WATER REUSE AND ENVIRONMENTAL CONSERVATION PROJECT

CONTRACT NO. EDH–I–00–08–00024–00 ORDER NO. 04

ADDENDUM TO ZARQA IWTP - ASSESSMENT OF TREATMENT ALTERNATIVES/FEASIBILITY STUDY

November 2014

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NOVEMBER 2014

Submitted to:

USAID Jordan

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Jordanian Technical Regulation JS 893/2006: Water-Reclaimed Domestic Wastewater

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LIST OF ACRONYMS

CAPEX	Capital cost estimate
CTW	Constructed treatment wetland
DAF	Dissolved air flotation
DFZC	Development and Free Zones Commission
FOB	Freight on board
FOG	Fat, oil, and grease
FRP	Fiberglass-reinforced plastic
FS	Feasibility assessment
GoJ	Government of Jordan
H&S	Health and safety
HCP	Headworks Control Panel
HERO	High efficiency reverse osmosis
HRT	Hydraulic residence time
IWRM	Integrated Water Resource Management
IWTP	Industrial Wastewater Treatment Plant
IX	ion exchange
K-T	Kepner-Tregoe
KTD	King Talal Dam
LAH	High level alarm
LAL	Low level alarm
LALL	Low low level
LH	High level
LHH	High high level
LL	Low Level
MBR	Membrane Bioreactor
MoEnv	Ministry of Environment
MBAS	Methylene Blue Active Substances
MSL	Mean sea level
MWI	Ministry of Water and Irrigation
O&M	Operations and maintenance
OPEX	Operating cost estimate
P&ID	Piping and Instrumentation Diagrams
PFD	Process Flow Diagrams
PLC	Programmable logic controller
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl chloride
RSS	Royal Scientific Society
RO	Reverse osmosis
SCADA	Supervisory control and data acquisition
SS	Stainless steel
TCC	Total capital equipment
TDS	Total dissolved solids
TIC	Total installed cost
TN	Total nitrogen
TPE	Total process equipment
TSS	Total suspended solids
USAID	US Agency for International Development
WAJ	Water Authority of Jordan
WRECP	Water Reuse and Environmental Conservation Project
WWTP	Wastewater Treatment Plant
ZCI	Zarqa Chamber of Industry
ZLD	Zero liquid discharge

1 INTRODUCTION

1.1 Background

The Government of Jordan (GOJ) recognizes the urgent need to protect and conserve scarce resources through regulation, education, and coordination with industry, local communities and the private sector. To address this need, the United States Agency for International Development (USAID) and the GOJ launched the Water Reuse and Environmental Conservation Project (WRECP). The project supports the improvement of the regulatory environment; industry training and networking on pollution prevention and environmental management; landfill and "hot spot" rehabilitation; water reuse to support community livelihoods; and kingdom-wide biosolids management. The implementing contractor is AECOM. This five-year program consists of four tasks aimed at increased efficiency in the use of water and energy, and improved liquid and solid waste handling practices in the industrial sector of Jordan. Under Task 2, Pollution Prevention and Industrial Water Management, the project team is conducting activities that specifically support the industrial sector.

Under Sub-task 2.3b, Design and Engineering Services for Industrial Wastewater Treatment Plants, the project team is preparing technical solutions that address critical wastewater treatment needs in an integrated water resources management (IWRM) context. As part of this work, the project team worked with USAID-Amman and other Jordan-based partners, including the Ministry of Environment (MoEnv), Ministry of Water and Irrigation (MWI), Development and Free Zones Commission (DFZC), and the Zarqa Chamber of Industry (ZCI) in the identification of a site in the Zarqa Area for a potential new industrial wastewater treatment plant (IWTP).

This report is an addendum to, and must be read in conjunction with, the *Zarqa IWTP – Assessment of Treatment Alternatives/Feasibility Study,* January 2013*,* (2013 FS), prepared by the WRECP. That report documented the evaluation of multiple treatment alternatives to serve the Zarqa Industrial Area.

Based on feedback from the Jordan-based partners, the project team subsequently identified an additional alternative for wastewater treatment in the Zarqa area and recommended that it be included in the evaluation of alternatives. The new alternative would take advantage of excess capacity at Samra (an existing domestic wastewater treatement plant (WWTP)) and considers a pretreatment option for the industrial wastewater. Effluent from the IWTP pretreatment facility would be discharged to a domestic WWTP for final treatment and would be reused, along with the treated domestic wastewater, in the plant vicinity. This report documents the recommended additional evaluation and is presented as an addendum to the 2013 feasibility study (FS).

As in the 2013 FS, capital and annualized operating costs are included as part of the evaluation. The addendum includes estimates of capital cost and annualized operating cost for the new pretreatment alternative. The capital costs are based on the same information used in the 2013 evaluation, but operating costs reflect current (2014) pricing. In order to provide a consistent basis for comparison, the operating costs for the alternatives evaluated in the 2013 FS have been updated in this addendum to reflect the 2014 pricing.

1.2 Project Objectives

One of the overarching goals of the WRECP is to foster a change in strategic thinking in the industrial sector, to bring a more integrated water resources management perspective to wastewater pollution abatement in the industrial sector.

The specific objective for the Zarqa IWTP is to develop a cost-effective treatment and disposal alternative that meets the needs of beneficiary partners such as ZCI and its constituencies, including providing opportunities for water conservation via reuse and optimal cost of operations. To this end, each of the 2013 FS alternatives was designed to produce effluent suitable for reuse in the vicinity of the selected site. The additional pretreatment alternative is designed to produce effluent which meets the requirements for discharge to a domestic wastewater treatment plant. The pretreated effluent will not interfere with the domestic plant's ability to produce effluent which meets the requirements for beneficial reuse (i.e. irrigation). Thus, the pretreatment alternative also provides water for beneficial reuse in accordance with the project objectives.

1.3 Project Area

As described in the 2013 FS, Zarqa is one of Jordan's major industrial centers and is home to a large number of Jordanian factories, spread over a large area in and around the city of Zarqa. Industrial facilities in Zarqa cover a wide spectrum of sectors, with varying levels of wastewater management capacity. There is no centralized industrial wastewater treatment plant at Zarqa to collect and treat industrial discharges, so current wastewater practices typically require transport of wastes to offsite disposal facilities, co-mingling of industrial wastes in the domestic sewer system, or unpermitted discharges to the nearby environment. One of the major environmental concerns related to current wastewater treatment and disposal practices in Zarqa is the contamination of surface and groundwater resources with industrial pollutants. Industrial pollution abatement in Zarqa is therefore a critical issue for the MoEnv, MWI, and other agencies (ZCI 2011).

The 2013 FS presented the evaluation of options for a single site (the Hallabat site) outside the Zarqa Industrial Area. At the time of the evaluation, ZCI had access to this site of about 500 Dunums (25 Ha) outside Zarqa city on the highway near Ad Dulail, Hallabat and Khalidia in a location known as Wadi Al Ghudran. Plans had been developed for a possible industrial estate to be located adjacent to the potential IWTP site. Since the area around the potential Hallabat IWTP site is undeveloped, it was anticipated that it could be used for various reuse applications. Specifically, the evaluation assumed that treated effluent from a plant at this site could be used for irrigation and to rehabilitate the surrounding Badia rangeland for specific uses such as agricultural reuse for growing fodder as well as restoring natural grazing areas. Depending on the alternative selected for implementation, it might be necessary for the IWTP owner/operator to negotiate agreements and/or regulatory approvals for access to additional land for reuse.

The new pretreatment alternative evaluated in this addendum was initially developed to be located adjacent to the As-Samra domestic wastewater treatment plant, but it is designed so that it could be located in proximity to any existing domestic wastewater treatment plant in the greater Zarqa area. Similar to the Hallabat site evaluated in the 2013 FS, the As-Samra site is surrounded by open land. There is sufficient space on which the IWTP could be located.

The location of the As-Samra treatment plant site is shown in Figure 1-1, along with the potential Hallabat site (as adjacent to the New Industrial Estate) and Zarqa city. The As-

Samra WWTP is located in Al Khirbeh As-Samra area within Al Hashimyyah District in Zarqa Governorate. It is 13 km north of Zarqa and 36 km from Downtown Amman (32° 9'15.28"N / 36° 9'50.38"E).

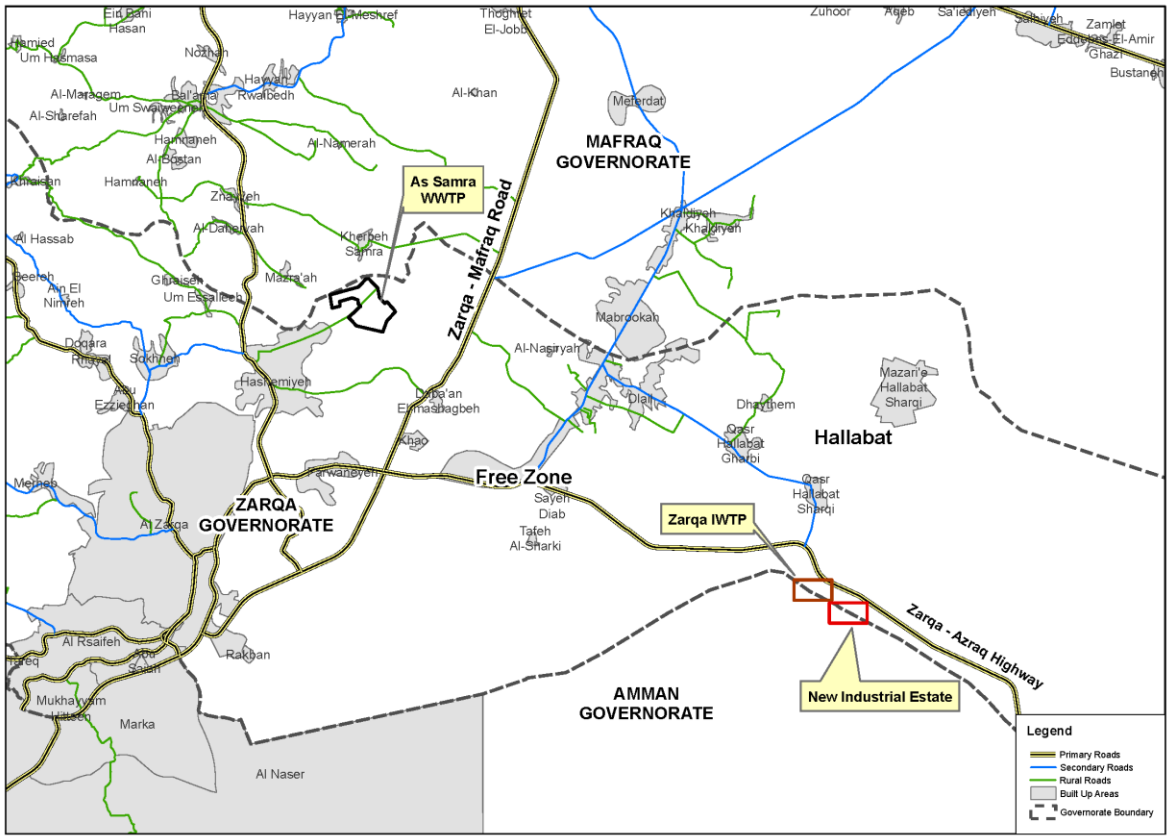

Figure 1-1 Location Plan for Potential Zarqa Area IWTP Sites

2 PROJECT CONDITIONS

Section 2 of the 2013FS outlines the project conditions in the Hallabat area, including the climate, geology and geotechnical hydrogeologic and aquifer considerations. A summary of the pretreatment (As-Samra) site conditions, as derived from the October 2014 Preliminary Environmental and Social Impact Assessment for As-Samra Biosolids Monofill prepared by the WRECP, is provided in this section. It should be noted that information in the 2014 PEIA was obtained from the As-Samra Plant Company Environmental and Social Impact Assessment Study for the Expansion of As-Samra Wastewater Treatment Plant Final ESIA Report completed by WRECP in 2012.

2.1 CLIMATE

The climate of Jordan in general is classified as “Eastern Mediterranean” and is characterized by summers that are dry with high temperatures, and winters with moderate overnight frosts and occasional snowfall events, especially over the highlands. Average annual temperatures can typically range from a minimum of 13.6°C to a maximum of 25.5°C. Rainfall occurs in October through May with the most extensive rainfall being in December, January and February; an average annual rainfall of 123.4 mm was recorded in the period of 2009-2013, with the maximum rainfall (136.0 mm) being in 2013.

2.2 GEOLOGY, TOPOGRAPHY GEOTECHNICAL CONSIDERATIONS

While no geologic or geotechnical information has been obtained by the project team for a specific pretreatment site, data is available for the As-Samra WWTP location itself. The information in Sections 2.2.1 through 2.2.5 below is based on that data.

The general geology of the project area shows that the site is dominated by rock consisting of Basalt belonging to Abed Olivin Basalt Geologic formation of Pliocene of upper Tertiary. This formation is exposed partly at the sides of nearby wadis, and covers the Wadi As Sir limestone formation which is exposed at areas within the As-Samra WWTP. The Basaltic formation at the study area is covered mostly by superficial deposits of soil, alluvium, and Pleistocene sediments. The thickness of the superficial deposits ranges from 1.5 m to more than 10 m based on drilled borings in the area.

2.2.1 Superficial Deposits

Superficial deposits in the study area can be differentiated into Pleistocene gravels, soil and alluvial deposits.

2.2.1.1 *Pleistocene Gravels*

Pleistocene gravels are deposited in neighboring areas south and southwest of the study area. They consist of alternating beds of gravels, conglomerates, soil and carbonaceous arenaceous marl; these sediments are early Pleistocene in age.

2.2.1.2 *Soil*

Thick brown and pale brown soils characterize the study area. They consist of silty clay associated with basalt clasts. The soil in the study area is characterized as well-drained with low run-off potential.

2.2.1.3 *Alluvium*

Alluvium sediments of Holocene include alluvial deposits of ephemeral wadis and associated flood plains. They consist of different faces of moderate to unsorted matrix and clast-supported conglomerates. Clasts are in the range of sand to cobbles size.

2.2.2 Abed Olivine Basalt Formation

The volcanic exposures are represented by the Abed Olivine Phyric Basalt Formation that is exposed adjacent to and within the study area. It covers the Wadi As Sir Limestone

formation. Abed Olivine Phyric Basalt Formation is dark to medium grey and brown to dark brown in color where it is weathered, and dark grey-black to bluish black on fresh surfaces. It is holocrystalline, medium to fine grained, constituted of porphyritic basalt flows and boulders with microvesicular texture. Petro-graphically, the formation is relatively uniform in mineralogical composition, characterized by phenocrysts of olivine, less commonly of plagioclase and very rarely of pyroxene. The formation is comprised of a thick and massive flow unit with a total thickness of 20 m in the study area which is of the Pliocene age (4 Ma).

2.2.3 Structural Geology

Regionally, the major fault systems in the area are the Berin Fault (E-W) and the Amman Hallabat Fault System (NE-SW). The Berin Fault is located approximately 6 km south of the study area whereas the Amman Hallabat Fault is located approximately 15 km southeast of the study area.

The nearest minor faults to the study area are located as follows:

- WNW-ESW Faults: Two faults were recorded: the first is located 2 km to the north of study area, while the second one is located 1.5 km south of the study area. The downthrown (which is the downward displacement of rock formations) of these two faults are towards northeast.
- NE-SW Fault: A fault trending with this direction was recorded and downthrows towards the northwest.

2.2.4 Seismic Impact

According to Jordan's seismic map, the project area is located within area 2A and has a seismic zone factor (Z) of 0.15 which indicates moderate seismic activity.

2.2.5 Topography

The main characteristic feature of the area's topography is the Amman-Zarqa syncline, which is the cause for the clear topographic relief seen northwest and southeast of the Zarqa River and which has slopes of 20% to 30%. The Amman-Zarqa syncline starts southwest of Amman and ends northeast of Zarqa. This syncline is constituted of mountains on its northern and western sides with clear topographic relief and elevations reaching up to 1,000-1,085 m above mean sea level (MSL). The Amman-Zarqa syncline also dictates the west-east flow direction of the groundwater.

Furthermore, elevations in the area range from about 450 m to 1,000 m above MSL, decreasing progressively towards the east and more sharply to the west in the direction of the Jordan Rift Valley. The Zarqa River is the only water body passing through the area.

A site specific survey and geotechnical investigation would need to be completed as part of the design stage for the IWTP. The investigation should include evaluation of conditions during the winter months as well as during the summer months.

2.3 HYDROGEOLOGY AND AQUIFER CONSIDERATIONS

2.3.1 Water Resources

As-Samra WWTP is located within the Amman-Zarqa Basin, one of the important fresh groundwater sources in Jordan. The basin area is approximately 3950 km^2 and covers mainly Amman Zarqa and Mafraq cities.

The drainage pattern in Amman-Zarqa basin is primarily towards the west into the Jordan Valley area. Zarqa River main drainage course originates from the Amman area, as noted in the WRECP *ESIA for The Expansion of As-Samra Wastewater Treatment Plant*. The final effluent of As-Samra WWTP flows into the Zarqa River through Wadi Dhuleil and then

collects in King Talal Dam (KTD). The treated water supports the irrigation water which is supplied to the Jordan Valley.

The basin is bordered by the Yarmouk Basin to the North, the Azraq Basin to the East and South, the Dead Sea Basin to the South-West, and by the Reft Sidis Basin to the West. Within the Amman-Zarqa Basin, the most important aquifer is the Amman-Wadi Sir (B2/A7) system.

Groundwater, surface, and non-conventional water resources in the basin area are described below:

Groundwater

The Amman-Zarqa basin is divided into two parts: an eastern part north-east of Wadi Zarqa that flows to the west; and a western part, extending to the west of Wadi Zarqa, that flows to the east. The direct recharge to the basin comes from precipitation, floodwater flows and infiltration resulting from irrigation activities. The groundwater quality in the basin is affected by various factors such as over pumping, inflows of wastewater and leaching of solid wastes.

There are three aquifer systems (Upper, Middle, and Lower) in the project area. Additional information regarding these aquifers is provided in the project's 2014 PEIA.

The depth of the groundwater in the project area ranges between 45-70 m. The groundwater flows in the same direction of Wadi Dulail stream. Groundwater in the vicinity of As-Samra WWTP is monitored regularly by a third party (RSS) in order to investigate and analyze the effect of As-Samra WWTP effluent. Regulated wells are shown on Figure 2-1). Detailed information regarding the monitored wells is presented in the 2014 PEIA.

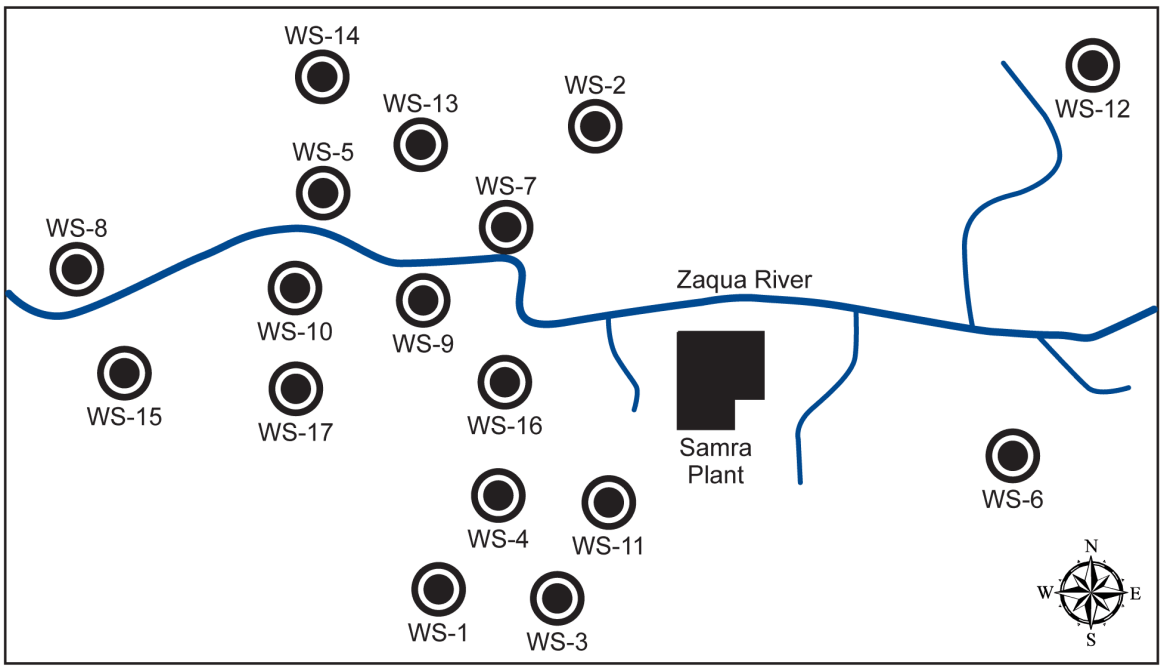

Figure 2-1: Locations of Groundwater Wells Monitored by the RSS

As presented in the 2014 PEIA, recent results of groundwater quality tests for several monitoring wells indicate concentrations of some constituents are higher than the maximum allowable limits for drinking water as per the Jordanian Standards (JS 286/2008) and/or pose some degree of restriction on irrigation uses according to the *FAO Irrigation and Drainage*

Paper, Water Quality for Agriculture, 1989 referenced in the PEIA. Constituents with concentrations which impose irrigation restrictions include: sulfate (SO_4), bicarbonate (HCO_3), sodium (Na), Chloride (Cl), Boron (B), Total Hardness (TH), nitrate ($NO_{3)}$.

Surface Water

The main surface water resources in the project area are:

- Wadi Dhuleil. Effluent from As-Samra WWTP discharges to the Wadi Dhuleil stream. The stream rises in the desert that is northeast of the project area.
- Seil Al-Zarqa. This originates in the Amman urban area.
- Al-Zarqa River. This rises from a spring near Amman, called Ain Ghazal. Zarqa River constitutes of two tributary streams that join the river at Sukhna. The River flows about 50 km downstream of As-Samra towards King Talal Dam (KTD).
- King Talal Dam (KTD). This dam was built as a reservoir with a total capacity of 86 MCM. It is located on the Zarqa River, and it stores water from rain and treated wastewater from As-Samra WWTP to be used for irrigation in the Jordan Valley.

Treated Wastewater (Non-Conventional Resources)

Treated wastewater at As-Samra WWTP is discharged to Wadi Dhuleil and flows downstream towards the Zarqa River. Treated wastewater formed about 55% of the total inflow to King Talal Dam (KTD). Mixed effluent from As-Samra and natural base flows and runoff are stored at KTD for irrigation. Water is released from KTD through a hydroelectric facility and passes down the river channel to a series of diversion weirs that serve irrigation projects in the Jordan Valley, as discussed in the WRECP's *ESIA for The Expansion of As-Samra Wastewater Treatment Plant*.

Water quality is monitored from different locations up and downstream of As-Samra WWTP, to measure the effect of discharging its effluent to streams. According to the 2014 Preliminary EIA, most of the monitored chemical characteristics meet the criteria limits of JS (893:2006): only the NO_3levels are higher than those specified in the standards for certain irrigation uses and E.coli levels are higher than the limits for certain irrigation uses and discharges to surface water.

No specific hydrogeologic information has been obtained by the project team for the pretreatment site. A site specific investigation of groundwater depths would need to be conducted as part of the design stage for the IWTP. Depending on the local requirements, it may also be necessary to collect samples of groundwater for submittal to a laboratory for chemical analysis.

2.4 EXISTING TREATMENT AND EFFLUENT DISPOSITION AT SAMRA

The As-Samra Wastewater Treatment Plant is a comprehensive domestic wastewater treatment system serving the Amman Russeifa-Zarqa basin, where approximately 60% of Jordan's population lives. A Master Plan funded by USAID in 1997 for the Amman-Zarqa basin from 2000 through the year 2025 recommended the construction and expansion of As-Samra WWTP in two phases: phase one is the construction of As-Samra WWTP through the year 2015; in phase two, As-Samra WWTP will be expanded through the year 2025. Phase 1 (designed to serve a population of 2.27 million with a capacity of 267,000 m^3/day) construction was completed in 2008. Phase one included the construction of West Zarqa and Hashimyyah Pumping Station, Ain Ghazal Pretreatment Plant, and Conveyor lines to the WWTP from the three facilities. In 2010, it was decided to increase the capacity of As-Samra WWTP by 40% (from 267,000 m^3/day to 367,000 m^3/day), consistent with the recommendation made in the Master Plan.

Wastewater coming from Ain Ghazal Pretreatment Facility flows into two Pelton turbines in the inlet structure and generates electrical power. That wastewater is then mixed with the wastewater coming from Hashimyyah and Zarqa pumping stations and distributed into two grit and sulfide removal tanks, each divided into two chambers. Heavy particles, oil and grease and sulfide are removed in this stage. The effluent is then distributed into four primary settling tanks and up to 65% of the total suspended solids, and 40% of the BOD_5 are removed.

