REPORT ON THE STATUS OF OPERATION AND MAINTENANCE PROGRAM ACTIVITIES AT SIX WATER TREATMENT PLANTS IN JORDAN

Prepared for

THE WATER AUTHORITY OF JORDAN
MINISTRY OF IRRIGATION AND WATER
HASHEMITE KINGDOM OF JORDAN

JULY 2004

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EXECUTIVE SUMMARY

This report presents the findings of the CDM operation and maintenance (O&M) audit team that visited six operating water treatment plants in the Kingdom of Jordan, between January 20th and January 29th, 2004. Each of the plants have been in operation for five years or less, and were originally constructed and/or upgraded with the assistance of USAID who provided funding for associated capital works and engineering. Four of these plants are using Fibrotex microfiltration units, the fifth facility is using membrane microfiltration technology, and the sixth facility is using conventional floc/coagulation/sand filtration technology. All of the plants are owned and operated by the WAJ with the exception of the Wadi Sir facility which is operated by LEMA LEMA, a partnership between France's Lyonnaise Des Eaux and Jordan's Montgomery Arabtech Jardaneh and handles the Zai Water Treatment Plant which is responsible for supplying 40% of the capital's water needs. In addition, LEMA looks after 100 water wells, a 4,500km-long water network, 1,500km of sewers, two wastewater treatment plants and 270,000 subscribers.

O&M Audit – Quick Summary Description

What is it?

- Systematic procedure for obtaining and evaluating objective evidence of O&M organization and practice.

Why do it?

- When an independent opinion is needed in addition to internal views.
- For comparison purposes, when setting performance targets for new and existing facilities.

What is the value of it?

- To highlight system deficiencies and a lack of crucial management functions in O&M.
- To make international comparisons.
- To help make the O&M function transparent.

General Overview

The water plants included in this audit are five examples of WAJ managed plant O&M efforts and one example of a private sector O&M company, LEMA managed operations. According to WAJ, each of the six plants are providing reliable service within the design limits of the facility. The status of O&M at the LEMA managed plant is considered equal to the status of O&M at the WAJ managed plants. No noticeable difference was found in equipment condition, level of maintenance, operator knowledge, spare parts availability, delays in making repairs, or general safety practices.

Each of the six plants visited were producing quality water at the design rate of flow. The general condition of the plants was above average when compared to similar facilities being operated by WAJ. It is believed that the higher design standards, construction quality, and equipment quality used at these facilities is the major reason for these facilities continued good performance to date. However, current practices of postponing periodic routine maintenance will eventually result in lower overall condition at these plants also.

The basic elements of a sound program of maintenance (maintenance task list, schedule, record keeping) are understood by plant managers although rarely practiced. Each WAJ plant manager has expressed his desire to improve the status of maintenance at his particular facility by having a set of maintenance tasks performed at a certain frequency, and wants these tasks to be scheduled and

performed thoroughly by qualified staff. The first problem in achieving this is simply trying to implement prevention in a reactive environment. At the plants, work isn't planned, parts aren't available, and/or staff technical skills for performing the maintenance task are missing.

Concluding Statement

The greatest benefit of performing this O&M audit has been informational. The information resulting from this O&M audit can now be used to help prioritize technical, managerial, financial, and policy issues regarding the management and budget for the facilities.

One of the secondary goals of this audit task was to demonstrate, if possible, the benefit of measuring certain priority O&M functions (percent of time equipment is out of service, spare parts procurement time, number of work orders completed, etc) as a method of bringing about some improvement, e.g., the situation of O&M can't permanently improve if it is not measured routinely. However, currently the plants are operating without benefit of standardized management systems making data collection and comparisons nearly impossible. In the absence of effective management systems at the plant level, it is unlikely that tools for evaluating specific aspects of O&M status and performance will produce any great effect.

1.0 Introduction

1.1 Purpose

The purpose of this report is to present the findings of site visits to six Water Authority of Jordan (WAJ) water treatment plants, to comment on the status of operation and maintenance activities being completed by staff and offer suggestions for improvement. One of the major goals of this operation and maintenance (O&M) audit task has been to gain an understanding of how each of the six subject water treatment facilities and associated equipment are currently operated and maintained, why these O&M strategies were chosen, and what the most significant problems are for facility site O&M staff and WAJ central managers. In addition, the results of this O&M audit are meant to provide a starting point or baseline from which WAJ can measure the effectiveness of any improvements and ongoing O&M activities.

1.2 Background

Current problems with the operation and maintenance (O&M) of existing water treatment facilities is recognized as a key constraint to the sustainability of water service delivery in the served areas. In order to address these problems WAJ has requested CDM to assist them in completing an audit for assessing the status of current O&M operations at six water treatment facilities.

1.3 Approach

What this O&M Audit Included:

- Interviews with WAJ plant managers, WAJ central management staff, plant O&M personnel, and LEMA private service contractors;
- A review of facility/equipment condition, maintenance history documentation, and equipment service contracts where possible;
- Spot checks of equipment and facility process performance and control methods;
- Review of treated water quality and unit process trend data where available (turbidity, coliform count, filter head-loss, temperatures, pressures, electrical, etc.) over time.

The audit team also looked for equipment preventive maintenance schedules and strategies to determine if the facilities are being maintained optimally and, if possible, develop a preliminary list of recommended improvements that support improved maintenance.

Facilities Included in This O&M Audit:

Six WTP were included in this O&M audit the six WTPs is included in this audit are presented in **Table 1**. The plants location map is presented in **Figure 1**

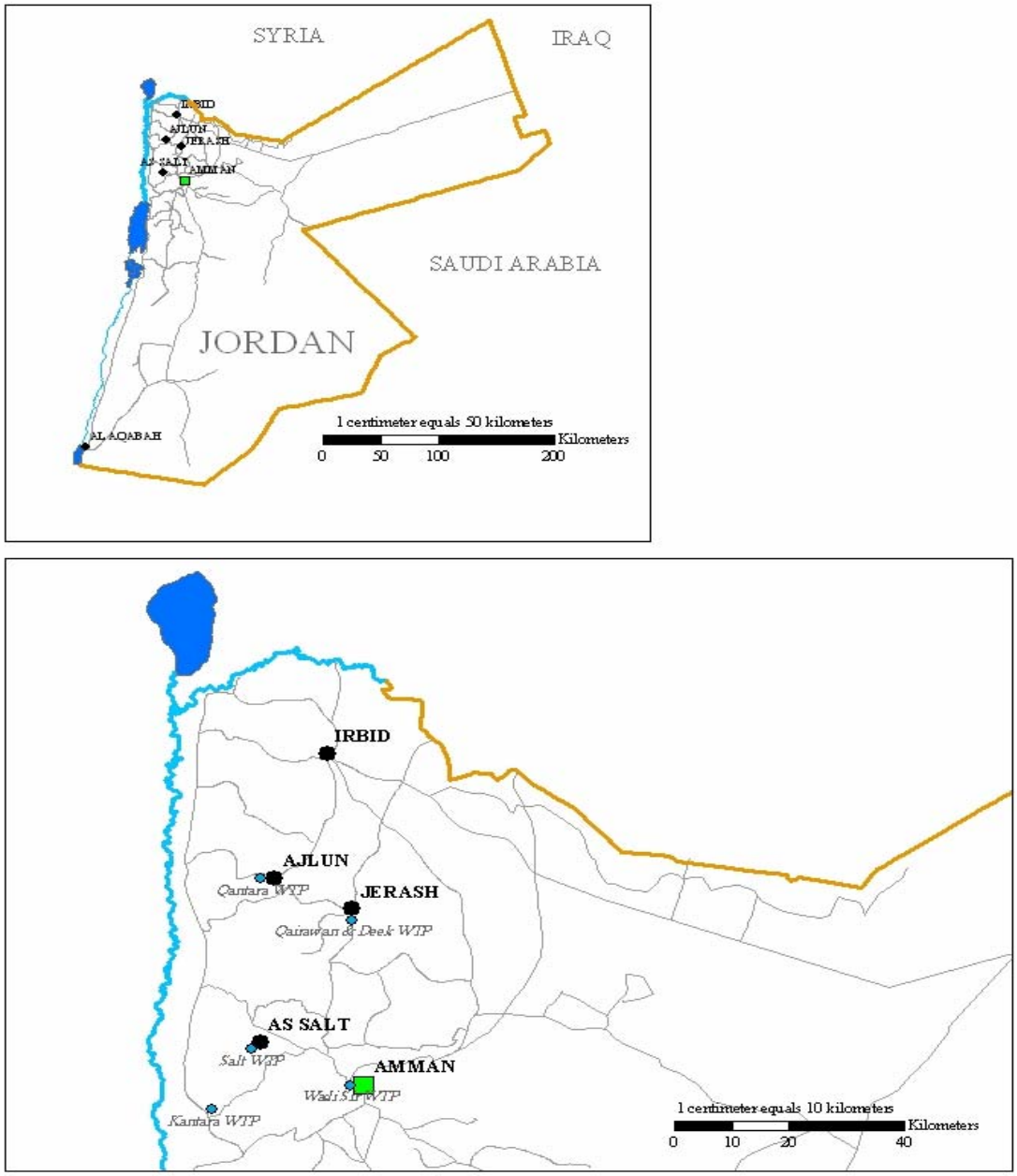


Figure 1: Location Map

Table 1: Facilities Included in this O&M Audit

WTP Name	Technology Type	Design Capacity	Year Built	Source Water
Qairawan	S&L automatic backwashing Fibrotex filters	150 m^3/h	1999	Qairawan Spring
Qantara	S&L automatic backwashing Fibrotex filters	150 m^3/h	1999	Qantara Spring
Deek	S&L automatic backwashing Fibrotex filters	150 m^3/h	1999	Deek Spring
Wadi Sir	S&L automatic backwashing Fibrotex filters	400 m^3/h	1999	Qairawan Spring
Kafrein	Floc/Coagulation/Sand Filtration	255 m^3/h	2001	3-artisien wells
Salt	Membrane Microfiltration	1000 m^3/h	2001	Hazeer, Bguria and Al-Shuraia Springs

Definition of O&M Audit Key Terms

Operation refers to the procedures and activities involved in the actual delivery of potable water service, e.g. abstraction, treatment, pumping, transmission and distribution of drinking water.

Maintenance refers to activities aimed at keeping existing water facility capital assets in serviceable condition, e.g. by repairing water treatment filters, disinfection systems, distribution pumps, etc.

O&M are the activities related to the performance of routine, preventive, predictive, scheduled, and unscheduled actions aimed at preventing equipment failure or decline with the goal of increasing efficiency, reliability, and safety.

Operational Efficiency represents the life-cycle cost-effective mix of preventive, predictive, and reliability-centered maintenance technologies, coupled with equipment calibration, tracking, and maintenance management capabilities all targeting reliability, safety, water quality, and system efficiency.

2.0 Audited Treatment Plants

2.1 Summary Information of the Six Water Plants

The collected relevant information on the six water treatment plants are summarized in Table 2

Table 2: Summary information on the Six Water Plants

Description	Qantara	Qairawan	Deek	Wadi Sir	Kafrein	Salt
TREATMENT TECHNOLOGY	S&L Filters	S&L Filters	S&L Filters	S&L Filters	Coagulation and Sand filtering	UF Membrane
GENERAL INFORMATION						
Group responsible for O&M	WAJ	WAJ	WAJ	LEMA	WAJ	WAJ
Date of commissioning	1999	1999	1999	1999	2001	Aug. 02
Design flow, m^3/day	3600	3600	3600	9600	6120	24000
Average actual flow, m3/day	720	2200	2050	5900	4010	10,400
Total flow treated, m^3 x 1000 Year 2000	239	391	845	902	-	-
Total flow treated, m^3x 1000 Year 2001	249	312	653	1,467	NA	777[1]
Total flow treated, m^3x 1000 Year 2002	282	647	790	2,065	1,065	3,282
Total flow treated, m^3x 1000 Year 2003	345	807	747	2,152	1,464	3,794
Service Population ix 1000	15[2]	35[2]	30[2]	50[2]	35[2]	90[2]
Plant Difficulty Rating (Low, Med, High)	Low	Low	Low	Low	Medium	High
WAJ FACILITY ANNUAL BUDGET INFORMATION						
Annual O&M Budget for last year, JD x 1000	NA[3]	NA[3]	NA[3]	84,742	NA[3]	NA[3]
Budget breakdown - Spare Parts	NA[3]	NA[3]	NA[3]	83000	NA[3]	NA[3]
Budget breakdown - Staffing	NA[3]	NA[3]	NA[3]	NA[4]	NA[3]	NA[3]
Budget breakdown - Chemicals	NA[3]	NA[3]	NA[3]	1742	NA[3]	NA[3]
Budget breakdown - Electricity	NA[3]	NA[3]	NA[3]	NA[4]	NA[3]	NA[3]
FACILITY CAPITAL COST INFORMATION						
Facility total asset value assigned by WAJ, JD x 1000	NA[5]	NA[5]	NA[5]	NA[5]	NA[5]	NA[5]
Facility total construction cost, JD x 1000	1,100	1,100	1,100	1,200	2,660	5,325
Facility mechanical and electrical cost, JD x 1000	NA[6]	NA[6]	NA[6]	NA[6]	NA[6]	NA[6]
FACILITY STAFFING INFORMATION						
Total number of full time O&M staff assigned to plant	4	4	4	8	12	10
No. of Engineers	0	0	0	0	1	2
No. of Operators	4	4	4	6	8	8
No. of Mechanics	0	0	0	0	0	0
No. of Electricians	0	0	0	0	0	0

[1] Five months production
[2] As estimated by WAJ, the exact population is not accurately known due to the various water sources feeding complex distribution network.
[3] The WTP doesn't have a specific annual budget. Budgeting for O&M are made for all the facilities within a Governorate in one budget. Funds for WTP O&M are requested on as needed basis from relevant WAJ-Governorate.
[4] LEMA's budget for staff and power is not available for Wadi Sir Plant separately.
[5] Information is not available, WAJ does not assign assets value for a specific plant.
[6] Information is not available.

