8,852
	Hai Makka al-Mukarramah	702	974	1,270	1,429	1,504	1,676
	Hai al-Ahmad	4,173	5,788	7,548	8,493	8,940	9,961
	Hai Nassar	2,282	2,339	2,398	2,459	2,521	2,585
	Hai al-Zawahreh	18,324	18,787	19,261	19,748	20,246	20,757
	Hai al-Qamar	3,482	3,570	3,660	3,752	3,847	3,944
	Hai Qurtuba	3,650	3,743	3,837	3,934	4,033	4,135
	Hai al-Jneineh	3,803	5,274	6,877	7,739	8,146	9,076
	Hai al-Jabr	1,900	1,997	2,099	2,206	2,318	2,437
	Hai al-Ameera Haya	15,008	20,816	27,142	30,544	32,150	35,821
	Hai Shomar	4,000	5,548	7,234	8,140	8,569	9,547
	Hai al-Bustan	3,500	4,854	6,330	7,123	7,497	8,354
	Hai al-Zarqa'a al-Jadida	25,782	26,433	27,101	27,785	28,487	29,206
	Hai al-Batrawi	33,254	46,121	60,139	67,676	71,235	79,369
	Hai al-Hirafyeen	33	30	30	30	30	30
	Hai al-Hashemeyah al-Janoubiyah	5,111	5,240	5,373	5,508	5,647	5,790
	Hai Ma'amel al-Toub	774	1,074	1,400	1,576	1,658	1,848
Birein District	Birein	1,415	1,587	1,740	1,891	2,041	2,190
	Umm Rummaneh	1,289	1,446	1,586	1,723	1,860	1,996
	al-Kamsha	1,493	1,674	1,836	1,996	2,154	2,311
	al-Alouk	759	851	934	1,015	1,095	1,175
	Hai Sarout	1,420	1,592	1,746	1,897	2,047	2,197
	Marhab	778	873	958	1,040	1,123	1,205
	Rujm al-Shok	831	933	1,023	1,111	1,199	1,287
	al-Naseriyah	612	687	753	818	883	948
	al-Mikman	588	660	723	786	848	910
	al-Masarrah al-Sharqiyah	433	485	532	578	624	670
	al-Masarrah al-Gharbiya	519	582	639	694	749	804
	al-Makhdat	29	32	36	39	42	45
	al-Khillah	284	319	350	380	410	440
	Maqam Eisa	628	704	772	839	906	972
	Ein Saber	704	789	866	941	1,015	1,089
	al-Bireh	401	450	494	536	579	621

Table 1: Population Distribution Projections

	Neighbourhood	2010	2015	2020	2025	2030	2035
	al-Riyadh	527	591	648	704	760	815
	al-Sahhara	66	74	82	89	96	103
Birein District	al-Ouweillieh	168	188	206	224	242	259
	Wadi Suwwan	251	281	308	335	362	388
	Umm Fatyer	122	136	150	163	176	188
	Ein al-Hawaya	99	111	122	132	143	153
	Umm Khasheibah	425	477	523	569	614	658
	Umm al-Biyar	498	558	612	665	718	770
Dhuleil District	al-Dhuleil	33,312	37,359	40,973	44,523	48,047	51,560
	Qasr al-Hallabat al-Sharqi	2,197	2,464	2,702	2,936	3,169	3,400
	Qasr al-Hallabat al-Gharbi	2,966	3,326	3,648	3,964	4,277	4,590
	al-Deheitem	310	347	381	414	447	479
	Sayeh Diyab	329	369	405	440	475	509
	Mazare'e Hallabat	180	201	221	240	259	278
Russeifa Municipality	Hai Awajan al-Shamali	297	272	272	272	272	272
	Hai Umm Jarada	738	1,024	1,335	1,502	1,581	1,762
	Hai al-Jundi	4,657	4,895	5,144	5,407	5,683	5,972
	Hai al-Ameer Ali	4,865	4,988	5,114	5,243	5,375	5,511
	Hai Kharrouba al-Sharqi	344	315	315	315	315	315
	Hai Kharrouba al-Gharbi	302	420	547	616	648	722
	Hai al-Arateqa	9,484	9,723	9,969	10,220	10,479	10,743
	Hai al-Arab	5,584	5,725	5,869	6,018	6,169	6,325
	Hai al-Hussein	10,709	10,089	10,089	10,089	10,089	10,089
	Hai al-Jabal al-Shamali	33,975	34,833	35,712	36,614	37,539	38,487
	Hai al-Khalediyah	4,157	4,262	4,370	4,480	4,593	4,709
	Hai al-Qadessiyah	25,873	26,527	27,197	27,883	28,587	29,309
	Hai Awajan al-Gharbi	15,557	15,949	16,352	16,765	17,188	17,622
	Hai Umm Jarada al-Shamali	6,960	7,136	7,316	7,501	7,690	7,885
	Hai Umm Jarada al-Gharbi	4,595	4,711	4,830	4,952	5,077	5,206
	Hai al-Daheriyah	5,718	5,387	5,387	5,387	5,387	5,387
	Hai Iskan al-Ameer Talal	4,508	4,247	4,247	4,247	4,247	4,247
	Hai al-Razi	2,198	2,254	2,311	2,369	2,429	2,490
	Hai al-Tatweer al-Hadari	20,120	18,954	18,954	18,954	18,954	18,954
	al-Mustashfa	69	77	84	92	99	106
	Hai al-Rasheed al-Janoubi	8,728	8,949	9,175	9,406	9,644	9,887
	Hai al-Hurriyah	2,705	2,749	2,749	2,749	2,749	2,749