The settled water is then distributed into eight biological reactors that consist of three zones:

- Anoxic Zone for exogenous denitrification
- Oxic Zone for BOD_5 removal and initial nitrification
- Endogenous Zone for complete nitrification

Effluent passes through eight secondary clarifiers, and flows to two plug flow chlorine contact basins.

Primary sludge from the primary settling tanks is thickened in three covered circular thickeners, while the biological sludge from the aeration tanks is thickened in three covered Dissolved Air Flotation units (DAF). The two are then mixed together in a covered tank before being pumped to four anaerobic digesters. The sludge is kept in the anaerobic digesters for three weeks at 35ºC where it is mixed thoroughly. The digested sludge flows then to the digested sludge storage tank prior to being pumped to 25 solar evaporation basins where it is dried to about 30% dry solids (DS). Lime is used if necessary for sludge stabilization (Degrémont Jordan, 2008).

In summary, the facility consists of grit and sulphide removal, biological treatment, and chlorination. The biological treatment is an activated sludge process with an anoxic tank for denitrification. After the treated water is chlorinated, the effluent meets the Jordanian Standards 893/2006 (see Attachment). The effluent is discharged to a drainage wadi that flows to the Zarqa river and is ultimately captured in the King Talal Dam (KTD) reservoir for reuse as agricultural irrigation water in the Jordan Valley.

Primary and biological sludge is thickened and anaerobically digested. Digested sludge is dried in solar evaporators and Biogas produced in the digestors is used for the production of electricity.

Figure 2-2 illustrates the As-Samra WWTP processes.

2.5 REGULATORY REQUIREMENTS

The 2013 FS outlines the existing regulatory requirements for the IWTP at the Hallabat site (Section 2.5). Of particular importance to treatment and disposal practices in connection with that dedicated industrial wastewater treatment plant is Jordanian Standard No. 202/2007 which governs the reuse of industrial treatment plant effluents and the discharges of industrial treatment plant effluent to surface waters. The Jordanian Standard No. 1145/2006, which governs sludge management (albeit in the context of domestic wastewater treatment facilities) is also highly relevant.

For this addendum, the requirements relative to an industrial pretreatment facility discharging to a domestic wastewater treatment plant are applicable. In Jordan, the discharge of commercial and industrial wastewater into a domestic/municipal wastewater

system requires written approval from the Water Authority of Jordan (WAJ) and must conform to the requirements summarized in *Instructions for Discharging Industrial and Commercial Wastewater into the Wastewater Sewer and its Amendments for the Year 1998* (WAJ). The limits specified in these instructions are listed in Section 4.1.4 of this addendum.

The final treated effluent from the domestic wastewater treatment plant is subject to the requirements listed in Jordanian Standard 893/2006.

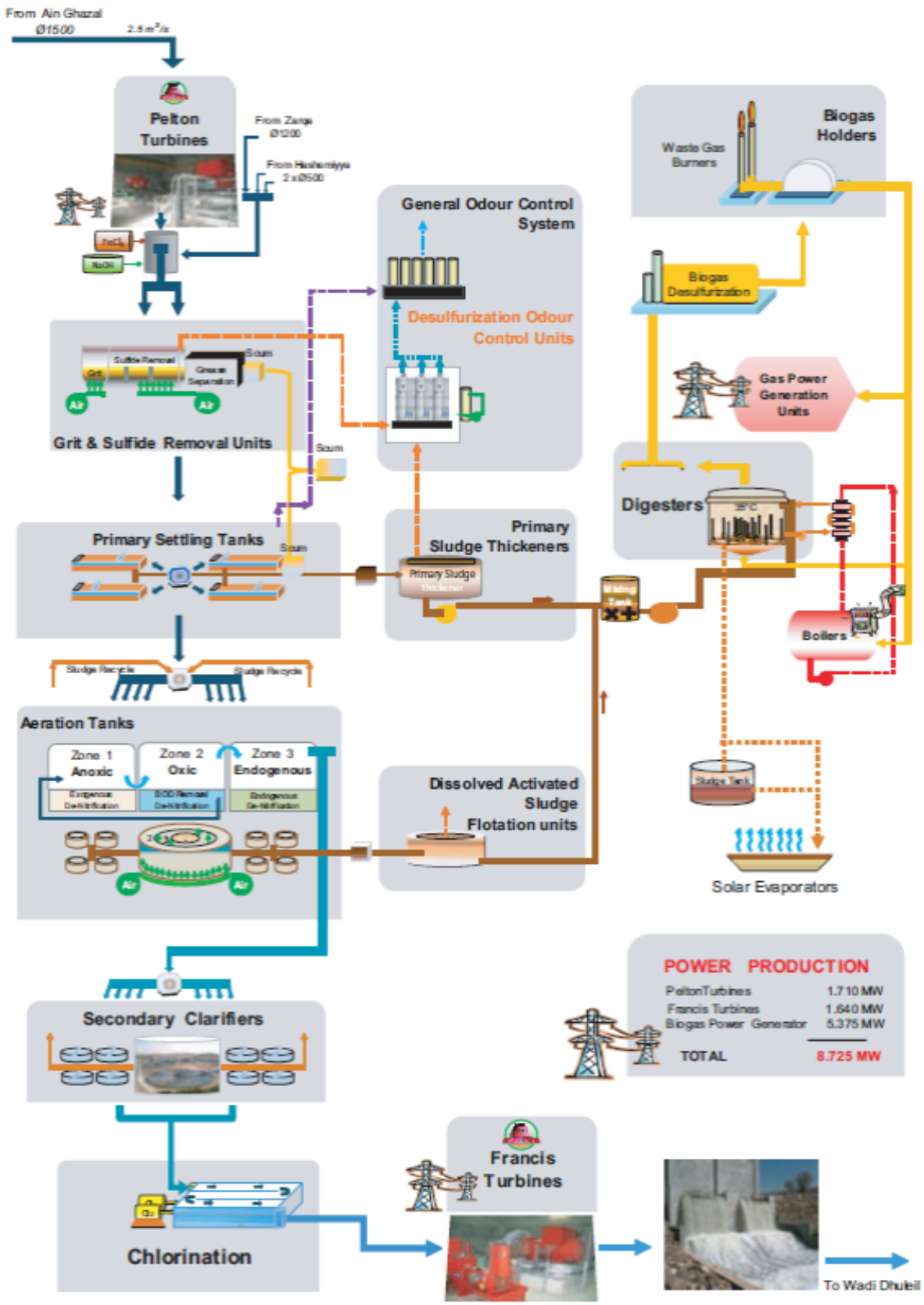

Figure 2-2: As-Samra Wastewater Treatment Processes (Degrémont Jordan, 2008)

3 WASTEWATER SAMPLING AND CHARACTERIZATION

3.1 SUMMARY OF SAMPLING AND CHARACTERIZATION

In order to develop design criteria for the Zarqa area IWTP, a sampling and characterization study was conducted to assess the industrial wastewater quantity and quality currently generated in the Zarqa area. The characterization study was also used to develop criteria that are representative of the wastewater that would be expected to be received at the IWTP. The 2013 FS report documented, in detail, the waste characterization study. The study was required because there is no existing centralized plant with representative monitoring data. The resulting wastewater characterization has been used for the basis of design for the pretreatment alternative also.

In general, the study first required identification and classification of industries in the Zarqa area, and determination of which industries generate wastewater. Surveys and interviews were conducted to assess the likelihood of an industry contributing to a centralized IWTP. Limited available facility effluent data was evaluated and combined with new data collected specifically for the study for each of the established industry sectors. Flow-weighted averages were developed for design parameters. A projection was also made for future flow rates to the IWTP, recognizing that the area is characterized by its strong potential to accommodate additional industrial facilities within the service zone.

Based on the study, the initial design flow for the Zarqa IWTP was established to be 2,500 m^3/d, to address the current minimum anticipated flow need. The plant will be designed with provisions to add parallel treatment modules, each with the capability to accommodate an additional anticipated 2,500 m^3/d: These flows represent the typical daily flow during the normal work week. The daily flows on a 7-day basis would be expected to be somewhat less.

Information regarding the design concentrations for wastewater anticipated to be treated at the IWTP is provided in Section 4.

4 DESIGN BASIS AND TREATMENT ALTERNATIVES

This section summarizes the basis of design for developing treatment alternatives for the proposed regional IWTP in Zarqa. A brief description of the alternatives evaluated in the 2013 FS is included. A detailed description of the new pretreatment alternative and the process control and sparing philosophies considered as part of its evaluation is provided. A more detailed design basis and detailed descriptions of the original four alternatives evaluated can be found in Section 4 of the 2013 FS.

4.1 DESIGN CRITERIA FOR THE PROPOSED TREATMENT SYSTEM

In general, and as detailed in Section 4 of the 2013 FS, the acts, codes and regulations of the Hashemite Kingdom of Jordan are the controlling criteria for the design of the project.

4.1.1 Design Flow Rates – Peak Factors

Consistent with project team experience with other industrial flows, the vast majority of flow is expected to occur Sunday through Thursday during customary daytime working hours, and peak flows may be several times the average flow. The treatment system must be capable of accommodating both the average and peak influent flows.

Table 4-1 presents a summary of the design flows for the IWTP. The flow rates provided in the table represent the maximum daily and peak hourly influent flows anticipated to be encountered at the plant. The design hourly flow rate is based on the daily equalized flow assuming it occurs uniformly for the entire 24-hour day, while the peak hourly flow rate is based on the maximum daily flow received at the facility over a 6-8 hour period. As the IWTP will include facilities for flow equalization, the higher flows would occur only in the receiving station and headworks equipment prior to equalization.

Table 4-1. Proposed Design Flow Rates

Parameter	Daily Flow Rate (m^3/day)	Hourly Flow Rate (m^3/h)
Design (Maximum Daily) Flow Rate(1)	2,500	104.2
Peak Hourly Flow Rate (2)		600

Notes:

1. *Equalized flow rate. The treatment system must be hydraulically designed for continuous operation at this flow rate, taking into account any cleaning or maintenance cycles.*
2. *Peak hourly flow rate based on ten 30 m^3 capacity tanker trucks offloaded in 30 minutes; this flow is restricted to the portion of the plant between the Inlet Works (Receiving Stations and Headworks) and Equalization Tank.*

4.1.2 Project Limits of Work

The pretreatment IWTP would be located on a single parcel of land adjacent to an existing WWTP such as As-Samra. All the proposed structures and buildings would be located within the boundary of the treatment plant site. The only expected offsite elements would be routing for tanker truck access roads, piping to the WWTP facilities for effluent and sludge disposition, and perhaps, piping from the WWTP facility to the IWTP for utilities, such as service and/or potable water.

4.1.3 Chemical Composition

The design basis for the chemical composition of the influent wastewater is presented in Table 4-2, below. A discussion of the development of this characterization is presented under Sub-section 3.5 in the 2013 FS. As discussed in that Sub-section, the actual IWTP influent concentrations will vary depending on which industries eventually discharge to the Zarqa IWTP, and the quantity and quality of wastewater discharged on a particular day. For this reason, it will be necessary to monitor influent concentrations on a regular basis, and it may be necessary to make adjustments to the treatment process to accommodate any significant variations from the design conditions. For example, nutrient (nitrogen and phosphorous) levels will be monitored to determine if any supplemental nutrient addition is required.

Table 4-2. Wastewater Quality and Design Parameter Values

Parameter	Unit	Minimum	Maximum	Average	Design Value
pH	SU	6.4	7.4	7	7
BOD_5 (total)	mg/L	921	1,300	1,102	1,300
BOD soluble	mg/L	514	698	637	698
COD (total)	mg/L	2,072	2,871	2515	2,871
COD soluble	mg/L	1,183	1,616	1,445	1,616
TSS	mg/L	750	1,391	983	1,391
FOG	mg/L	21	60	42	60
NH_3	mg/L	14	23	20	23
TKN	mg/L	44	60	53	60
PO_4-P	mg/L	0.2	11.7	6	11.7
TDS	mg/L	2,799	3,489	3,018	3,489
Na	mg/L	430	527	490	527
Cl	mg/L	665	788	708	788

4.1.4 Treated Effluent Quality Requirements

The alternatives evaluated for the Zarqa Hallabat IWTP site considered various processes to provide treatment prior to reuse. As such, the standards associated with reuse of industrial wastewaters were applicable, and were documented in the 2013 FS.

This addendum includes an alternative that provides pretreatment of industrial waste flows prior to discharge to a domestic wastewater treatment plant. In that context, the Pretreatment Standards for Industrial Wastewater Discharges to Domestic Collection systems (summarized in Table 4-3) would apply to the effluent of the IWTP pretreatment facility.

Table 4-3. Pretreatment Standards for Industrial WW Discharge to Domestic WW Collection Systems

Parameter		Limit	
Hydrogen Ion Concentration	pH	5.5 to 9.5	Range
Temperature	T	65°C	Maximum
Fat, Oil, Grease, Wax	FOG	100 mg/L	Maximum
Hydrocyanic acid-forming compounds	HCN	1.0 mg/L	Maximum
Phenolic compounds (as Phenol)	Phenols	10 mg/L	Maximum
Sulfides (as H_2S)	Sulfides	10 mg/L	Maximum
Methylene Blue Active Substances	MBAS	40 mg/L	Maximum
Chrome*	Cr	5.0* mg/L	Maximum
Copper*	Cu	4.5* mg/L	Maximum
Tin	Sn	10 mg/L	Maximum
Beryllium	Be	5.0 mg/L	Maximum
Nickel*	Ni	4.0* mg/L	Maximum
Cadmium*	Cd	1.0* mg/L	Maximum
Arsenic	As	5.0 mg/L	Maximum
Barium	Ba	10 mg/L	Maximum
Lead*	Pb	0.6* mg/L	Maximum
Manganese	Mn	10 mg/L	Maximum
Silver*	Ag	1.0* mg/L	Maximum
Boron	B	5.0 mg/L	Maximum
Mercury*	Hg	0.5* mg/L	Maximum
Iron	Fe	50 mg/L	Maximum
Zinc	Zn	15 mg/L	Maximum
Cobalt*	Co	0.05* mg/L	Maximum
Selenium*	Se	0.05* mg/L	Maximum
Lithium	Li	5.0 mg/L	Maximum
Vanadium*	V	0.1* mg/L	Maximum
Aluminum	Al	5.0 mg/L	Maximum

** Provided the combined total of these elements together does not exceed 10 milligrams per liter.*

These standards have been developed to ensure that industrial discharges do not interfere with the domestic WWTP processes, and to ensure that the WWTP effluent meets its discharge requirements. In this case, since the effluent at As-Samra is currently used for irrigation in the Jordan Valley, the Effluent Limits for Reclaimed Domestic Wastewater Used for Irrigation would apply.

It should be noted that some level of pretreatment and/or segregation of wastes from certain facilities may be required prior to their discharge to the Zarqa pretreatment IWTP. In particular, highly concentrated oily or total dissolved solids (TDS) waste streams should not be accepted at the facility. Although the pretreatment IWTP should be able to accommodate some elevated levels of these constituents in individual facility flows, large quantities of these wastes could interfere with the pretreatment process, and the ability to meet the pretreatment requirements for discharging to the domestic WWTP. For the purpose of this feasibility evaluation, we have assumed that the IWTP will not accept hazardous waste, sludges or treatment byproducts such as brines and reject streams with extremely high levels of TDS and/or free oil.

4.1.5 **Solid Waste/Sludge Quality Requirements**

The residuals from the treatment of wastewater include fat, oil, and grease (FOG); screenings; grit; and sludge. The 2013 FS provided information regarding disposal requirements for these types of materials at the Hallabat IWTP site. Requirements for

disposal of these materials resulting from the As-Samra IWTP pretreatment facility are listed below:

Disposal of FOG, Screenings, and Grit
Fat, oil and grease (FOG) collected at the Zarqa IWTP will be removed from the treatment process. As described for the Hallabat IWTP site, there are currently two options for ultimate disposal of these materials in the Zarqa area: incineration at an approved facility, or transport to Ain Ghazal, a pretreatment facility for managing FOG, screenings, and grit, for further (sludge) processing (current, widely accepted practice for facilities in the greater Amman area). Consistent with current practice at other IWTP facilities such as the Sahab IWTP, screenings and grit at the As-Samra location may be transported to the Al Ghabawi landfill for disposal. For the As-Samra pretreatment alternative, depending on the specific components of the industrial byproducts, it may be possible to combine some of these with similar materials at the domestic wastewater treatment plant.

It is recommended that the project proponent confirm with the various authorities that such practices will continue to be acceptable without the imposition of additional requirements.

Sludge Disposition
It is anticipated that the sludge generated at the IWTP pretreatment facility will be discharged to the domestic WWTP, processed for energy recovery in combination with the WWTP biosolids, and managed in accordance with the WWTP procedures. It is anticipated that the relatively small volume of sludge generated at the IWTP pretreatment facility will not negatively affect the management of solids at the domestic WWTP.

It is recommended that the project proponent conduct tests on the sludge immediately upon startup of the IWTP. Based on these results, clarification should be sought from the regulating authorities on issues related to processing and disposal requirements. This would include determining whether the sludge from the IWTP could be considered under the appropriate JS 1145/2006 Classification – see Table 4-3 above – for the purposes of discharge to the WWTP and/or disposal.

4.2 Overview of Treatment Alternatives

The project team considered and evaluated four industrial wastewater treatment alternatives (A, A2, B, and C) for the Zarqa Industrial wastewater treatment plant as part of the 2013 FS. Each of these proposed treatment alternatives includes a similar concept for wastewater receiving and pretreatment and for sludge management. The alternatives were developed based on their unique wastewater treatment process and/or regulatory/economic considerations for effluent reuse/disposition.

This addendum provides a fifth alternative, Alternative D, which incorporates the same concept as each of the previous alternatives for wastewater receiving and pretreatment, but then relies on discharge to a domestic WWTP for final effluent and sludge disposition. A brief summary of the alternatives is provided below. Alternative D is then explored in greater detail.

Alternative A – Provide Primary (Chemical), Secondary (Biological) and Tertiary Treatment (Reverse Osmosis) for Agricultural and/or Industrial Water Reuse
Alternative A includes chemical addition systems and dissolved air flotation (DAF) to remove suspended solids, and some dissolved metals, biological treatment to remove organic compounds including nitrogen, and tertiary treatment employing a high efficiency reverse osmosis (HERO) process to remove dissolved solids. Alternative A is the most robust of the alternatives evaluated and treated effluent will satisfy current regulatory requirements for

Reclaimed Industrial Wastewater Used for Irrigation (JS 202/2007 Divisions II and III) and the effluent limits for Reclaimed Industrial Wastewater Discharges to Surface Waters (Wadi discharges). As such, the effluent will provide a year-round source of irrigation water, with the ability to discharge to surface water for storage if there is no demand for irrigation water.

Alternative A2

It is anticipated that the effluent from Alternative A could also satisfy certain non-potable industrial needs, particularly in the future, when the planned industrial estate is established. The only potential current industrial reuse opportunity identified to date is associated with the nearby quarries, which use water for dust control. Alternative A2 incorporates the same treatment systems as Alternative A, but assumes that some of the treatment byproducts can be mixed with partially treated effluent and used by the nearby quarries for dust control. The remaining treated effluent remains available for reuse for agricultural purposes.

Alternative B – Provide Primary (Chemical), and Secondary (Biological) Treatment with Polishing in a Constructed Treatment Wetland (CTW) for Experimental Water Reuse in Agriculture

As with Alternative A, Alternative B includes chemical addition systems and dissolved air flotation (DAF) to remove suspended solids, and biological treatment to remove organic compounds. Alternative B, however, employs a constructed treatment wetland (CTW) to polish the effluent, removing some of the dissolved solids and residual organic compounds, including nitrogen, before it is discharged from the IWTP. It is anticipated that the treated effluent will satisfy the majority of regulatory requirements for Reclaimed Industrial Wastewater Used for Irrigation (JS 202/2007 Divisions II and III) and will provide a reliable source of irrigation water to support a full-scale pilot evaluation of agricultural wastewater reuse. While concentrations of dissolved solids and some specific inorganics may exceed regulatory criteria, it is anticipated that salt-tolerant species can be selected for the pilot-scale evaluation. With Alternative B, it is anticipated that the CTW will be part of the IWTP, while the experimental irrigation process with the resulting effluent would take place offsite and not be considered a component of the IWTP.

Alternative C – Provide Primary (Chemical), and Secondary (Biological) Treatment with Reuse of Effluent to Support Salt-Tolerant Plant Growth

Similar to Alternatives A and B, Alternative C includes chemical addition systems and dissolved air flotation (DAF) to remove suspended solids, and biological treatment to remove organic compounds including nitrogen. Alternative C, however, is designed to utilize the partially treated biological system discharge in a natural system incorporating a carefully selected mixture of salt-tolerant plant species. The mixture will be designed to fully absorb the effluent flow, and support the restoration of the surrounding Badia. In this case, the natural system will be considered a component of the IWTP. Thus, Alternative C represents a zero liquid discharge (ZLD) system with no net effluent flow. In order to consume the entire effluent flow, the natural system is large and would need to be located on area beyond the current IWTP Site boundary, thus requiring negotiation regarding land ownership and land acquisition.

Alternative D – Provide Primary (Chemical) Treatment for Pretreatment

For Alternative D, industrial wastewater will be pretreated prior to discharge to As-Samra WWTP for water reuse, and solids will be processed at As-Samra WWTP for energy recovery and disposal. As with each of the original alternatives, Alternative D includes chemical addition systems and dissolved air flotation (DAF) to remove suspended solids. Alternative D, however, is a pretreatment system only, and does not include biological treatment. The effluent from the DAF will be pumped directly to a domestic wastewater treatment plant, which will further treat the effluent to meet the established standards for

reuse. Similarly, it is assumed that all sludge produced in the DAF unit will also be pumped to the sludge handling systems at the domestic treatment plant.

A detailed discussion of Alternatives A, A2, B, and C is presented in the 2013 FS. A detailed discussion of Alternative D is presented below.

4.3 Alternative D – Provide Primary (Chemical) Pretreatment for Discharge to a Domestic WWTP

Alternative D involves pretreatment of projected wastewater influent flows to meet the established regulatory standards for industrial pretreatment discharging to a robust domestic wastewater treatment plant. At the domestic wastewater treatment plant, the effluent will be treated such that the final effluent meets the established Jordanian irrigation reuse and discharge standards. For example, if Alternative D is located at As-Samra, the ultimate reuse of the wastewater would be for irrigation of the Jordan Valley and the standards for reuse of domestic wastewater for irrigation would apply.

Figure 4-1 provides a simplified block flow diagram illustrating Alternative D with flow information for major equipment items summarized. Concentration information for waste streams is also provided. For concentrations of the feed and effluent from various treatment units, see Table 4-4 below, which presents the design criteria for the main treatment units. As depicted, Alternative D discharges approximately 2,400 m^3/day effluent to the domestic wastewater treatment plant. This effluent has the potential to be reused after appropriate treatment at a wastewater treatment plant with biological treatment.

Figure 4-1: Alternative D - Simplified Block Flow Diagram

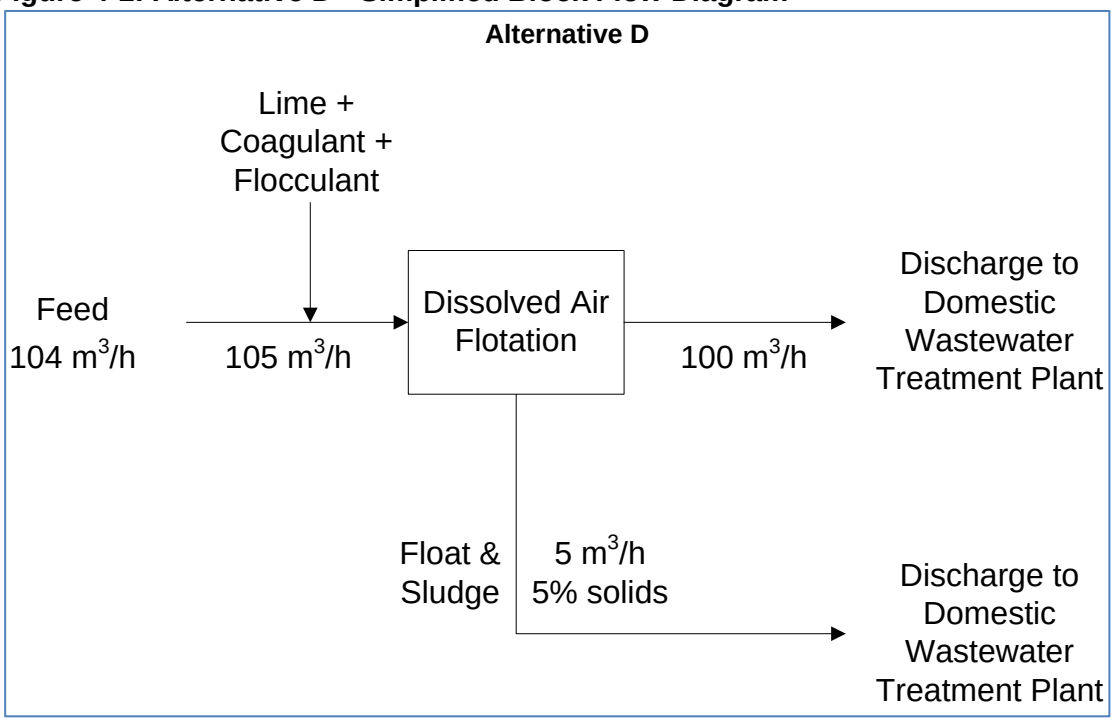

Table 4-4. Alternative D Design Criteria

Parameter	**Units**	**DAF Feed**	**DAF Effluent/ Biotreatment Feed**
Flow rate	m^3/d	2,500	2,400
TSS	mg/L	2,400	120
TDS	mg/L	3,500	3,500
COD	mg/L	2,800	1,700
BOD	mg/L	1,300	800
Total N	mg/L	70	70

A more detailed Block Flow Diagram and a Material Balance for Alternative D are provided in Addendum Appendices 1 and 2, respectively. An Equipment Layout (Plot Plan) is included in Addendum Appendix 3.