No. of Labors	0	0	0	2	3	0

2.2 Qantara Water Treatment Plant

Treatment Technology	S&L automatic backwashing Fibrotex filters
Manager name and title:	Muhamad Al-Muhaisen, Engineer
Phone Number:	962 77 218304
Design Flow:	150 m^3/hour
Current flow:	75 m^3/hour
Year plant built:	1999
Most recent upgrade:	July 2000, addition of UV pretreatment and post chlorination system equipment.

General Observations During Audit Visit

- The **plant was not operating** at the time of the site visit due to high turbidity levels (above 16 NTU) in the raw water supply feeding the plant. Weather conditions for this day were heavy rain and flood conditions in some areas. This plant routinely experiences high raw water turbidity levels during periods of prolonged rain events.

- **Operations Records**: This plant keeps a logbook for recording basic operational information.

- **Maintenance Approach**: This plant reports that they never ask the WAJ Central Workshop Department for assistance with maintenance. Operator staff is used to performing repair work as needed. No routine schedule for preventive maintenance is being followed.

- **Staff Transportation to plant**: Because this plant is located along bus routes, transportation is not reported as a problem for staff getting to and from work. This plant has been assigned one vehicle from the WAJ.

- **Overdue Maintenance**: The UV lamps were last changed more than 2-years ago. These lamps are overdue for replacement. The time delay between the 1st and 2nd filter elements change was too long.

- This plant delivers treated water through a gravity line. However, WAJ reports that this line cannot handle the design flow of the plant under gravity conditions and for this reason they **plan on adding one treated water pump** to pressure pump this line.

- **Plant staff is four Operators,** who each work 24-hr shifts, one day on shift and two days off. Operators also perform simple maintenance tasks.

- **Operation Difficulty Rating**: Low

Maintenance History

Summary of major part replacements or repairs made since the time of facility commissioning

- Fibrotex filter element 1st replacement, February 2001 - replaced all.
- Fibrotex filter element 2nd replacements, December 2003 – replaced all.
- UV lamp replacements (11 lamps total to date)

- Chemical cleaning for UV lamps (two times)
- Air Compressor belt replacement (one belt set to date)
- Changed Compressors oil/air separator
- Numerous electrical contactors have been replaced in the MCC (reason for this is unknown).
- Cleaning the raw and finished water wells (once a year)
- Changed sampling submersible pump (once)

Major Equipment Out-of-Service

At the time of audit site visit the following equipment were out of service

- Two of eight filter air control valves (twist action control valves) are not working.
- One filter flow control valve is reported to **have a problem.**

2.3 Qairawan Water Treatment Plant

Treatment Technology:	S&L automatic backwashing Fibrotex filters
Manager name and title:	Ali Bani Mustafa, Engineer
Phone Number:	962 77 783393
Design Flow:	150 m^3/hour
Current flow:	130 m^3/hour
Year plant built:	1999
Most recent upgrade:	July 2000, addition of UV pretreatment and post chlorination system equipment.

General Observations During Audit Visit

- **Operations Records**: This plant keeps a logbook for recording basic operational information.

- **Maintenance Approach**: This plant reports that they occasionally ask the WAJ Central Workshop Department for assistance with major repair type maintenance only. Operator staff is used to performing simple repair work as needed. No routine schedule for preventive maintenance is being followed.

- **Staff Transportation to plant**: Because this plant is located along bus routes, transportation is not reported as a problem for staff getting to and from work.

- **Overdue Maintenance**: The UV lamps were last changed more than 2 years ago. These lamps are overdue for replacement. In addition, the filter run time between the 1st and 2nd filter elements change was too long.

- **Air Compressor Control Panel Repairs**: This plant experienced a problem with the compressor shutdown control sequence (cool-down run period after compressor unloads). WAJ Central Workshop Department staff was called to do troubleshooting and make repairs. The WAJ workshop staff was able to restore the compressor to be able to run but in doing so the compressor normal shutdown step (protective cool-down run period) was bypassed. WAJ is currently working with a local control panel specialist company to replace certain control components and return the control panel wiring to original as-built configuration.

- **Operation Difficulty Rating**: Low

Maintenance History

Summary of major part replacements or repairs made since the time of facility commissioning)

- Fibrotex filter element 1st replacement, February 2001 - replaced all.
- Fibrotex filter element 2nd replacements, October 2003 - replaced all.
- Replaced one backwash modulating valve body
- Maintenance for filters backwash mechanism (up/down and squeezing assembly)
- UV lamp replacements (11 lamps total to date)
- UV lamps chemical cleaning (three times)
- Air Compressor belt replacement (1 belt set to date)
- Replaced compressors oil / air separator (three times)
- Replaced Compressors cooling fan
- Replaced contactor in compressors control panel
- Replaced contactor in the air dryer system
- Conducted full maintenance for the chlorinators (repair kit)

Major Equipment Out-of-Service

At the time of audit site visit the following equipment were out-of-service

- Three of Nine UV lamps not working.
- One of two post chlorinators is not working.
- Two of two air compressors (both can run but have control panel wiring problems)
- One of one chlorine scrubber.

2.4 Deek Water Treatment Plant

Treatment Technology:	S&L automatic backwashing Fibrotex filters
Manager name and title:	Ali Bani Mustafa, Engineer
Phone Number:	962 77 783393
Design Flow:	150 m^3/hour
Current flow:	150 m^3/hour
Year plant built:	1999
Most recent upgrade:	July 2000, addition of UV pretreatment and post chlorination system equipment.

General Observations During Audit Visit

- **The plant was not operating** at the time of the site visit due to low demand for water. Raw water turbidity was 1.3 NTU.

- **Operations Records**: This plant keeps a logbook for recording basic operational information.

- **Maintenance Approach**: This plant reports that they occasionally ask the WAJ Central Workshop Department for assistance with maintenance. Operator staff is used to performing repair work as needed. No routine schedule for preventive maintenance is being followed.

- **Overdue Maintenance**: The UV lamps are due for replacement.

- **Plant staff is five Operators**, two operators work an 8-hour day shit and one operator works alone for a 16-hour night shift. Operators also perform simple maintenance tasks.

- WAJ reports that they are planning on adding **a desalination treatment plant** at this site, fed by two wells from the Gaza camp area.

- **Operation Difficulty Rating**: Low

Maintenance History

Summary of major part replacements or repairs made since the time of facility commissioning)

- Fibrotex filter elements 1st replacement, February 2001 - replaced all.
- Fibrotex filter elements 2nd replacements, October 2003 replaced all.
- UV lamp replacements (9 lamps total to date)
- UV wiper motor replaced
- UV lamps chemical cleaning (two times)
- Air Compressor belt replacement (2 belt sets to date)
- Replaced oil/air separator
- Air dryer refrigeration unit repaired (local shop completed repairs)
- Maintenance for chlorinators
- Replaced belts of the chlorine room exhaust fans

Major Equipment Out-of-Service

At the time of audit site visit the following equipment were outof service

- Emergency air cylinders missing – off site for more than two months for refill. Associated with emergency air pack breathing apparatus for protection against **chlorine gas.**

2.5 Wadi Sir Water Treatment Plant

Treatment Technology:	S&L automatic backwashing Fibrotex filters
Manager name and title:	Ali Al Qura'an, Engineer (LEMA)
Phone Number:	962 77 484266
Design Flow:	400 m^3/hour
Current flow:	300 m^3/hour
Year plant built:	1999
Most recent upgrade:	July 2000, addition of UV pretreatment and post chlorination system equipment.

General Observations During Audit Visit

- **Operations Records:** This plant keeps a logbook for recording basic operational information. Operational reports go to the Zai WTP, which is also being operated by LEMA.

- **Maintenance Approach**: Maintenance is not scheduled. Staff from the Zai WTP completes repairs when **Wadi Sir operator staff need help**.

- **Staff Transportation to plant**: This is not reported to be a problem.

- **Overdue Maintenance**: UV lamps are overdue for replacement.

- **Plant staff is eight Operators**, two operators work an 8-hour day shift and two operators work a 16-hour night shift. Operators also perform simple maintenance tasks.

- **Operation Difficulty Rating:** Low

Maintenance History

Summary of major part replacements or repairs made since the time of facility commissioning

- Fibrotex filter elements 1st replacement, February 2001 - replaced all.
- Fibrotex filter elements 2nd replacements, March 2003 - replaced all.
- Replaced modulating valve for Filter 4
- Replaced one air lift motor
- UV lamp replacements (3 x18 lamps total to date)
- UV lamps chemical cleaning (5 times)
- Air Compressor belt replacement (2 x 2 belt sets to date)
- Replaced timer for compressor control panel
- Replaced transformer for compressors control panel
- Replaced wiring for compressor 1
- Replaced oil / air separator (two times)
- Replaced oil filter for compressors
- Maintenance for V10K chlorinators using repair kits
- Replaced chlorine detector
- Replaced impellers for chlorine motive pumps (2)
- Replaced motor of chlorine room exhaust fan
- Replaced belts for chlorine exhaust fan

Major Equipment Out-of-Service

At the time of audit site visit the following equipment were out-of-service

- Chlorine detector for chlorine room
- Chlorine cylinder scales
- Scrubber turned off due to non-functioning chlorine leak detector
- Filter flow control valve actuator (significant air leak)
- Air compressor controls (pressure switch settings seem to need adjustment; blower does not unload at design set point)

2.6 Kafrein Water Treatment Plant

Treatment Technology	Flocculation/Coagulation/Sand filtering
Manager name and title:	Reyad Muhsen, Engineer
Phone Number:	962 5 359 0152
Design Flow:	255 m^3/hour
Current flow:	250 to 270 m^3/hour
Year plant built:	2001
Most recent upgrade:	None

General Observations During Audit Visit

- **Operations Records**: This plant has a PC computer and keeps good records of operational parameters (flow, chemical feed, power outage, BW flows, etc.) Historic data is being trended and graphed as a method of presentation.

- **Maintenance Approach:** This plant relies on the WAJ Central Workshop Department for all maintenance activities other than simple repairs and lubrication. No written records of completed maintenance were available at the time of the audit visit. Staff report performing normal lubrication for equipment including clarifier drives, motor bearings, etc.

- **Process Control Laboratory**: The laboratory room looks to be unused.

- **Manual batching of chemicals**: Because both the duty and standby chemical transfer pumps are broken, plant staff have been batching coagulation chemicals by hand and adding the mixture to the tank.

- WAJ is in the process of adding a new pump and distribution main to provide 50 m^3/day of treated water to the nearby military base.

- Plant staff is one engineer, 8 operators and 3 laborers.