Table 1: Population Distribution Projections

	Neighbourhood	2010	2015	2020	2025	2030	2035
	Hai Ja'far al-Tayar al-Janoubi	1,327	1,394	1,465	1,540	1,619	1,701
	Hai Ja'far al-Tayar	8,280	8,489	8,704	8,923	9,149	9,380
Russeifa Municipality	Hai al-Rasheed al-Shamali	12,958	13,285	13,620	13,964	14,317	14,678
	Hai Jraiba	7,987	11,077	14,444	16,254	17,109	19,062
	Hai al-Ghaidaniyah	547	759	990	1,114	1,172	1,306
	Hai Ein Shabwa	292	405	527	594	625	696
	Hai al-Msheirfah	13,012	13,341	13,678	14,023	14,377	14,740
	Hai al-Msheirfah al-Gharbi	3,183	3,264	3,346	3,431	3,517	3,606
	Hai al-Msheirfah al-Janoubi	3,563	3,653	3,745	3,840	3,936	4,036
	Hai al-Iskanat	9,475	9,714	9,959	10,211	10,469	10,733
	Hai Abu Ghalyoon	3,131	3,290	3,458	3,635	3,820	4,015
	Hai Jabal al-Ameer Faisal	20,415	20,930	21,459	22,001	22,556	23,126
	Hai al-Wananat	705	665	665	665	665	665
	Theodor Shneller	92	103	113	122	132	142
	Hai al-Fakhourah	2,698	2,467	2,467	2,467	2,467	2,467
	Hai Abu Sayyah	2,411	2,704	2,966	3,223	3,478	3,732
	Hai Hitteen Camp	42,706	43,784	44,890	46,023	47,185	48,377
al-Hashemiyah District	Hai al-Hashemiyah	20,405	20,920	21,448	21,990	22,545	23,115
	Hai Iskan al-Hashemiyah	6,632	6,799	6,971	7,147	7,328	7,513
	Hai al-Fayha'a	1,220	1,251	1,283	1,315	1,348	1,382
	al-Sukhneh	15,289	17,146	18,805	20,434	22,051	23,664
	Abu al-Zeighan	2,563	2,875	3,153	3,426	3,697	3,967
	Dogara	2,251	2,525	2,769	3,009	3,247	3,484
	Ein al-Nimra	158	177	194	211	228	244
	Ghareisa	804	901	989	1,074	1,159	1,244
	Umm Suleih	2,579	2,892	3,172	3,447	3,720	3,992
al-Hashemiyah District	al-Ghuneiyah	663	743	815	886	956	1,026
	Daba'an	293	328	360	391	422	453
	Tawaheen al-Adwan	57	64	70	76	82	88
	al-Hasab	57	64	70	76	82	88
	al-Ruhail	396	445	488	530	572	614
Azraq Distric	Azraq	10,871	12,192	13,371	14,530	15,680	16,826
	King Abdullah Bin Abdul Aziz City		67,945	121,824	220,000	339,071	430,400
	al-Majd City		31,800	42,400	42,400	42,400	42,400
	Total	**921,454**	**1,083,280**	**1,215,486**	**1,362,782**	**1,519,791**	**1,662,628**

APPENDIX 5 WASTEWATER FLOW DISTRIBUTION PROJECTIONS

Table 1: Water Consumption Distribution Projections (m^3/day)

	Neighbourhood	2010	2015	2020	2025	2030	2035
Zarqa District	al-Tafeh	67	75	82	89	96	103
	al-Rukban	17	19	21	23	25	26
	Khaw	36	40	44	48	51	55
	al-Farwaniyeh	11	12	13	14	15	16
Zarqa Municipality	Hai al-Hadiqa	408	429	440	451	462	474
	Hai al-Nuzha	652	702	738	776	796	816
	Hai al-Hussein	2,010	2,010	2,010	2,010	2,010	2,010
	Hai al-Wasat al-Tijary	1,685	1,771	1,815	1,861	1,907	1,907
	Hai al-Nasr	1,327	1,327	1,327	1,327	1,327	1,327
	Hai Ramzi	3,123	3,282	3,365	3,450	3,518	3,518
	Hai Shaker	1,245	1,309	1,342	1,376	1,410	1,446
	Hai al-Basateen	477	603	717	823	899	922
	Hai Ma'soum	2,448	2,573	2,638	2,704	2,772	2,842
	Hai al-Hashemi	460	582	691	793	867	938
	Hai al-Ghweireyeh	2,969	2,969	2,969	2,969	2,969	2,969
	Hai al-Ameer Mohammad	1,573	1,653	1,695	1,738	1,781	1,826
	Hai al-Shyoukh	909	956	980	1,004	1,030	1,056
	Hai Barakh	769	808	828	849	871	893
	Hai Ibn Sina	669	703	721	739	758	777
	Hai al-Iskan	405	426	437	448	459	471
	Hai al-Dhubbat	440	462	474	486	498	511
	Hai al-Janna'a	2,124	2,232	2,288	2,346	2,405	2,466
	Hai al-Thawra al-Arabiyah al-Kubrah	2,206	2,319	2,377	2,437	2,499	2,562
	Hai al-Jundi	561	590	605	620	635	652
	Hai al-Masane'e	240	258	272	285	293	300
	Hai Tarwq Bin Zeyad	655	688	705	723	741	757
	Hai Tarwq Bin Zeyad	644	644	644	644	644	644
	Hai al-Ameer Hamzah	1,255	1,319	1,352	1,386	1,421	1,457
	Hai al-Jabal al-Abyad	1,619	1,701	1,744	1,788	1,834	1,880
	Hai al-Ameera Rahmah	1,016	1,068	1,094	1,122	1,150	1,179
	Hai al-Ameer Hassan	1,156	1,215	1,246	1,277	1,309	1,343
	Hai al-Malek Talal	1,412	1,485	1,522	1,560	1,600	1,640

Table 1: Water Consumption Distribution Projections (m^3/day)

	Neighbourhood	2010	2015	2020	2025	2030	2035
	Hai Awajan	167	180	189	199	204	209
	Hai al-Falah	905	975	1,025	1,077	1,104	1,132
	Hai Umm Bayadhah	1,101	1,393	1,655	1,899	2,076	2,246
Zarqa Municipality	Hai al-Dweik	750	949	1,127	1,293	1,414	1,530
	Hai al-Madina al-Munawara	329	417	495	568	621	672
	Hai Makka al-Mukarramah	320	405	481	552	603	653
	Hai al-Ahmad	371	469	557	639	699	756
	Hai Nassar	658	832	989	1,134	1,240	1,341
	Hai al-Zawahreh	1,832	1,926	1,975	2,024	2,075	2,128
	Hai al-Qamar	348	366	375	385	394	404
	Hai Qurtuba	365	384	393	403	413	424
	Hai al-Jneineh	338	427	507	582	637	689
	Hai al-Jabr	532	673	799	917	1,002	1,085
	Hai al-Ameera Haya	1,332	1,686	2,003	2,298	2,513	2,718
	Hai Shomar	300	380	451	517	566	612
	Hai al-Bustan	400	506	601	690	754	816
	Hai al-Zarqa'a al-Jadida	2,578	2,710	2,778	2,848	2,920	2,994
	Hai al-Batrawi	2,952	3,735	4,438	5,092	5,567	6,023
	Hai al-Hirafyeen	3	3	3	3	3	3
	Hai al-Hashemeyah al-Janoubiyah	511	537	551	565	579	594
	Hai Ma'amel al-Toub	22	22	22	22	22	22
Birein District	Birein	113	127	139	151	163	175
	Umm Rummaneh	103	116	127	138	149	160
	al-Kamsha	119	134	147	160	172	185
	al-Alouk	61	68	75	81	88	94
	Hai Sarout	114	127	140	152	164	176
	Marhab	62	70	77	83	90	96
	Rujm al-Shok	67	75	82	89	96	103
	al-Naseriyah	49	55	60	65	71	76
	al-Mikman	47	53	58	63	68	73
	al-Masarrah al-Sharqiyah	35	39	43	46	50	54
	al-Masarrah al-Gharbiya	42	47	51	56	60	64
	al-Makhdat	2	3	3	3	3	4
	al-Khillah	23	26	28	30	33	35
	Maqam Eisa	50	56	62	67	72	78
	Ein Saber	56	63	69	75	81	87