4.3.1 **Process Description**

4.3.1.1 ***Receiving Station and Headworks***

Receiving Station
The Receiving Station has been selected to accommodate an average flow of 2,500 m^3/day delivered to the pretreatment site by tanker truck. The Receiving Station consists of a number of individual truck unloading facilities, a bar screen, receiving tank, raw wastewater pumps, and additional space for truck parking while they wait for dewatering. The station will be constructed to accommodate trucks ranging in size from 9 to 36 m^3. In order to accommodate peak flows (which are anticipated to occur weekdays during normal working hours) unloading facilities for a total of 10 trucks (with an average capacity of 30 m^3) are provided. Assuming that the contents of each truck can be unloaded in a half hour, the peak hourly flow for the receiving station is 600 m^3/hour.

Trucks will offload by gravity to a channel, using hoses carried on board their trucks. Hard piping with cam lock connections will be provided at each individual unloading station to facilitate unloading. The channel will be equipped with a retractable cover, to minimize odors, and a bar screen to intercept any large solids (rags, papers, packaging, etc, that might be mixed with the wastewater). Raw wastewater will flow by gravity to a covered receiving tank (T-400) with a capacity of 400 m^3. The submersible Headworks Feed Pumps (P-400 A/S) will be located within the receiving tank, and will be sized to accommodate the peak hourly flow.

Vapors from the covered channel and receiving tank will be controlled and discharged through the Inlet Works Biofilter (G-400) to minimize odors in the vicinity. The Inlet Works Biofilter will be located at grade adjacent to the Receiving Tank, and will consist of a steel tower unit with internal plastic trays or packing material which will support biological growth. Vapors will be displaced from the tank, and into the tower, as water flows into the Receiving Tank and channel. In addition, a fan (PF-400 A/S) will be installed to provide a constant negative pressure within the system, and to ensure an appropriate air exchange rate to prevent buildup of explosive or toxic vapors. Organic constituents in the vapor stream will be degraded as the vapor flows up through the tower. The tower will accommodate vapor flows of up to 3,000 m^3/hour based on an estimated headspace of approximately 600 m^3 and an air exchange rate of 5 air changes per hour (to mitigate the buildup of H_2S and other, possibly explosive gases). The filtered vapor stream will be discharged to the ambient air through the top of the tower.

Headworks

The plant's pretreatment system includes a Package Headworks System (G-401), which is comprised of systems for fine screening, grit removal, and grease removal and has been selected to provide primary treatment of the tanker discharge to protect the IWTP process pumps and equipment. The pretreatment system discharges into the Equalization Tank. The Headworks System and pumps are designed to accommodate the hourly peak flows from the receiving station. A summary of the Headworks package follows:

Fine Screening - The fine screening unit will collect and remove influent solids larger than 6mm (¼ inch) from the raw wastewater flow stream, and to wash and dewater the screenings. The screening unit includes a rotating basket type microstrainer, rotating rake and cleaning comb, screenings hopper, screw conveyor and wash press, wash system, gear motor driver, and endless bagger. The screening system is installed in a stainless steel tank, which is completely enclosed with hinged stainless steel access cover, complete with gasket and turn locks to minimize emissions. The spray wash system is completely enclosed to reduce spray water, aerosols, and leakage. Screened wastewater discharges into the aerated grit chamber.

Grit Removal - The aerated grit removal system settles and removes sand and grit from the influent wastewater flow in order to prevent their accumulation in downstream process units where they are harmful due to their abrasive nature. The system consists of the grit tank, odor control pipe, grit horizontal screw conveyor, grit inclined screw conveyor, grit washing system, discharge hopper, and the positive displacement air blower, piping, and diffused air system. Diffused air enhances the grit settlement to the grit chamber's hopper bottom where the grit horizontal screw moves the grit to a hopper near the front of the unit. The grit inclined screw lifts the grit from the hopper, washes the grit as it rises and discharges the grit into the grit container. Grit removal is an important treatment process, which helps extend the life of all downstream equipment. When in the normal operating position, the grit screw unit is periodically operated based on a timed cycle or manually operated. The washed and dewatered grit is discharged into a portable grit container, which, when full, is manually removed. The contents are transferred to a dumpster using a forklift; the dumpster is periodically hauled offsite for grit/screenings disposal.

Grease Collection - The grease collection and removal system collects and removes scum and grease floating on the wastewater surface of the Headworks System chamber. The collected concentrated scum and grease removed from the chamber is combined with the washed grit and hauled offsite for disposal. The grease collection and removal system includes grease chamber with separation wall and hopper, scraper blade pulled by a cable and driver, grease pump, and associated facilities. The Headworks System tank has a vertical separation wall with slots for grease and oil penetration from the aerated grit tank into the adjacent grease chamber. The grease chamber has a scraper blade, which is pulled by a drive unit via a cable. The blade pushes the grease and oil along the grease chamber towards the grease weir, over a weir, and into the hopper. A grease pump is connected to the bottom of the hopper. The grease pump discharge pipeline connects to the auger tube of the inclined grit screw unit for dewatering together with the grit. The grease pump is a progressive cavity type pump.

4.3.1.2 ***DAF Equipment for Solids Removal***

Treatment will be provided to remove suspended solids (both organic and inorganic) and allow some precipitation of dissolved solids from the screened wastewater. Chemically enhanced DAF has been selected mainly based on its tolerance for variations in influent wastewater composition which are anticipated for the Zarqa IWTP. In addition, the footprint for the DAF unit is significantly less than that of other flocculation/clarification equipment.

A key consideration in the removal of solids is optimization of pH to cause precipitation of certain dissolved solids from solution. The addition of hydrated lime, or $Ca(OH)_2$ allows for pH adjustment, and enables precipitation of metal hydroxides. In this case, where the water may be reused for irrigation, lime is preferable to caustic (NaOH) since it will add Calcium rather than Sodium ions to the water, and increase the effluent Sodium Absorption Ratio (SAR), thereby increasing the ability to reuse the water for irrigation. It is assumed that the DAF will be operated at a pH of approximately 8.5 to 9, but the target pH can be adjusted to optimize selected dissolved metals concentrations.

Lime Handling System

Lime will be used for pH adjustment and control. It is assumed that lime will be purchased as hydrated lime [$Ca(OH)_2$], and delivered by tanker truck. It is anticipated that the lime storage and feed equipment will be provided by a single vendor and that the Lime Storage/Feeder Vendor Package (G-402) will include several pieces of equipment. The lime will be offloaded from a truck to a carbon steel lime storage silo with a conical bottom. A silo capacity of 45 m^3 will provide approximately 7 days of storage. The lime silo will include a bin activator which prevents bridging or rat holing of the silo contents. It is anticipated that compressed air will be injected into the silo on a timed basis, and the dedicated air compressor will operate as necessary to maintain the required pressure in the receiver tank. A reverse jet filter will also be provided to prevent moisture in ambient air from entering the silo and control lime dust during delivery operation.

The lime feeder will operate as required to feed the hydrated lime to the approximately 2-m^3 carbon steel Lime Slurry Tank (T-401) at a rate of approximately 110kg/hr. Waste water and/or utility water will be added to the tank to achieve the desired lime concentration (approximately 12%) in the slurry. The tank is fitted with baffles to ensure adequate mixing. A stainless steel Lime Slurry Agitator (G-403) will maintain the tank contents as slurry. The level of the tank contents will be monitored and used to control the flow of water to the tank, and lime feed rate. A low liquid level in the tank would shut down the agitator.

Lime slurry will be pumped to the treatment system via centrifugal Slurry Circulation Pumps (P-401 A/S). The pumps will normally operate continuously, but will start up and shut down based on liquid levels in the lime slurry tank. Excess slurry will be continuously returned to the tank. A safety shower and eye wash system will be provided in the vicinity of the lime processing equipment in case of accidental exposures to the lime slurry.

Acid Feed System

Sulfuric Acid used for pH control will be delivered by tanker truck and stored in an Acid Storage Tank (T-402) constructed of HDPE. The pH of wastewater discharged from the Headworks will be monitored and a single Acid Metering Pump (P-402) will be paced by the pH control system. If required, the pump will deliver acid to the Equalization Tank (T-403) feed line. The pH Control In-Line Mixer (G-404) will ensure adequate mixing of wastewater with either acid or lime slurry.

The Acid tank has been designed to accommodate a minimum of a 20-day supply of a concentrated acid solution.

Equalization

An Equalization Tank (T-403) will be incorporated to provide equalization of flows from the receiving station, mixing of the pH-adjusted wastewater and residence time prior to precipitation. The 6,000-m^3 subsurface concrete tank will include a tank cover, and piping for collection and treatment of its odorous vapor stream in the Equalization Tank Biofilter (G-407). Tank mixing will be provided by Equalization Tank Mixers (G-405 A/B/C/D). Liquid

level in the tank will be monitored and used to control a valve on the tank's effluent line. The DAF Unit Feed Pumps (P-403 A/S) will be installed within the Equalization Tank and will transfer wastewater from the Tank at a rate based on the liquid level in the Tank.

The Equalization Tank Biofilter (G-407) will be located at grade adjacent to the Equalization Tank, and will consist of a steel tower unit with internal plastic trays or packing material which will support biological growth. Vapors will be displaced from the tank, and into the tower, as water flows into the Equalization Tank. In addition, a fan will be installed to provide a constant negative pressure within the system, and to ensure an appropriate air exchange rate to prevent buildup of explosive or toxic vapors. Organic constituents in the vapor stream will be degraded as the vapor flows up through the tower. The tower will accommodate vapor flows of up to 6,250 m^3/hour based on an estimated headspace of approximately 1,250 m^3 and an air exchange rate of 5 air changes per hour (to mitigate the buildup of H_2S and other, possibly explosive gases). The filtered vapor stream will be discharged to the ambient air through the top of the tower.

Coagulant and Flocculant Storage/Feed Systems
Coagulant and flocculant will be added to the Equalization Tank effluent line prior to the DAF to enhance the separation of the precipitated solids.

Liquid coagulant (such as ferric chloride) used in flocculation and solids separation will be delivered by tanker truck and stored in the HDPE Coagulant Storage Tank (T-404). The tank capacity (6 m^3) will accommodate a minimum 7-day supply of concentrated coagulant. Coagulant Metering Pump (P-404) will deliver coagulant to the Equalization Tank effluent line. The Coagulant In-Line Mixer (G-406) will ensure mixing of the coagulant with the wastewater prior to flocculation.

Concentrated liquid organic flocculant will be delivered in totes and transferred to the HDPE Flocculant Storage Tank (T-405) via the Flocculant Transfer Pump (P-406). Utility water will also be fed to the tank to provide the appropriate dilution ratio for feed to the treatment plant. The flocculant storage tank mixer (G-408) will provide mixing for the dilution. Diluted flocculant at approximately 0.5% solution will be delivered to the concrete Flocculation Tank via the Flocculant Metering Pump (P-405) designed to provide approximately 15 minutes residence time for coagulation/flocculation.

The Flocculation Tank (T-406) will be fitted with a Flocculator (G-411) to aid in the mixing of coagulant and flocculant with the wastewater and the formation of flocs in the tank.

Dissolved Air Flotation (DAF) System
Solids will be separated and removed from the wastewater in the packaged DAF system (G-409), which includes several components. Wastewater will flow by gravity from the Flocculation Tank to the Dissolved Air Flotation Tank (T-407). The approximate 7.5-m diameter by 2-m high concrete tank will be fitted with a DAF Unit Mechanism to aid in continued coagulation/flocculation. Within the tank, solids will either settle to the bottom, or float to the top. The DAF Float/Sludge will collect in the DAF Float Tank (T-408), where the Sludge Pumps will transfer the separated solids (mainly float) to the domestic wastewater treatment plant sludge processing area. The DAF Recycle Pumps are used to transfer a portion of the clarified effluent through the carbon steel DAF Air Saturation Tank and back into the DAF unit feed line. Centrifugal pumps will be provided for both the DAF Float/Sludge and Recycle streams. The DAF Air Compressors supply air to saturate the recycle stream at an elevated pressure (approx. 4.5 atm). When the pressurized recycled stream is discharged to the DAF tank, air micro-bubbles are released from the solution, agglomerating solids as they float to the surface. Treated effluent will be discharged over the DAF weir to an Effluent

Pumping Station (T-409) from which it will be pumped to the WWTP. The DAF unit operation will be controlled by a dedicated PLC control system.

4.3.1.3 *Sludge Management*

DAF float and sludge will be pumped (via Sludge Pumps) to the domestic wastewater treatment plant, where it will be combined and managed with the domestic treatment biosolids.

4.3.1.4 *Utilities*

Compressed instrument air may be required for a number of new instruments associated with the treatment system. An Instrument Air Package (G-410) will be installed to provide instrument quality air to all instruments. The Package will consist of an Air Compressor and Receiver/Separator. It will also include a Cooler, Drier, Filter, and Knockout Pot to ensure that the air is free of moisture and particulate prior to its use in any instruments. The Package (G-410) will be located within the Chemical Building and has been designed to provide 8.5 Nm^3/hr of air at 6.9 bar.

Since Alternative D will be located at the site of an operating wastewater treatment plant, it is anticipated that there will be an existing source of both potable and utility water for the IWTP pretreatment facility. It is assumed that both potable and utility water will be stored in tanks at the pretreatment IWTP site. Utility water will normally be provided for dilution of DAF flocculant and lime slurry makeup as well as to supply Utility Stations which will be part of the IWTP pretreatment system. Potable water would be provided as a backup to the utility water, and would be used for the Emergency Eye Wash and Shower Stations in the vicinity of the Lime Storage/Slurry locations, as well as in the vicinity of the Acid Storage Tank. Potable water supply will serve the treatment facility restrooms and administrative facilities.

4.4 Site Development Considerations

Alternative D was designed as an alternative that could be constructed at or near an existing domestic wastewater treatment plant. Based on an initial site layout shown in Appendix 3, the area of buildable land required for Alternative D is approximately 20,000 m^2 for the initial capacity of 2,500 m^3/day, with a total approximate area of 35,000 m^2 required for ultimate build-out at 7,500 m^3/day. Site development considerations would need to be evaluated when a specific site is chosen. Additional study of the site would include survey, geotechnical investigation, and review of site drainage requirements. Consideration would also need to be given to potential future modifications or expansions to the pretreatment facility, and the ability to accommodate these on the selected site.

4.5 Process Control Philosophy

It is anticipated that the pretreatment system will be served by a single supervisory control and data acquisition (SCADA) system. The SCADA system will provide real-time monitoring and data logging for all of the main system components. The centralized SCADA will allow the operator to make adjustments to each of the main system components from a single location. The SCADA would also coordinate the operation of emergency generator(s), and any potential changes in the treatment system operations when there is a power outage.

Local control panels will be provided for specific mechanical equipment. The local panel will allow for the equipment to be shut down and restarted from the equipment location, or returned to automatic operation. The local panels will be tied into the SCADA system.

Although not discussed specifically below, secondary containment with leak detection monitoring and alarms will be provided for all chemical tanks. Where alarms are indicated for process control, the alarm would be provided both at the SCADA and locally.

4.5.1 Receiving Station and Headworks

Receiving Station
Flow meters will be provided for each individual unloading station, with a single flow totalizer to provide information regarding the quantity of wastewater discharged from each truck, and the total flow to the treatment system.

The receiving tank will be fitted with two submersible pumps and a series of level switches. Normally, one pump will operate with the second serving as an installed spare. However, a lead/lag configuration will be used to allow both pumps to operate in case additional pumping capacity is required. The pumps will be configured to allow for periodic switching of the lead/lag configuration to promote even wear on both pumps.

The lead pump will be activated and switched on when wastewater reaches an established level in the tank (LH). The pump will operate until the water level drops below an established low level (LL). If the water level continues to rise, the lag pump will be activated when a high, high level (LHH) is reached. If the water level continues to rise, an alarm (LAHHH) will be activated to alert the operator that influent pumping rates are exceeding the receiving tank and raw wastewater pumping capacities. Both pumps will be shut down and an alarm will be activated in the event of a low, low level (LALL). The pumps will have hand off/on controls.

Vapors will be automatically displaced from the receiving channel and tank and into the tower, as wastewater is offloaded from trucks at the Receiving Station. A biofilter will continuously remove odors from the vapor stream prior to its discharge to the atmosphere.

Headworks
The local Headworks Control Panel (HCP) system regulates all functions of the Headworks System both in automatic and hand modes. The basic control philosophy is as follows:

1. The switch on impulse for the mechanical fine screen is activated by the level control system or a time-dependent auto-start control.
2. The horizontal and vertical grit screw conveyors are controlled by a timer.
3. The grease removal paddle must be operated by the systems adjacent control panel. When the grease removal paddle arrives at the tank edge between the grease trap and grease collection chamber, a power monitor switches off the motor. A grease pump is located at the bottom of the hopper and is connected to the tube of the inclined grit screw unit. The grease pump will cycle per the grease removal cycle.
4. The compressor for the grit trap aeration system is permanently switched on. The individual air tubes can be adjusted to specific site requirements using separate ball valves.

4.5.2 Equalization and DAF Equipment for Solids Removal

Lime Handling System
The lime handling system operation will be Programmable Logic Controller (PLC) controlled. Level indicators and a high and low level alarm (LAH and LAL) will be provided on the lime silo to prevent overfilling and to provide an indication of when lime needs to be ordered. The lime silo package will include a bin activator which injects compressed air into the silo on a timed basis to prevent bridging of the silo contents. The air compressor will operate as

necessary to maintain the required pressure in the receiver tank. The reverse jet filter works to continuously prevent moisture in ambient air from entering the silo.

The lime feeder will operate continuously to feed hydrated lime to the Lime Slurry Tank. Waste water and/or utility water will be added to the tank to achieve the desired lime concentration (approximately 10%) in the slurry. The tank is fitted with baffles to achieve adequate mixing. An agitator will maintain the tank contents as slurry. The level of the tank contents will be monitored and used to control the flow of water to the tank, and lime feed rate. A low liquid level in the tank will shut down the agitator.

Lime slurry will normally be pumped to the treatment system continuously, but will start up and shut down based on liquid levels in the lime slurry tank. The lime slurry feed rate is controlled by a diaphragm valve on the slurry feed line. The valve is opened or closed based on signals from pH sensors installed prior to, and after, the Equalization Tank. Excess slurry is returned to the lime slurry tank. A backpressure regulator is provided on the slurry return line to allow operation of the flow control valve. High and low level alarms are provided on the lime slurry tank.

The final design for the system will establish a set point for flocculation at a specific pH. If the Equalization Tank effluent pH is outside the range of approximately 0.5 pH units, the lime slurry flow will be adjusted and an alarm will be activated. In order to address the potential for lime scaling on the probes, two probes are provided on the effluent line with monitoring of the pH differential. One of the probes is manually selected as the controlling probe. An alarm is provided when the differential exceeds 0.1 pH units, indicating that scaling may be affecting the measurements and that cleaning of one or both of the probes is required. The operator can also switch the selection of the controlling probe. The pH probes are intended to be readily removable in order to allow for the anticipated need for frequent cleaning and calibration.

Equalization Tank

An Equalization Tank will be incorporated in the proposed treatment plant to provide equalization of flows from the influent pumping station, mixing of the pH-adjusted wastewater, and residence time for precipitation. The liquid level in the tank will be monitored and used to operate a flow control valve on the tank's effluent line. The valve will be opened or closed to the extent necessary to maintain the set level and a minimum flow to the DAF. Low and high level alarms (LAL, LAH) will provide a signal to the operator that unusual flow conditions may be occurring. Continuous mixing of the tank contents will be provided by mixing pumps and submerged propeller mixers installed within the tank.

A biofilter will continuously remove odors from the vapor stream prior to its discharge to the atmosphere. Vapors will be automatically displaced from the tank and into the tower, as water flows into the Equalization Tank.

A local control panel will be provided for the Equalization Tank submersible pumps.

Acid Feed System

The pH of wastewater discharged from the Receiving Station will be monitored, and a single acid metering pump will be paced by the pH control system. If required, the pump will deliver acid from the acid storage tank to the Equalization Tank feed line prior to in-line mixing of the lime slurry and wastewater. A level indicator will be provided on the acid storage tank, and high and low level alarms (LAH, LAL) will prevent overfilling and notify the operator when the tank needs to be filled. The system will be tied into the chemical storage area local control panel.

Coagulant and Flocculant Storage/Feed Systems

Coagulant and flocculant will be added to the Equalization Tank effluent line prior to the DAF to enhance the separation of the precipitated solids. The target dosage for both chemicals will be established based on evaluation of jar test results, during system start-up. A signal from the flow control valve on the Equalization Tank effluent line will pace both the coagulant and flocculant metering pumps, to provide a constant dosage. Coagulant will be injected prior to an in-line mixer, and flocculant will be added directly to the flocculation tank.

A level indicator will be provided on the Coagulant Storage Tank, and high and low level alarms (LAH, LAL) will prevent overfilling and notify the operator when the tank needs to be filled.

A level indicator and switch will be provided on the flocculant storage/aging tank. When the liquid level drops below an established set point (LL), the switch will activate the flocculant transfer pump to transfer concentrated flocculants from the tote in which it will be delivered to the storage/aging tank. The switch will also open a valve on the utility water line to provide the appropriate dilution ratio for the concentrated flocculant. High and low level alarms (LAH, LAL) in the storage/aging tank will provide an indication to the operator if there is an unusual condition in the flocculant delivery system. A mixer will be used to keep the diluted flocculant mixed.

The Flocculation Tank will be fitted with a flocculator with a variable speed drive to allow manual adjustment of the mixing of coagulant and flocculant with the wastewater to optimize the formation of flocs in the tank.

The system will be tied into the chemical storage area local control panel.

Dissolved Air Flotation (DAF) System

Solids will be separated and removed from the wastewater in the DAF system, which includes several components. The DAF saturation tank is fitted with both pressure and level controllers. The level control operates a valve on the saturation tank discharge line to maintain the level of the tank contents at approximately half full. The pressure control operates a valve on the airline from the associated compressor system, as necessary, to maintain the established pressure (approximately 4.5 atm) in the tank. A pressure control valve on the DAF tank influent line maintains the pressure in the DAF feed line. Treated effluent will be continuously discharged over the DAF weir into the Effluent Pumping Station. A portion of the DAF effluent is continuously recycled by pumping it back through the saturation tank and into the DAF feed line. A pump continuously transfers the separated float to the DAF Float/Sludge tank. Settled solids are periodically pumped on a timed basis to the DAF Float/sludge tank by opening a valve on the DAF sludge line. A local control panel will be provided for the DAF system.

Effluent Pumping Station

The effluent pumping station will be fitted with two submersible pumps and a series of level switches in order to pump the pretreated effluent to the domestic wastewater treatment plant, such as As-Samra. Normally, one pump will operate with the second serving as an installed spare The pump will be activated and switched on when wastewater reaches an established level in the tank (LH). The pump will operate until the water level drops below an established low level (LL). If the water level continues to rise, an alarm (LAH) will be activated to alert the operator that influent pumping rates are exceeding the receiving tank and raw wastewater pumping capacities. The pump will be shut down and an alarm will also be activated in the event of a low, low level (LAL). The pumps will have hand off/on controls.

4.5.3 Sludge Management

The float and sludge from the DAF will accumulate in the DAF Float tank, where it will also be pumped to the domestic WWTF, via the Sludge pumps. There will be two solids handling Sludge Pumps. One pump will normally operate, with the second serving as an installed spare. The pumps will operate based on level control.

4.5.4 Utilities

An Instrument Air Package can be installed to provide instrument quality air where it is required. The Package will consist of an Air Compressor and Receiver/Separator. It will also include a Cooler, Drier, Filter, and Knockout Pot to ensure that the air is free of moisture and particulates prior to its use in any instruments. The Package will be located in the Process and Controls Building. Signals will be provided from the compressed air systems to the SCADA to provide an alarm when not functioning.

It is anticipated that tanks will be provided to store potable and utility water at the site. A level indicator will be provided on each storage tank, and high and low level alarms (LAH, LAL) will prevent overfilling and notify the operator when the tank needs to be filled.