- **Operation Difficulty Rating**: MEDIUM, this facility is slightly more complicated than the four S&L Fibrotex filtration plants and less difficult than the Salt Microfiltration membrane WTP

Maintenance History

Summary of major part replacements or repairs made since the time of facility commissioning

- Replacement of chemical dosing pumps
- Conducted repairs for Alum transfer pump
- Re-installed the filters control software several times
- Replaced solenoid valves of filter control valves (4)
- Clarifier gear drive oil change
- Air compressor oil change

Major Equipment Out-of-Service

At the time of audit site visit the following equipment were out-of-service

- **Compressor air dryer** (staff report moisture in air supply piping for filter valves pneumatic actuators)
- **Chemical Transfer Pumps** (impeller wear, replacement parts are delayed because they are considered for use in making 'chemical weapons'
- **Chemical Feed Pumps,** LMI (original chemical feed pumps are not working and have been replaced with local market purchased Italian pumps which seem to be working okay. Plant staff found it easier to replace the original pumps with new units rather than do all that is required to import the needed pump repair kits.
- **Filter Control Panel Indicator Lights,** numerous lights were burned and not replaced. Bulbs are reported to be available in the local market
- **Filter Flow Control Valve Actuators**, several actuators are not working and need to be repaired or replaced

2.7 Salt Water Treatment Plant

Treatment Technology: Microfiltration Membrane
Manager Name and Title: Jamal Al-Jouhari, Engineer
Phone Number: 962 5 355 9480

Design Flow: 1000 m^3/hour
Current flow: 450 m^3/hour
Year plant built: 2001
Most recent upgrade: None

General Observations During Audit Visit

- **Operations Records**: This plant keeps a logbook for recording basic operational information. Some operational records are available through the plant SCADA computer system.

- **Maintenance Approach**: Plant manager has prepared a preventive maintenance schedule following the guidelines presented in manufacture manuals.

- **Membrane Repairs were ongoing during the time of the plant visit.** Plant staff was 'pinning' damaged membrane hollow-core fibers following sonic testing. Staff report that sonic testing is performed every 3 months.

- **Plant staff is eight Operators**, two operators work a 24-hour shift.

- **Operation Difficulty Rating**: HIGH, This facility is considered more difficult to operate and maintain than the five other WTP facilities due to the more sophisticated controls and instrumentation included within.

Maintenance History

Summary of major part replacements or repairs made since the time of facility commissioning

- Membrane replacements
- Membrane cartridge O-ring replacements (found equivalent O-rings in local market)
- Water softener unit
- Various valve repairs
- Backwash tank draining and cleaning
- Air Compressor oil & oil filters were replaced each
- (3000) working hours
- Air Compressors:
    1. Oil & oil filters were replaced each (3000) working hours
    2. Air filters were replaced each (3000) working hours
    3. Oil separator was replaced each (6000) working hours

- The coalesser filter and the membrane filter located after air dryer No.3 were replaced. However, filters were not replaced for the No1 and No.2 units due to a lack of spare parts.
- The 10-inch coalesser filter located on the main control air line was replaced.

Major Equipment Out-of-Service

At the time of audit site visit the following equipment were out-of-service

- Motorized valves
- Raw water chlorine residual analyzer (Analyzer was sent back to the USA for needed repairs. Repairs have been completed and the analyzer is now in Jordan with ***the local agent who has been holding this unit (for 6-months) waiting for WAJ payment of 1500JD.***

2.8 Plants Shutdowns at Wadi Sir, Qairawan, Deek and Qantara

Data collected from the Water Treatment Plants at Wadi Sir, Qairawan, Deek and Qantara show that the plants were shutdown for various reasons in the past three years. The major reasons for plant shutdowns were:

- High levels of biological contamination: exceeded the limits recommended by the Higher Committee for Water Quality

- High levels of turbidity: The plants are set to treat water with turbidity levels below 15 NTU.

- High levels of Nematodes: The applied standard requires that any stage of the free living organisms (Nematodes) should not exceed one living organism per liter in more than three of six samples taken in three consecutive days (two samples per day with six hours minimum time-gap between samples).

- Turbidity/Low Demand: The plants are also shutdown for a combination of two factors, which are low demand and high turbidity. This occurs in wintertime when Qantara is shutdown for low general demand.

- Low demand. In some cases even though the raw water turbidity is low, the demand for water at Qantara area is supplied from other sources.

- Contamination with petroleum products: This was related to one event in Ajlun area where an old abandoned underground diesel tank that contained amounts of diesel started leaking. The diesel was noticed in the spring's waters.

- Repairs. On some cases the operators were forced to shutdown the plant for repairs at the plants or in the pump stations.

The available data variation in duration; Qantara and Deek springs records included operation information for 1183 days. Qantara records show 673 days while Wadi Sir books show 759 days. The information regarding the plant shutdown percentages by site are presented in the following table and graphic:

Table 3: Percentage of Plant Shutdowns during the period of 1999/2000 to September 2002

Reasons For Plant Shutdowns	Wadi Sir (759 days)	Qairawan (1183 days)	Qantara (673 days)	Deek (1183 days)
For High Levels of Contamination	36%	14%	1%	1%
For High Levels of Turbidity	2%			
For High Levels of Nematodes		3%	1%	2%
Turbidity / Low Demand			16%	
Low Demand			12%	
Petroleum Contamination			7%	
Repair	1%		4%	

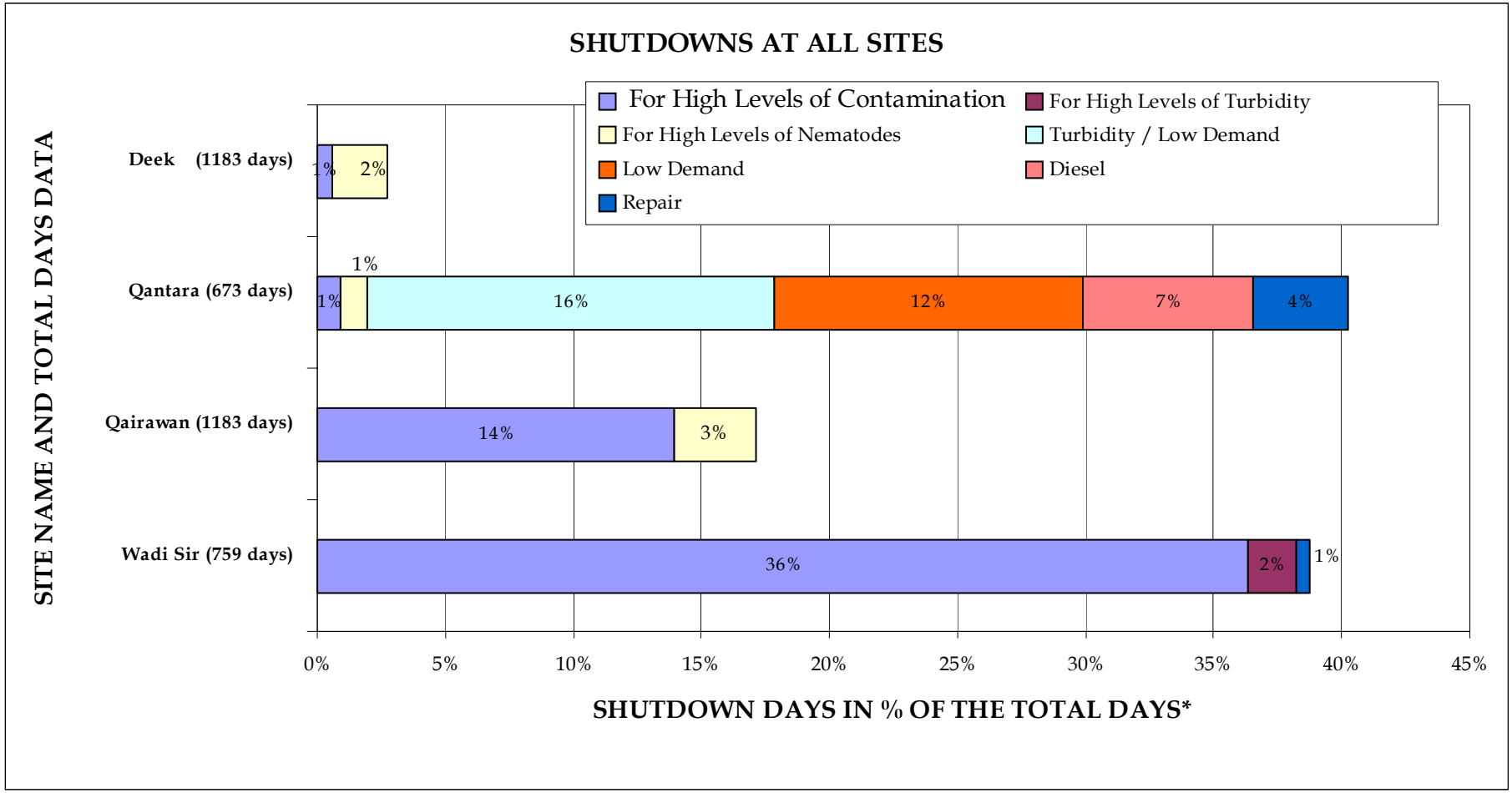
Table 4: Number of Occurances and Percentage of Plant Shutdowns during the period of October 2002 to October 2003

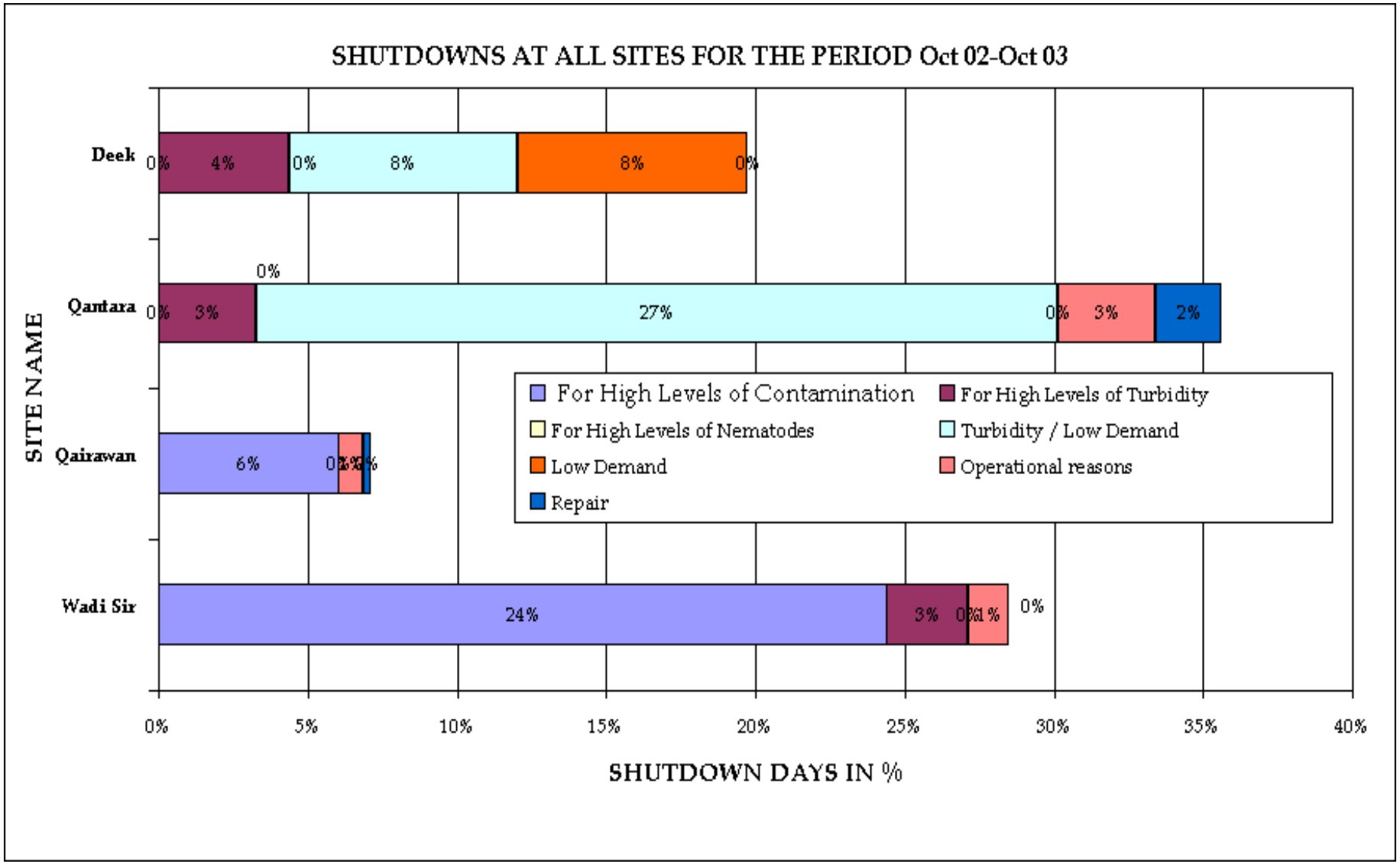
	Wadi Sir	Qairawan	Qantara	Deek
For High Levels of Contamination	89	22	0	0
For High Levels of Turbidity	10	0	12	16
For High Levels of Nematodes	0	0	0	0
Turbidity / Low Demand	0	0	98	28
Low Demand	0	0	0	28
Operational reasons	5	3	12	0
Repair	0	1	8	0