Table 1: Water Consumption Distribution Projections (m^3/day)

	Neighbourhood	2010	2015	2020	2025	2030	2035
	al-Bireh	32	36	39	43	46	50
	al-Riyadh	42	47	52	56	61	65
	al-Sahhara	5	6	7	7	8	8
Birein District	al-Ouweillieh	13	15	16	18	19	21
	Wadi Suwwan	20	22	25	27	29	31
	Umm Fatyer	10	11	12	13	14	15
	Ein al-Hawaya	8	9	10	11	11	12
	Umm Khasheibah	34	38	42	45	49	53
	Umm al-Biyar	40	45	49	53	57	62
Dhuleil District	al-Dhuleil	2,665	2,989	3,278	3,562	3,844	4,125
	Qasr al-Hallabat al-Sharqi	176	197	216	235	253	272
	Qasr al-Hallabat al-Gharbi	237	266	292	317	342	367
	al-Deheitem	25	28	30	33	36	38
	Sayeh Diyab	26	30	32	35	38	41
	Mazare'e Hallabat	14	16	18	19	21	22
Russeifa Municipality	Hai Awajan al-Shamali	27	27	27	27	27	27
	Hai Umm Jarada	21	21	21	21	21	21
	Hai al-Jundi	466	502	527	554	568	583
	Hai al-Ameer Ali	486	511	524	537	551	565
	Hai Kharrouba al-Sharqi	31	31	31	31	31	31
	Hai Kharrouba al-Gharbi	27	34	40	46	51	55
	Hai al-Arateqa	948	997	1,022	1,048	1,074	1,101
	Hai al-Arab	558	587	602	617	632	648
	Hai al-Hussein	1,009	1,009	1,009	1,009	1,009	1,009
	Hai al-Jabal al-Shamali	3,397	3,571	3,661	3,753	3,848	3,945
	Hai al-Khalediyah	416	437	448	459	471	483
	Hai al-Qadessiyah	2,587	2,719	2,788	2,858	2,931	3,005
	Hai Awajan al-Gharbi	1,556	1,635	1,676	1,719	1,762	1,807
	Hai Umm Jarada al-Shamali	696	732	750	769	788	808
	Hai Umm Jarada al-Gharbi	460	483	495	508	521	534
	Hai al-Daheriyah	539	539	539	539	539	539
	Hai Iskan al-Ameer Talal	425	425	425	425	425	425
	Hai al-Razi	220	231	237	243	249	255
	Hai al-Tatweer al-Hadari	1,895	1,895	1,895	1,895	1,895	1,895
	al-Mustashfa	7	8	8	9	10	11
	Hai al-Rasheed al-Janoubi	873	917	941	964	989	1,014

Table 1: Water Consumption Distribution Projections (m^3/day)

	Neighbourhood	2010	2015	2020	2025	2030	2035
	Hai al-Hurriyah	271	275	275	275	275	275
	Hai Ja'far al-Tayar al-Janoubi	133	143	150	158	162	166
	Hai Ja'far al-Tayar	828	870	892	915	938	962
Russeifa Municipality	Hai al-Rasheed al-Shamali	1,296	1,362	1,396	1,432	1,468	1,505
	Hai Jraiba	267	300	329	357	386	414
	Hai al-Ghaidaniyah	49	61	73	84	92	99
	Hai Ein Shabwa	26	33	39	45	49	53
	Hai al-Msheirfah	1,301	1,368	1,402	1,438	1,474	1,511
	Hai al-Msheirfah al-Gharbi	318	335	343	352	361	370
	Hai al-Msheirfah al-Janoubi	356	374	384	394	404	414
	Hai al-Iskanat	947	996	1,021	1,047	1,073	1,100
	Hai Abu Ghalyoon	313	337	354	373	382	392
	Hai Jabal al-Ameer Faisal	2,041	2,146	2,200	2,255	2,312	2,371
	Hai al-Wananat	66	66	66	66	66	66
	Theodor Shneller	9	10	11	12	13	14
	Hai al-Fakhourah	247	247	247	247	247	247
	Hai Abu Sayyah	193	216	237	258	278	299
	Hai Hitteen Camp	4,271	4,488	4,602	4,718	4,837	4,857
al-Hashemiyah District	Hai al-Hashemiyah	2,040	2,145	2,199	2,254	2,311	2,370
	Hai Iskan al-Hashemiyah	663	697	715	733	751	770
	Hai al-Fayha'a	122	128	131	135	138	142
	al-Sukhneh	1,529	1,715	1,880	2,043	2,205	2,366
	Abu al-Zeighan	205	230	252	274	296	317
	Dogara	180	202	222	241	260	279
	Ein al-Nimra	13	14	16	17	18	20
	Ghareisa	64	72	79	86	93	100
	Umm Suleih	206	231	254	276	298	319
al-Hashemiyah District	al-Ghuneiyah	53	59	65	71	76	82
	Daba'an	23	26	29	31	34	36
	Tawaheen al-Adwan	5	5	6	6	7	7
	al-Hasab	5	5	6	6	7	7
	al-Ruhail	32	36	39	42	46	49
Azraq District	Azraq	870	975	1,070	1,162	1,254	1,346
	King Abdullah Bin Abdul Aziz City		5,000	13,500	23,000	34,000	45,040

Table 1: Water Consumption Distribution Projections (m^3/day)

	Neighbourhood	2010	2015	2020	2025	2030	2035
	al-Majd City		3,180	4,240	4,240	4,240	4,240
	Total	**90,578**	**105,673**	**120,279**	**134,683**	**149,891**	**164,837**

Table 2: Wastewater Generation Distribution Projections (m^3/day)