4.6 Sparing Philosophy and Design for Life Expectancy

This Section provides a brief description of the approach towards equipment sparing philosophy and the design life expectancies for the process equipment, piping, instrumentation, electrical, and structural elements that make up the complete IWTP.

In general, the new pumps and blowers in critical services will be provided with spare equipment. Sparing of the other wastewater treatment equipment is based on process stability and assumed reliability, as indicated below.

4.6.1 Receiving Station and Headworks

Headworks Feed Pumps

As described in Section 5.4.1, the Headworks Feed Pumps are designed so that, during the design flow operation, one pump will operate with the second serving as an installed spare. However, a lead/lag configuration could be used to allow both pumps to operate during extremely high flows when additional pumping capacity may be desired.

Headworks

Fans are provided to assist with the circulation of air to the Inlet Works and equalization Tank Biofilters. The fans should operate continuously, and therefore a installed spare fan should be provided for each Biofilter system.

Blowers are provided as part of the aerated grit chamber in the Headworks Package. One blower will operate continuously and the second blower will serve as an installed spare.

Mechanical equipment provided as part of the Headworks Package includes the mechanical screen and the grease removal paddle. Spare mechanical equipment should be stored on site.

4.6.2 **DAF**

Lime Handling System
A compressor and receiver tank are provided as part of the Lime Silo Package to inject compressed air into the silo on a timed basis. Because the silo could operate temporarily without the compressor, no spare is provided.

A lime feeder provided as part of Package G-402 which will operate as required to feed the hydrated lime to the lime slurry tank (T-401). Since it is possible to mix the lime feed manually if necessary, no sparing of the lime feeder is provided. Similarly, no sparing of the lime slurry agitator (G-403) is provided since manual mixing could be provided on a batch basis, if required and spare parts can be kept on hand for the agitator.

Lime slurry is pumped to the treatment system via slurry circulation pumps (P-401A/S). One pump will operate continuously, with the second pump serving as an installed spare. The pumps will normally operate continuously, but will start up and shut down based on liquid levels in the lime slurry tank.

Acid Feed System
Acid used for pH control will be delivered by tanker truck and stored in the Acid Storage Tank (T-402). A single Acid Metering Pump (P-402) will be paced by the pH control system and, if required will deliver acid to the Equalization Tank feed line. Since this is to be intermittent operation, a single metering pump will be provided. A pH Control In-Line Mixer (G-404) will be provided to ensure complete mixing of the acid, lime slurry, and wastewater. Since spare parts can be kept on hand for the mixer in case maintenance or repair of the mixer is required, no installed spare is provided. These spare parts should include a Spool piece to be used as a replacement for the In-line Mixer in the event that it needs to be taken out of service.

Equalization Tank
The Equalization Tank mixing will utilize 4 submerged propeller mixers (G-405 A/B/C/D). This will achieve minimum partial mixing even if one mixer is out of operation.

DAF Unit Feed Pumps
The DAF Unit Feed Pumps (P-403 A/S) are located in Equalization Tank. One pump will be operating while the other pump will provide 100% stand-by capacity.

Flocculation Tank and DAF Unit
The Flocculation Tank (T-406) and the Dissolved Air Flotation Tank (T-407) are designed as single train units. The most critical components of the DAF unit are:

- DAF Air Compressors, and
- DAF Recycle Pumps.

All the above rotating equipment is provided with 100% spare units. Since spare parts can be kept on hand for the Flocculator, (G-411) and DAF Unit Mechanism (G-409) in case maintenance or repair is required, no installed spares are provided.

Sludge Pumps
Two Sludge Pumps (P-409A/S) will be provided. One pump will be operating while the other pump will provide 100% stand-by capacity.

Coagulant and Flocculant Feed Systems
Liquid coagulant used in flocculation and DAF solids separation will be delivered by tanker truck and stored in the Coagulant Storage Tank (T-404). Concentrated liquid flocculant will be delivered in totes and transferred to the Flocculant Storage Tank (T-405) via the single Flocculant Transfer Pump (P-406). Since the DAF unit can temporarily operate with limited chemical addition, each tank is provided with a single metering pump (P-404 and P-405). Since spare parts can be kept on hand for the Flocculant Storage Tank Mixer (G-408) and Coagulant In-line Mixer (G-406) no installed spares are provided. These spare parts should include a Spool piece to be used as a replacement for the In-line Mixer in case it needs to be taken out of service.

DAF Effluent Pumps
The DAF Effluent Pumps (P-408 A/S) are located in the Effluent Pumping Station. One pump will be operating while the other pump will provide 100% stand-by capacity.

4.6.3 **Design Life Expectancy**

The design life expectancies for the process equipment, piping, instrumentation, electrical, and structural elements that make up the complete IWTP vary. In general, the civil elements such as buildings and structural concrete have a design life expectancy of 50 – 60 years or longer. Process piping (for example carbon steel in services where corrosion rates are lower than 0.5 mpy) will have an expected life of 60 - 75 years. Storage tanks have an expected life of 30 – 40 years. The design life expectancy for mechanical equipment items (in particular items with moving/rotating parts) will be less than that of other plant elements; a 15- 18 year design life is typical.

The expected life of any particular item (mechanical equipment, piping, buildings, structural concrete) in a process plant is dependent on attention to inspection and maintenance, as well as proper operation within intended operating limits. An equipment item is made up of a large number of individual components. It may be necessary to repair or replace many of these components over the life of the equipment item in order to keep it in service. Corrosion can reduce equipment life if paints and other protective coatings are not periodically renewed. Following a recommended schedule for lubrication can be critically important to mechanical items. In general, failure to provide appropriate preventative maintenance, repair or replace worn parts can lead to a reduced plant life.

It is not unusual for an IWTP to be subjected to an increase in the average load or duty requirements as compared to the original specification. Changes of this nature however, tend to reduce plant life expectancy. Feed characteristics can change so that equipment wear is either increased or decreased. Thus, changes in wastewater quality and composition can also impact the useful life of the facility.

5 EQUIPMENT, PIPING & BUILDING DESIGN CRITERIA

Section 5 in the 2013 FS provides a detailed description of the basic equipment, piping and building design criteria for each of the full treatment alternatives. Most of the criteria considered in the current evaluation of the pretreatment alternative is identical to the criteria which was considered in the 2013 FS. This section thus includes only a summary and/or refers to the 2013 FS where that information has already been provided, and includes a description of new information which was not part of the 2013 FS.

5.1 Design Criteria for WW Receiving Station, Pumps and Pumping Stations

5.1.1 General

As indicated in the 2013 FS, it is anticipated that the proposed Zarqa IWTP will be constructed in three phases and each phase may involve a different concept for conveyance of wastewater to the IWTP. Initially, (Phase I) wastewater will be transported by tanker trucks to the IWTP from individual industrial facilities located throughout the Zarqa area. The Phase I lift station will be located at the IWTP. It is likely that Phase 2 and 3 will involve construction of a centralized receiving facility in the vicinity of the existing concentrated industrial area, and/or a new planned industrial estate, along with conveyance by a forcemain. The lift stations associated with Phase 2 and 3 will likely be located at these remote receiving facilities

For the purpose of this addendum, the lift station design criteria is anticipated to be the same as that described in the 2013 FS. Depending on requirements of the domestic WWTP at which the pretreatment facility would be located, there may be other design criteria considerations.

5.1.2 WW Receiving, Screening, FOG and Grit Removal, Flow Measurement and Odor Control

Wastewater will be delivered to the pretreatment plant by tankers. The assumptions for receiving at the pretreatment plant are the same as those described in the 2013 FS. A summary of those follows:

- Average daily flow rate 2,500 m^3/d
- Average hourly flow rate 104 m^3/hr
- Tanker volume (Max) 30 m^3
- Tanker emptying time 30 minutes
- Duration of tankers receiving 12 hours
- Maximum number of tankers 20 tankers/hr
- Peak hourly flow rate 600 m^3/hr

The tanker receiving station will include 10 tanker discharge locations. Considering that the tanker will need 30 minutes for emptying, the station will allow to empty 20 tankers in one hour.

5.2 Design Criteria for Tanks, Sumps and Vessels

The criteria for design of tanks, sumps, and vessels for the pretreatment plant are the same as that described in the 2013 FS. All of the wastewater carrying tanks will generally use concrete or carbon steel as the recommended material of construction, while the associated piping systems will be constructed with coated carbon steel, polyvinyl chloride (PVC), or ductile iron. The exceptions to this are that stainless steel will be used for air piping and FRP will be specified for some of the corrosive services. With the exception of acid, chemical feed systems will generally use high-density polyethelyne (HDPE) material for the respective chemical storage tanks and all the associated piping will be either 316L SS tubing or PVC pipe. The acid storage tank will be fiberglass-reinforced plastic (FRP).

Process tankage such as the receiving and equalization tanks, flocculation and DAF tanks, will be concrete structures. However, due to the high sulfates (SO_4) content (up to 600 mg/L) in the wastewater stream, all concrete structures should utilize a sulfate resistant cement to ensure sufficient protection against possible sulfate corrosion of the concrete sections of the proposed treatment plant.

5.3 Design Criteria for Buildings and the Other Above-Ground Structures

5.3.1 Roadway Design Criteria

Roadway design criteria for the pretreatment IWTP will be the same as that described in the 2013 FS.

5.3.2 Structural Design Requirements

5.3.2.1 *General*

The structural design criteria to be used in the design of buildings and other structures associated with the pretreatment IWTP shall, in general, be the same as those described in the 2013 FS. Site-specificThe pretreatment plant shall include the following buildings and process structures:

A. **Chemical Storage/Process Equipment Building.** The building will be approximately 50 m x 40 m. The buildings can be combined for Alternative D, as much less space for chemical storage and protection of process equipment is required for a pretreatment facility. Structural criteria is the same as described in the 2013 FS. The chemical (coagulant and flocculant) storage tanks shall be located in the Chemical Storage portion of the building, while process equipment such as pumps and compressors and electrical equipment will be located in the Process Equipment portion of the building. Each of these tanks shall be fiberglass or high density polyethylene. The building floors shall be constructed such that secondary containment is provided for all tanks and other process equipment.
B. **Administrative and Laboratory Building.** The building will be approximately 65 m x 15 m. Similar construction as above, this building may not be necessary if there is space for laboratory and/or administrative offices in existing buildings at As-Samra, or other domestic WWTP location.
C. **Receiving Tank.** Rectangular cast-in-place reinforced concrete tank. The tank shall be open on the top and a separate cover shall be provided for odor control.
D. **Equalization Tank.** Rectangular cast-in-place reinforced concrete tank covered, supported on raft foundation, the walls shall be fair faced internally and externally. Steel bridge shall be provided on top for walkway and access.
E. **DAF Tank.** Circular cast-in-place reinforced concrete tank open on the top, supported on raft foundation, the walls shall be fair faced internally and externally. Steel bridge shall be provided on the top by the DAF equipment vendor.
F. **DAF Float Tank.** Square cast-in-place reinforced concrete tank open on the top. One of the bottom corners shall be filled in with concrete, creating an approximate 45

degree slope.

G. **Flocculation Tank.** Circular cast-in-place reinforced concrete tank open on the top, supported on raft foundation, the walls shall be fair faced internally and externally. Steel bridge shall be provided on the top.
H. **Lime Slurry Tank, Lime Silos and Lime Storage Feeders.** The lime slurry tank is a carbon steel structure. The silo and feeder are part of a package which will include vendor-specified materials, although it is anticipated that these pieces will be carbon steel and rested on one raft foundation with a small pedestal for each item of equipment.
I. **Effluent Pumping Station.** Rectangular cast-in-place reinforced concrete tank. The tank shall be open on the top.

5.3.2.2 ***Structural Codes and Standards, Loading Criteria and Materials***

Structural criteria codes and standards, loading criteria and structural materials associated with the pretreatment IWTP shall be the same as those described in the 2013 FS.

5.3.3 **Architectural Requirements**

The architectural design criteria requirements for the pretreatment IWTP shall be the same as those described in the 2013 FS.

5.3.4 **Electrical Requirements**

5.3.4.1 ***Design Standards***

The electrical design criteria associated with the pretreatment IWTP shall be the same as those described in the 2013 FS.

5.3.4.2 ***Project Components***

The electrical project components associated with the pretreatment IWTP shall be essentially the same as those described in the 2013 FS. The electrical load requirements will be less for the pretreatment facility than those described in the 2013 FS and are summarized in Table 5-1 below.

5.3.5 **Mechanical Requirements**

The mechanical design criteria associated with the pretreatment IWTP shall be essentially the same as those described in the 2013 FS

Table 5-1. IWTP Electromechanical Equipment (Alternative D)

Item No.	Equipment	Location	Qty.	Duty	Standby	Motor Power (KW)	Panel Power (KW)
P-400 A/S	Headworks Feed Pumps	Headworks	2	1	1	55	55
PF-400 A/S	Inlet Works Biofilter Fan	Headworks	2	1	1	2.2	2.2
P-401 A/S	Slurry Circulation Pumps	Outside Chemical Building (near Lime Slurry Tank)	2	1	1	8	8
PF-401 A/S	Equalization Biofilter Fan	Equalization Tank	2	1	1	3	3
P-402 AS	Acid Metering Pump	Chemical/ Process Building	1	1	0	0.37	0.37
P-403 A/S	DAF Unit Feed Pumps	Equalization Tank	2	1	1	22	22
P-404	Coagulant Metering Pump	Chemical/ Process Building	1	1	0	0.37	0.37
P-405	Flocculant Metering Pump	Chemical/ Process Building	1	1	0	0.37	0.37
P-406	Flocculant Transfer Pump	Chemical/ Process Building	1	1	0	0.37	0.37
P-407 A/S	Utility Water Pumps	Chemical/ Process Building	2	1	1	2.2	2.2
P-408 A/S	DAF Effluent Pumps	Effluent Pumping Station	2	1	1	22	22
G-101	Headworks Package - Miscellaneous Equipment	Headworks	1	1	0	1	1
G-102	Lime Storage/Feeder Vendor Package- Air compressor	Outside Chemical Building	2	1	1	4	4

G-102	Lime Storage/Feeder Vendor Package- Lime feeder	Outside Chemical Building	1	1	0	3	3
G-103	Lime Slurry Agitator	Lime Slurry Tank (Outside Chemical Building)	1	1	0	5	5
G-105 A/B/C/D	Equalization Tank Mixers	Equalization Tank	4	4	0	55	220
G-108	Flocculant Storage Tank Mixer	Chemical/ Process Building	1	1	0	1.5	1.5
G-109	DAF Vendor Package- Recyle Pumps	Chemical/ Process Building	2	1	1	22	22
G-109	Sludge Pumps	Chemical/ Process Building	2	1	1	2.2	2.2
G-109	DAF Vendor Package-Air Compressors	Chemical/ Process Building	2	1	1	5.5	5.5
G-124	Instrument Air Vendor Package	Chemical/ Process Building	2	1	1	1.5	1.5
G-125	Flocculator	Flocculation Tank	1	1	0	1.5	1.5
Total Power (KW)							**218**
Total Power (KVA)							**383**

5.4 Other Process Design Criteria

Other process design criteria were described for the treatment systems evaluated in the 2013 FS. The criteria associated with the unit operations proposed for pretreatment Alternative D in this addendum include the following systems:

- Receiving Station and Headworks
- Chemical Feed System
- Flow Equalization
- Flocculation Tank
- Dissolved Air Flotation (DAF) Clarifier
- Effluent Quality Monitoring

5.4.1 Receiving Station and Headworks

Design Basis

Receiving Tank

Design Conditions: Design Pressure: Atmospheric full of liquid (specific gravity 1.0 g/cm^3)
Design Temperature: 65 ^{O}C
Storage Capacity – less than 1 hour
Dimensions:
Length – 10 m, Width – 10 m, Height – 4 m (with steel cover)
Nominal Volume - 400 m^3
Materials of Construction: Concrete

Inlet Works Biofilter

Vapor Flow = 3000 m^3/h -5 exchanges/hr of normal operating headspace (600 m3)
Volume Loading Rate = 50 m^3/m^2.h
Empty Bed Residence Time = 90 seconds.
Dimensions – 5.0 m x 5.0 m (to be confirmed by vendor)
Height - 2.7 m (to be confirmed by vendor)

Inlet Works Biofilter Fan

No of Fans – 2 (One operating and one spare)
Capacity: 4,000 m^3/h
ΔP: 0.07 Bar
Motor: 2.2 kW
Material of Construction: Non-sparking

Headworks Feed Pumps

Design Conditions:
No of Pumps – 2 (One operating and one spare)
Capacity: 600 m^3/h
ΔP: 2.0 Bar
Motor: 55 kW
Material of Construction: DI/DI

Headworks Vendor Package

Package includes systems for fine screening, grit removal, and grease removal.
Design Conditions:
Design Pressure: Atmospheric full of liquid (specific gravity 1.0 g/cm^3)
Design Temperature: 65 ^{O}C
Capacity: 600 m^3/h

Headworks Blowers (To be confirmed by vendor)

No of Blowers – 2 (one operating and one spare)
Capacity: 219 m^3/h
ΔP:0.5 Bar
Motor: 3 kW
Material of Construction: DI/DI
Type – Centrifugal

5.4.2 **Chemical Feed Systems**

5.4.2.1 ***Hydrated Lime Feed and Slurry System***

Design Basis

Lime Storage/Feeder Vendor Package

Includes Lime Silo with reverse Jet Filter, Rotary Feeder and Air Compressor

Lime Silo -Includes Reverse Jet Filter to control lime emissions
Design Conditions: Design Pressure: Atmospheric, full of hydrated lime powder (Bulk Density - 950 kg/m^3)
Design Temperature: 100 ^{O}C
Silo Dimensions: Diameter – 2.8 m
Side wall depth – -9.0 m
Bottom Cone Angle – 60 degrees
Operating Volume – 57 m^3
Materials of Construction: Carbon Steel

Lime Feeder
Design Conditions: To deliver hydrated lime to the lime slurry tank
Maximum lime feed rate – 130 kg/h
Variable feed rate controlled by liquid level in the lime slurry tank

Air Compressor
Design Conditions: Provide compressed air to bin activator
Capacity – 50Nm^3/h
Discharge Pressure – 4.1 bar
Motor size – 4 kW

Lime Slurry Tank
Design Conditions: Design Pressure: Atmospheric, full of liquid (specific gravity 1.2 g/cm^3)
Design Temperature: 100 ^{O}C
Dimensions: Diameter – 1.5 m
Side wall depth – 1.1 m
Top Liquid Level – 0.8 m
Materials of Construction: Carbon Steel

Lime Slurry Agitator
Design Conditions: Top entering open top tank agitator
Design Pressure: Atmospheric, full of liquid (specific gravity 1.2 g/cm^3)
Design Temperature: 100 ^{O}C
Minimum Power Requirements: 1.0 kW/m^3, low speed/low shear agitation (lime slurry is abrasive)
Materials of Construction: 316L Stainless Steel

Slurry Circulation Pumps
Design Conditions: No of Pumps: two (One operating and one spare)
Capacity: 18 m^3/h recessed impellor pump
Differential pressure (ΔP): 2.5 Bar
Motor: 8 kW
Material of Construction: Ductile Iron

5.4.2.2 ***Acid Addition System***

Design Basis

Acid Storage Tank
Design Conditions: Design Pressure: Atmospheric full of liquid (specific gravity 1.8 g/cm^3)
Design Temperature: 65 ^{O}C

Storage Capacity – greater than 20 days
Dimensions:
Diameter – 2.0 m, Height – 2.0 m
Nominal Volume - 6.0 m^3
Materials of Construction: HDPE

Acid Metering Pump

Design Conditions: No of Pumps – one
Capacity: 0 – 0.12 m^3/h paced by pH analyzer/controller at the outlet from Inlet Works
Differential pressure (ΔP): 7.5 Bar
Motor: 0.37 kW
Material of Construction: Polytetrafluoroethylene (PTFE) Diaphragm

5.4.2.3 ***Coagulant Addition System - Alum or Ferric Chloride***

Design Basis

Coagulant Storage Tank

Design Conditions: Design Pressure: Atmospheric full of liquid (specific gravity 1.5 g/cm^3)
Design Temperature: 65 ^{O}C
Storage Capacity – greater than 7 days
Dimensions:
Diameter – 2.0 m, Height – 2.0 m
Nominal Volume - 6.0 m^3
Materials of Construction: HDPE

Coagulant Metering Pump

Design Conditions: No of Pumps – one
Capacity: 0 – 0.02 m^3/h paced by the flow controller at the feed line to the Flocculation Tank
Differential pressure (ΔP): 7.5 Bar
Motor: 0.37 kW
Material of Construction: PTFE Diaphragm

5.4.2.4 ***Flocculant Addition System***

Design Basis

Flocculant Storage / Aging Tank

Design Conditions: Design Pressure: Atmospheric full of liquid (specific gravity 1.2 g/cm^3)
Design Temperature: 65 ^{O}C
Storage Capacity – one shift
Dimensions:
Diameter – 1.45 m, Height – 0.95 m (dome or flat roof)
Nominal Volume - 1.6 m^3
Materials of Construction: HDPE

Flocculant Storage Tank Mixer

Design Conditions: Top entering tank agitator – low speed paddle agitator
Approximate power input – 1.0 kW/m^3
Design Temperature: 65 ^{O}C
Motor Size: 1.5 kW
Materials of Construction: 316L Stainless Steel

Flocculant Transfer Pump

Design Conditions: No of Pumps – one
Capacity: 0 – 0.14 m^3/h gear pump to transfer concentrated flocculant from flocculant tote to the Flocculant Storage /Aging Tank
Differential pressure (ΔP): 7.5 Bar
Motor: 0.37 kW
Material of Construction: Ductile Iron

Flocculant Metering Pump

Design Conditions: No of Pumps – one
Capacity: 0 – 0.12 m^3/h paced by the flow controller at the feed line to the Flocculation Tank
Differential pressure (ΔP): 7.5 Bar
Motor: 0.37 kW
Material of Construction: PTFE Diaphragm

5.4.3 **Flow Equalization**

Design Basis

Equalization Tank

Design Conditions: Design Pressure: Atmospheric full of liquid (1.0 g/cm^3)
Design Temperature: 65 ^{O}C
Storage Capacity – two days
Dimensions:
Length – 47.5 m, Width – 21 m, Height – 6 m (with steel cover)
Nominal Volume - 6,000 m^3
Materials of Construction: Concrete

Equalization Tank Mixers

Type: Submerged Propeller
No. of Mixers*:* – 4
Approximate power input – 35 W/m^3
Design Temperature: 65 ^{O}C
Motor Size: 55 kW each
Material of Construction: DI/316L SS Propellers

Equalization Tank Biofilter

Vapor Flow = 6,250 m^3/h -5 exchanges/hr of normal operating headspace (1,250 m^3)
Volume Loading Rate = 50 m^3/m^2.h
Empty Bed Residence Time = 90 seconds.
Dimensions – 7.2 m x 7.2 m (to be confirmed by vendor)
Height - 2.7 m (to be confirmed by vendor)

Equalization Biofilter Fan

No of Fans – 2 (One operating and one spare)
Capacity: 6,250 m^3/h
ΔP: 0.07 Bar
Motor: 3 kW
Material of Construction: Non-sparking

DAF Unit Feed Pumps

Design Conditions:
No of Pumps – 2 (One operating and one spare)
Capacity: 130 m^3/h
ΔP: 2.0 Bar
Motor: 22 kW
Material of Construction: DI/DI

5.4.4 Flocculation Tank and Flocculator Mechanism

Design Basis

Flocculation Tank
Sizing Basis:
15 minutes retention time at average flow conditions of 104.2 m^3/h
3.6 m diameter, 3.0 m side wall depth; capacity of 30.5 m^3
Maximum water depth – 2.7 m
Design Conditions:
Design Pressure: Atmospheric, full of liquid (specific gravity 1.0 g/cm^3)
Design Temperature: 65 ^{O}C
Materials of Construction: Reinforced concrete

Flocculator
Design Conditions:
Top entering open top tank agitator – low speed paddle agitator with variable speed gearbox.
Approximate power input – 60 W/m^3
Velocity gradient - 150 sec^{-1}
Design Temperature: 65°C
Materials of Construction: 316L Stainless Steel

5.4.5 Dissolved Air Flotation

Design Basis

Provisions could be made for the flotation tank to be covered in the future for odor and VOC emission control, if it is determined to be necessary.