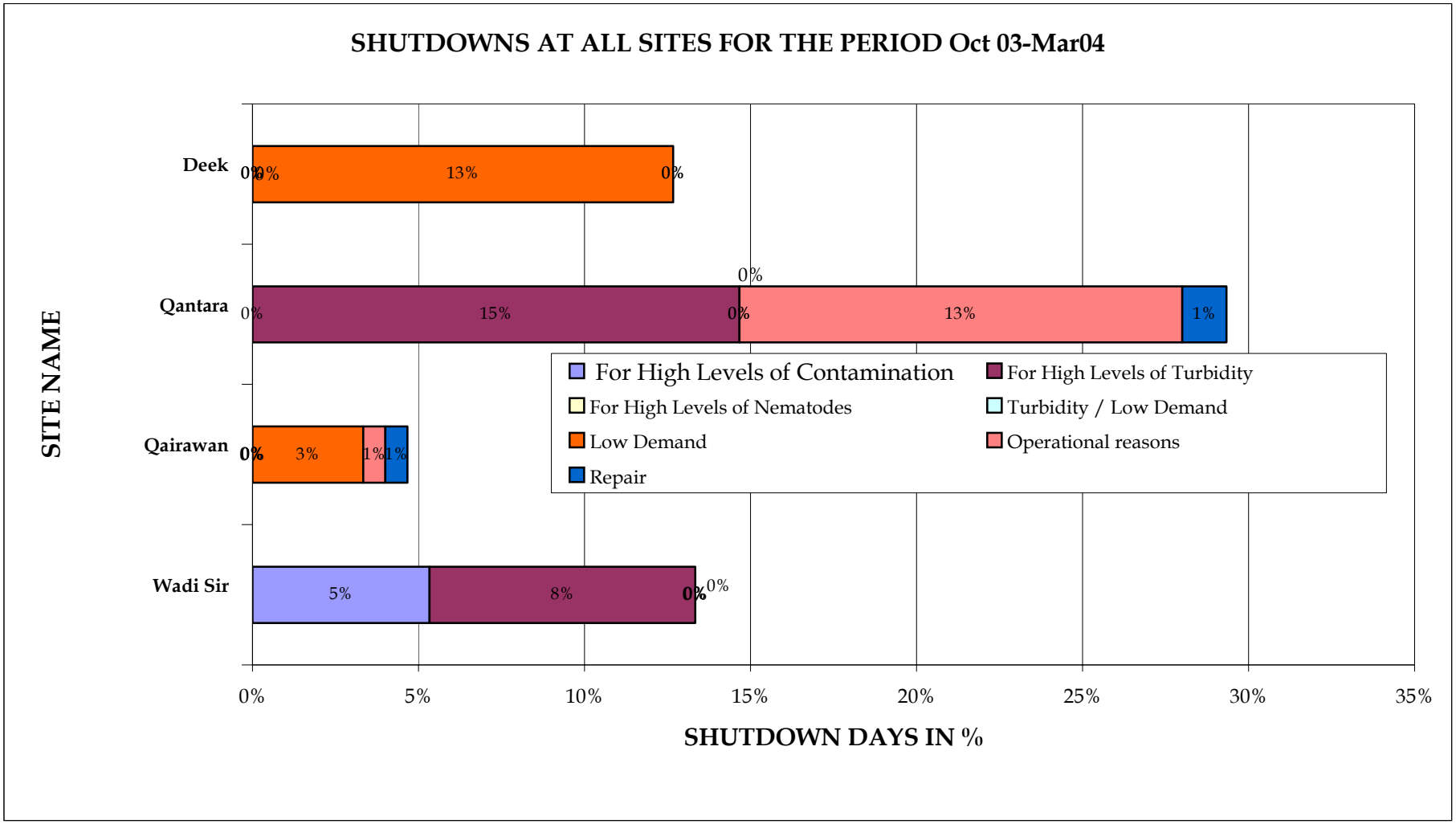
For High Levels of Contamination	24%	6%	0%	0%
For High Levels of Turbidity	3%	0%	3%	4%
For High Levels of Nematodes	0%	0%	0%	0%
Turbidity / Low Demand	0%	0%	27%	8%
Low Demand	0%	0%	0%	8%
Operational reasons	1%	1%	3%	0%
Repair	0%	0%	2%	0%

Table 5: Number of Occurances and Percentage of Plant Shutdowns during the period of October 2003 to March 2004

	Wadi Sir	Qairawan	Qantara	Deek
For High Levels of Contamination	8	0	0	0
For High Levels of Turbidity	12	0	22	0
For High Levels of Nematodes	0	0	0	0
Turbidity / Low Demand	0	0	0	0
Low Demand	0	5	0	19
Operational reasons	0	1	20	0
Power Failure	0	0	0	2
Repair	0	1	2	0
For High Levels of Contamination	5%	0%	0%	0%
For High Levels of Turbidity	8%	0%	15%	0%
For High Levels of Nematodes	0%	0%	0%	0%
Turbidity / Low Demand	0%	0%	0%	0%
Low Demand	0%	3%	0%	13%
Operational reasons	0%	1%	13%	0%
Power Failure	0%	0%	0%	1%
Repair	0%	1%	1%	0%


SHUTDOWNS AT ALL SITES
For High Levels of Contamination
For High Levels of Turbidity
For High Levels of Nematodes
Turbidity / Low Demand
Low Demand
Diesel
Repair
SITE NAME AND TOTAL DAYS DATA
Deek (1183 days)
1%
2%
Qantara (673 days)
1%
1%
16%
12%
7%
4%
Qairawan (1183 days)
14%
3%
Wadi Sir (759 days)
36%
2%
1%
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
SHUTDOWN DAYS IN % OF THE TOTAL DAYS*


SHUTDOWNS AT ALL SITES FOR THE PERIOD Oct 02-Oct 03
SITE NAME
Deek
Qantara
Qairawan
Wadi Sir
0%
4%
0%
8%
8%
0%
0%
3%
27%
0%
3%
2%
6%
24%
3%
0%
1%
0%
For High Levels of Contamination
For High Levels of Turbidity
For High Levels of Nematodes
Turbidity / Low Demand
Low Demand
Operational reasons
Repair
0%
5%
10%
15%
20%
25%
30%
35%
40%
SHUTDOWN DAYS IN %


SHUTDOWNS AT ALL SITES FOR THE PERIOD Oct 03-Mar04
SITE NAME
Deek
Qantara
Qairawan
Wadi Sir
0%
0%
13%
0%
0%
15%
0%
0%
13%
1%
0%
3%
1%
1%
5%
8%
0%
0%
For High Levels of Contamination
For High Levels of Turbidity
For High Levels of Nematodes
Turbidity / Low Demand
Low Demand
Operational reasons
Repair
0%
5%
10%
15%
20%
25%
30%
35%
SHUTDOWN DAYS IN %

3.0 GENERAL DISCUSSION

3.1 Overall Impressions

In general, the plants that were visited were all in operational condition with operator staff in attendance, treated water quality was reported to be meeting all national standards, facility appearance looked good, on-line instrumentation was operating, and plant managers/engineers demonstrated a clear understanding of their assigned responsibilities. The general condition of the installed equipment was still good but starting to shows some signs of neglect or missed maintenance.

3.2 O&M Status Indicators

3.2.1 Plant Water Quality and Overall Reliability

Table 5: Plant Water Quality and Overall Reliability

O&M Status Indicator	Status
Plants are producing treated water, which meet all water quality standards.	Yes
The quantity of water produced at the plants (m^3/hour) is within the design rates for the facilities.	Yes
Plants are kept in operation	Yes
Operator Absentee Rate?	Low

3.2.2 Plant Operations Staff and Plans

Table 6: Plant Operations Staff and Plans

O&M Status Indicator	Status
Plant managers/engineers are competent for responsibilities.	Yes
Plant Operators are competent for responsibilities.	Yes
Water quality record– Tracking of product water quality and non-compliance situations.	Yes
Operating standards/procedures in place and updated.	Some
Technical data produced as aid in operations.	Some
Technical information shared throughout organization.	minimal
Systems to increase staff knowledge and provide training in place.	No
Adequate in-house promotions policy in place and being used.	No

3.2.3 Maintenance Planning and Documentation

Table 7: Maintenance Planning and Documentation

O&M Status Indicator	Status
Equipment and plant facilities adequately protected by a maintenance program. Operator staff actively look for equipment requiring repair and take appropriate action.	Not formal
Do the plants have a formal maintenance plan?	No
If so, is that plan approved by the WAJ central authority?	No
Do the plants have a copy of the documentation required under the plan?	No
Do the plants have a process for periodically revising the maintenance plan?	No
Efficient distribution of work between facility operations and central maintenance departments?	Ad hock
Inventory control systems being used? – An accurate accounting of spare parts?	Missing
Backlog of corrective maintenance tracked? – An indicator of workload issues and effectiveness of preventive/predictive maintenance programs.	Not tracked
Work orders generated/closed out tracked? – Tracking of work orders generated and completed (closed out) over time allows WAJ to better understand workloads and better schedule staff.	No
Energy use being tracked? – A key indicator of equipment performance, level of efficiency achieved, and possible degradation.	No
Tools and spare parts easily accessible to staff who are performing maintenance.	No

3.2.4 Safety Practices and Plans

Table 8: Safety Practices and Plans

O&M Status Indicator	Status
Plant safety plan available and understood by all staff.	No
Adequate safety equipment available, ready for use, routinely tested and maintained. (Example, air masks and tanks for chlorine spills, first aid kits, chlorine cylinder repair kits, fire extinguishers).	No
Does plant staff participate in safety training refresher courses?	No
Are plant safety drills routinely performed?	No
Safety records being kept? – Commonly tracked either by number of loss-of-time incidents or total number of reportable incidents. Useful in getting an overall safety picture.	No

3.2.5 Private Sector Maintenance Planning

Table 9: Private Sector Maintenance Planning

O&M Status Indicator	Status
Do the plants have a maintenance plan for addressing the repair of sophisticated instrumentation and controls?	No
Do the plants have a plan, which calls for some special maintenance activities to be 'routinely' performed by the WAJ Central Workshop or private O&M service contractors?	No

3.3 Discussion of O&M Status Observations

3.3.1 Maintenance and Spare Parts

The purchase, delivery, and storage of materials are an integral part of a water utility O&M management system and, as such, status checks were included in the O&M audit.

The **relative high number of repairs outstanding** and reasons for this offered by plant managers reflects overall problems with obtaining spare parts. Further analysis of spare part delivery time indicators (see note below) may help identify possible causes of the problems.

The **accessibility of spare parts** is reported to be one of the major constraints to O&M performance at the plants. Problems reported by WAJ plant managers in obtaining the required spare parts include:

- Parts not available in local market.
- Procedures for obtaining spare parts from outside of Jordan are difficult and time consuming.
- Problems are sometimes reported in supplying centrally managed spares to the sites.
- Plant manager spending limits (200 JD max) slow down the procurement process. In some cases it is easier to hire a private contractor to perform the repair work because in this case the contractor is then responsible for obtaining the spare part even if it is from the local market.
- Certain specialty equipment (for example the LMI chemical feed pumps) are considered to be items which can be used in the manufacture of chemical weapons and as such the importation of associated spare parts requires a special waiver from the Customs Department. WAJ reports that importation of these types of spare parts is exceedingly difficult and not practical.

- Relatively few spare parts have been used for the age of the facilities. For example, air compressor air inlet cartridge filters should be replaced at least annually but new filters don't seem to have been purchased. This suggests that maintenance is not being carried out to the required extent.

- The delivery time for new spare parts, especially if procured from foreign sources, is reported to be a lengthy and often a complicated process. The effectiveness of the materials supply chain to the stores, including the ordering procedure, needs improvement.

3.3.2 Lack of Financial Management Information Systems

Financial records are kept at the central level, are not easily found, and the plant managers do not have copies. The only way to retrieve historic maintenance cost information it seems is by a detailed examination of all works carried out. Record keeping methods have no means of classifying the work undertaken into capital, operation, and maintenance.