	Neighbourhood	2010	2015	2020	2025	2030	2035
Zarqa District	al-Tafeh	58	65	71	78	84	90
	al-Rukban	15	17	18	20	21	23
	Khaw	31	35	38	41	45	48
	al-Farwaniyeh	9	10	11	12	13	14
Zarqa Municipality	Hai al-Hadiqa	355	373	382	392	402	412
	Hai al-Nuzha	567	611	642	675	692	710
	Hai al-Hussein	1,749	1,749	1,749	1,749	1,749	1,749
	Hai al-Wasat al-Tijary	1,466	1,541	1,579	1,619	1,659	1,659
	Hai al-Nasr	1,155	1,155	1,155	1,155	1,155	1,155
	Hai Ramzi	2,717	2,856	2,928	3,002	3,061	3,061
	Hai Shaker	1,083	1,138	1,167	1,197	1,227	1,258
	Hai al-Basateen	415	525	624	716	782	802
	Hai Ma'soum	2,129	2,238	2,295	2,353	2,412	2,473
	Hai al-Hashemi	400	506	601	690	754	816
	Hai al-Ghweireyeh	2,583	2,583	2,583	2,583	2,583	2,583
	Hai al-Ameer Mohammad	1,368	1,438	1,474	1,512	1,550	1,589
	Hai al-Shyoukh	791	831	852	874	896	919
	Hai Barakh	669	703	721	739	758	777
	Hai Ibn Sina	582	612	627	643	659	676
	Hai al-Iskan	353	370	380	389	399	409
	Hai al-Dhubbat	383	402	412	423	433	444
	Hai al-Janna'a	1,848	1,942	1,991	2,041	2,093	2,146
	Hai al-Thawra al-Arabiyah al-Kubrah	1,920	2,017	2,068	2,121	2,174	2,229
	Hai al-Jundi	488	513	526	539	553	567
	Hai al-Masane'e	209	225	236	248	255	261
	Hai Tarwq Bin Zeyad	570	599	614	629	645	658
	Hai Tarwq Bin Zeyad	560	560	560	560	560	560
	Hai al-Ameer Hamzah	1,092	1,147	1,176	1,206	1,236	1,268
	Hai al-Jabal al-Abyad	1,408	1,480	1,518	1,556	1,595	1,636
	Hai al-Ameera Rahmah	884	929	952	976	1,001	1,026
	Hai al-Ameer Hassan	1,006	1,057	1,084	1,111	1,139	1,168
	Hai al-Malek Talal	1,229	1,292	1,324	1,358	1,392	1,427
	Hai Awajan	145	157	165	173	177	182
	Hai al-Falah	787	848	892	937	961	985
	Hai Umm Bayadhah	958	1,212	1,440	1,652	1,806	1,954

Table 2: Wastewater Generation Distribution Projections (m^3/day)

	Neighbourhood	2010	2015	2020	2025	2030	2035
Zarqa Municipality	Hai al-Dweik	653	826	981	1,125	1,230	1,331
	Hai al-Madina al-Munawara	286	362	431	494	540	584
	Hai Makka al-Mukarramah	278	352	419	480	525	568
	Hai al-Ahmad	322	408	485	556	608	658
	Hai Nassar	572	724	860	987	1,079	1,167
	Hai al-Zawahreh	1,594	1,676	1,718	1,761	1,806	1,851
	Hai al-Qamar	303	318	326	335	343	352
	Hai Qurtuba	318	334	342	351	360	369
	Hai al-Jneineh	294	372	441	507	554	599
	Hai al-Jabr	463	585	695	798	872	944
	Hai al-Ameera Haya	1,159	1,467	1,743	1,999	2,186	2,365
	Hai Shomar	261	330	392	450	492	532
	Hai al-Bustan	348	440	523	600	656	710
	Hai al-Zarqa'a al-Jadida	2,243	2,357	2,417	2,478	2,541	2,605
	Hai al-Batrawi	2,568	3,250	3,861	4,430	4,843	5,240
	Hai al-Hirafyeen	3	3	3	3	3	3
	Hai al-Hashemeyah al-Janoubiyah	445	467	479	491	504	516
	Hai Ma'amel al-Toub	20	20	20	20	20	20
Birein District	Birein	98	110	121	132	142	152
	Umm Rummaneh	90	101	110	120	129	139
	al-Kamsha	104	117	128	139	150	161
	al-Alouk	53	59	65	71	76	82
	Hai Sarout	99	111	122	132	143	153
	Marhab	54	61	67	72	78	84
	Rujm al-Shok	58	65	71	77	83	90
	al-Naseriyah	43	48	52	57	61	66
	al-Mikman	41	46	50	55	59	63
	al-Masarrah al-Sharqiyah	30	34	37	40	43	47
	al-Masarrah al-Gharbiya	36	41	44	48	52	56
	al-Makhdat	2	2	2	3	3	3
	al-Khillah	20	22	24	26	29	31
	Maqam Eisa	44	49	54	58	63	68
	Ein Saber	49	55	60	65	71	76
	al-Bireh	28	31	34	37	40	43
	al-Riyadh	37	41	45	49	53	57
	al-Sahhara	5	5	6	6	7	7

Table 2: Wastewater Generation Distribution Projections (m^3/day)

	Neighbourhood	2010	2015	2020	2025	2030	2035
Birein District	al-Ouweillieh	12	13	14	16	17	18
	Wadi Suwwan	17	20	21	23	25	27
	Umm Fatyer	8	10	10	11	12	13
	Ein al-Hawaya	7	8	8	9	10	11
	Umm Khasheibah	30	33	36	40	43	46
	Umm al-Biyar	35	39	43	46	50	54
Dhuleil District	al-Dhuleil	2,318	2,600	2,852	3,099	3,344	3,589
	Qasr al-Hallabat al-Sharqi	153	171	188	204	221	237
	Qasr al-Hallabat al-Gharbi	206	231	254	276	298	319
	al-Deheitem	22	24	27	29	31	33
	Sayeh Diyab	23	26	28	31	33	35
	Mazare'e Hallabat	12	14	15	17	18	19
Russeifa Municipality	Hai Awajan al-Shamali	24	24	24	24	24	24
	Hai Umm Jarada	19	19	19	19	19	19
	Hai al-Jundi	405	436	459	482	494	507
	Hai al-Ameer Ali	423	445	456	468	479	492
	Hai Kharrouba al-Sharqi	27	27	27	27	27	27
	Hai Kharrouba al-Gharbi	23	30	35	40	44	48
	Hai al-Arateqa	825	867	889	912	935	958
	Hai al-Arab	486	511	523	537	550	564
	Hai al-Hussein	878	878	878	878	878	878
	Hai al-Jabal al-Shamali	2,956	3,107	3,185	3,265	3,348	3,432
	Hai al-Khalediyah	362	380	390	400	410	420
	Hai al-Qadessiyah	2,251	2,366	2,426	2,487	2,550	2,614
	Hai Awajan al-Gharbi	1,353	1,422	1,458	1,495	1,533	1,572
	Hai Umm Jarada al-Shamali	606	636	653	669	686	703
	Hai Umm Jarada al-Gharbi	400	420	431	442	453	464
	Hai al-Daheriyah	469	469	469	469	469	469
	Hai Iskan al-Ameer Talal	369	369	369	369	369	369
	Hai al-Razi	191	201	206	211	217	222
	Hai al-Tatweer al-Hadari	1,649	1,649	1,649	1,649	1,649	1,649
	al-Mustashfa	6	7	7	8	9	9
	Hai al-Rasheed al-Janoubi	759	798	818	839	860	882
	Hai al-Hurriyah	235	239	239	239	239	239
	Hai Ja'far al-Tayar al-Janoubi	115	124	131	137	141	144
	Hai Ja'far al-Tayar	720	757	776	796	816	837