Design Conditions / Sizing Basis
For oil/solids removal: DAF flotation tank to be 7.5 m in diameter (internal)
Influent: Net Forward Flow – 105 m^3/h
TSS –2,500 mg/L
FOG - 66 mg/L
Recycle Flow - 25% - 50% of forward flow
Saturation Pressure for Air – 5.0 bar (max)
Effluent: TSS - 123 mg/L max.
FOG - 3 mg/L

Mechanical Design:

DAF Vendor Package
Dissolved Air Flotation Tank (Tank not included in package, but Vendor to confirm design)
Flotation tank to be provided with bottom sludge rake, float skimmer and trough, launders, scum box, still well, and weirs
Design Conditions:

Design Pressure: -2/+14 inches of w.c. (plus full of liquid)
Design Temperature: 65 °C
Storage Capacity – two days
Dimensions:
Diameter – 7.5 m, Height – 2.2 m (sloped bottom)
Nominal Volume - 97 m^3

Operating conditions:
Pressure: Atmospheric
Temperature: 20 - 35 °C
Material of Construction: Concrete
Leak detection required

DAF Air Saturation Tank (To be confirmed by vendor)

Design conditions:
Design Pressure – 7 bar
Design Temperature - 65°C

Operating conditions:
Pressure: 4.5 to 5.0 bar
Temperature: 20 - 35°C

Material of Construction: Carbon steel

DAF Air Compressors (one operating and one spare)(To be confirmed by vendor)

Design conditions: Provide compressed air to DAF Air Saturation Tank
Capacity – 60 Nm^3/h
Discharge Pressure: 5.2 bar
Motor size – 5.5 kW

Material of Construction: DI/DI

DAF Recycle Pumps (To be confirmed by vendor)

Design Conditions:
No of Pumps – 2 (one operating, one spare)
Capacity: 60 m^3/h
ΔP: 5 Bar
Motor: 22 kW
Material of Construction: DI/DI
Type – Centrifugal Pump

DAF Float/Sludge Pumps (To be confirmed by vendor)

Design Conditions:
No of Pumps – 2 (one operating, one spare)
Capacity: 10 m^3/h
ΔP: 1.5 Bar
Motor: 1.1 kW
Material of Construction: DI/DI
Type –Recessed Impellor Pump

DAF Float Tank (Not included in package)

Design Conditions:
Design Pressure: full of liquid
Design Temperature: 65 °C
Storage Capacity – 1.25 hours
Dimensions:
Length– 2.1 m, Width – 2.1 m, Height – 2.0 m (sloped bottom)
Nominal Volume - 4.2 m^3

5.4.6 **Effluent Pumping**

Design Basis

Effluent Pumping Station (Not including in package)
Design Conditions:
Design Pressure: full of liquid
Design Temperature: 65 °C
Storage Capacity – 15 min
Dimensions:
Length– 4.3 m, Width – 4.3 m, Height – 2.3 m
Nominal Volume - 37.5 m^3

DAF Effluent Pumps (Not included in package)
No of Pumps – Two (One operating and one spare)
Capacity: 130 m^3/h
ΔP: 2 Bar
Motor: 22 kW
Material of Construction: DI/DI
Type – Submersible Solids Handling Pump

5.4.7 **Sludge Management**

The Sludge Pumps are designed to pump the sludge from the DAF Float Tank to As-Samra or other domestic wastewater treatment plant sludge processing area.

Sludge Pumps
Design Conditions:
No of Pumps – 2 (one operating, one spare)
Capacity: 5.6 m^3/h
ΔP: 5 Bar
Motor: 2.2 kW
Material of Construction: DISS
Type –Progressive Cavity Pump

5.4.8 **Effluent Quality Monitoring**

Final effluent quality will be monitored using automatic samplers operating in the flow proportional composite sample collection mode. A grab sample could be taken from the effluent sampling station at any time of the day. The automatic samplers will be paced based on 4-20 mA signal from the respective flow meters located in the final effluent line(s). The final effluent flow rate will be constantly measured and recorded.

If required by the Jordanian regulatory agency, the treated effluent pH could be monitored on a continuous basis with pH analyzer/recorder. However, this arrangement has not been included in the current design.

6 TREATED WASTEWATER REUSE

Beneficial use of treated wastewater is one of the key elements affecting the recommendation of the process alternative. In this section, water reuse objectives and applications are described briefly, and reuse options are discussed.

6.1 Overview

The use of municipal wastewater effluent is a well-established practice in Jordan. WAJ is the government entity managing the operation of municipal wastewater treatment plants and signing contracts with end users for the use of reclaimed water. As of 2010, WAJ had 168 such contracts, mostly for agricultural applications, allowing beneficial uses of reclaimed water (Task 4 Site Selection Report, 2011). In fact, effluent from the As-Samra WWTP is currently reused for irrigation in the Jordan River valley.

The use of *industrial* wastewater effluent has been less common, partly because the water used by industry has been a small fraction of the Kingdom's total water consumption (approximately 5 percent, according to Jordan's Water Strategy 2009), and many small industries have been simply transferring the wastewater directly to designated disposal sites. Some industrial facilities have pretreatment systems at their sites and discharge the minimally treated industrial wastewater into a municipal sewer collection network. However, in light of increasing water demand by industry, beneficial use of appropriately treated industrial wastewater is becoming a crucial component in the industrial facilities' water and environmental management.

The 2013 FS presented a generalized conceptual description of potential water reuse options explored for the Zarqa IWTP Hallabat site. The reuse scenarios presented were somewhat hypothetical, two of which would potentially be conducted on an experimental basis, pending regulatory authorization. The aim of the program would be to show that the appropriate and safe reuse of industrial wastewater with elevated salinity is a viable option for similar projects located in similar climes.

The proposed reuse scenario associated with the pretreatment Alternative D in this addendum is less hypothetical in that the effluent would be discharged to a facility with an established reuse system in place. The pretreatment IWTP effluent would be added to As-Samra's current flow and increase its reuse capacity.

6.1.1 Reuse Objectives

As described in the 2013 FS, one of the overarching goals of the Water Resources and Environmental Conservation Project is to foster a change in strategic thinking in the industrial sector to bring a more integrated and sustainable water resources management perspective to wastewater pollution abatement in the industrial sector. The specific objective for the Zarqa IWTP is to develop a cost-effective treatment and disposal alternative that meets the needs of stakeholders such as the Zarqa Chamber of Industry (ZCI) and its constituents, including consideration of integrating opportunities for sustainable polishing and water conservation for beneficial reuse while mitigating the cost of operations. This proposed reuse of wastewater is designed to meet these objectives. Using treated effluent to the fullest extent includes the potential for beneficial reuse, provided that reuse can be accomplished cleanly and efficiently and provided that the selected application is appropriate for the native environment and for local populations.

6.1.2 Regulatory Requirements

Relevant regulatory requirements for the environmental management of industrial wastewater were listed in the 2013 FS. Among these requirements, treatment, discharge and reuse of industrial wastewater are regulated under Jordanian Standard JS 202/2007, Water-Industrial Wastewater Treatment (summary shown in Table 6-1) and discharge of

reclaimed domestic wastewater is regulated under Jordanian Standard JS 893/2006 (summary shown in Table 6-2). In JS 202/2007, requirements for the physical, chemical and biological quality of treated effluent are specified for the intended purposes. As indicated in the 2013 FS, the quality requirements are similar, but for some parameters (e.g. total suspended solids (TSS), Nitrate, total nitrogen (TN), TDS and Methylene Blue Active Substances (MBAS)) and for certain reuse applications, industrial wastewater effluent is allowed to have higher concentrations than the effluent from domestic wastewater treatment plants.

The relevant regulatory requirements for the reuse of water in this addendum are those outlined in JS 893/2006, as the pretreated effluent will be treated at a domestic wastewater treatment plant prior to discharge for reuse. The requirements identified in JS 202/2007 for industrial wastewater are applicable to Alternatives A, A2, B, and C, as discussed previously in the 2013 FS.

Some specific thoughts concerning regulatory requirements in the context of the various IWTP treatment alternatives are presented after the tables.

Table 6-1: JS 202/2007 Quality Limits for Water Reuse and Wadi Discharge for Reclaimed Industrial Wastewater

Parameter	Unit	I. Cooked vegetables, Parks, Playgrounds sides of roads within city limits	II. Fruit trees, Sides of roads outside city limits, and landscape	III. Field crops, industrial crops and forest trees	Cut flowers	Wadi Discharge
Group A						
BOD	mg/L	30	200	300	15	60
COD	mg/L	100	500	500	50	150
DO	mg/L	>2			>2	>2
TSS	mg/L	50	200	300	15	60
pH	pH unit	6-9	6-9	6-9	6-9	6-9
Turbidity	NTU	10			5	15
Nitrate	mg/L	30	45	70	45	80
Ammonium	mg/L					5.0
TN	mg-N/L	45	70	100	70	70
E coli	/100mL	100	1000		<1.1	1000
Helminths	/L	≤1	≤1	≤1	<1	<0.1
FOG	mg/L	8	8	8	2	8
Group B						
Phenol	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002
TDS	mg/L	2000	2000	2000	2000	2000
MBAS	mg/L	100	100	100	100	25
T Phosphate	mg/L	30	30	30	30	15
Chloride	mg/L	400	400	400	400	350
Sulfate	mg/L	500	500	500	500	300
Bicarbonate	mg/L	400	400	400	400	400
Sodium	mg/L	230	230	230	230	-
Magnesium	mg/L	100	100	100	100	-

Table 6-1: JS 202/2007 Quality Limits for Water Reuse and Wadi Discharge for Reclaimed Industrial Wastewater

Parameter	Unit	I. Cooked vegetables, Parks, Playgrounds sides of roads within city limits	II. Fruit trees, Sides of roads outside city limits, and landscape	III. Field crops, industrial crops and forest trees	Cut flowers	Wadi Discharge
Calcium	mg/L	230	230	230	230	-
Aluminum	mg/L	5	5	5	5	2
Arsenic	mg/L	0.1	0.1	0.1	0.1	0.05
Beryllium	mg/L	0.1	0.1	0.1	0.1	0.1
Copper	mg/L	0.2	0.2	0.2	0.2	1.5
Fluoride	mg/L	2.0	2.0	2.0	2.0	2.0
Iron	mg/L	5.0	5.0	5.0	5.0	5.0
Lithium	mg/L	0.075	0.075[a]	0.075	0.075	2.5
Manganese	mg/L	0.2	0.2	0.2	0.2	0.2
Molybdenum	mg/L	0.01	0.01	0.01	0.01	0.01
Nickel	mg/L	0.2	0.2	0.2	0.2	0.2
Lead	mg/L	0.2	0.2	0.2	0.2	0.2
Selenium	mg/L	0.05	0.05	0.05	0.05	0.05
Cadmium	mg/L	0.01	0.01	0.01	0.01	0.01
Zinc	mg/L	5.0	5.0	5.0	5.0	5.0
Boron	mg/L	1.0	1.0	1.0	1.0	1.0
Chromium	mg/L	0.1	0.1	0.1	0.1	0.1
Mercury	mg/L	0.002	0.002	0.002	0.002	0.002
Vanadium	mg/L	0.1	0.1	0.1	0.1	0.1
Cobalt	mg/L	0.05	0.05	0.05	0.05	0.05
Cyanide	mg/L	0.1	0.1	0.1	0.1	0.05
SAR	-	9	9	9	9	9
Color						15

Table 6-1: JS 202/2007 Quality Limits for Water Reuse and Wadi Discharge for Reclaimed Industrial Wastewater

Parameter	Unit	I. Cooked vegetables, Parks, Playgrounds sides of roads within city limits	II. Fruit trees, Sides of roads outside city limits, and landscape	III. Field crops, industrial crops and forest trees	Cut flowers	Wadi Discharge
TOC	mg/L					55
Temp change	^{o}C					6

Note: TDS = total dissolved solids, MBAS = methyl blue active substances (detergents), SAR = sodium adsorption ratio

Table 6-2: JS 893/2006 Quality Limits for Water Reuse and Wadi Discharge for Reclaimed Domestic Wastewater

Parameter	Unit	I. Cooked vegetables, Parks, Playgrounds sides of roads within city limits	II. Fruit trees, Sides of roads outside city limits, and landscape	III. Field crops, industrial crops and forest trees	Wadi Discharge
Group A					
BOD	mg/L	30	200	300	60
COD	mg/L	100	500	500	150
DO	mg/L	>2	-	-	>1
TSS	mg/L	50	150	150	60
pH	pH unit	6-9	6-9	6-9	6-9
Turbidity	NTU	10	-	-	
Nitrate	mg/L	30	45	45	45
Ammonium	mg/L	-	-	-	
TN	mg-N/L	45	70	70	70
E coli	/100mL	100	1,000	-	1,000
Helminths	/L	< or = 1	< or = 1	< or = 1	< or = 1
FOG	mg/L	8.0	8.0	8.0	8.0
Group B					
Phenol	mg/L	<0.002	<0.002	<0.002	<0.002
TDS	mg/L	1,500	1,500	1,500	1,500
MBAS	mg/L	100	100	100	25
T Phosphate	mg/L	30	30	30	15
Chloride	mg/L	400	400	400	350
Sulfate	mg/L	500	500	500	300
Bicarbonate	mg/L	400	400	400	400
Sodium	mg/L	230	230	230	200
Magnesium	mg/L	100	100	100	60

Table 6-2: JS 893/2006 Quality Limits for Water Reuse and Wadi Discharge for Reclaimed Domestic Wastewater

Parameter	Unit	I. Cooked vegetables, Parks, Playgrounds sides of roads within city limits	II. Fruit trees, Sides of roads outside city limits, and landscape	III. Field crops, industrial crops and forest trees	Wadi Discharge
Calcium	mg/L	230	230	230	200
Aluminum	mg/L	5	5	5	2.0
Arsenic	mg/L	0.1	0.1	0.1	0.05
Beryllium	mg/L	0.1	0.1	0.1	0.1
Copper	mg/L	0.2	0.2	0.2	0.2
Fluoride	mg/L	1.5	1.5	1.5	1.5
Iron	mg/L	5.0	5.0	5.0	5.0
Lithium	mg/L	2.5[1]	2.5[1]	2.5[1]	2.5
Manganese	mg/L	0.2	0.2	0.2	0.2
Molybdenum	mg/L	0.01	0.01	0.01	0.01
Nickel	mg/L	0.2	0.2	0.2	0.2
Lead	mg/L	5.0	5.0	5.0	0.2
Selenium	mg/L	0.05	0.05	0.05	0.05
Cadmium	mg/L	0.01	0.01	0.01	0.01
Zinc	mg/L	5.0	5.0	5.0	5.0
Boron	mg/L	1.0	1.0	1.0	1.0
Chromium	mg/L	0.1	0.1	0.1	0.02
Mercury	mg/L	0.002	0.002	0.002	0.002
Vanadium	mg/L	0.1	0.1	0.1	0.1
Cobalt	mg/L	0.05	0.05	0.05	0.05
Cyanide	mg/L	0.1	0.1	0.1	0.1
SAR	-	9	9	9	6.0

Note: TDS = total dissolved solids, MBAS = methyl blue active substances (detergents), SAR = sodium adsorption ratio

1. Lithium limit is 0.075 mg/L for citrus crops

6.2 Reclaimed Water Characteristics and Availability

Expected flows and effluent quality for each of the treatment alternatives for the Zarqa IWTP at Hallabat were discussed in detail in the 2013 FS. The important parameters in determining the reuse applications, especially for irrigation, were listed as:

- Total dissolved solids (TDS)
- Total nitrogen (TN)
- Ammonium (NH_4^+)
- Nitrate (NO_3^-)

The alternative described in this addendum, Alternative D, is a pretreatment alternative which will produce approximately 2400 m^3/day of pretreated effluent meeting the requirements for discharge to a domestic WWTP. The relatively small quantity of pretreated effluent represents less than 1% of the total flow at As-Samra which can be easily accommodated in the existing WWTP equipment and will not affect the WWTP facility's ability to meet the requirements for reuse of its effluent and management of biosolids. The pretreated effluent will thus provide approximately 2400 m^3/day additional water for reuse with the treated domestic WWTP effluent.

A summary comparison of the reuse potential for each of the alternatives is provided in Table 6-3.

Table 6-3: Reclaimed Water Availability/Characteristics and Comparison With Reuse Requirements

Parameter	Alternative A	Alternative A2	Alternative B	Alternative C	Alternative D	JS202: 2007 (Class I)
Flow at capacity, m^3/d	2,500	2,000*	1,900	0 after use in experimental tree plantation	2,400	-
BOD, mg/L	~0	~0	1	3	770	30
TDS, mg/L	1,800	1,600	2,700	3,550	3,530	2,000
Total Nitrogen, mg-N/L	7	6	4	8	70	45
Ammonium N, mg-N/L	~0	~0	~0	~0	23	-
Nitrite/Nitrate, mg/L	24	22	12	25	32	30
Remarks:	Meets standards for all types of irrigation. Appropriate for limited types of industrial applications.		TDS level exceeds limit for any reuse application or wadi discharge, but is less than 3,000 mg/L for use on an experimental basis.	Does not meet standards for irrigation; Alternative designed for zero discharge from the IWTP	Standards for irrigation are not relevant. Instead, meets standards for discharge of pretreated effluent to domestic WWTP. Effluent from As As-Samra meets reuse criteria identified in JS893:2006	Relevant only for Alternatives A, A2, B, C.

*Note: excludes 500 m^3/day for industrial reuse.

7 COMPARISON OF ALTERNATIVES AND RECOMMENDATION

7.1 General Overview

This section provides a comparative assessment of the alternatives considered for the Zarqa IWTP. The comparison includes the 2013 FS alternatives, and follows the criteria and format outlined in that document, but has been updated to include the pretreatment option (Alternative D) described in this addendum. A brief summary of advantages and disadvantages for each alternative is provided in Section 7.2. The criteria for evaluation and selection of alternatives are reiterated from the 2013 FS in Section 7.3. A comparison of technologies is made with respect to non-monetary aspects (environmental, health and safety and technical factors) in Sections 7.4 and 7.5, respectively. The basis for the cost estimates is provided and the alternatives are compared in Section 7.6 with respect to economic considerations. Finally the recommended alternative is identified in Section 7.7.

7.2 Brief Discussion of Proposed Alternatives

Alternative A – Chemical, Biological and TDS Removal for Agricultural and/or Industrial Water Reuse

Alternative A is the most robust of the alternatives evaluated, and treated effluent will satisfy current regulatory requirements for Reclaimed Industrial Wastewater Used for Irrigation (JS 202/2007 Division II and Division III) and the effluent limits for Reclaimed Industrial Wastewater Discharges to Surface Waters. As such, the effluent will provide a year-round source of irrigation water and will include storage to address seasonal variations in demand for irrigation water.

Advantages:

- Effluent will satisfy JS 202/2007 (Division II and Division III)
- Effluent could be reused for irrigation and/or reused as non-potable water in various industrial applications
- Will provide water for Badia restoration
- System will generate composted sludge suitable for agricultural use
- All process units are well proven in similar applications

Disadvantages

- Highest capital and operating costs of the alternatives under study
- Most complicated treatment system of all the alternatives (same as A2)
- Treatment byproducts require evaporation with some offsite disposal
- Will require highly skilled operating labor

Alternative A2 – Chemical, Biological and TDS Removal and Partial Reuse of RO Reject in Local Quarries

Alternative A2 is essentially the same as A1 except for the elimination of a byproduct stream. It is anticipated that the effluent from Alternative A2 could also satisfy certain non-potable industrial needs, particularly in the future, when the planned industrial estate is established. The only potential current industrial reuse opportunity identified to date is associated with the nearby quarries, which use water for dust control Any remaining treated effluent will be available for reuse for agricultural purposes as outlined in Alternative A above.

The principal advantage of Alternative A2 over A is that byproduct evaporation and offsite disposal would be required only when/if there is no demand for water from local quarries.

Alternative B – Chemical, Biological Treatment with Polishing in a Constructed Treatment Wetland (CTW) for Experimental Water Reuse in Agriculture

Alternative B employs a natural system, a constructed treatment wetland (CTW) to polish the effluent, removing some of the dissolved solids and residual organic compounds, including nitrogen, before it is discharged from the IWTP. It is anticipated that the treated effluent will satisfy the majority of regulatory requirements for Reclaimed Industrial Wastewater Used for Irrigation (JS 202/2007) Divisions II and III and will provide a reliable source of irrigation water to support a full-scale pilot evaluation of agricultural wastewater reuse. While concentrations of dissolved solids and some specific inorganics may exceed regulatory criteria, it is anticipated that salt-tolerant species can be selected for the pilot-scale evaluation. With Alternative B, it is anticipated that the CTW will be part of the IWTP, while the experimental irrigation process with the resulting effluent would take place offsite and would not be considered a component of the IWTP.

Advantages:

- Effluent could be reused for irrigation
- Uses natural technology for TDS removal
- Wetland plants could be harvested and used as feed material for livestock or sludge amendment material
- Wetlands will sequester carbon and form habitat for diverse animal species
- Will provide water for Badia restoration
- System will generate composted sludge suitable for agricultural use

Disadvantages

- Requires significantly larger footprint than Alternative A
- Treated effluent may not satisfy current regulatory requirements (JS202/2007) with respect to TDS, and will require approval to use on an experimental basis
- Due to the evaporation and plant uptake, treated effluent flow will be reduced by approximately 25%

Alternative C – Chemical and Biological Treatment with Reuse of Effluent to Support Salt-Tolerant Plant Growth

Alternative C, is designed to utilize the partially treated biological system effluent in a natural system incorporating a carefully selected mixture of salt-tolerant plant species. The mixture will be designed to fully absorb the effluent flow, and support the restoration of the surrounding Badia. In this case, the natural system (an upland native tree plantation) will be considered a component of the IWTP. Thus, Alternative C represents a zero liquid discharge (ZLD) system with no net effluent flow. In order to consume the entire effluent flow, the natural system is large and would need to be located on area beyond the current IWTP site boundary, thus requiring negotiation of such access

Advantages:

- Partially treated effluent will be reused for irrigation of salt tolerant species
- Salt tolerant plants will sequester carbon and form habitat for diverse animal spices
- Will provide water for Badia restoration
- System will generate composted sludge suitable for agricultural use

Disadvantages

- Requires significantly larger footprint than other alternatives, outside the boundaries of land currently available for IWTP
- Will require approval to implement on an experimental basis
- Due to the evaporation and plant water uptake there will be no effluent available for traditional irrigation reuse
- Will not consistently meet TDS limits for Wadi disposal(for current TDS design of 3500 mg/L)

Alternative D – Chemical Pretreatment

Alternative D involves pretreatment and is designed to meet the requirements for subsequent discharge to a domestic WWTP. The industrial pretreatment effluent would receive additional treatment and then be incorporated in the WWTP's reuse program (i.e. for irrigation). Separated sludge would also be discharged to the domestic WWTP. The industrial sludge would be incorporated with the WWTP's biosolids processing and reuse program (i.e. for compost for agricultural purposes).

Advantages:

- More centrally located than the Hallabat site; potentially lower transport costs for industries
- Effluent will satisfy applicable standards (Pretreatment Standards for Industrial WW Discharge to Domestic WW Collection Systems)
- Effluent from domestic wastewater treatment plant is expected to satisfy JS 893/2006, such that the end use of the treated wastewater could be reused for irrigation
- Anticipated that sludge could be incorporated with the WWTP biosolids for composting and agricultural reuse
- Limited footprint required
- All process units are well proven in similar applications
- Lowest capital and operating costs of the alternatives under study

Disadvantages

- Requires access to a domestic WWTP with some excess capacity
- Fee to discharge to domestic wastewater treatment plant will likely be required
- Limited control over end use of the effluent

A summary comparison is presented in Figure 7-1.

ALTERNATIVES	SYSTEMS/PROCESSES: TREATMENT	SYSTEMS/PROCESSES: REUSE	ISSUES: SUSTAINABILITY	ISSUES: JS202/2007 DIV. II & DIV. III COMPLIANCE	ISSUES: O & M	ISSUES: FOOTPRINT	COST ESTIMATES / OPERATING COSTS ($)
A	Chemical and biological treatment	Remove TDS (RO) → Evaporate → Produce 2500 m³/d high-quality effluent for irrigation	All five provide water for Badia, promote agribusiness	Complies	Skilled operators, high maintenance, well established treatment system	Hallabat site (500 dunums) is sufficient for ultimate capacity of 7,500 m³/d	CAPEX 37.9 MM OPEX[2] 2.73/m³-NET 5.74/m³ (Including capital recovery)[8]
A2		Remove TDS (RO) → Reuse RO reject in local quarries → Produce 2000 m³/d high-quality effluent for irrigation and 500 m³/d for quarry					CAPEX 37.9 MM OPEX[3] 2.75/m³-NET 5.77/m³ (Including capital recovery)[8]
B		Reduce TDS in 15 hectares of constructed wetlands → Produce 1880 m³/d for limited irrigation		Partially complies, (requires authorization for wetland treatment)	Simple operation, low maintenance, experimental method	Hallabat site is sufficient for Phase 1 only (2,500 m³/d). Additional 350 dunums required for Phase 2/3 (7,500 m³/d total)	CAPEX 25.9 MM OPEX[4] 3.01/m³-NET 5.07/m³ (Including capital recovery)[8]
C		Reuse all water in 80 hectares of on-site agribusiness (salt-tolerant plants)		Not regulated, (agribusiness requires authorization)		Hallabat site is not sufficient for Phase 1; An additional 6,450 dunums required for Phase 1 (2,500 m³/d).[1] CAPEX excludes $1.5 million to acquire additional land.	CAPEX 23.1 MM OPEX[5] 2.21/m³-NET 4.05/m³ (Including capital recovery)[8]
D	Chemical pretreatment → Treatment at outside domestic wastewater treatment plant	Produce an additional 2400 m³/d high-quality effluent for irrigation reuse with domestic WWTP treated effluent		Should not affect compliance of domestic WWTP; complies with pretreatment standards	Simple operation, low maintenance	35 dunums required for 7,500 m³/d. As Samra WWTP site has sufficient land area available.	CAPEX 11.7 MM OPEX[6, 7] 1.71/m³-NET 2.64/m³ (Including capital recovery)[8]

Reduces fresh water demand by quarries

Wetlands sequester carbon, provide animal habitat

Uses less energy

Maximizes use of existing equipment at domestic WWTP and avoids construction of duplicate equipment

1. Alternative C additional land requirements include 450 dunum for planting the tree stand and up to an additional 6,000 dunums for planting of a winter barely fodder crop.
2. OPEX assumes reclaimed water revenue based on $0.45 USD per m³ for Alternative A.
3. OPEX assumes reclaimed water revenue based on $0.45 USD per m³ for Alternative A2.
4. OPEX assumes reclaimed water revenue based on $0.30 USD per m³ for Alternative B.
5. OPEX assumes no reclaimed water revenue for Alternative C, however, agribusiness income from barley based on $300 USD per hectare.
6. OPEX assumes no reclaimed water revenue for Alternative D and includes a $0.45 USD per m³ pretreated effluent discharged to sewer to As Samra or other treatment plant.
7. Pretreatment solids discharged to As Samra WWTP at $10/MT dry weight basis.
8. Capital recovery based on 18 years at 3% interest.