3.3.3 Inadequate Maintenance Budget

Plant annual maintenance budgets are financed through transfer payments from higher-level government departments. Except for Wadi Sir, plant managers do not know what their financial allocations are at the start of the year and do not have separate budget lines for O&M.

3.3.4 Unknown Asset Base

There are no inventories of assets, which are under the control of the plant managers. Consequently, condition surveys are not carried out, and O&M work plans are not based on an assessment of needs.

3.3.5 Lack of a Planning Process

The above problems make it very difficult, if not impossible, to develop effective strategic and short-term plans for O&M. Failure-based maintenance is used with little scope for preventive or even routine maintenance to be effective. Strategic planning for O&M is necessary to ensure that the optimum value is obtained from the infrastructure assets.

3.4 General Recommendations

3.4.1 Improve WAJ Senior Management Support for O&M

WAJ plant managers need to obtain full support from WAJ senior management in order to carry out an effective maintenance program. A good way to start is by establishing a written maintenance plan and obtaining upper management approval. Such a management-supported program is very important because it allows necessary activities to be scheduled with the same priority as other management actions. Approaching O&M by equating it with better reliability for water quality, increased productivity, energy efficiency, safety, and customer satisfaction is one way to gain management attention and support.

3.4.2 Implement Basic O&M Management Systems at the Plants

Three missing O&M management systems, which are most needed, are 1) maintenance management system, 2) financial management system, and 3) operations management system. These key management systems allow the O&M staff to have a plan of activities on a routine basis.

The most important aspect to the O&M of any facility is equipment reliability. A maintenance management system establishes a schedule for activities such as routine inspection and lubrication of mechanical components, periodically rotating equipment from the lead to the standby status to equalize wear and provide time to perform more significant maintenance activities, and keep plant staff familiar with operational activities associated with changes in operating various pieces of equipment.

Keeping track of how money is expended, whether for chemicals, maintenance supplies and materials or other operating expenses provides the managers with a means for estimating future budget requirements, identifying equipment with unusually high maintenance costs which may be candidates for replacement, and a comparison from year to year whether efficient use of consumables is being monitored and achieved.

Operations management plans establish a basic approach to an operating strategy and identify target values for key process parameters. This helps operators and managers maintain a consistent O&M treatment scheme in daily monitoring of the process, and also provides valuable insights when the plant performance does not meet expectations.

Combined, these three management systems represent important tools available to facilities to improve performance consistency, better plan for future needs, particularly budget requirements, and ensure the full value of the investment in the treatment works is achieved and realized by the communities they serve.

3.4.3 Implement Basic O&M Status Reports

It is recommended that WAJ work on standardizing certain O&M functions in such a way that they can be easily monitored and measured. For example, following a standard method at each plant for recording when equipment goes out of service and tracking the steps of obtaining parts and completing repairs is helpful. Later when preparing O&M status reports, the critical information concerning a process or operation can be compared with a base period. For example, compare the amount of money spent on spare parts for different fiscal years and at different plants. Or, compare monthly chemical use against the same month for the prior year, or against the same month in a particular base year. The point of such comparisons in O&M status reports is not to assign blame for poor maintenance and inefficient systems, but rather to motivate efficiency improvement through improved maintenance.

APPENDIX A

O&M Task Scope of Work

Jordan Watershed/Water Quality Management Program

Contract Number: HRN-I-00-99-00011-00

Task Order: 805

Task 3: Treatment Plants Operation & Maintenance

Work plan

Prepared by CDM Environmental Health Project

July 2003

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1 - Background

This Task constitutes a follow-on to the O&M training work conducted in phase one of the program. The first phase implemented classroom and hands-on Arabic/English training for 21 old and new operators and engineers at three WTPs (Qairawan, Deek and Qantara). The training included classroom presentations/workshops on basic water treatment processes; in particular those processes which are used in the three treatment plants (Filtration, UV irradiation and chlorination). Hands-on training followed the classroom training on the same subjects, and using the equipment discussed in the classroom training.

After the training sessions, it was concluded that there was great confidence that the information imparted during the training will be well utilized. However, one major problem surfaced: equipment suffers from a lack of preventive maintenance due to prior years' inadequate attention. Further work is needed at the facilities to safeguard the significant investments that USAID and GOJ have made. Also noted were several institutional obstacles in staffing, procurement, and other areas that serve to hinder smooth O&M at WAJ facilities. There is a need to define the O&M problems in the institution as a whole and implement changes to prevent existing equipment deterioration and to protect future investments.

2 - Objectives

The objectives of Task 3 are:

- Train the operators to conduct textbook repairs on the filters with hands-on instruction and in reference to the O&M manuals.
- Develop a Preventative Maintenance Schedule with O&M staff at WAJ's Qairawan, Qantara and Deek facilities.
- Provide an O&M needs assessment for six WAJ facilities (Qairawan, Qantara, Deek, Wadi Sir, Kafrein and Salt) to USAID that sets the stage for implementing improved O&M throughout the institution.

3 - Approach

Pre-Start Coordination: Task 3 deals with six operating water treatment plants. It's critical that these plants continue operating without interruptions that would impact the normal water supply of the areas served by those plants. The following Engineers of WAJ will be contacted for coordination to make sure all are informed of the schedules and activities and areprepared for this task:

- Khaled Al-Kodah: WAJ counter part for the Task 3. Assistant Secretary General for Water Projects.
- Ali Bani Mustafa: WAJ-Jerash, manger of Qairawan and Deek WTP

- Muhammad Al-Muhaisen: WAJ-Ajlun, manger of Qantara WTP.
- Ryad Muhsen: WAJ-South Shuneh, manger of Kafrein WTP.
- Jamal Al-Johari: WAJ-Salt, manager of Salt WTP.
- Sa'ad Abu Hamour: LEMA, Responsible for Wadi Sir WTP.

Site Visits and Interviews with Operations Staff: Before any physical evaluation of water treatment facility equipment is undertaken or equipment vendors are brought on-site, the responsible WAJ operation and maintenance staff will be interviewed to gain insight on facility(s) operability, reliability, and performance. The WAJ O&M staff works with this equipment day-in and day-out so their knowledge of the equipment, controls, and support systems is invaluable. CDM/EHP will interview appropriate staff and, where available, review historical operating and maintenance records.

Physical Assessments: After the completion of staff interviews the six WAJ water treatment facilities (Qairawan, Qantara, Deek, Wadi Sir, Kafrein and Salt) will be inspected to:

- Become familiar with existing operations, deficiencies, and problems
- Establish existing equipment condition
- Estimate the capacity of the existing facilities
- Identify preliminary mechanical, electrical, and instrumentation upgrades necessary to improve station reliability (Qairawan, Qantara, and Deek facilities only)
- Document any health and safety concerns

Operation & Maintenance personnel from CDM/EHP will complete this inspection of the water treatment facilities. Based on previous site visits, additional specialist personnel are not considered necessary for completing this task and therefore have not been included in the task budget.

4 - Work Plan

Subtask 1- Training on Filter Repairs:

This subtask will deal with three typical Package Filters installed at three water treatment plants (Qairawan, Qantara and Deek). The manufacturer, Smith & Lovless (S&L), will be contracted to provide an engineer or technical specialist in filter repair. The contract with S&L will include development of a repair training plan for the operators and a schedule for each of the three sites. All equipment that was provided with the S&L filters will be addressed, including the backwashable depth filters, air compressors, the pneumatic system, pneumatic valves, control panels, and all other items that are part of the "Filter Package". The work will be conducted over two trips:

Trip 1: In Trip 1 the S&L engineer will conduct inspection of each component of the filter packages. If a repair need was identified and the required spare part was available in WAJ stores, then the repair will be done by the operators and/or the maintenance supervisors under the S&L engineer's supervision and directions. A 5-day trip is anticipated. If the spare part is not available in the stores, it will be added to a list of procurement needs for delivery and installation during the second S&L trip.

Trip2: After purchase and delivery of the required spare parts identified in Trip 1, the S&L engineer will perform a second trip to supervise the operators and/or the maintenance supervisors to complete the outstanding corrective maintenance that was identified in Trip 1. A 10-day trip is anticipated.

The work on Subtask 1 will be organized as follows:

1. Contact S&L to coordinate and agree on dates for implementation of Trips 1 and 2.
2. Coordinate with WAJ on dates of implementation.
3. Develop S&L's draft subcontract and forward for review.
4. Finalize andsign S&L's subcontract.
5. Conduct Trip 1 and inspect the equipment.
6. Produce list of required repairs.
7. Produce lists of needed spare parts
8. Check WAJ stores to determine which needed spare parts are available.
9. For available spare parts, conduct training on repairs by instruction and inspection of the repair work completed by the O&M staff.
10. Develop list of spare parts to be purchased for Trip 2.
11. Solicit quotation for the spare parts to be purchased.
12. Order and ship spare parts.
13. Coordinate customs clearance for imported spare parts.
14. Coordinate with S&L engineer for Trip 2.
15. Conduct trip 2
16. Conduct training on repairs using the imported spare parts by instructing the O&M staff performing the work, and inspecting the completed repairs.
17. Interface with the O&M specialist working on Subtask 3 for input for those activities.
18. Produce a report on work performed in Subtask 1.

Subtask 2- Develop Preventive Maintenance Schedule:

This subtask is designed for the three WTPs in Qairawan, Qantara and Deek. The plants are similar except for some differences in the site layouts. The treatment steps in all three plants include UV irradiation, filtration and post chlorination. Each plant has a library of manufacturers' O&M manuals in addition to manuals developed by the construction contractor. It's estimated that the manuals have more than 15,000 pages of information regarding the various parts of the equipment, including the manufacturers' recommendations for preventive maintenance (PM). The need for implementing a PM schedule was evident during the training work in Phase 1 of this program. Many equipment units were not serviced for up to three years, although the instructions for periodic maintenance for all equipment were available in the manuals. The activities in this subtask will be to develop a PM schedule by extracting all PM instructions from the manuals and establishing a schedule in Excel format for the PM work

needed for any period of time. This schedule would also help in planning for procurement of spare parts in advance of needs.

The activities in Subtask 2 will be organized as follows:

1. Contact the O&M specialist coordinate the work and agree on schedules.
2. Interview the plant managers and operates to solicit input, points of concern, and to discuss the project goals, approach, roles, etc. Review their existing maintenance programs.
3. Obtain input on specific maintenance needs related to the filters from the S&L engineer.
4. Review equipment lists developed by WAJ. Develop a list of equipment in each plant (beginning framework for PM program). Develop and assign equipment identification numbers to each equipment item.
5. Collect equipment specific design data from equipment data plates and manufacturer's manuals. Working with facility O&M staff, determine WAJ local maintenance capabilities for maintenance of each piece of equipment, and for maintenance capabilities where work is performed by a central maintenance group and/or outside contractors.
6. Extract available PM instructions from existing equipment manuals.
7. Contact equipment vendors/manufacturers for additional PM information, service manuals, etc, as needed.
8. Develop PM tasks and schedule (elapsed running time and calendar based requirements). Develop Preventive Maintenance (PM) schedules in cooperation with plant staff.
9. Review and finalize the PM program, provide final PM program to plant managers and maintenance supervisors.
10. Train plant managers and maintenance supervisors on the PM program components.
11. Produce a report on work performed in Subtask 2.

Subtask 3 - O&M Needs Assessment

This subtask - is designed to conduct an institutional O&M needs assessment for WAJ's six water treatment plants at Qairawan, Qantara, Deek, Wadi Sir, Kafrein and Salt, especially taking into consideration the evolving Jordan water sector and MWI's privatization efforts.

This subtask will be accomplished through the performance of an O&M audit. The O&M audit is a tool to help bring about water utility performance improvement and is based on the concept of *monitoring the performance of operation and maintenance and using the results to improve the situation.*

An added benefit from the O&M audit is that it provides the prerequisite information needed to prepare <u>action plans</u> to improve both the function and structure of the management processes for O&M. These action plans are not required deliverables under this Task Order but will form recommended follow-on work tasks that the WAJ may decide to implement later. An O&M audit sets the stage for further institutional development of a utility.

The work on Subtask 1 will be organized as follows:

1. Contact the O&M specialist to coordinate the work and agree on the schedules.
2. Contact the plants' managers and agree on the schedules.
3. Conduct site visits and interview the plant managers and maintenance supervisors.
4. Produce objective overview on the WAJ O&M practice and organization.
5. Establish the status and effectiveness of the O&M service now being provided by the WAJ.
6. Identify where system deficiencies and management limitations exist.
7. Provide a snapshot of existing performance and limitations which can be used for comparative purposes when re-measuring WAJ utility performance at some later date.
8. Produce a final report assessing the current O&M practices and needs at the six facilities.