Table 2: Wastewater Generation Distribution Projections (m^3/day)

	Neighbourhood	2010	2015	2020	2025	2030	2035
Russeifa Municipality	Hai al-Rasheed al-Shamali	1,127	1,185	1,215	1,245	1,277	1,309
	Hai Jraiba	233	261	286	311	335	360
	Hai al-Ghaidaniyah	42	53	64	73	80	86
	Hai Ein Shabwa	23	29	34	39	42	46
	Hai al-Msheirfah	1,132	1,190	1,220	1,251	1,282	1,315
	Hai al-Msheirfah al-Gharbi	277	291	298	306	314	322
	Hai al-Msheirfah al-Janoubi	310	326	334	342	351	360
	Hai al-Iskanat	824	866	888	911	934	957
	Hai Abu Ghalyoon	272	293	308	324	332	341
	Hai Jabal al-Ameer Faisal	1,776	1,867	1,914	1,962	2,012	2,063
	Hai al-Wananat	58	58	58	58	58	58
	Theodor Shneller	8	9	10	11	11	12
	Hai al-Fakhourah	215	215	215	215	215	215
	Hai Abu Sayyah	168	188	206	224	242	260
	Hai Hitteen Camp	3,715	3,905	4,004	4,105	4,208	4,226
al-Hashemiyah District	Hai al-Hashemiyah	1,775	1,866	1,913	1,961	2,011	2,061
	Hai Iskan al-Hashemiyah	577	606	622	637	654	670
	Hai al-Fayha'a	106	112	114	117	120	123
	al-Sukhneh	1,330	1,492	1,636	1,778	1,918	2,059
	Abu al-Zeighan	178	200	219	238	257	276
	Dogara	157	176	193	209	226	243
	Ein al-Nimra	11	12	14	15	16	17
	Ghareisa	56	63	69	75	81	87
	Umm Suleih	179	201	221	240	259	278
al-Hashemiyah District	al-Ghuneiyah	46	52	57	62	67	71
	Daba'an	20	23	25	27	29	32
	Tawaheen al-Adwan	4	4	5	5	6	6
	al-Hasab	4	4	5	5	6	6
	al-Ruhail	28	31	34	37	40	43
Azraq District	Azraq	757	849	931	1,011	1,091	1,171
	King Abdullah Bin Abdul Aziz City		4,350	11,745	20,010	29,580	39,185
	al-Majd City		2,767	3,689	3,689	3,689	3,689
	Total	**78,803**	**91,935**	**104,643**	**117,175**	**130,406**	**143,408**

APPENDIX 6 TOPOGRAPHICAL SURVEY OF MAIN SEWER SYSTEM

Table 1 Important Unopened Manholes above 200 mm Dia.

Zone	Line Name	Manhole Name	Easting	Northing	Elevation	Remarks
EZ	400-1	400-1-14	255453.41	169018.33	538.82	Manhole cover flipped over
EZ	700-1	700-1-13	255246.58	170997.72	517.51	Manhole cover flipped over
EZ	700-1	700-1-17	255456.48	170822.50	519.37	Covered by concrete
EZ	800 -1	800-1-19	255101.56	168884.26	554.75	Could not be opened (stuck)
EZ	800 -1	800-1-20	255077.26	168806.43	555.96	Could not be opened (stuck)
EZ	800 -1	800-1-21	255055.97	168731.80	555.58	Covered by concrete
EZ	800 -1	800-1-37	254908.17	167576.61	555.88	Could not be opened (stuck)
EZ	800 -1	800-1-39	254910.44	167417.65	558.02	Could not be opened (stuck)
EZ	800 -1	800-1-40	254910.76	167336.36	560.30	Could not be opened (stuck)
EZ	800 -1	800-1-41	254910.74	167279.46	561.91	Could not be opened (stuck)
EZ	800 -1	800-1-43	254894.71	167084.62	563.67	Could not be opened (stuck)
EZ	800 -1	800-1-44	254882.39	167022.70	563.98	Could not be opened (stuck)
EZ	800 -1	800-1-45	254870.42	166957.98	564.29	Could not be opened (stuck)
EZ	800 -1	800-1-47	254837.34	166763.18	565.31	Could not be opened (stuck)
EZ	800 -1	800-1-48	254825.40	166700.20	565.61	Could not be opened (stuck)
EZ	800 -1	800-1-49	254814.25	166640.45	566.09	Could not be opened (stuck)
EZ	800 -1	800-1-50	254800.49	166555.39	567.09	Could not be opened (stuck)
EZ	800 -1	800-1-51	254792.28	166510.54	567.84	Could not be opened (stuck)
EZ	800 -1	800-1-52	254788.30	166487.89	568.11	Could not be opened (stuck)
EZ	800 -1	800-1-7	255293.68	170948.20	517.98	Could not be opened (stuck)
WZ	300-17	300-17-10	251748.90	164235.40	580.90	Could not be opened (stuck)
WZ	300-17	300-17-11	251780.60	164235.88	586.16	Could not be opened (stuck)
WZ	300-17	300-17-12	251797.68	164236.51	588.39	Could not be opened (stuck)
WZ	300-17	300-17-13	251832.53	164248.70	589.92	Could not be opened (stuck)
WZ	300-17	300-17-7	251651.67	164265.81	561.51	Could not be opened (stuck)
WZ	300-17	300-17-8	251683.62	164253.88	567.88	Could not be opened (stuck)
WZ	300-17	300-17-9	251731.09	164238.12	577.28	Could not be opened (stuck)
WZ	300-21	300-21-1	251632.86	163486.57	558.99	Manhole cover flipped over
WZ	300-D	300-D-7	250575.96	158840.42	601.83	Could not be opened (stuck)
WZ	400-A	1000-1-26	251639.65	163702.15	544.45	Covered by concrete
WZ	400-A	400-A-35	252741.85	162169.82	565.94	Covered by back fill
WZ	400-A	400-A-38	252751.71	161979.28	567.17	Covered by back fill
WZ	400-A	400-A-7	252076.96	163352.03	550.62	Could not be opened (stuck)
WZ	400-A	400-A-9	252197.28	163301.29	555.59	Covered by a large rock
WZ	500-5	500-5-1	244542.50	157943.64	658.87	Covered by concrete
WZ	500-5	500-5-10	244554.56	157559.61	660.63	Covered by concrete
WZ	500-5	500-5-11	244540.94	157515.45	660.93	Covered by concrete
WZ	500-5	500-5-12	244528.47	157494.89	661.04	Covered by concrete