Figure 7-1 Comparison of Alternatives for Zarqa IWTP

7.3 Criteria for Evaluation and Selection of Alternatives

This section provides an overview of the criteria used to evaluate the various wastewater treatment control options (alternatives) presented in both the 2013 FS and this addendum report. The criteria have been subcategorized into financial, technical and environmental considerations and, ultimately, each criterion is assigned a weighting factor (as described below) which, when combined with a score given for each technical alternative, results in an overall score for the alternative. The following sections provide a generic discussion of each criterion along with any other factors that have also been considered in coming up with the final ranking.

7.3.1 Environmental / Health and Safety Considerations

7.3.1.1 *Water and Solids Reuse Potential*

The reuse potential for water and solids associated with the IWTP activities is a key factor in evaluating the feasibility of various treatment processes. The quality of the treated effluent water will be quite important, as this will determine the degree to which the plant effluent can be reused. Effluent quality, water and solids reuse potential, and manner of reuse will all be important factors in determining the most appropriate treatment alternative.

7.3.1.2 *Regulatory Approval*

Any treatment scenario considered for the project will require regulatory approval before it can be implemented. The likelihood of approval and/or the ease with which such approval can be obtained will be considered important.

7.3.1.3 *Non-Compliance Risks*

The risk of non-compliance with applicable regulations and/or authorizations is considered as part of the evaluation process. The actual impact of any non-compliance is also considered.

7.3.1.4 *Health and Safety Risks to Operators*

Health and safety is always a very important consideration and for this project will consist of evaluation of potential risks during operation of equipment, handling of chemicals, and handling of or exposure to treated effluent.

7.3.1.5 *Solids Handling*

Factors to be considered here include the quantity of solids generation, requirements for sludge removal, and whether the sludge is considered hazardous or not.

7.3.1.6 *Odor Control*

Due to the nature of wastewater treatment in general, odor abatement is typically very important. The degree to which the given alternative requires odor abatement and/or the ease with which such control measures can be implemented will be considered important factors.

7.3.1.7 *Sustainability*

In general terms, sustainability is the capacity to endure. For this project, sustainability will be considered to include management of resources, which is typically based on economics. In addition, technologies that reduce the consumption of resources will be highly rated.

7.3.1.8 *Land Area Requirements*

The land area or footprint to be occupied by equipment specified in each alternative will be considered in the scoring of each technology. In general, the less space required, the more desirable the option.

7.3.1.9 *Badia Restoration and Agribusiness Development*

Badia restoration is an important goal in Jordan. Thus, the ability of the IWTP to aid in such restoration is considered an important criteria for evaluating potential treatment alternatives.

7.3.2 Technical Considerations

7.3.2.1 *Operator Skill Requirement and Ease of Maintenance*

In Jordan, a key factor in the category of technical considerations is the level of skill or training required to operate the treatment plant, and the ease of maintaining the plant in accordance with manufacturer recommendations. One consideration is the experience and familiarity that plant operators in the country have with the specific technical alternative. Such experience and familiarity would foster a fast learning curve for the ultimately selected alternative.

7.3.2.2 *Operational Flexibility*

This refers to the ability of the particular technology to adapt to changes in circumstances such as low and peak flows or wide swings in influent characterization. Technologies that are able to easily respond to such situations quickly will be rated higher than those that are not.

7.3.2.3 *Process Reliability*

This is an inherent quality of the process or technology and is based on whether the alternative is technically sound and robust and whether it has been in widespread use for some time. Newer technologies with less experience would be rated lower than older, conventional methods.

7.3.2.4 *Process Instrumentation and Control*

All of the considered alternatives will employ significant levels of process instrumentation, control loops, parameter measurement and other operational features. The degree to which the process is automated or has the ability to eliminate the need for operator interaction would result in higher ratings.

7.3.2.5 *Equipment Resilience*

Equipment resilience is a measure of expectations pertaining to the strength and longevity of the alternative and/or its key components. This parameter would relate to materials of construction as well as design considerations.

7.3.2.6 ***Future Expansion Flexibility***

Future expansion refers to the possibility of increased wastewater flow in the future and the ability of the specific alternative to be able to adapt to such future needs. Flexibility in this regard will be highly rated.

7.3.2.7 ***Simplicity of Construction***

This refers to the ease of equipment installation and the ability to conduct construction related activities with minimal disruption of other ongoing work. This might also incorporate factors that relate to the need for complex site modifications or heavy equipment to assist with installation.

7.3.2.8 ***Construction Labor Skills Required***

This refers to the labor skill required for the equipment installation, and is based on the amount of mechanical equipment, instrumentation and controls which are required to be installed.

All of the alternatives considered require routine daily, monthly and/or annual maintenance. The degree to which such maintenance can be easily incorporated into the existing facility maintenance program will be considered advantageous with regard to the rating scheme.

7.3.3 **Financial Considerations**

7.3.3.1 ***Capital Investment Cost***

One of the primary factors in technology evaluation is the total installed cost (TIC) or capital investment. First, the total process equipment (TPE) cost is determined including tanks, drums, vessels, towers, pumps, blowers, compressors, fans and other key system components. Then, common industry factors are used to adjust the TPE for such items as piping and mechanical work, civil, engineering, electrical, instrumentation, fire protection, insulation, painting and freight to arrive at a total capital cost (TCC). Additional factors are then used to account for project management, engineering and construction management to enable calculation of the TIC.

7.3.3.2 ***Annual Operating Cost***

The other key financial factor to consider is the annual operating cost for the given alternative. This cost consists of both direct (labor, maintenance and utilities) and indirect (overhead, taxes, insurance, administrative costs and consumables) operating costs. In addition, for this evaluation, a second annual operating cost is considered which includes the cost of capital recovery, based on a certain life expectancy for the equipment and an assumed interest rate. The annual operating cost obviously includes electrical power requirements, chemical usage and annual maintenance.

7.3.4 **Technology Rating Scheme**

Determination of the best alternative will be based on all of the criteria discussed in this section and will make use of a standard methodology referred to as a K-T analysis. K-T stands for Kepner-Tregoe, for the authors who originally pioneered the approach. The approach involves three steps – weighting, rating and scoring.

7.3.4.1 *Weighting Criteria*

Each of the criteria discussed in this section will be assigned a weighting factor based on its importance in the overall evaluation process. Weighting factors from 1 to 10 are used, with 1 assigned to criteria having little importance and 10 being assigned to factors that are most important. It should be noted that not all of the weightings need to be used; for example, a 10 could be assigned to every factor being considered if all were deemed equally important.

7.3.4.2 *Rating Scale*

The second step in the evaluation process is to rate each factor in terms of its effectiveness and/or score. For this process, ratings of 1 to 5 are used where:

- 1 = worst
- 2 = below average
- 3 = average
- 4 = good (above average)
- 5 = best

As with the weighting criteria, not all of the ratings need be used if, for example, all factors considered are above average for the technology being considered.

7.3.4.3 *Detailed Matrix Evaluation and Scoring*

The final step in the process is to determine the overall score for the alternative. This is done by multiplying the rating by the weighting factor (for each criterion) and then summing all of the scores over all of the factors considered. The technology with the highest overall score is the preferred alternative.

7.4 Environmental, Health and Safety Considerations

This section provides a discussion of the primary environmental as well as health and safety (H&S) factors that were considered in evaluating the alternatives.

7.4.1 Water and Solids Reuse Potential

Each of the alternatives includes credit for the use of effluent for irrigation. Since the quality of water generated for irrigation reuse in Alternatives A, A2, and D is anticipated to consistently meet the reuse requirements, it is deemed to have a higher reuse potential than the experimental effluent that will be available for reuse in Alternatives B and C. The industrial reuse by the quarries in Alternative A2 is deemed to be of equal reuse potential as the irrigation water in A, A2, and D.

Each of the alternatives includes sludge composting, and the anticipated quantity and quality of the resulting composting material is expected to be essentially identical for each alternative. For Alternative D, the composting would occur offsite, whereas it would occur onsite for each of the other alternatives.

7.4.2 Regulatory Approval

Alternative A and A2 are designed to consistently meet Jordanian standard JS202/2007 with respect to all regulated parameters, and would therefore not be anticipated to require any unusual regulatory approval.

Alternative B is considered an experimental treatment, and the efficiency of the TDS removal by the CTW needs to be further evaluated. Regulatory approval of the experimental operation would be required since the effluent does not meet existing reuse standards.

Effluent generated in Alternative C will be fully reused in the experimental tree plantation so there is no effluent. Approvals to conduct the experimental tree plantation under Alternative C, however, would also be required prior to implementation, since the quality of the effluent generated in that system cannot be guaranteed, and there are no existing standards for that type of use.

Alternative D is designed to meet the pretreatment standards for discharge to a domestic wastewater treatment plant, while allowing the effluent from the domestic wastewater treatment plant to continue to meet Jordanian standard JS893/2006 for effluent reuse. Regulatory approval may be required, however, for the reuse of domestic WWTP effluent if it receives industrial waste.

Thus, Alternatives A, and A2 are considered most favorably, with Alternative D, next, in terms of regulatory approval.

7.4.3 **Non-Compliance Risks**

There is a certain level of risk of non-compliance for each of the alternatives, if not operated properly. However, if operated properly, Alternatives A and A2 will satisfy regulatory requirements and should not be considered as very high risk for non-compliance. Since the proposed wetlands in Alternative B are considered an experimental treatment system with respect to the TDS removal, there is a possibility of non-compliance with the promulgated TDS standards. Alternative C will be designed as zero discharge facility and therefore not considered for non-compliance in terms of discharge standards. However, the risk of non-compliance with the design criteria is potentially significant to the success of the experimental tree plantation. Alternative D t, if operated properly, should prevent the discharge of highly toxic materials, which could interfere with the biological processes at the WWTP. Since the pretreated effluent will discharge to a much larger domestic wastewater treatment plant, it is unlikely that any upsets in the pretreatment system will have significant impact on the domestic wastewater treatment plant and the ultimate effluent quality. Thus, Alternatives A, A2, and D are considered most favorably, with slightly less favorable consideration for B and C.

7.4.4 **Health and Safety Risks to Operators**

Each of the alternatives involves the use of chemicals (lime, acid, polymer, coagulant, and/or caustic) and their inherent health and safety issues. Alternative A, Alternative A2, and Alternative B involve chlorination which presents additional health and safety issues. It is assumed that a significantly greater quantity of chemicals and level of oversight will be required for dissolved solids removal in Alternative A and A2 which may be associated with greater risks to operators.

7.4.5 **Solids Handling**

All alternatives, with exception of Alternative D, will include a dedicated solids handling process consisting of an aerobic digester (sludge stabilization) followed by a sludge dewatering screw press. Partially dewatered sludge cake will be further treated using sludge composting technology. The total sludge quantity (primary DAF and activated sludge), and quality does not vary significantly between the alternatives.

The composting process will require addition of bulking agent. Because of uncertainty regarding the availability and quality of suitable materials, it is assumed that the bulking

agent will consist of a combination of recycled compost and raw amendment material. The amendment material will likely consist of woodchips and/or organic material harvested from the constructed treatment wetlands (CTW) system (applicable to Alternative B), the tree plantation (in Alternative C), and/or or other nearby sources. Since Alternatives B and C would present on-site sources of this material, these may be more favorable in terms of solids processing.

Alternative D does not have on-site solids handling processes, but rather will pump the solids to the domestic wastewater treatment plant's solids handling processes. Therefore, Alternative D may be considered even more favorable in terms of solids processing.

7.4.6 **Odor Control**

Most of the offensive odors associated with the IWTP are anticipated to be generated in the wastewater receiving area, the receiving tank and the equalization tank. In order to control odors, these tanks will be provided with an air-tight cover and vented to a biofilter for odor destruction. Because these processes are the same for each Alternative, the biofilter system and its effectiveness for each of the Alternatives will essentially be the same.

With the exception of Alternative D, each of the Alternatives includes aerobic treatment processes. In general, properly designed and operated aerobic systems will not generate offensive odors. However, since Alternative D does not include biological processes, the possibility of upsets in those processes is eliminated. Therefore, the potential for odors is anticipated to be less for Alternative D.

7.4.7 **Sustainability**

All of the alternatives will provide an environmentally responsible wastewater management option for existing industries in the Zarqa area. While each results in consumption of resources (power and chemicals), the IWTP has the capacity to reduce impacts to ground and surface water by improperly treated discharges. The wastewater in each alternative is ultimately used for irrigation and/or industrial purposes, thereby also decreasing the freshwater demand for those purposes. Effluent from each of the alternatives has the potential to develop a new form of agribusiness in Zarqa governorate. Because Alternatives B, C, and D require slightly less power and chemicals than the other alternatives, they are considered more sustainable. In addition, Alternative D, which requires less maintenance than Alternative B and Alternative C, is considered the most sustainable.

7.4.8 **Land Area Requirements**

Based on the estimated plot plans developed, the land area required for Alternative D is the smallest, followed by Alternative A and then A2. Alternative B will require additional land dedicated to Constructed Treatment Wetlands (CTW), and Alternative C will include real estate outside of IWTP boundaries. Alternatives B and C use more land area, but the additional area for those alternatives are both natural systems (a CTW for Alternative B and an upland native tree plantation in Alternative C).

7.4.9 **Badia Restoration and Agribusiness Development**

Badia restoration is an important goal in Jordan. Agribusiness development is described as a way to restore these rangelands through an integrated approach of plant selection and water management. Each of the alternatives proposed in the 2013 FS will produce water for this purpose, and the reuse programs could demonstrate rangeland restoration through crop selection that will enhance community livelihoods by generating a sustainable supply of

essential resources from self-propagating grasses, shrubs, and trees. The treated effluent produced in Alternative D will produce water for irrigation in the Jordan Valley. Since this is already established agricultural area, its reuse would not be considered Badia restoration. But, it could be considered additional agribusiness development.

Since the quality of water produced in Alternatives A, A2, and D is anticipated to consistently meet existing Jordanian standards for irrigation, it would offer the most potential for a wide range of uses and crops. Under Alternative A2, slightly less water is available for irrigation, as some of it is used for industrial purposes which do not support the Badia restoration. Treated effluent from Alternative B would also be available for agricultural reuse on an experimental basis. The quantity of water would be somewhat less than that for Alternatives A and A2, and it could only be used for selected salt-tolerant species. Similarly, the upland native tree plantation incorporated in Alternative C would be maintained on an experimental basis, and the particular species would be limited to those with high salt tolerance. Alternative C would provide the greatest level of control over the reuse since it is incorporated as part of the treatment process.

An overview of the technology assessment with respect to environmental and H&S factors is presented in Table 7-1.

Table 7-1. Environmental and Health and Safety Factors

Evaluation Criteria	Weight Factor	Alternative A	Alternative A2	Alternative B	Alternative C	Alternative D
		Rating	Rating	Rating	Rating	Rating
Water Reuse Potential	8	5	5	3	3	5
Regulatory Approval	6	5	5	2	2	4
Non-Compliance Risk	7	4	4	2	3	4
Health & Safety Risk to Operators	8	3	3	4	5	5
Solids Handling	8	3	3	5	5	4
Odor Control	5	4	4	4	4	5
Sustainability	9	2	2	4	4	5
Land Area Requirements	5	4	4	2	1	5
Badia Restoration/ Agribusiness	9	5	4	3	3	4

Rating of each criteria based on the following scale:
1 = worst; 2 = below average; 3 = average; 4 = good (above average); 5 = best
Weighting factors are based on a scale of 1 (lowest) to 10 (highest)

7.5 Technical Considerations

Technical considerations discussed in this section include items such as ease of operation, process control, equipment selection and maintenance issues, possible expansion flexibility, and simplicity of construction.

7.5.1 Operator Skill Requirement and Ease of Maintenance

Alternatives A and A2

Operational considerations associated with Alternatives A and A2 will be significantly greater than that for other Alternatives. Alternative A includes biological treatment (activated sludge using Membrane Bioreactor (MBR) technology). The biological treatment system requires a

fundamental understanding of biology and a specific understanding of the aerobic treatment technology. The operating personnel will require specific training prior to the plant start-up and commissioning. The equipment for suspended and dissolved solids removal (ultrafiltration membranes, ion exchangers, reverse osmosis (RO) membranes) and management of the concentrated reject streams (evaporation ponds) requires regular monitoring and maintenance. For example, if the operators are not attentive to membrane pressure buildup and if the maintenance cleaning is not done at the regular intervals, or if the regeneration of ion exchange units is not performed satisfactorily, the process can prematurely fail.

The operators would need significant training to understand these processes, and the operating conditions required to achieve the effluent quality, as well as the operations and maintenance (O&M) requirements for the specific equipment purchased. Operation of the sludge processing equipment (aerobic sludge digestion, screw press dewatering and composting) will require site specific training. Alternative A2 will require additional operation requirements to manage the mixing, chlorination, and disposition of treatment byproducts to the offsite quarries for reuse.

Alternative B

Operational considerations associated with Alternative B will be simpler than those for Alternatives A and A2. The conventional activated sludge system is considerably easier to operate than the MBR system in Alternatives A and A2. The mechanical equipment for solids removal (ultrafiltration membranes, ion exchangers, RO membranes) is not included in this Alternative. While some training regarding the operation, monitoring, and maintenance of the CTW system will be required, it is anticipated that the training will be less involved, and the level of oversight less than for Alternatives A and A2.

Alternative C

Operational considerations associated with Alternative C will be similar to the requirements outlined in Alternative B. Operators will need to be trained on the operation, monitoring and maintenance of the upland native tree stand instead of the CTW system, although the skills required are expected to be quite similar.

Alternative D

Operational considerations associated with Alternative D will be even less than those outlined for Alternatives B and C. Alternative D only has the pretreatment processes and does not include an activated sludge system. For this reason, Alternative D requires the least operator training and maintenance.

7.5.2 **Operational Flexibility**

All of the treatment alternatives provide a certain level of flexibility with a large capacity equalization tank to allow for long-term equalization of flow and chemical variability in the IWTP influent. Alternatives A and A2 include significantly more mechanical equipment with specific operational requirements and offer the least room for operational flexibility. Upsets in the chemical and biological treatment systems will impact the downstream membranes and equipment. Alternatives B and C, on the other hand, involve a biological treatment system with relatively simple operating parameters. Upsets in the biological system may be able to be absorbed in the CTW, or within the native upland tree plantation. Similarly, Alternative D will discharge to a domestic wastewater treatment plant with biological treatment. Thus, Alternatives B, C, and D provide slightly better operational flexibility.

7.5.3 **Process Reliability**

The technologies associated with Alternatives A, A2, and D are well-demonstrated technologies which have been in widespread use for some time. The reuse of treated effluent for irrigation has been demonstrated, but the proposed reuse by quarries for dust control is not known to have been demonstrated. The use of the CTW to remove TDS in Alternative B, and the reuse proposed for Alternatives B and C have been demonstrated in laboratory and small-scale projects. Alternatives B and C would be implemented on an experimental basis, and are therefore considered a less reliable process in this evaluation.

7.5.4 **Process Instrumentation and Control Requirements**

Alternatives A and A2 are the most complex treatment systems, in terms of mechanical operations, and as such, include the most complex process instrumentation & control systems. As such, the system allows for automated control systems of all its components. Alternatives B and C are based on a classical chemical treatment followed by an activated sludge biological treatment with relatively simple process instrumentation & control systems. The natural treatment systems do not allow for a high level of automated control since human monitoring of the system conditions is required. Alternative D only requires the relatively simple instrumentation & control systems related with the classical chemical treatment, and does not require as much human monitoring as Alternatives B and C.

7.5.5 **Equipment Resilience**

The equipment provided in Alternatives A and A2 can all be specified to provide resilience to the range of anticipated IWTP conditions. The natural systems in Alternatives B and C involve plants and living organisms that may be less resilient to changes in IWTP conditions. Alternative D can be specified to provide resilience both in the pretreatment equipment, as well as downstream in the equipment at the treatment plant.

7.5.6 **Future Expansion Flexibility**

For Alternatives A and A2, it will be relatively easy to add unit operations and expand the treatment capabilities in the future based on increased flow or concentrations. With the increased flow rates, Alternative B would likely require additional real estate to accommodate constructed treatment wetlands.

Since Alternative C already requires acquisition of property beyond the current IWTP parcel footprint, any future expansion will be subject to additional land ownership negotiation and the other commercial constraints.

Alternative D involves pretreatment only. If space is available, it will be relatively easy to add additional unit operations to increase the level of treatment provided.

7.5.7 **Simplicity of Construction**

Based on the number and complexity of structures required, Alternative D is the simplest to construct, followed by Alternatives B and C, and then Alternatives A and A2. Based on the amount of earthwork required and the area on which equipment will be operated, Alternative D also offers the most simplicity of construction due to fewer pieces of equipment than any of the other alternatives. Alternative C requires the greatest amount of earthwork for the reuse area, followed by B and then A and A2.

7.5.8 Construction Labor Skills Required

Based on the amount of mechanical equipment, instrumentation, and controls, which will be required for each alternative, the skills required for installation will be greatest for Alternatives A and A2, and slightly less for Alternatives B, C, and D.

An overview of the technology assessment with respect to technical factors is presented in Table 7-2.

Table 7-2. Technology Assessment, Technical Factors

Evaluation Criteria	Weight Factors	Alternative A	Alternative A2	Alternative B	Alternative C	Alternative D
		Ratings	Ratings	Ratings	Ratings	Ratings
Operator Skill Requirement and Ease of Maintenance	7	2	2	4	4	5
Operational Flexibility	9	3	3	4	4	4
Process Reliability	10	5	5	3	2	5
Process Instrumentation & Control	2	5	5	3	3	5
Equipment Resilience	7	4	4	3	3	4
Future Expansion Flexibility	10	5	5	3	2	5
Simplicity of Construction	10	3	3	4	4	5
Construction Labor Skills Required	8	3	3	4	4	5

Rating of each criteria based on the following scale:
1 = worst; 2 = below average; 3 = average; 4 = good (above average); 5 = best
Weighting factors are based on a scale of 1 (lowest) to 10 (highest)

7.6 Economic Assessment

Economic assessment includes considerations associated with the capital investment costs, operating costs and the cost of effluent disposal, or the income associated with reusable effluent. Figure 7-1 provides a summary of the estimated capital and operating costs, which are described in Sections 7.6.1 and 7.6.2.

7.6.1 Capital Investment Cost

The basis used for development of the total estimated installed capital costs for each of the full treatment Alternatives evaluated for the Hallabat site are presented in Appendices P, V, and DD of the 2013 FS. The capital cost estimate for Alternative D evaluated in this addendum is provided in Addendum Appendix 4.

Similar to the information presented in the 2013 FS, the factored capital cost estimate (+/- 35% accuracy) represents the direct cost for equipment, labor and construction, project management, detail engineering, procurement, construction management, and start-up assistance for the complete system.

The capital cost for equipment items is based on vendor-provided quotes, assuming the equipment is “freight on board” (FOB). That is the cost is based on the assumption that the

equipment is loaded on a truck, ready for shipment at the fabricator's location. The cost estimate table includes a cost factor to account for equipment transportation from the vendor/fabricator's location to the construction site. An installation factor was applied to individual equipment items to estimate total installed cost based on equipment cost. The costs for detailed engineering, construction management and supervision, site civil, electrical, mechanical, start-up assistance, and so on are all factored costs. The installation factor assumes that the site will not require additional extensive preparation beyond those included in the line item for site drainage improvements (assumed to be the same for all Alternatives). The capital cost of minor piping and mechanical modifications of equipment is estimated based on vendor quotes and/or project team experience. The estimates include capital recovery based on 18 years at 3% interest.