5 - Deliverables

1. The Diagnostic trip by S&L will produce two lists: a) list of required corrective maintenance tasks and b) list of required spare parts.
2. Filter Repair Plan and Filter O&M Training Plan: Five English language copies of the filter repair plan and five copies of the training plan will be prepared.
3. Repairs of the WTP Filters [up to budget estimate of $8,000/plant for spare parts]: Necessary repairs identified in Subtask 1 will be conducted by the plant operators and maintenance supervisors with instruction and supervision by the S&L engineer and inspection of the work. Training records of WAJ local and central O&M staff participation with these filter repair activities will be kept and delivered at the end of the training program (employee name, job position, and number of contact hours). A report of the work performed will be prepared.
4. Preventive Maintenance Schedule(s) for each of the three Water Treatment Facilities, Qairawan, Deek and Qantara. Two copies of the English and Arabic versions of the final electronic (Microsoft Excel format) PM schedule will be delivered. Five hard copies of each final PM schedule in English and Arabic will also be delivered. A report of the work performed will be prepared.
5. Water Treatment Facility(s) O&M Audit Report covering Qairawan, Qantara, Deek, Wadi Sir, Kafrein and Salt facilities. Five copies of a draft O&M audit report and ten copies of a final report will be prepared.

6 - Assumptions

The assumptions made in estimating the filter repairs were based on inspection and discussions that occurred during Phase I and are as follows:

1. O&M manuals: a complete set of the O&M manuals now exists at each WTP site, a second complete set for each plant also exists at each plant manager's offices. The original sets

provided by S&L/Morganti were found in the WAJ stores. We anticipate no need to purchase additional O&M manuals.

2. Spare parts: Some of the original spare parts provided by S&L/Morganti that will likely be needed in the filter repairs were found in the WAJ stores. We have reserved an estimate of $8,000/site (total $24,000) for additional parts.
3. Fibrotex Elements: At the time of Phase 1 training, WAJ was in the process of procuring new filter elements for all sites as part of routine maintenance. WAJ has contacted S&L, or are in the process of contacting S&L, to procure the elements, and these are not included in this project budget. It's assumed that all plants with S&L filters have now had their filter elements replaced with new ones purchased by WAJ.
4. WAJ procured (or will procure before this task starts) minor tools for Qairawan, Qantara and Deek sites – this apparently minor task, requiring several internal approvals, is in fact a significant indication of the WAJ's determination to implement future major institutional changes. [Estimate $200/WTP]
5. WAJ procured (or will procure before the task starts) one portable turbidimeter and standards to provide capability to test turbidity of the filtrate of each filter element on site. [Estimate $1,000].
6. Eng. Ali Bani Mustafa with help from his operators and maintenance supervisors has created maintenance log-sheets for each single piece of equipment.
7. The PM schedule jointly developed by the project and WAJ plant managers will be adhered to

TASK 3: OPERATION AND MANITENACE SCHEDULE

		W18	W19	W20	W21	W22	W23	W24	W25	W26	W27	W28	W29	W30	W31	W32	W33	W34	W35	W36	W37	W38	W39	W40	W41	W42	W43	W44
	SuubTasks	11-Sep-03	18-Sep-03	25-Sep-03	02-Oct-03	09-Oct-03	16-Oct-03	23-Oct-03	30-Oct-03	06-Nov-03	13-Nov-03	20-Nov-03	27-Nov-03	04-Dec-03	11-Dec-03	18-Dec-03	25-Dec-03	01-Jan-04	08-Jan-04	15-Jan-04	22-Jan-04	29-Jan-04	05-Feb-04	12-Feb-04	19-Feb-04	26-Feb-04	04-Mar-04	11-Mar-04
1	Training on Filters Repairs																											
	Develop/ Finalize / sign S&L's subcontract.																											
	Conduct Trip 1																											
	Order/ship/custom clear spare parts																											
	Conduct Trip 2																											
2	Develop Preventive Maintenance Schedule																											
	Site visits / Interviews / Data Collection																											
	Extract PM instructions from manuals																											
	Develop PM tasks and schedule																											
	Training on PM tasks and schedule																											
	Produce Technical Memo																											
3	O&M Needs Assessment																											
	Site visits / Interviews / Data Collection																											
	Produce objective overview on the WAJ O&M practice and organization.																											
	Establish the status and effectiveness of the O&M service																											
	Identify O&M system deficiencies																											
	Produce Technical Memo																											

APPENDIX B

Guidelines for Establishing a Maintenance Program at WAJ Water Plants

1 Introduction
2 Maintenance Program Features
3 Types of Maintenance
4 Maintenance Program Goals
5 Basic Tools and Equipment
6 Spare Parts

APPENDIX B
Guidelines for Establishing a Maintenance Program at WAJ Water Plants

1. Introduction

WAJ should develop a sound maintenance program to ensure the reliability of each of the six water treatment plants which were a part of this study. A well-planned and scheduled system of maintenance will reduce breakdowns, extend equipment life, and provide for efficient use of manpower. A sound maintenance management system will also provide WAJ with important information for predicting future maintenance needs and preparing needed maintenance budgets.

Because WAJ does not currently have a formal maintenance program in place for the water plants, one objective of this report is to provide WAJ with guidelines upon which a sound maintenance program can be constructed. While developing a detailed maintenance program document is beyond the scope of the subject O&M audit, this appendix section does provide basic guidance for developing a sound maintenance program including:

- A listing of the basic features of a sound maintenance program
- An introduction to the basic types of maintenance as they relate to the WAJ water treatment plants.
- A listing of goals for the maintenance program.
- A preliminary listing of basic tools and equipment
- A preliminary listing of recommended spare parts.

Each of these items is discussed in more detail below.

2. Maintenance Program Features

CDM recommends that the WAJ water plant maintenance program should be kept as simple and logical as possible. It should not be rigid but continually open for review, updating, and improvement, based on past operating experience. A sound program need not be elaborate to effect reliable facility operations, reductions in downtime and expensive and untimely repairs and replacements. The basic features of a sound maintenance program should include the following:

An Overall O&M Manual

A key element of any maintenance program is the creation of a system Operation and Maintenance (O&M) manual. The "O" part of an O&M manual should provide an overview of the system components, describe the purpose of the system and how the

system is intended to operate, discuss the regulatory impacts and consequences of poor system performance and equipment failure, provide an organization chart showing the relative placement of and roles served by key organizations associated with the system (i.e., WAJ plant staff, and Governorate assistant Secretary General staff, WAJ central senior managers, etc), describe a set of Standard Operating Procedures (SOPs) to be followed by both operations and maintenance staff, and list emergency contact information for key WAJ and local governorate staff as well as fire and police. The "M" part of an O&M manual should include a listing of system start-up and shutdown procedures, normal preventative maintenance tasks, an overview of basic safety procedures, and contact information for key equipment suppliers and outside contractors employed by WAJ to help maintain the system. This portion of the manual is not intended to instruct maintenance personnel on how to execute equipment specific preventative maintenance tasks – this information is provided in the manufacturer specific O&M manuals.

The O&M manual should be updated annually. It is important to note that operations staff should be familiar with the maintenance needs of the system and should thus review the "M" portion of the manual. Conversely, maintenance staff must understand the purpose of the system and the consequences of poor system performance and equipment failure. Thus, maintenance staff should also review the "O" portion of the manual. This manual can also serve as an orientation and training tool for new staff

Record Keeping

A system of record keeping to provide quick access to necessary equipment data information, manufacturer's operation and maintenance (O&M) manuals, previous repairs and costs, and system performance data should be developed to assist WAJ plant staff with maintaining the treatment facilities.

Equipment data and manufacturer's O&M manuals were submitted to WAJ by the general contractor near the end of construction. This information needs to be stored in an orderly manner and in a location easily accessible to plant staff. WAJ managers will also need to keep this information up to date as equipment is replaced, changed, or added.

WAJ should also develop a system for tracking previous repairs and costs as a maintenance management system is not currently in place at the plants. Ideally, this system would be computerized using an equipment inventory database. But more simplified paper based records could also be employed.

Preventative Maintenance

A preventative maintenance program is essential for maximizing equipment life and minimizing equipment downtime. Much of the equipment at the plants is continuously operating and the system will be essentially never offline for very long.

As a result, WAJ staff will have minimal opportunities to conduct preventative maintenance without incurring some system downtime. As noted above, the overall O&M manual should describe the preventative maintenance plan and the manufacturer's O&M manuals consulted for equipment specific instructions on executing the maintenance. Appendix - __ provides a liting of recommended preventive maintenance tasks and system checks associated with the four water plants in _____.

Lubrication Program

A detailed lubrication program is essential for maximizing equipment life and minimizing equipment maintenance. While this is part of a preventative maintenance program, it is listing separately to emphasize its importance.

Proper Planning and Scheduling

Proper planning and scheduling of lubrication, preventive, and corrective maintenance work, and personnel is important to ensure that equipment is being maintained efficiently and in a timely manner.

Storage and Inventory System

An adequate, well-coordinated storage and inventory system for spare parts, tools, and supplies should be developed and updated regularly. Ideally this would involved a computer based system but simple paper based systems can also be employed.

Training

An on-going training program for maintenance personnel should be conducted. At a minimum, the training program should include a review of the O&M manual, a review of health and safety procedures, a review of the system SOPs and emergency response procedures, and training on the operation and maintenance of any new equipment introduced into the system.

3. Types of Maintenance

Effective maintenance is a prerequisite to proper water treatment plant performance. For purposes of this report for WAJ, maintenance activities have been divided into four categories: detective maintenance, preventative maintenance, corrective maintenance, and major repair maintenance. A brief discussion of some considerations for each type of maintenance and how they relate to the WAJ water plants are follows.

Detective Maintenance

Tasks designed to check whether something still works are known as "Detective Maintenance". These tasks are sometimes also sometimes called "functional checks" or "failure finding". Detective maintenance or failure finding applies only to hidden

or unrevealed failures and must be proactively checked since the function may not be routinely employed under normal system operating conditions. For example, the high-high discharge pressure switch for the air compressor will only be activated under high pressure situations, which should normally not occur – thus, WAJ maintenance staff will not have any day-to-day or even seasonal feedback indicating whether these pressure switches still function properly. To verify that the pressure switches are still operating correctly, they must be manually tripped or an high discharge pressure condition manually initiated. Similar situations exist for the chlorine leak detectors, turbidity alarms, filter differential pressure, and other equipment. Instrument calibration for the turbidity and pH meters would also fall under this category.

Preventative Maintenance

Preventive maintenance is generally conducted routinely and can generally be performed while the water treatment system is in operation. It is generally carried out more frequently than corrective maintenance. This includes the routine inspection of equipment, lubrication, and minor equipment adjustments, replacement of chlorine residual monitor reagents, etc.

Corrective Maintenance

Corrective maintenance is the service performed while the water treatment system is in operation or with a minimum of equipment downtime. For example, this would include most preventative maintenance activities such as _____oil changes, PLC troubleshooting, turbidity analyzer and chlorine residual analyzer parts replacement and repairs, valve actuator replacements/repairs, etc.

Major Repair Maintenance

Major repair maintenance or alterations are infrequent conducted and generally occur when a unit or the entire system is out-of-service. They are normally performed by trained maintenance personnel or are contracted out. This type of maintenance usually involves large expenditures of money and would normally be scheduled (if possible) during the _____ months when the _____. Examples of major maintenance would include Fibrotex filter replacement, replacement of the large valves, overhauling of the _____, etc.

4. Maintenance Program Goals

Goals for the maintenance program should include:

- Increase the reliability of equipment.
- Minimize interruptions of various systems and reduce downtime.
- Control maintenance costs.

- Increase productivity of employees and better utilize the available work force by scheduling the work assignments of the maintenance staff.
- Improve plant safety.
- Avoid excessive maintenance.
- Keep accurate records to establish equipment breakdown frequencies.
- Establish cost records so that excessive costs can be highlighted and decisions to repair or replace equipment can be based on solid facts.
- Provide for better conservation of assets by eliminating premature equipment replacement.
- Minimize large-scale repairs.
- Increase water plant facility performance through better overall equipment condition and reliability.
- Control the availability of spare parts and replacement parts.
- Assure that proper tools and equipment are available when maintenance work is assigned.