Zone	Line Name	Manhole Name	Easting	Northing	Elevation	Remarks
WZ	500-5	500-5-2	244540.15	157896.70	659.44	Covered by concrete
WZ	500-C	500-C-1	251691.45	163656.27	544.79	Covered by concrete
WZ	500-C	500-C-10	252034.20	163335.13	549.05	Covered by concrete
WZ	500-C	500-C-11	252066.77	163325.29	549.46	Covered by concrete
WZ	500-C	500-C-12	252094.60	163318.86	550.59	Covered by concrete
WZ	500-C	500-C-13	252119.71	163311.53	550.09	Covered by concrete
WZ	500-C	500-C-15	252146.51	163288.79	550.20	Covered by concrete
WZ	500-C	500-C-16	252166.40	163265.84	550.35	Covered by a large rock
WZ	500-C	500-C-17	252227.09	163209.55	551.62	Covered by a large rock
WZ	500-C	500-C-2	251745.14	163610.19	545.36	Covered by a concrete
WZ	500-C	500-C-3	251800.23	163570.24	545.70	Covered by a concrete
WZ	500-C	500-C-4	251844.03	163525.70	546.29	Covered by a concrete
WZ	500-C	500-C-5	251870.36	163486.50	546.78	Covered by a concrete
WZ	500-C	500-C-6	251907.81	163427.69	547.75	Covered by a concrete
WZ	500-C	500-C-7	251953.80	163377.40	548.21	Covered by a concrete
WZ	500-C	500-C-8	251997.64	163353.59	548.43	Covered by a concrete
WZ	500-C	500-C-9	252005.87	163344.20	548.21	Covered by a concrete
WZ	800-A	800-A-10	252020.91	163300.22	550.13	Covered by back fill
WZ	800-A	800-A-11	252088.02	163283.33	550.93	Covered by back fill
WZ	800-A	800-A-13	252191.96	163194.66	552.41	Covered by back fill
WZ	800-A	800-A-8	251910.23	163368.43	550.44	Covered by back fill
WZ	800-B	800-B-166	245314.59	158483.59	648.59	Covered by a concrete
WZ	800-B	800-B-171	245141.95	158392.51	651.22	Covered by a concrete
WZ	800-B	800-B-172	245087.71	158365.42	652.34	Covered by a concrete
WZ	800-B	800-B-177	244831.55	158288.01	654.70	Covered by a large rock
WZ	800-B	800-B-178	244798.13	158278.10	655.31	Covered by a large rock
WZ	800-B	800-B-180	244743.63	158239.33	655.53	Covered by a large rock
WZ	800-B	800-B-181	244715.14	158215.71	655.84	Covered by a large rock
WZ	800-B	800-B-183	244671.04	158159.46	656.24	Covered by a large rock
WZ	800-B	800-B-186	244597.60	158004.68	657.99	Covered by a large rock
WZ	800-B	800-B-188	244566.89	157913.46	658.48	Covered by a large rock
WZ	800-B	800-B-189	244549.24	157865.54	658.04	Covered by a large rock
WZ	800-B	800-B-191	244571.87	157746.73	659.11	Covered by a large rock
WZ	800-B	800-B-194	244570.27	157599.66	661.13	Covered by a large rock
WZ	800-B	800-B-195	244563.79	157557.18	661.31	Covered by a large rock
WZ	800-B	800-B-196	244549.47	157522.80	661.79	Covered by a large rock
WZ	800-B	800-B-198	244506.34	157439.95	662.40	Covered by a large rock
WZ	800-B	800-B-199	244497.77	157434.36	662.28	Covered by a large rock

APPENDIX 7 FLOW MONITORING DATA

Manhole Ref. No. :	MH-2			Pipe Dia. : 400 mm				
Location :	South East of Zarqa West P.S.							
Period :	From Monday, Feb. 15, 2010 03:59 PM till Monday, Feb. 22, 2010 03:14 PM							
Day	Monday / Tuesday	Tuesday / Wed	Wed / Thursday	Thursday / Friday	Friday / Saturday	Saturday / Sunday	Sunday / Monday	Period - Week
Time	03:59 PM to 03:54 PM	03:59 PM to 03:54 PM	03:59 PM to 03:54 PM	03:59 PM to 03:54 PM	03:59 PM to 03:54 PM	03:59 PM to 03:54 PM	03:59 PM to 03:54 PM	03:59 PM to 03:54 PM
Min. Daily Flow (m3/hr.)	48.42	53.91	55.92	64.47	64.07	67.64	48.02	48.02
Max. Daily Flow (m3/hr.)	279.84	303.92	325.84	413.64	336.14	277.64	250.46	413.64
Ave. Daily Flow (m3/hr.)	150.06	152.84	163.68	193.31	180.43	154.24	135.80	161.58
Ave. Total Daily Flow (m3/day)	3,601.50	3,668.06	3,928.37	4,639.35	4,330.43	3,701.67	3,259.32	3,877.98

Manhole Ref. No. :	MH-3			Pipe Dia: 240 mm				
Location :	South of Zarqa West P.S.							
Period :	From Wednesday, Feb. 17, 2010 14:29 PM till Thursday, Feb. 18, 2010 14:24 PM							
Day	Monday / Tuesday	Tuesday / Wed	Wed / Thursday	Thursday / Friday	Friday / Saturday	Saturday / Sunday	Sunday / Monday	Period - Week
Time	14:29 PM to 14:24 PM	14:29 PM to 14:24 PM	14:29 PM to 14:24 PM	14:29 PM to 14:24 PM	14:29 PM to 14:24 PM	14:29 PM to 14:24 PM	14:29 PM to 14:24 PM	14:29 PM to 14:24 PM
Min. Daily Flow (m3/hr.)	25.15	22.31	22.62	0.00				22.31
Max. Daily Flow (m3/hr.)	82.62	78.49	82.56	0.00				82.62
Ave. Daily Flow (m3/hr.)	46.55	46.65	43.25					45.48
Ave. Total Daily Flow (m3/day)	1,117.21	1,119.52	1,037.93					1,091.56