The capital cost estimate in the 2013 FS excluded the costs for acquiring additional land, if required. Alternative B would require an additional 350 dunums for phases 2/3. Alternative C would require 450 dunums for planting the tree stand and up to an additional 6,000 dunums for planting of a winter barely fodder crop, for the initial phase (2,500 m^3/d). No additional land is required for Alternative D.

Zarqa Chamber of Industry costs, escalation, and allowances for any future scope change are not included in the estimate. Applicable Jordanian or other taxes are also excluded.

7.6.2 **Annual Operating Cost**

The operating cost data are based on the project team's in-house data for energy costs, sludge disposal, chemical costs and labor costs as well as miscellaneous cost items, such as laboratory costs and the expected plant maintenance costs. This addendum includes an updated annual operating cost estimate for each of the alternatives evaluated as part of the 2013 FS, which incorporates current operating cost data. The current costs include increases for labor ($3.75/h to $5.63/h) and electricity ($0.0781/kw to $0.14/kw), adjustments for chemicals: sulfuric acid ($300/MT to $625/MT), ferric chloride ($400/MT to $444/MT), polymers ($3.8/kg to $6.5/kg) hydrated lime ($175/MT to $150/MT), and process water ($3.5/$m^3$ to $2.7/$m^3$). Overall, the operating costs increased for each Alternative that was previously evaluated. These changes had the greatest impact on Alternatives A and A2, which require more labor and higher electricity consumption.

It should be noted that the plant maintenance figure includes labor and material for routine mechanical, electrical, and instrumentation maintenance. Also included is the cost for periodic replacement of the rotating equipment pieces. The operating cost summary assumes that the plant will be operated 24 hours/day, 7 days/week. Insurance rates are generally accepted industry standards. The financial charge (capital recovery) for this project is based on a 3% interest rate (assuming donor financing) for a period of 18 years.

In the 2013 FS, the operating cost also considers potential income associated with the IWTP operation. For Alternatives A and A2, it is assumed that the treated effluent can be sold to nearby farmers at a modest price of $0.45 USD per m^3 (significantly less than typically charged for purchasing potable water) for irrigation use while no income is anticipated to be generated for the water reused by the quarries. The effluent from Alternative B would also be expected to produce income, and it is assumed that it is also sold to nearby farmers at a rate slightly less than that for Alternatives A and A2, at approximately $0.30 USD per m^3, to account for the potential elevated TDS in the effluent. No income from the Alternative C effluent is included since it is used as part of the treatment process, but it is assumed that the crop production associated with that Alternative produces an income ($300 USD per hectare of barley).

In this current evaluation, the effluent from Alternative D will not produce an income. Rather, there will be a sewer discharge fee ($0.45 USD per m^3) associated with discharging the pretreated effluent to the domestic wastewater treatment plant. Additionally, it is assumed that there will be a fee of approximately $10/MT dry weight basis to discharge the pretreatment solids to As As-Samra or other domestic wastewater treatment plant.

The basis for development of the total estimated annualized cost and the costing assumptions for each of the Alternatives are presented in Addendum Appendix 5. This includes the revised estimated annualized operating cost estimates for the alternatives previously evaluated in the 2013 FS.

An overview of the technology assessment with respect to *economic* factors is presented in Table 7-3.

Table 7-3. Technology Assessment, Economic Factors

Evaluation Criteria	Weight Factors	Alternative A	Alternative A2	Alternative B	Alternative C	Alternative D
		Rating	Rating	Rating	Rating	Rating
Capital Investment Costs	10	2	2	3	4	5
Annual Operating Costs	10	2	2	3	4	5

Rating of each criteria based on the following scale:
1 = worst; 2 = below average; 3 = average; 4 = good (above average); 5 = best
Weighting factors are based on a scale of 1 (lowest) to 10 (highest)

Finally, the overall evaluation matrix depicting the weighting and scoring scheme and ranking of the technologies considered is shown in Table 7-4.

Table 7-4: Treatment Alternatives – Overall Evaluation Matrix

ZARQA IWWTP - Treatment Alternatives Evaluation Matrix

Evaluation Criteria	Weight Factor [b]	Rating of Technical Alternatives [a]									
		Alternative A		Alternative A2		Alternative B		Alternative C		Alternative D	
		Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Environmental Considerations --			**249**		**240**		**215**		**225**		**295**
Water Reuse Potential	8	5	40	5	40	3	24	3	24	5	40
Regulatory Approval	6	5	30	5	30	2	12	2	12	4	24
Non-Compliance Risks	7	4	28	4	28	2	14	3	21	4	28
Health & Safety Risks to Operators	8	3	24	3	24	4	32	5	40	5	40
Solids Handling	8	3	24	3	24	5	40	5	40	4	32
Odor Control	5	4	20	4	20	4	20	4	20	5	25
Sustainability	9	2	18	2	18	4	36	4	36	5	45
Land Area Requirements	5	4	20	4	20	2	10	1	5	5	25
Badia Restoration/Agribusiness	9	5	45	4	36	3	27	3	27	4	36
Technical Considerations --			**233**		**233**		**223**		**203**		**299**
Operator Skill & Ease of Maintenance	7	2	14	2	14	4	28	4	28	5	35
Operational Flexibility	9	3	27	3	27	4	36	4	36	4	36
Process Reliability	10	5	50	5	50	3	30	2	20	5	50
Process Instrumentation & Control	2	5	10	5	10	3	6	3	6	5	10
Equipment Resilience	7	4	28	4	28	3	21	3	21	4	28
Future Expansion Flexibility	10	5	50	5	50	3	30	2	20	5	50
Simplicity of Construction	10	3	30	3	30	4	40	4	40	5	50
Construction Labor Skills Required	8	3	24	3	24	4	32	4	32	5	40
Financial Considerations --			**40**		**40**		**60**		**80**		**100**
Capital Investment Costs	10	2	20	2	20	3	30	4	40	5	50
Annual Operating Costs	10	2	20	2	20	3	30	4	40	5	50
OVERALL SCORES:			**522**		**513**		**498**		**508**		**694**

(a) Rating of each criteria based on the following scale:
1 = worst; 2 = below average; 3 = average; 4 = good (above average); 5 = best
(b) Weighting factors are based on a scale of 1 (lowest) to 10 (highest)

7.7 Recommended Alternative

Based on the detailed evaluation using the Kepner-Tregoe (K-T) technology rating as presented in Table 7-4 above, the recommended alternative is Alternative D. This Alternative scored 694 points in the K-T ratings analysis. The remaining alternatives each scored significantly lower ranging from 498 to 522 points. Alternative D represents the most favorable alternative based on environmental, health and safety issues; technical merits, and economic considerations.

Based on the above results, it is recommended that the project consider Alternative D as the preferred treatment system for preliminary design and further development.

If a full stand-alone treatment alternative is desired, then Alternative A or A2 is recommended based on initial feedback from the project stakeholders, indicating their preference for an alternative which does not involve experimental components.

8 PROJECT IMPLEMENTATION

Project implementation using a Design-Build project delivery method was specified in AECOM's Contract with USAID. A discussion of the anticipated project implementation for the Zarqa IWTP was provided in the 2013 FS. The information and additional evaluation presented in this Addendum does not require changes to that discussion.

The design criteria and cost estimates for all alternatives considered in this report and in the 2013 FS consider the initial phase (2,500 m^3/d) of IWTP development only. The capital cost estimate for Alternative D for the initial phase is 11.7 MM USD. The following provides a discussion regarding potential costs for the future second (an additional 2,500 m^3/day, 5,000 m^3/day total) and third (an additional 2,500 m^3/day, 7,500 m^3/day total) phases of development.

It is assumed that no additional buildings would be required for the second and third phases, as the design of the buildings for the initial phase considered this future expansion. It is also anticipated that the truck facility at Alternative D can handle the initial phase and that the subsequent capacity from phases two and three will arrive at the site via remote pump station or pipeline. In addition, it is assumed that some spare equipment may be shared between phases or treatment trains. Based on these assumptions, the estimated capital costs for Alternative D including the second phase (5,000 m^3/d total) and for ultimate capacity (7,500 m^3/d) would be 20.5 MM USD, and 29.3 MM USD, respectively.

9 REFERENCES

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Jordanian Standards for Industrial Wastewater (JS: 202/2007). National Standard - Third Edition.

JS202:2007 (2007) Jordanian Standards for Water – Industrial Reclaimed Wastewater, Amman, Jordan.

JS 893/2006 Quality Limits for Water Reuse and Wadi Discharge for Reclaimed Domestic Wastewater

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Water Authority of Jordan (WAJ). Instructions for Discharging Industrial and Commercial Wastewater into the Wastewater Sewer and its Amendments for the Year 1998.

Water Design-Build Council. 2010. The Municipal Water and Wastewater Design-Build Handbook, 2nd Edition.

Water Design-Build Council. 2008. The Municipal Water and Wastewater Design-Build Handbook.

Zarqa Chamber of Industry, on-site visits to and meetings with industrial facility staff in Zarqa, 2011.

Attachment

Jordanian Technical Regulation JS 893/2006: Water-Reclaimed Domestic Wastewater

JS893:2006 Quality Limits for Water Reuse and Wadi Discharge

Parameter	Unit	A. Cooked vegetables, Parks, Playgrounds and sides of roads within city limits	B. Fruit trees, Sides of roads outside city limits, and landscape	C. Field crops, industrial crops and forest trees	D. Cut flowers	Groundwater recharge	Wadi discharge
Group A							
BOD	mg/L	30	200	300	15	15	60
COD	mg/L	100	500	500	50	50	150
DO	mg/L	>2			>2	>2	>1
TSS	mg/L	50	150	150	15	50	60
pH	pH unit	6-9	6-9	6-9	6-9	6-9	6-9
Turbidity	NTU	10			5	2	
Nitrate	mg/L	30	45	45	45	30	80
Ammonia	mg/L					5.0	
TN	mg-N/L	45	70	70	70	45	70
E coli	/100mL	100	1000		<1.1	<2.2	1000
Helminths	/L	≤1	≤1	≤1	<1	≤1	<0.1
FOG	mg/L	8	8	8	2	8	8
Group B							
Phenol	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
TDS	mg/L	1500	1500	1500	1500	1500	1500
MBAS	mg/L	100	100	100	15	25	25
T Phosphate	mg/L	30	30	30	30	15	15
Chloride	mg/L	400	400	400	400	350	350
Sulfate	mg/L	500	500	500	500	300	300
Bicarbonate	mg/L	400	400	400	400	400	400

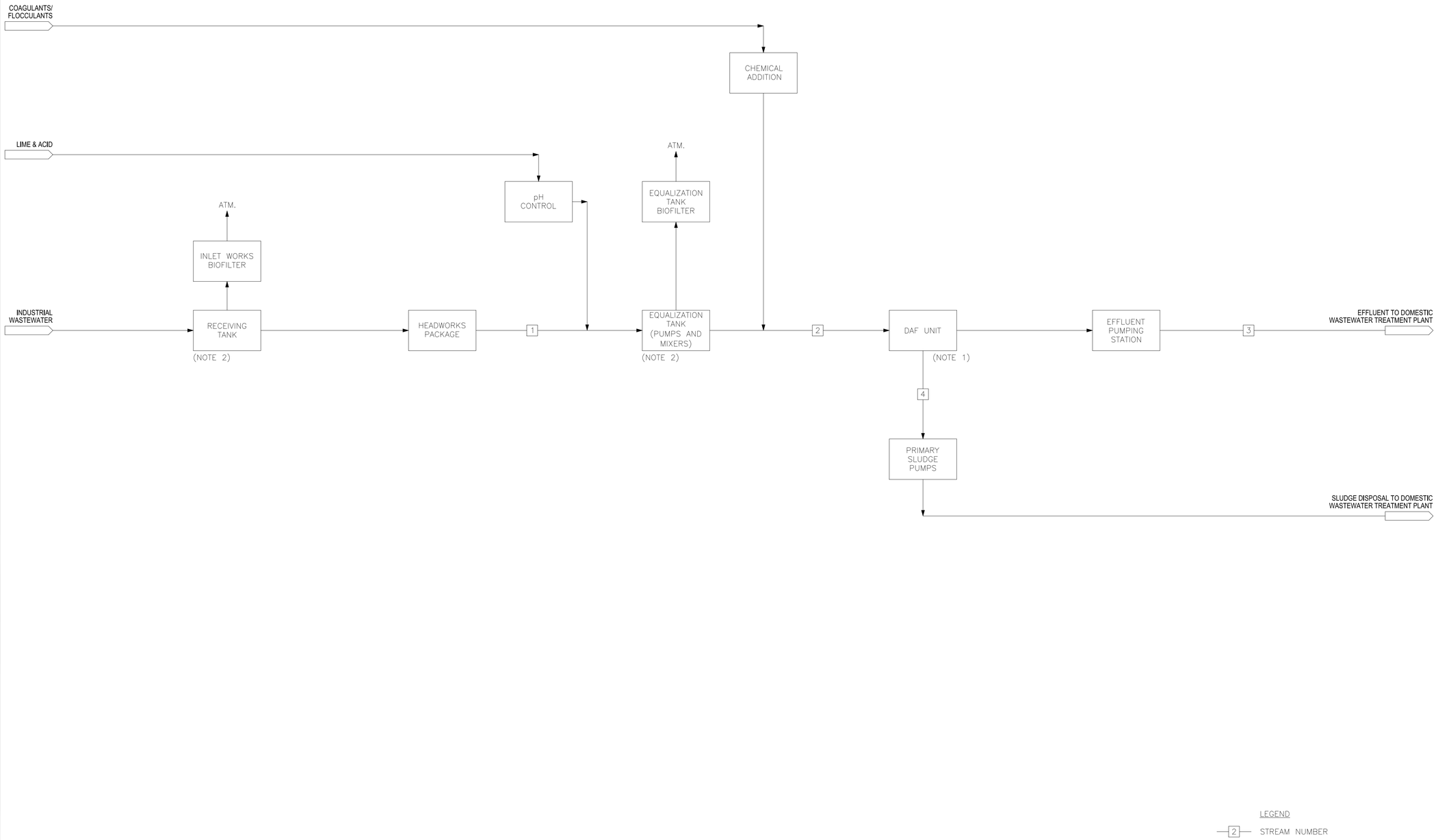
Sodium	mg/L	230	230	230	230	200	200
Magnesium	mg/L	100	100	100	100	60	60
Calcium	mg/L	230	230	230	230	200	200
Aluminum	mg/L	5	5	5	5	2	2
Arsenic	mg/L	0.1	0.1	0.1	0.1	0.05	0.05
Beryllium	mg/L	0.1	0.1	0.1	0.1	0.1	0.1
Copper	mg/L	0.2	0.2	0.2	0.2	1.5	0.2
Fluoride	mg/L	2.0	2.0	2.0	2.0	2.0	1.5
Iron	mg/L	5.0	5.0	5.0	5.0	5.0	5.0
Lithium	mg/L	2.5	2.5	2.5[a]	0.075	2.5	2.5
Manganese	mg/L	0.2	0.2	0.2	0.2	0.2	0.2
Molybdenum	mg/L	0.01	0.01	0.01	0.01	0.01	0.01
Nickel	mg/L	0.2	0.2	0.2	0.2	0.2	0.2
Lead	mg/L	0.2	0.2	0.2	0.2	0.2	0.2
Selenium	mg/L	0.05	0.05	0.05	0.05	0.05	0.05
Cadmium	mg/L	0.01	0.01	0.01	0.01	0.01	0.01
Zinc	mg/L	5.0	5.0	5.0	5.0	5.0	5.0
Boron	mg/L	1.0	1.0	1.0	1.0	1.0	1.0
Chromium	mg/L	0.1	0.1	0.1	0.1	0.05	0.02
Mercury	mg/L	0.002	0.002	0.002	0.002	0.001	0.002
Vanadium	mg/L	0.1	0.1	0.1	0.1	0.1	0.1
Cobalt	mg/L	0.05	0.05	0.05	0.05	0.05	0.05
Cyanide	mg/L	0.1	0.1	0.1	0.1	0.1	0.1
SAR	-	6	9	9	9	9	6

[a] for citruc crops, the limit is 0.075 mg/L

Note: TDS = total dissolved solids, MBAS = methyl blue active substances (detergents), SAR = sodium adsorption ratio

Addendum Appendix 1

Alternative D - Block Flow Diagram



NOTES:

1. DAF UNIT IS COMPLETE SYSTEM INCLUDING SATURATION TANK RECYCLE PUMPS AND FLOCCULATION SYSTEM.
2. INCLUDES VAPOR CONTROL.

DRAFT

Purpose of Issue	Rev.	Date	By	Chk'd	App.
ADDENDUM	0	10/14	KPB	KH	JW

Consultant :

IMPLEMENTED BY AECOM IN ASSOCIATION WITH ENGICON

Client :

USAID - JORDAN

Project:

ZARQA INDUSTRIAL WASTEWATER TREATMENT PLANT

Title:

BLOCK FLOW DIAGRAM TREATMENT CONFIGURATIONS ALTERNATIVE D

Design: K.H.	Drawn: K.P.B.	Checked: J.W.
Scale:	Date: OCTOBER 2014	Approved: --

Drawing Number: **BFD-ALT-D**

Rev.: **0**

File: J:\Cadfiles\CADD\JORDAN\ZARQA\Block Flow Diagrams\Zarqa Block Flow Diagrams.dwg Layout: Alternative D User: kanyk Plotted: Oct 10, 2014 - 2:28pm Xref's:

Addendum Appendix 2

Alternative D - Material Balance

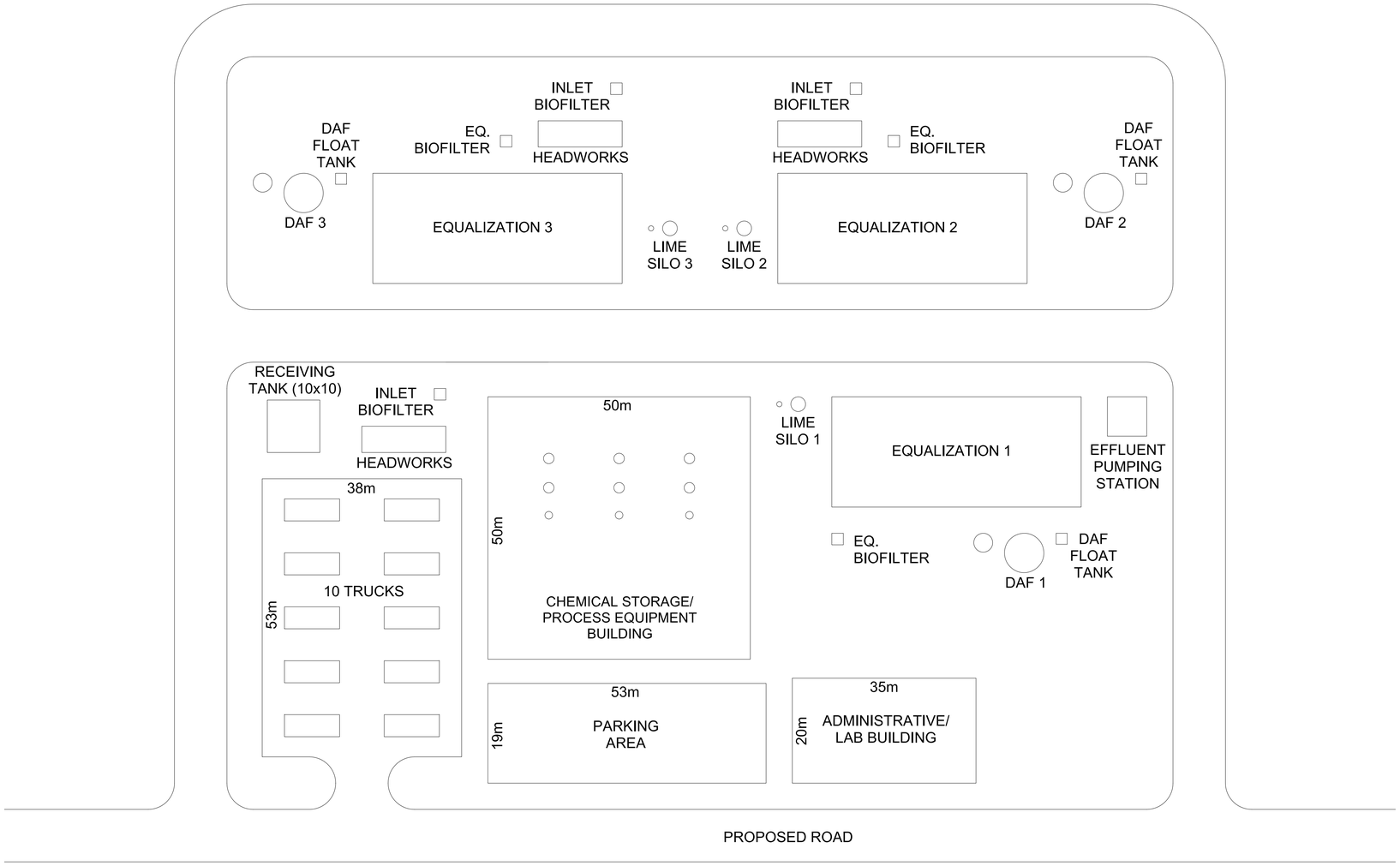
ZARQA
Future Industrial Wastewater Treatment Plant
Material Balance - Alternative D -October 2014

Stream Number		1	2	3	4	4
Stream Description	**Units**	**Influent**	**DAF Influent**	**DAF Effluent**	**DAF Float/ Sludge to WWTP**	**DAF Float/ Sludge to WWTP (Dry weight)[1]**
Flow Rate	m^3/hr	104.2	105.2	100.4	4.5	
SG[5]	--	1.00	1.00	1.00	1.05	
pH	--	6.4-7.4				
BOD_5	mg/L	1300	1288	773	12820	228097
BOD_5 (soluble)	mg/L	698	691	622	2265	40304
COD	mg/L	2871	2844	1706	28313	503743
COD (soluble)	mg/L	1616	1601	1441	5245	93312
TDS	mg/L	3489	3528	3528	3705	65917
TSS	mg/L	1391	2370	124	52500	934083
FOG	mg/L	60	60	3	1326	23594
Phenol	mg/L	0.02	0.02	0.02	0.02	0.37
MBAS	mg/L	1.0	1	1	5	97
NO_3	mg/L	32	32	32	33	590
NH_3	mg/L	23	23	23	24	429
NO_2	mg/L	2	2	2	2	33
TKN	mg/L	60	59	41	456	8119
Total N	mg/L	67	67	67	70	1246
PO_4.P	mg/L	11.7	12	10	38	676
Cl	mg/L	788	781	663	3426	60961
SO_4	mg/L	634	628	565	2058	36609
F	mg/L	0.2	0	0	1	12
HCO3	mg/L	279.0	276	249	905	16110
Na	mg/L	527	522	287	5778	102806
Mg	mg/L	115	114	11	2402	42740
Ca	mg/L	303	300	30	6329	112611
SAR	Unitless	6.5	6.5	6.5	6.8	121
Al	mg/L	9.3	9.2	3.8	131.1	2333
Cr	mg/L	0.5	0.5	0.4	1.9	34
Cu	mg/L	0.9	0.8	0.0	19.3	344
Fe	mg/L	81.5	80.7	0.0	1881.9	33483
Mn	mg/L	1.3	1.3	1.3	1.4	25
Ni	mg/L	0.690	0.683	0.683	0.718	13
Pb	mg/L	0.16	0.158	0.158	0.166	3.0
Cd	mg/L	0.010	0.010	0.010	0.010	0.19
Zn	mg/L	3.9	3.8	1.5	55.3	984
CN	mg/L	0.06	0.059	0.001	1.370	24
As	mg/L	0.05	0.050	0.005	1.043	19
Hg	mg/L	0.012	0.012	0.005	0.166	2.9
TCC	MPN/ 100 mL					
TTCC	MPN/ 100 mL					
Flow Rate	kg/hr	104,167	105,167	100,431	4,736	4,736
BOD_5	kg/hr	135	135	78	58	58
BOD_5 (soluble)	kg/hr	73	73	62	10	10
COD	kg/hr	299	299	171	128	128
COD (soluble)	kg/hr	168	168	145	24	24
TDS	kg/hr	363	371	354	17	17
TSS	kg/hr	145	249	12	237	237
FOG	kg/hr	6.3	6	0.300	6	6
Phenol	kg/hr	0.002	0.002	0.002	0.000	0.000
MBAS	kg/hr	0.104	0.104	0.080	0.02	0.02
NO_3	kg/hr	3.3	3.3	3.2	0.15	0.15
NH_3	kg/hr	2.4	2.4	2.3	0.11	0.11
NO_2	kg/hr	0.188	0.19	0.18	0.008	0.008
TKN	kg/hr	6.2	6.2	4.2	2.1	2.1
Total N	kg/hr	7.0	7.0	6.7	0.32	0.32
PO_4.P	kg/hr	1.2	1.2	1.0	0.17	0.17
Cl	kg/hr	82	82	67	15	15
SO_4	kg/hr	66	66	57	9.3	9.3
F	kg/hr	0.021	0.021	0.018	0.003	0.003
HCO3	kg/hr	29	29	25	4	4
Na	kg/hr	55	55	29	26	26
Mg	kg/hr	12	12	1.1	11	11
Ca	kg/hr	32	32	3.0	29	29
SAR	kg/hr	0.68	0.68	0.65	0.03	0.03
Al	kg/hr	0.97	0.97	0.38	0.59	0.59
Cr	kg/hr	0.05	0.05	0.04	0.01	0.01
Cu	kg/hr	0.09	0.09	0.001	0.09	0.09
Fe	kg/hr	8.5	8.5	0.000	8.5	8.5
Mn	kg/hr	0.14	0.14	0.13	0.01	0.01
Ni	kg/hr	0.07	0.07	0.07	0.003	0.003
Pb	kg/hr	0.02	0.02	0.02	0.001	0.001
Cd	kg/hr	0.001	0.001	0.001	0.000	0.000
Zn	kg/hr	0.40	0.40	0.15	0.25	0.25
CN	kg/hr	0.006	0.006	0.000	0.006	0.006
As	kg/hr	0.005	0.005	0.001	0.005	0.005
Hg	kg/hr	0.001	0.001	0.001	0.001	0.001
TCC	kg/hr	0.000	0.000	0.000	0.000	0.000
TTCC	kg/hr	0.000	0.000	0.000	0.000	0.000
Water	kg/hr	103,658	104,507	100,064	4,483	4,483