5. Basic Tools and Equipment

It is recommended that the following basic tools and equipment be available to support the operation and maintenance of each water plant:

1. Safety Equipment including confined space entry special equipment and systems (used for chlorine leak response).
2. Portable ventilation fans and duct
3. Gas sampling equipment for confined space entry
4. First aid supplies
5. Safety shoes
6. Foul weather clothing
7. Chemical handling protective clothing and equipment
8. Hard hats

9. Gloves

10. Hoses

11. Grounds maintenance equipment

12. Various mechanics hand tools

13. Lubrication equipment

14. Various plumber's tools

15. Amp meter

16. Pressure gauges

17. Portable sump pump

18. Small portable generator, and

19. Various power hand tools

19. Fire extinguishers for conventional and electrical fires

It is likely that WAJ already has much of the above equipment listed above, but some equipment may need to be purchased to complete the list.

6. Spare Parts

Spare parts are the extra items the equipment manufacturer or maintenance specialist predicts will be needed to correct potential malfunctions in equipment, analyzers, and instrumentation and controls. They generally consist of parts that are vulnerable to breakage and short life expectancy, parts that usually have a long delivery time or are difficult to obtain, or parts that are critical to system operability. The decision to stock these parts should be based on a particular part's importance to the water treatment process, cost, and delivery time.

Listed below is an initial list of spare parts that CDM recommends being kept on hand to minimize equipment downtime and increase the reliability of facility equipment. This list is preliminary and should be reevaluated each year.

1. UV lamps

2. UV intensity detector

3. air compressor air inlet filters

4. Air compressor oil filters

5. Air compressor solenoid valves

6.

7. pH sensor

8. Float switches – one for each type used (discuss further with supplier and CRAA – may not be needed)

9. Level switch

10. Pressure switch

11. Flow switch (may be supplied under construction contract – CDM to verify)

12. Ultrasonic level transducer

13. Various control components for Local Control Panels (lamps, relays, transformers, fuses)

14. Miscellaneous Fuses (various sizes)

15. Lubricants

16. Valve actuator for filter valves

17. MCC

    - Replacement cover bolts, cage nuts, and door fasteners
    - Replacement fuses
    - Replacement lamps and lens caps
    - Replacement starter coil (each size)
    - Overload heaters for each size used
    - Overload relay for each size used
    - Motor circuit protector for each size used
    - Circuit breaker rating plug for each size used

18. Soft Starters

- Complete manufacturer's spare parts kit
- Fuse

APPENDIX C

O&M Audit Kick-off Meeting Materials

Flipchart No.1

WHAT ARE SOME OF THE CONSTRAINTS EFFECTING THE O&M ACTIVITIES IN YOUR WTP?

The information listed below was supplied by WAJ O&M Managers who attended the O&M Audit Kickoff meeting.

General constraints to good O&M at water plants:

- Poor raw water quality (especially during wet weather events).
- Lack of simple pretreatment.
- Lack of spare parts in the WTP and the possibility of getting those at short notice .
- Efficiency of the operational staff and its capability in dealing with minor problems.
- Lack of trained staff with suitable background.
- Scheduled continuous maintenance program.
- Unavailability of specialized central staff for maintenance.
- Lack of incentives.
- Difficult long procedures to get spare parts.
- Prohibiting private maintenance contracts.

WTP specific constraints:

<u>Al-Kafrein WTP</u>

- Frequent power outages for unknown reasons (without notice).
- Unavailability of specialized Technicians .
- Limited transportation access/ long distance between well &TP.
- Unavailability of guards at the well site/vandalism.
- Unavailability of spare parts in the local market.

<u>Wadi Sir</u>

- The WTP not functioning during winter season because of high turbidity.
- Increase pollution concentration in the water source.
- Unavailability of computer software for operation.

<u>Salt WTP</u>

- Unavailability of specialized maintenance staff.
- Difficult long procedures to get spare parts.
- Limited ceiling of direct expenses amount.
- Training.

Flipchart No.2

WHAT ARE THE MOST CRITICAL CONSTRAINTS TO OPERATION AND MAINTENANCE AT WATER TREATMENT PLANTS?

The information listed below was supplied by WAJ O&M Managers who attended the O&M Audit Kickoff meeting. The items were selected from Flipchart No.1 and are those items identified by WAJ O&M Managers to be priority constraints limiting O&M performance at water plants.

- **Lack of central staff specialist in maintenance.**
- **Lack of qualified operators.**
- **Lack of transportation means dedicated for the WTPs**
- **Lack of spare parts in the local market / central stores**
- **The length of the required time to get the spare parts**
- **Lack of activated operation programs**
- **Lack of recurrent training**
- **Lack of incentives**

Flipchart No.3

WHAT ARE THE AVAILABLE RECORDS AND REPORTS WHICH CAN BE PROVIDED BY WAJ AND USED IN MONITORING O&M PERFORMANCE?

The information listed below was supplied by WAJ O&M Managers who attended the O&M Audit Kickoff meeting. .

- **The quantity of influent and effluent water from the station**
- **Data of the water quality / daily (influent/effluent)**
- **The amount of chemicals consumed daily**
- **Daily breakdown report**
- **Operation report**
- **Water and electricity consumption**
- **Job orders**
- **Costing reports which include maintenance + employee+ spare parts**

Flipchart No.4

IF YOU WERE ASKED TO PREPARE A SUMMARY REPORT ABOUT THE STATUS OF O&M AT ONE W.T.P., WHAT INFORMATION WOULD YOU INCLUDE IN YOUR REPORT?

The information listed below was supplied by WAJ O&M Managers who attended the O&M Audit Kickoff meeting.

- **Electrical and mechanical breakdowns number - causes & what has been done.**
- **Times of power outage / monthly report**
- **Unit cost of treated water**
- **Employee attendance**
- **Maintenance expenses**
- **Time needs to finalize tasks**
- **Injury and accident reports**
- **Recommendations**

Flipchart No.5

WHAT ARE SOME 'INDICATORS' OF O&M STATUS THAT YOU THINK CAN ME MONITORED AT WATER PLANTS?

The information listed below was supplied by WAJ O&M Managers who attended the O&M Audit Kickoff meeting.

- **Number of power outages per month**
- **Amount of water produced**
- **Amount of Chemical per cubic meter**
- **Time required for maintenance**
- **Tools availability for maintenance**
- **Time needed to deliver spare parts**
- **Response time from the Central Workshop**
- **Time of response to hire an employee**
- **Number of non- operating days (operation and maintenance)**
- **Availability of computers to prepare maintenance and operating programs**

APPENDIX D

Trip Report -Smith & Loveless, Inc. – October 30, 2003 Trip

Smith &
Loveless, Inc.

14040 Santa Fe Trail Drive
Lenexa, KS 66215-1284, USA
Phone: (913) 888-5201
Fax: (913) 888-2173

Inter-Corporation Memorandum Date: May 24, 2004

To: Dan Fisher, Mehran Meserlain – CDM

Cc: Lanette Wickham, Stuart Marschall

From: Rick Pistorius

Subject: Trip Report

This memo will summarize my trip to visit Fibrotex® sites in Jordan the first week of May 2004. The trip was to continue work started in October to train operators and supervisors in operation and maintenance of the Fibrotex® systems.

The trip was originally scheduled to visit only the three sites visited last year that are under the direction of the Water Authority of Jordan (WAJ); Qairawan, Deek, and Quantara. However, following the success of last year's visit, the management firm for the Wadi Sir site requested a day during this trip for training at that location.

In general the sites were kept very clean and orderly. They are being used continuously for the production of drinking water for the communities they serve. As they were during my last visit, the operators and engineers were very interested in learning and were very helpful in carrying out various maintenance items.

The details of the visit to each site will be given below. However, there are a couple of general areas that need to be addressed at all the WAJ sites: Those are the Fibrotex® drive system and the air compressor system. For the Fibrotex® system, filtration efficiency if dependent on a normal backwash and a normal element packing following backwash. The air motor lubricators need to be provided with the proper lubricant, and the lift screws need routine lubrication with grease. Additionally, there needs to be operator attention during the backwash, on a routine basis to ensure that the action of the backwash is normal, and that the final packing is correct. Some periodic adjustments to the air control valve may be needed. Failure to provide the correct lubrication and adjustments will cause the Fibrotex® filter to not perform as it should.

The second major concern is the air compressors. These compressors are a flooded oil screw type, where the oil type and condition is critical to the life of the compressor. The manufacturer has strict guidelines on the type of lubricant and filters to use, as well as the replacement interval for these. These guidelines are not being followed, and the life of the compressors will most likely be reduced.

Wadi Sir Plant, May 2

This plant consists of 4 parallel AX-200 Fibrotex® filters. The plant typically operates at 350 m^3/hr. Each AX-200 is programmed to run at 100 m^3/hr, so the plant requirements are met with all 4 units running. Manual valves are partially closed in the feed to two of the units to get 75 m^3/hr from two units, and the designed flow of 100 m^3/hr from the others. A significant operational upgrade would be to provide an adjustable input to the PLC for automatic control of the flow at rates less than the design of 100 m^3/hr from each AX-200.

Raw water turbidity was at 0.426 NTU, with the filtrate at 0.164 NTU at a total water flow of 354 m^3/hr. The backwash water was chlorinated to .5 to 1.0 ppm prior to the Fibrotex®.

The Fibrotex® shaft heights were fairly uniform, but slightly higher than the desired 12-13cm. pack down. Some time was spent with the operators to adjust the air restrictor on each filter's lift motor to make them more uniform. The panel thumbwheel was adjusted to 7 (from 6) to bring them all down to the desired level. It was apparent that the lift screws, air motors, and lubricators had been well maintained, as the filters were all functioning well in backwash.

We had a discussion about when is the Fibrotex® filter element to be changed. The plant should be looking at the filter efficiency in the removal of turbidity, along with differential pressure, vs. time during the run. By tracking the filter performance over the

life of the filter, it will be possible to detect changes in efficiency that would signal a need to change a filter. This may be a more acceptable solution than to change the filter at 18-month intervals.

The plant had arranged for a local firm to manufacture the compressor oil separator elements, and the oil filters are from another source. The compressor oil is also being supplied locally, and is not from Quincy, the compressor manufacturer. These all appear to be functioning fine, as determined by the plant personnel.

One unit will not go into backwash automatically because of a leaking flow control valve (the system waits for flow shutoff before starting the backwash routine). The butterfly valve is possibly worn or the disc twisted on the stem. The valve bodies ordered by WAJ from S&L were still at the air port and not available for installation. If needed, additional valves can be ordered through CDM and S&L.

Deek Plant, May 3 & 4

This plant has two AX-200 Fibrotex® systems. When I arrived both systems were on line at a total flow of 154 m^3/hr. Feed turbidity was at 0.788 NTU and filtrate at 0.195 NTU on the on line turbidimeter. The operator indicated that 0.14 Chlorine was added to the backwash water.

Considerable time was spent with the air compressors. Several empty cans of automatic transmission fluid (ATF) were found near the compressors and the operator indicated this had been added to the compressor lubricant. The operator went ahead and changed the lubricant, replacing with Quincy synthetic oil, and also changed the lubricant filter, and lubricant/air separators.

The use of ATF in the compressors was discussed at length. This is not an approved fluid and I indicated that this was not acceptable practice. Following my trip I checked with Jim Everhart of Air Compressor Engineering, Inc., concerning this. His comments are that the plants should stay with the Quincy synthetic lubricant. The use of ATF would

lead to premature varnish buildup in the system and early bearing failure. Mixing fluids is probably also a worse problem. If it is desired to change to another lubricant (because of more readily available local supply), then it is recommended that a flush fluid be run through the compressor for 500 hours. The flush is available from Quincy. This flush should be used on the compressor(s) that have ATF in their systems.

It was noted that the Quincy synthetic lubricant is originally clear, but turns red quickly after use. This is a normal reaction, and is not a cause for alarm, according to Jim Everhart.

The inlet air filters ordered from Quincy were not the correct size. The ones ordered, based on information from the parts manual, were too short. Information on the control panel shows a different number (12542S0H350). The original filters were heavy duty, and the ones ordered were the standard model. It is recommended that the compressor model and serial number be added to the purchase order when ordering items from Quincy.

The wall mounted, lead/lag compressor control panel was not working, and a fuse was replaced. This control panel has been troublesome in the other plants as well. The general method of dealing with this has been to simply run the compressors on local, alternating each day which compressor is in service. This seems like a satisfactory approach.

The shaft heights in the Fibrotex® filters deviated considerably from the desired 12-13 cm height. The air restrictor valves on the bottom of each Fibrotex® were adjusted and it was explained to the operators and engineers about how this is adjusted and the need for having the shafts at the correct height. Filter performance may be adversely affected if this is not correct.