Manhole Ref. No. :	MH-4				Pipe Dia: 800 mm			
Location :	Mushairfeh – Russeifa							
Period :	From Monday, Mar. 15, 2010 4:04 PM till Monday, Mar. 22, 2010 03:44 PM							
Day	Monday / Tuesday	Tuesday / Wed	Wed / Thursday	Thursday / Friday	Friday / Saturday	Saturday / Sunday	Sunday / Monday	Period - Week
Time	04:04 PM to 03:59 PM	04:04 PM to 03:59 PM	04:04 PM to 03:59 PM	04:04 PM to 03:59 PM	04:04 PM to 03:59 PM	04:04 PM to 03:59 PM	04:04 PM to 03:44 PM	04:04 PM to 03:59 PM
Min. Daily Flow (m3/hr.)	63.25	52.53	78.39	92.81	62.35	64.21	42.79	42.79
Max. Daily Flow (m3/hr.)	370.47	503.04	417.14	655.17	499.37	377.79	394.65	655.17
Ave. Daily Flow (m3/hr.)	203.79	192.41	230.56	283.30	221.73	208.67	183.99	217.83
Ave. Total Daily Flow (m3/day)	4,890.86	4,617.95	5,533.37	6,799.26	5,321.55	5,008.14	4,415.71	5,227.90

Manhole Ref. No. :	MH-5				Pipe Dia. : 800 mm			
Location :	Russeifa							
Period :	From Monday, Mar. 08, 2010 12:10 PM till Monday, Mar. 15, 2010 10:45 AM							
Day	Monday / Tuesday	Tuesday / Wed	Wed / Thursday	Thursday / Friday	Friday / Saturday	Saturday / Sunday	Sunday / Monday	Period - Week
Time	12:10 PM to 12:05 PM	12:10 PM to 12:05 PM	12:10 PM to 12:05 PM	12:10 PM to 12:05 PM	12:10 PM to 12:05 PM	12:10 PM to 12:05 PM	12:10 PM to 10:45 PM	12:10 PM to 12:05 PM
Min. Daily Flow (m3/hr.)	1,461.06	386.84	811.51	559.23	304.42	237.99	1,413.13	237.99
Max. Daily Flow (m3/hr.)	2,625.00	2,732.91	2,704.68	2,866.34	3,571.46	5,583.89	5,508.72	5,583.89
Ave. Daily Flow (m3/hr.)	2,105.04	2,017.90	2,047.46	1,968.75	1,586.77	1,780.57	1,977.44	1,926.23
Ave. Total Daily Flow (m3/day)	50,521.03	48,429.53	49,139.00	47,249.90	38,082.37	42,733.80	47,458.47	46,229.50

Manhole Ref. No. :	MH-6				Pipe Dia: 700 mm			
Location :	Marka - Near Bridge							
Period :	From Sunday Feb. 21, 2010 04:00 PM till Sunday Feb. 28, 2010 04:45 PM							
Day	Monday / Tuesday	Tuesday / Wed	Wed / Thursday	Thursday / Friday	Friday / Saturday	Saturday / Sunday	Sunday / Monday	Period - Week
Time	04:00 PM to 03:55 PM	04:00 PM to 03:55 PM	04:00 PM to 03:55 PM	04:00 PM to 03:55 PM	04:00 PM to 03:55 PM	04:00 PM to 03:55 PM	04:00 PM to 03:55 PM	04:00 PM to 03:55 PM
Min. Daily Flow (m3/hr.)	46.50	39.15	33.90	57.08	201.15	61.93	26.65	26.65
Max. Daily Flow (m3/hr.)	270.14	277.69	279.87	395.83	389.00	534.99	470.85	534.99
Ave. Daily Flow (m3/hr.)	170.26	173.45	172.65	194.82	320.70	228.15	81.56	191.66
Ave. Total Daily Flow (m3/day)	4,086.32	4,162.85	4,143.61	4,675.68	7,696.80	5,475.64	1,957.40	4,599.76

Manhole Ref. No. :	MH-7				Pipe Dia. : 800 mm			
Location :	Marka							
Period :	From Monday, Feb. 22, 2010 05:02 PM till Monday, Mar. 01, 2010 02:02 PM							
Day	Monday / Tuesday	Tuesday / Wed	Wed / Thursday	Thursday / Friday	Friday / Saturday	Saturday / Sunday	Sunday / Monday	Period - Week
Time	05:02 PM to 04:57 PM	05:02 PM to 04:57 PM	05:02 PM to 04:57 PM	05:02 PM to 04:57 PM	05:02 PM to 04:57 PM	05:02 PM to 04:57 PM	05:02 PM to 02:02 PM	05:02 PM to 04:57 PM
Min. Daily Flow (m3/hr.)	14.99	14.31	17.00	31.15	101.15	0.00	24.95	0.00
Max. Daily Flow (m3/hr.)	57.15	58.99	105.80	351.37	338.87	633.75	415.03	633.75
Ave. Daily Flow (m3/hr.)	34.64	35.86	38.75	119.20	171.99	148.86	74.78	89.41
Ave. Total Daily Flow (m3/day)	831.26	860.56	930.00	2,860.90	4,127.71	3,572.71	1,794.66	2,145.78

Manhole Ref. No. :	MH-8				Pipe Dia. : 700 mm			
Location :	Marka							
Period :	From Monday, Mar. 08, 2010 10:07 AM till Monday, Mar. 15, 2010 09:57 AM							
Day	Monday / Tuesday	Tuesday / Wed	Wed / Thursday	Thursday / Friday	Friday / Saturday	Saturday / Sunday	Sunday / Monday	Period - Week
Time	10:07 AM to 10:02 AM	10:07 AM to 10:02 AM	10:07 AM to 10:02 AM	10:07 AM to 10:02 AM	10:07 AM to 10:02 AM	10:07 AM to 10:02 AM	10:07 AM to 09:57 AM	10:07 AM to 10:02 AM
Min. Daily Flow (m3/hr.)	196.82	187.98	169.31	149.99	143.92	156.55	146.48	143.92
Max. Daily Flow (m3/hr.)	293.87	303.64	493.35	279.24	323.52	318.77	277.53	493.35
Ave. Daily Flow (m3/hr.)	252.48	253.44	256.81	226.68	218.98	240.48	219.62	238.37
Ave. Total Daily Flow (m3/day)	6,059.52	6,082.61	6,163.43	5,440.39	5,255.62	5,771.59	5,270.95	5,720.81