Notes:
1. Shown as mg/kg dry sludge

Addendum Appendix 3

Alternative D - Plot Plan



Notes:-

DRAFT

Purpose of Issue	Rev.	Date	By	Chk'd	App.
ADDENDUM	0	10/14	KPB	KH	JW

Consultant :

IMPLEMENTED BY AECOM IN ASSOCIATION WITH ENGICON

Client :

USAID - JORDAN

Project:

ZARQA INDUSTRIAL WASTEWATER TREATMENT PLANT

Title:

PLANT LAYOUT ALTERNATIVE D

Design:	Drawn:	Checked:
K.H.	K.P.B.	J.W.
Scale: 1:2	Date: OCTOBER 2014	Approved: --

0 5 10 15 20 25 30 35 40 45 50

METERS

Drawing Number: **S-004**

Rev.: **0**

Addendum Appendix 4

Alternative D - Capital Cost Estimate

Zarqa Industrial Wastewater Treatment Plant
Capital Cost Estimate
ALTERNATIVE D

Process Equipment Items (Note 1)	Quantity	Unit Cost	Total Cost	Notes
General /Packaged Items				
Inlet Works Biofilter	1	$ 26,000	$26,000	AECOM Database
Headworks Vendor Package	1	$ 615,182	$615,182	AECOM Database
Lime Storage/Feeder Vendor Package	1	$ 379,750	379,750	Enpro quote
Lime Slurry Agitator	1	$ 5,200	5,200	Engicon
pH Control In-Line Mixer	1	$ 2,500	2,500	Engicon
Equalization Tank Mixers	4	$ 21,500	86,000	Engicon
Coagulant In-Line Mixer	1	$ 2,500	2,500	Engicon
Equalization Tank Biofilter	1	$ 32,000	32,000	Engicon
Flocculant Storage Tank Mixer	1	$ 4,200	4,200	Engicon
DAF Vendor Package	1	$ 300,000	300,000	AECOM Database
Instrument Air Vendor Package	1	$ 5,500	$5,500	Engicon
Flocculator	1	$ 13,000	13,000	Engicon
Drums, Vessels and Towers				
Receiving Tank*	1	$ -	-	
Lime Slurry Tank	1	$ 2,100	2,100	Engicon
Acid Storage Tank	1	$ 1,450	1,450	Engicon
Equalization Tank*	1	$ -	-	
Coagulant Storage Tank	1	$ 1,450	1,450	Engicon
Flocculant Storage Tank	1	$ 500	500	Engicon
Flocculation Tank*	1	$ -	-	
Dissolved Air Flotation Tank*	1	$ -	-	
DAF Float Tank*	1	$ -	-	
Effluent Pumping Station*	1	$ -	-	
* Concrete Tanks to be included in Site Work				
Pumps/Blowers/Compressors/Fans**				
Inlet Works Biofilter Fan	2	$ 4,000	8,000	AECOM Database
Headworks Feed Pumps	2	$ 70,000	140,000	AECOM Database
Equalization Biofilter Fan	2	$ 4,000	8,000	AECOM Database
Slurry Circulation Pumps	2	$ 4,000	8,000	Engicon
Acid Metering Pump	1	$ 2,800	2,800	Engicon
DAF Unit Feed Pumps	2	$ 19,000	38,000	Engicon
Coagulant Metering Pump	1	$ 1,200	1,200	Engicon
Flocculant Metering Pump	1	$ 1,200	1,200	Engicon
Flocculant Transfer Pump	1	$ 3,300	3,300	Engicon
Utility Water Pumps	2	$ 5,000	10,000	AECOM Database
DAF Effluent Pumps	2	$ 15,000	$30,000	AECOM Database
Sludge Pumps	2	$ 15,000	$30,000	AECOM Database
**Note that pump equipment prices are pump and motor only; controls are included in instrumentation and electrical factors.				
Total Process Equipment (T.P.E.)		$1,757,800	1,757,800	
Piping & Mechanical	T.P.E. x	1.00	1,757,800	
Civil - Site Work, Structures, Foundations & Earthwork	T.P.E. x	1.30	2,285,100	
Electrical	T.P.E. x	0.40	703,100	
Instrumentation	T.P.E. x	0.15	263,700	
Fire Protection	T.P.E. x	0.01	17,600	
Insulation	T.P.E. x	0.025	43,900	
Painting	T.P.E. x	0.05	87,900	
Total Capital Cost (T.C.C.) of Process Equipment			6,916,900	
Freight	T.P.E. x	0.08	140,600	Freight, Insurance, Customs, Duties & Clearance
Project Management, Engineering, and Contractor Overhead and Profit				
Contractor Field Indirects Including Profit, Home Office Engineering & Site Supervision	T.C.C. x	0.25	1,729,200	Includes mobilization, demobilization, general conditions.
Design/Build Engineer	T.C.C. x	0.10	691,700	
Owner's Representative Services	T.C.C. x	0.10	691,700	Construction Site Supervision, Shop Drawing Review, RFIs, plant O&M manuals, as-built drawings
Total Estimated Installed Cost of Process and Rolling Equipment	TIC		10,170,100	
Contingency	T.E.C. x	0.15	1,525,515	
Total Installed Cost (T.I.C.)			**11,695,615**	
Rounded Cost for Comparison Purposes			**11,700,000**	
Conversion to JD		0.7	**8,200,000**	

1) Process equipment costs are based on vendor quotations and cost data from other projects.
2) Excludes future escalation, spare parts, startup, taxes, permits, licenses and owners indirect costs.

Addendum Appendix 5

Updated Annualized Operating Cost Estimates

Zarqa Industrial Wastewater Treatment Plant
ANNUALIZED OPERATING COST ESTIMATE
ALTERNATIVE A

	Alternative A	Basis
DIRECT OPERATING COSTS: TREATMENT PLANT		
DIRECT LABOR (DL)		
(a) Operators (10 Operators)	$164,400	80 hours/day @$5.63/hr
(b) Supervisors	$41,100	25% of operating labor
MAINTENANCE (ML)		
(a) Labor (3 Maintenace Personnel)	$49,300	24 hours/day @$5.63/hr
(b) Material/Spare Parts	$34,500	70% of maintenance labor
UTILITIES/CHEMICALS/OTHER DIRECT COSTS		
Electricity	$894,000	$0.14/kWhr
Hydrated Lime (Bulk Delivery)	$260,700	$250/MT
Sulfuric Acid (Bulk Delivery)	$9,500	$650/MT as 96% Solution
Ferric Chloride (Bulk Delivery)	$95,600	$444/MT as 49% Solution
Chemicals (Polymers)	$132,500	4 kg/MT DS- $8/kg
Hydrochloric Acid (Bulk Delivery)	$17,900	$350/MT as 36% Solution
Caustic (Bulk Delivery)	$82,600	$600/MT as 49% Solution
RO/UF Cleaning Chemicals	$15,000	Allowance
RO Membrane & IE Resin Replacements	$80,000	Allowance
Process Water	$19,700	$2.70/m^3
Sodium Hypochlorite	$10,600	$0.35/kg - 12% Chlorine Solution
Operating Consumables/Personel Protection	$10,000	Allowance
Laboratory Services	$10,000	Regulatory Testing
Evaporation Pond Solids Disposal	$63,000	$12/m3; Includes transportation
DIRECT OPERATING COSTS: COMPOSTING		
DIRECT LABOR (DL)		
(a) Operators (4 Operators)	$65,800	32 hours/day @$5.63/hr
(b) Supervisors	$16,500	25% of operating labor
MAINTENANCE (ML)		
(a) Labor (2 Mantenance Personnel)	$32,900	16 hours/day @$5.63/hr
(b) Material/Spare Parts	$16,500	70% of maintenance labor
OTHER DIRECT COSTS		
Amendment Material	$0	365 d/yr at $0/kg
Fuel	$32,850	$0.90/L
INDIRECT OPERATING COSTS:		
OVERHEAD	$142,600	44% of DL + 12% ML
PROPERTY TAX	$189,300	Not Applicable
INSURANCE	$34,600	0.15%of Capital Cost
ADMINISTRATION EXPENSES/CONSUMABLES	$378,600	1%of Capital Cost
INDIRECT OPERATING INCOME:		
EFFLUENT REUSE INCOME/M^3 OF EFFLUENT	($410,625.00)	365 d/y at $0.45/m^3 as income
COMPOSTING INCOME/KG OF COMPOST	$0.00	365 d/y at $0/kg as income
DIRECT AND INDIRECT OPERATING COSTS	**$2,489,425**	
O&M COST / M^3 OF INFLUENT[1]:	**$2.73**	**BASED ON DIRECT & INDIRECT COSTS + INCOME**
OPERATING COSTS INCLUDING CAPITAL RECOVERY		
ANNUAL COST OF CAPITAL RECOVERY:	**$2,752,100**	**18 Repayment Periods at 3% Interest Rate**
TOTAL ANNUALIZED OPERATING COST[1]:	**$5,241,525**	**INCLUDING CAPITAL RECOVERY**
PRODUCTION COST / M3 OF INFLUENT[3]:	**$5.74**	**INCLUDING CAPITAL RECOVERY + INCOME**

Notes:

1. This assumes there is no fee to discharge to the IWTP and there is no income for reuse of the treated effluent.

2. Costs are in USD.

3. The discharge fee would need to be this cost in order to break even.

Zarqa Industrial Wastewater Treatment Plant
ANNUALIZED OPERATING COST ESTIMATE
ALTERNATIVE A2

	Alternative A2	Basis
DIRECT OPERATING COSTS: TREATMENT PLANT		
DIRECT LABOR (DL)		
(a) Operators (10 Operators)	$164,400	80 hours/day @$5.63/hr
(b) Supervisors	$41,100	25% of operating labor
MAINTENANCE (ML)		
(a) Labor (3 Maintenace Personnel)	$49,300	24 hours/day @$5.63/hr
(b) Material/Spare Parts	$34,500	70% of maintenance labor
UTILITIES/CHEMICALS/OTHER DIRECT COSTS		
Electricity	$895,300	$0.14/kWhr
Hydrated Lime (Bulk Delivery)	$260,700	$250/MT
Sulfuric Acid (Bulk Delivery)	$9,500	$650/MT as 96% Solution
Ferric Chloride (Bulk Delivery)	$95,600	$444/MT as 49% Solution
Chemicals (Polymers)	$132,500	4 kg/MT DS- $8/kg
Hydrochloric Acid (Bulk Delivery)	$17,900	$350/MT as 36% Solution
Caustic (Bulk Delivery)	$82,600	$600/MT as 49% Solution
RO/UF Cleaning Chemicals	$15,000	Allowance
RO Membrane & IE Resin Replacements	$80,000	Allowance
Process Water	$19,700	$2.70/m^3
Sodium Hypochlorite	$10,600	$0.35/kg - 12% Chlorine Solution
Operating Consumables/Personel Protection	$10,000	Allowance
Laboratory Services	$10,000	Regulatory Testing
Evaporation Pond Solids Disposal	$0	$12/m3; Includes transportation
DIRECT OPERATING COSTS: COMPOSTING		
DIRECT LABOR (DL)		
(a) Operators (4 Operators)	$65,800	32 hours/day @$5.63/hr
(b) Supervisors	$16,500	25% of operating labor
MAINTENANCE (ML)		
(a) Labor (2 Mantenance Personnel)	$32,900	16 hours/day @$5.63/hr
(b) Material/Spare Parts	$16,500	70% of maintenance labor
OTHER DIRECT COSTS		
Amendment Material	$0	365 d/yr at $0/kg
Fuel	$32,850	$0.90/L
INDIRECT OPERATING COSTS:		
OVERHEAD	$142,600	44% of DL + 12% ML
PROPERTY TAX	$189,300	Not Applicable
INSURANCE	$34,600	0.15%of Capital Cost
ADMINISTRATION EXPENSES/CONSUMABLES	$378,600	1%of Capital Cost
INDIRECT OPERATING INCOME:		
EFFLUENT REUSE INCOME/M^3 OF EFFLUENT	($328,500.00)	365 d/y at $0.45/m^3 as income
EFFLUENT QUARRY REUSE INCOME/M^3 OF EFFLUENT	$0	365 d/y at $0/m^3 as income
COMPOSTING INCOME/KG	$0	365 d/y at $0/kg as income
DIRECT AND INDIRECT OPERATING COSTS	**$2,509,850**	
O&M COST / M^3 OF INFLUENT[1]:	**$2.75**	**BASED ON DIRECT & INDIRECT COSTS + INCOME**
OPERATING COSTS INCLUDING CAPITAL RECOVERY		
ANNUAL COST OF CAPITAL RECOVERY:	**$2,752,100**	**18 Repayment Periods at 3% Interest Rate**
TOTAL ANNUALIZED OPERATING COST[1]:	**$5,262,000**	**INCLUDING CAPITAL RECOVERY**
PRODUCTION COST / M3 OF INFLUENT[3]:	**$5.77**	**INCLUDING CAPITAL RECOVERY + INCOME**

Notes:
1. This assumes there is no fee to discharge to the IWTP and there is no income for reuse of the treated effluent.
2. Costs are in USD.
3. The discharge fee would need to be this cost in order to break even.

Zarqa Industrial Wastewater Treatment Plant
ANNUALIZED OPERATING COST ESTIMATE
ALTERNATIVE B

	Alternative B	Basis
DIRECT OPERATING COSTS: TREATMENT PLANT		
DIRECT LABOR (DL)		
(a) Operators (7 Operators)	$115,100	56 hours/day @$5.63/hr
(b) Supervisors	$28,800	25% of operating labor
MAINTENANCE (ML)		
(a) Labor (2 Mantenance Personnel)	$32,900	16 hours/day @$5.63/hr
(b) Material/Spare Parts	$23,000	70% of maintenance labor
UTILITIES/CHEMICALS/OTHER DIRECT COSTS		
Electricity	$712,500	$0.14/kWhr
Hydrated Lime (Bulk Delivery)	$260,700	$250/MT
Sulfuric Acid (Bulk Delivery)	$9,500	$650/MT as 96% Solution
Ferric Chloride (Bulk Delivery)	$95,600	$444/MT as 49% Solution
Chemicals (Polymers)	$132,200	4 kg/MT DS- $8/kg
Process Water	$4,900	$2.70/$m^3$
Sodium Hypochlorite	$10,600	$0.35/kg - 12% Chlorine Solution
Operating Consumables/Personel Protection	$8,000	Allowance
Laboratory Services	$10,000	Regulatory Testing
DIRECT OPERATING COSTS: WETLAND		
DIRECT LABOR (DL)		
(a) Operators (2 Operators)	$32,900	16 hours/day @$5.63/hr
(b) Supervisors	$8,200	25% of operating labor
MAINTENANCE (ML)		
(a) Labor (1 Mantenance Personnel)	$16,400	8 hours/day @$5.63/hr
REPLACEMENT		
Herbaceous Crops	$84,400	$0.75/plant; 10% Replaced/yr[6]
Salt Tolerant Shrubs	$140,600	$5/plant; 10% Replaced/yr[6]
Adsorbent Material	$562,500	$30/m3; 1 cell replaced per year[6]
Biomass for Reuse as Amendment Material in Composting	$0.00	$0/kg
Disposal fee for replaced Adsorbent Material[5]	$0	$0/m3; Includes transportation[6]
DIRECT OPERATING COSTS: COMPOSTING		
DIRECT LABOR (DL)		
(a) Operators (4 Operators)	$43,800	32 hours/day @$3.75/hr
(b) Supervisors	$11,000	25% of operating labor
MAINTENANCE (ML)		
(a) Labor (2 Mantenance Personnel)	$21,900	16 hours/day @$3.75/hr
(b) Material/Spare Parts	$11,000	70% of maintenance labor
OTHER DIRECT COSTS		
Amendment Material	$0	365 d/yr at $0/kg
Fuel	$32,850	$0.90/L
INDIRECT OPERATING COSTS:		
OVERHEAD	$118,100	44% of DL + 12% ML
PROPERTY TAX	$129,300	Not Applicable
INSURANCE	$38,800	0.15%of Capital Cost
ADMINISTRATION EXPENSES/CONSUMABLES	$258,600	1%of Capital Cost
INDIRECT OPERATING INCOME:		
EFFLUENT REUSE INCOME/M^3 OF EFFLUENT	($208,050.00)	365 d/y at $0.30/$m^3$ as income
COMPOSTING INCOME/KG	$0.00	365 d/y at $0/kg as income
DIRECT AND INDIRECT OPERATING COSTS	**$2,746,100**	
O&M COST / M^3 OF INFLUENT[1]:	**$3.01**	**BASED ON DIRECT & INDIRECT COSTS + INCOME**
OPERATING COSTS INCLUDING CAPITAL RECOVERY		
ANNUAL COST OF CAPITAL RECOVERY:	**$1,879,700**	**18 Repayment Periods at 3% Interest Rate**
TOTAL ANNUALIZED OPERATING COST[1]:	**$4,626,000**	**INCLUDING CAPITAL RECOVERY**
PRODUCTION COST / M3 OF INFLUENT[3]:	**$5.07**	**INCLUDING CAPITAL RECOVERY + INCOME**

Notes:
1. This assumes there is no fee to discharge to the IWTP and there is no income for reuse of the treated effluent.
2. Costs are in USD.
3. The discharge fee would need to be this cost in order to break even.

Zarqa Industrial Wastewater Treatment Plant
ANNUALIZED OPERATING COST ESTIMATE
ALTERNATIVE C

	Alternative C	Basis
DIRECT OPERATING COSTS:		
DIRECT LABOR (DL)		
(a) Operators (7 Operators)	$115,100	56 hours/day @$5.63/hr
(b) Supervisors	$28,800	25% of operating labor
MAINTENANCE (ML)		
(a) Labor (2 Mantenance Personnel)	$32,900	16 hours/day @$5.63/hr
(b) Material/Spare Parts	$23,000	70% of maintenance labor
UTILITIES/CHEMICALS/OTHER DIRECT COSTS		
Electricity	$711,300	$0.14/kWhr
Hydrated Lime (Bulk Delivery)	$260,700	$250/MT
Sulfuric Acid (Bulk Delivery)	$9,500	$650/MT as 96% Solution
Ferric Chloride (Bulk Delivery)	$95,600	$444/MT as 49% Solution
Chemicals (Polymers)	$132,200	4 kg/MT DS- $8/kg
Process Water	$4,900	$2.70/$m^3$
Sodium Hypochlorite	$10,600	$0.35/kg - 12% Chlorine Solution
Operating Consumables/Personel Protection	$8,000	Allowance
Laboratory Services	$10,000	Regulatory Testing
DIRECT OPERATING COSTS: UPLAND NATIVE TREE PLANTATION		
DIRECT LABOR (DL)		
(a) Operators (2 Operators)	$32,900	16 hours/day @$5.63/hr
(b) Supervisors	$8,200	25% of operating labor
MAINTENANCE (ML)		
(a) Labor (1 Mantenance Personnel)	$16,400	8 hours/day @$5.63/hr
REPLACEMENT		
Trees	$14,100	$50/tree; 1% Replaced/yr
Biomass for Reuse as Amendment Material in Composting	$0.00	$/kg
DIRECT OPERATING COSTS: COMPOSTING		
DIRECT LABOR (DL)		
(a) Operators (4 Operators)	$65,800	32 hours/day @$5.63/hr
(b) Supervisors	$16,500	25% of operating labor
MAINTENANCE (ML)		
(a) Labor (2 Mantenance Personnel)	$32,900	16 hours/day @$5.63/hr
(b) Material/Spare Parts	$16,500	70% of maintenance labor
OTHER DIRECT COSTS		
Amendment Material	$0	365 d/yr at $0/kg
Fuel	$32,850	$0.90/L
INDIRECT OPERATING COSTS:		
OVERHEAD	$132,200	44% of DL + 12% ML
PROPERTY TAX	$115,400	Not Applicable
INSURANCE	$38,800	0.15%of Capital Cost
ADMINISTRATION EXPENSES/CONSUMABLES	$230,800	1%of Capital Cost
INDIRECT OPERATING INCOME:		
EFFLUENT REUSE INCOME/M^3 OF EFFLUENT	$0.00	365 d/y at $0/$m^3$ as income
AGRIBUSINESS INCOME: TREES	$0.00	365 d/y at $0/$m^3$ as income
AGRIBUSINESS INCOME: BARLEY	($180,000.00)	$300/Ha as income
COMPOSTING INCOME/KG	$0	365 d/y at $0/$m^3$ as income
DIRECT AND INDIRECT OPERATING COSTS	**$2,015,950**	
O&M COST / M^3 OF INFLUENT[1]:	**$2.21**	**BASED ON DIRECT & INDIRECT COSTS + INCOME**
OPERATING COSTS INCLUDING CAPITAL RECOVERY		
ANNUAL COST OF CAPITAL RECOVERY:	**$1,677,900**	**18 Repayment Periods at 3% Interest Rate**
TOTAL ANNUALIZED OPERATING COST[1]:	**$3,694,000**	**INCLUDING CAPITAL RECOVERY**
PRODUCTION COST / M3 OF INFLUENT[3]:	**$4.05**	**INCLUDING CAPITAL RECOVERY + INCOME**

Notes:
1. This assumes there is no fee to discharge to the IWTP and there is no income for reuse of the treated effluent.
2. Costs are in USD.
3. The discharge fee would need to be this cost in order to break even.

Zarqa Industrial Wastewater Treatment Plant
ANNUALIZED OPERATING COST ESTIMATE
ALTERNATIVE D

	Alternative D	Basis
DIRECT OPERATING COSTS: TREATMENT PLANT		
DIRECT LABOR (DL)		
(a) Operators (4 Operators)	$65,800	32 hours/day @$5.63/hr
(b) Supervisors	$16,500	25% of operating labor
MAINTENANCE (ML)		
(a) Labor (1 Maintenace Personnel)	$16,400	8 hours/day @$5.63/hr
(b) Material/Spare Parts	$11,500	70% of maintenance labor
UTILITIES/CHEMICALS/OTHER DIRECT COSTS		
Electricity	$412,100	$0.14/kWhr
Hydrated Lime (Bulk Delivery)	$260,700	$250/MT
Sulfuric Acid (Bulk Delivery)	$9,500	$650/MT as 96% Solution
Ferric Chloride (Bulk Delivery)	$95,600	$444/MT as 49% Solution
Chemicals (Polymers)	$1,500	$8/kg
Process Water	$4,900	$2.70/$m^3$
Operating Consumables/Personel Protection	$5,000	Allowance
Laboratory Services	$7,500	Regulatory Testing
INDIRECT OPERATING COSTS:		
Pretreated Effluent Sewer Discharge Fee	$394,200	$0.45/$m^3$
Sludge Disposal/Sewer Discharge Fee	$22,250	$10/MT dry weight basis
OVERHEAD	$39,600	44% of DL + 12% ML
PROPERTY TAX	$58,500	Not Applicable
INSURANCE	$17,500	0.15%of Capital Cost
ADMINISTRATION EXPENSES/CONSUMABLES	$117,000	1%of Capital Cost
DIRECT AND INDIRECT OPERATING COSTS	**$1,556,050**	
O&M COST / M^3 OF INFLUENT[1]:	**$1.71**	**BASED ON DIRECT & INDIRECT COSTS + INCOME**
OPERATING COSTS INCLUDING CAPITAL RECOVERY		
ANNUAL COST OF CAPITAL RECOVERY:	**$850,300**	**18 Repayment Periods at 3% Interest Rate**
TOTAL ANNUALIZED OPERATING COST[1]:	**$2,406,350**	**INCLUDING CAPITAL RECOVERY**
PRODUCTION COST / M3 OF INFLUENT[3]:	**$2.64**	**INCLUDING CAPITAL RECOVERY + INCOME**

Notes:
1. This assumes there is no fee to discharge to the IWTP and there is no income for reuse of the treated effluent.
2. Costs are in USD.
3. The discharge fee would need to be this cost in order to break even.