Manhole Ref. No. :	MH-9				Pipe Dia. : 300 mm			
Location :	Next to Zarqa East P.S.							
Period :	From Sunday, Feb. 14, 2010 16:31 PM till Sunday Feb. 21, 2010 14:26 PM							
Day	Monday / Tuesday	Tuesday / Wed	Wed / Thursday	Thursday / Friday	Friday / Saturday	Saturday / Sunday	Sunday / Monday	Period - Week
Time	16:31 PM to 16:26 PM	16:31 PM to 16:26 PM	16:31 PM to 16:26 PM	16:31 PM to 16:26 PM	16:31 PM to 16:26 PM	16:31 PM to 16:26 PM	16:31 PM to 14:26 PM	16:31 PM to 14:26 AM
Min. Daily Flow (m3/hr.)	19.76	12.32	11.45	13.20	15.82	14.18	12.78	11.45
Max. Daily Flow (m3/hr.)	92.74	131.15	90.63	101.24	154.53	143.43	126.16	154.53
Ave. Daily Flow (m3/hr.)	57.22	59.02	54.79	57.32	64.96	58.49	49.94	58.31
Ave. Total Daily Flow (m3/day)	1,373.36	1,416.58	1,314.87	1,375.62	1,559.14	1,403.73	1,198.53	1,399.34

Manhole Ref. No. :	MH-10				Pipe Dia. : 800 mm			
Location :	South of Zarqa West P.S.							
Period :	From Sunday, Feb. 07, 2010 6:00 PM till Sunday Feb. 14, 2010 4:00 PM							
Day	Monday / Tuesday	Tuesday / Wed	Wed / Thursday	Thursday / Friday	Friday / Saturday	Saturday / Sunday	Sunday / Monday	Period - Week
Time	14:29 PM to 14:24 PM	14:29 PM to 14:24 PM	14:29 PM to 14:24 PM	14:29 PM to 14:24 PM	14:29 PM to 14:24 PM	14:29 PM to 14:24 PM	14:29 PM to 14:24 PM	14:29 PM to 14:24 PM
Min. Daily Flow (m3/hr.)	219.15	188.42	203.82	262.93	199.88	205.41	189.35	188.42
Max. Daily Flow (m3/hr.)	815.29	816.91	871.68	980.49	882.03	807.26	750.17	980.49
Ave. Daily Flow (m3/hr.)	483.32	497.38	520.99	584.37	518.90	499.67	443.92	505.98
Ave. Total Daily Flow (m3/day)	11,599.66	11,937.22	12,503.65	14,024.97	12,453.58	11,991.97	10,654.05	12,143.49

Manhole Ref. No. :	MH-11				Pipe Dia. : 460 mm			
Location :	Zarqa Power Station - Line from Free Zone							
Period :	From Sunday, Feb. 07, 2010 11:50 AM till Thursday, Feb. 14, 2010 11:50 AM							
Day	Monday / Tuesday	Tuesday / Wed	Wed / Thursday	Thursday / Friday	Friday / Saturday	Saturday / Sunday	Sunday / Monday	Period - Week
Time	11:50 AM to 11:45 AM	11:50 AM to 11:45 AM	11:50 AM to 11:45 AM	11:50 AM to 11:45 AM	11:50 AM to 11:45 AM	11:50 AM to 11:45 AM	11:50 AM to 11:45 AM	11:50 AM to 11:45 AM
Min. Daily Flow (m3/hr.)	63.29	81.45	56.90	50.29	52.56	49.42	33.89	33.89
Max. Daily Flow (m3/hr.)	235.37	235.72	260.15	233.40	246.71	305.01	158.87	305.01
Ave. Daily Flow (m3/hr.)	142.95	147.51	139.50	116.22	99.72	91.37	99.16	119.49
Ave. Total Daily Flow (m3/day)	3430.75	3540.29	3348.05	2,789.24	2,393.21	2,192.78	2,379.74	2,867.72

Manhole Ref. No. :	MH-12				Pipe Dia. : 700 mm			
Location :	Al Jaish Str.							
Period :	From Monday, Mar. 01, 2010 03:02 PM till Monday, Mar. 08, 2010 08:28 AM							
Day	Monday / Tuesday	Tuesday / Wed	Wed / Thursday	Thursday / Friday	Friday / Saturday	Saturday / Sunday	Sunday / Monday	Period - Week
Time	03:02 PM to 02:57 PM	03:02 PM to 02:57 PM	03:02 PM to 02:57 PM	03:02 PM to 02:57 PM	03:02 PM to 02:57 PM	03:02 PM to 02:57 PM	03:02 PM to 08:27 AM	03:02 PM to 02:57 PM
Min. Daily Flow (m3/hr.)	61.73	75.95	104.42	128.20	80.98	77.01	65.16	61.73
Max. Daily Flow (m3/hr.)	244.08	216.23	275.40	347.26	258.03	222.37	201.82	347.26
Ave. Daily Flow (m3/hr.)	142.76	151.00	179.23	216.79	165.51	159.52	128.23	164.70
Ave. Total Daily Flow (m3/day)	3,426.30	3,623.95	4,301.56	5,203.00	3,972.18	3,828.59	3,077.48	3,952.88

Manhole Ref. No. :	Zarqa WEST PS				Open Channel (Width): 1100 - 1000 mm			
Location :	Zarqa WEST PS							
Period :	From Monday, Mar. 01, 2010 08:34 AM till Monday, Mar. 08, 2010 07:29 AM							
Day	Monday / Tuesday	Tuesday / Wed	Wed / Thursday	Thursday / Friday	Friday / Saturday	Saturday / Sunday	Sunday / Monday	Period - Week
Time	08:32 AM to 08:29 AM	08:34 AM to 08:29 AM	08:34 AM to 08:29 AM	08:34 AM to 08:29 AM	08:34 AM to 08:29 AM	08:34 AM to 08:29 AM	08:34 AM to 07:29 AM	08:34 AM to 08:29 AM
Min. Daily Flow (m3/hr.)	1904.63	1415.53	1756.12	1,554.38	1,563.40	1,804.68	891.77	891.77
Max. Daily Flow (m3/hr.)	3824.14	2726.73	3289.05	3,002.42	3,383.01	3,378.98	3,096.80	3,824.14
Ave. Daily Flow (m3/hr.)	2780.23	2185.71	2532.69	2,425.18	2,513.22	2,669.52	1,992.95	2,445.55
Ave. Total Daily Flow (m3/day)	66,725.63	52,457.12	60,784.51	58,204.21	60,317.30	64,068.38	47,830.77	58,693.20