I had a discussion with Engineer Ali concerning when the filter elements need to be changed, in a similar manner to the discussion at the Wadi Sir plant (see above).

The butterfly flow control valve on filter set F122 was not shutting completely. The operators removed the valve and found the disc to be slightly eroded, allowing leakage past the disc. A valve body was taken from the spare flow control valve, and installed in the system. Flow control returned to normal with no leakage. It is recommended that in the future, the valves ordered should have stainless steel discs to increase the life. The erosion of the disc has been a problem in all the plants.

A shaft seal leak on Fibrotex® filter F121 #3 was noticed and brought to the attention of the plant. It was decided to change this seal, which requires removal of the housing, filter, and shaft. When the shaft was out, a coating of rubber was found on the shaft, at about the location of the seal. This filter was earlier found to not be operating incorrectly during backwash, with the shaft not going up and down due to an incorrectly set air restrictor valve. It is likely that as the shaft rotated during backwash it eventually deposited the rubber, and allowed the leak to develop. The plant personnel cleaned the shaft and completed the installation of a new seal, and the leak was stopped.

Qairawan Plant, May 5

Air compressor control panels have been modified by WAJ electricians and are not working well. In particular the compressors do not unload and run for the minimum 6 minutes when the desired pressure set point is obtained. As a result, the compressors generally run only short times and the oil does not reach the proper operating temperature which is so important to compressor life. Additionally, one compressor doesn't start without overloading a starter switch. A plan is in place to put these electrical panels back to the original state as soon as a needed solenoid valve is obtained.

The air lubricator for system F122 was found to be empty. The operator filled it with Quincy synthetic compressor oil. While this is probably acceptable for the air motors, it seems that the plant could have been better served if the valuable compressor oil was used for the compressor. Air motor oil should be used in the air lubricators. A type and

supply source in Amman is given in the O&M manual. Engineer Ali indicated he would order some.

The operators were instructed on the adjustment of air restrictor valves on system F121, in order to get the shafts at the desired height of 12-13 cm. In attempting to do the same to system F122, it was found that F122 #3 had a shaft stuck in the up position. The air motor was removed, and shaft greased, and the shaft moved by hand. Following reinstallation of the air motor it was found that the flow of air couldn't be adjusted properly with the air restrictor valve, and so the valve was replaced. I then noticed that the shaft was moving in a jerky manner, and that the nut at the bottom of the shaft was loose. The nut was realigned with the shaft and the setscrews tightened. Normal operation was then obtained.

Air lubricators on both systems were adjusted to show the operators how to get the desired 1-drop of oil/15 to 30 seconds.

Both compressors were low on oil. Operators and engineers were instructed on how to read the site glass. The glass should be full when the compressor is running loaded.

The water pump for the backwash water chlorinator was not working so the backwash water was not being chlorinated. It is important that the backwash water is chlorinated to 0.5 to 1.0-ppm chlorine to help keep the Fibrotex® filter clean. The chlorinator should be repaired as soon as possible.

Feed water turbidity was running at 0.26 NTU. The filtrate water turbidimeter was not working, and I believe this was also due to the pump failure in the preceding paragraph. Because of high nitrate levels at the plant, another source of water was being blended into the filtrate tank. Grab samples of this tank were taken at periodic intervals.

Quantara Plant, May 6 & 9

This plant consists of two AX-200's, with each designed for 75 m^3/hr. Raw water supply constraints limit the plant to only one of the systems running. System F122 has been running to supply the required water needs, while F121 has been down for over a year.

The air compressors were in better condition than the other two WAJ plants. The oil was changed last year according to the operators. They were using Quincy synthetic oil. The operators were manually alternating the duty compressor daily. There were no significant air leaks.

A small oil leak at the oil filter differential pressure indicator was fixed by replacing the indicator with a recently received spare. The air inlet filters were replaced. As indicated earlier, the air filters were not the correct size, but by stacking two together, they could be used.

The differential pressure indicators for the air/oil separators indicated a 'yellow' on one compressor and a 'red' on the other. These should be reading 'green', and the indication is that the separators on each compressor should be changed. This was not done during my visit, because the operators recalled the indicators were the same colors following the last change out. These should be checked again. It is important to bleed the air from the separator chamber to determine if the indicators will return to 'green'. It is also important that the separators be replaced on an annual basis.

The chlorine injector for the backwash water was not working the first day I arrived, but was replaced that evening. It is important that the backwash water for Fibrotex® be chlorinated to 0.5 to 1.0-ppm chlorine.

The air pressure regulators and air lubricators were adjusted on both Fibrotex® systems and the correct settings discussed with the operators.

The shaft heights on the Fibrotex® filters were not being maintained at the desired level of 12-13 cm. The operators and engineers were instructed on how this is accomplished. Three filters were stuck in the fully down position, which required that the lift air motor be removed and the shafts turned by hand. Unfortunately, the tool to turn the lead screw could not be found on site, and was borrowed from another location. Following removal of the motor, movement of the shaft by hand, and greasing of the lead screw, the air restricting valves were adjusted on all the Fibrotex® filters. It is important that the shaft height be checked regularly and that the shaft movement during backwash is determined to be normal. Failure to do so will result in potentially ineffective backwashes and poor filtration performance.

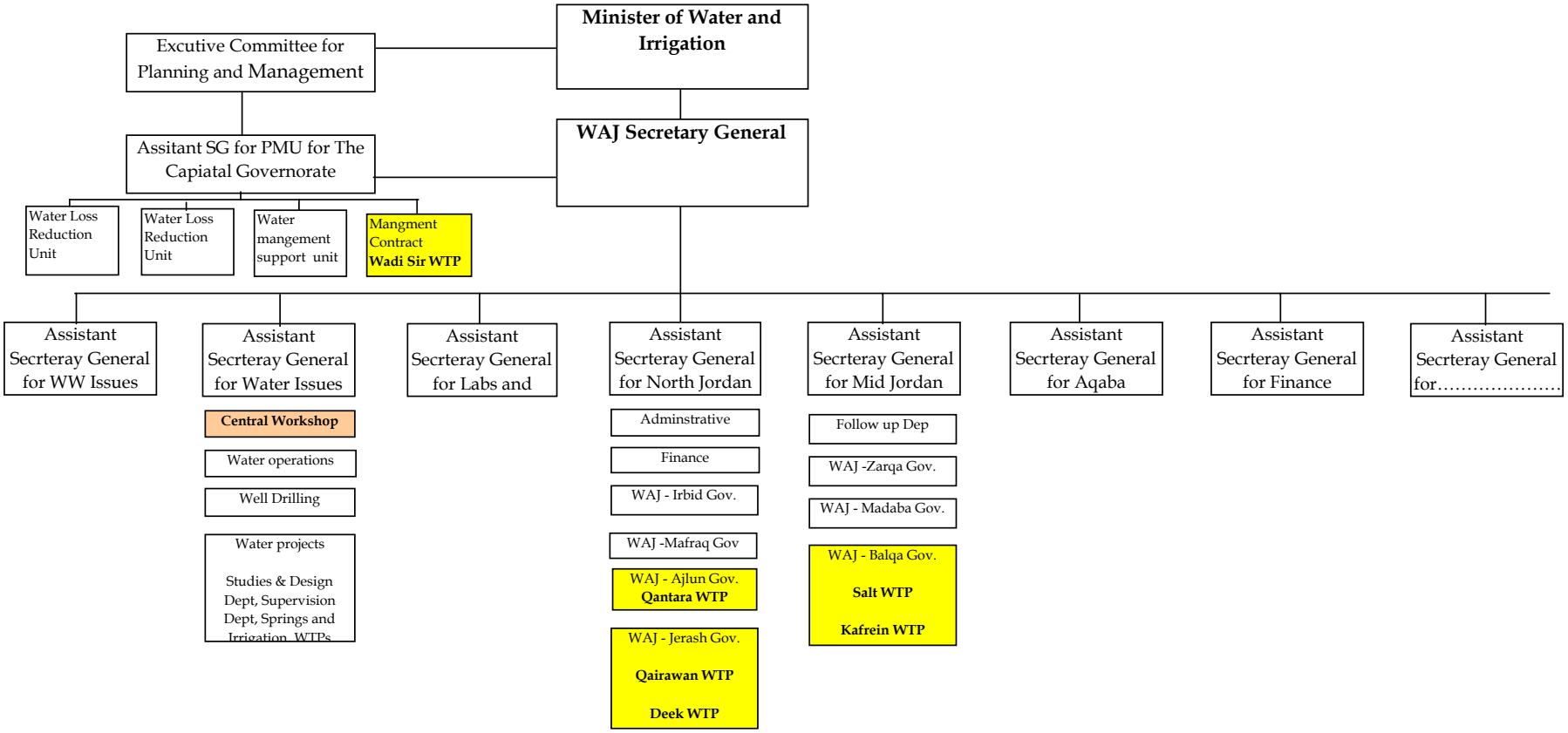
The flow control valve on system F121 had a severe air leak on the positioner. The positioner was removed and a diaphragm was found to have a hole it it. An attempt was made to replace this with one cut by hand from a sheet of rubber. This appeared to work initially, but quickly failed. Later it was learned that the Wadi Sir plant repaired a similar problem and has the material to replace the diaphragm. They will share the material with the Quantara plant.

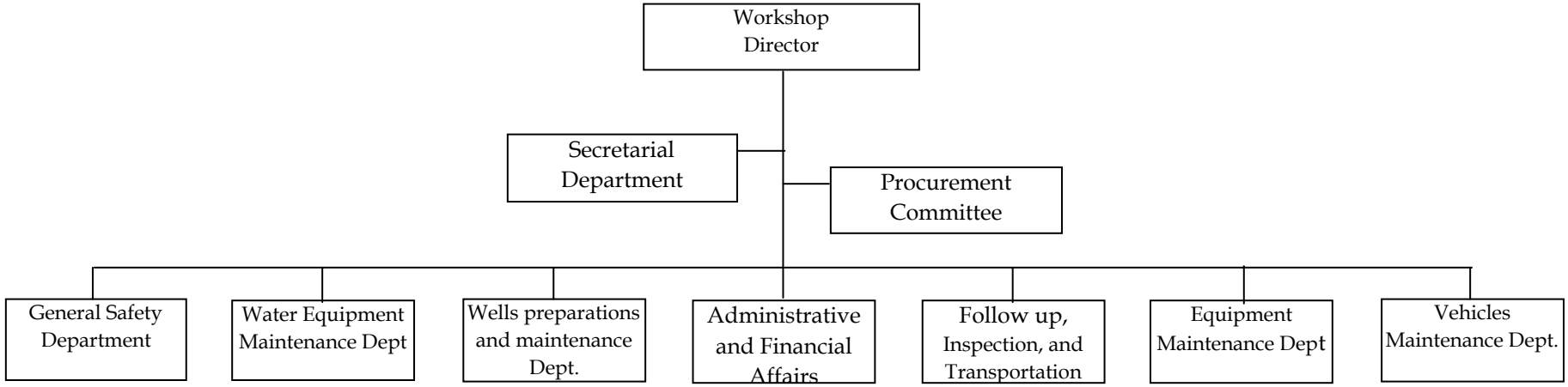
APPENDIX E

Water Plant Schematic Drawings of Process Flow

APPENDIX F

WAJ Organization Charts


Minister of Water and Irrigation
Excutive Committee for Planning and Management
WAJ Secretary General
Assitant SG for PMU for The Capiatal Governorate
Water Loss Reduction Unit
Water Loss Reduction Unit
Water mangement support unit
Mangment Contract Wadi Sir WTP
Assistant Secrteray General for WW Issues
Assistant Secrteray General for Water Issues
Central Workshop
Water operations
Well Drilling
Water projects
Studies & Design Dept, Supervision Dept, Springs and Irrigation WTPs
Assistant Secrteray General for Labs and
Assistant Secrteray General for North Jordan
Adminstrative
Finance
WAJ - Irbid Gov.
WAJ -Mafraq Gov
WAJ - Ajlun Gov. Qantara WTP
WAJ - Jerash Gov. Qairawan WTP Deek WTP
Assistant Secrteray General for Mid Jordan
Follow up Dep
WAJ -Zarqa Gov.
WAJ - Madaba Gov.
WAJ - Balqa Gov. Salt WTP Kafrein WTP
Assistant Secrteray General for Aqaba
Assistant Secrteray General for Finance
Assistant Secrteray General for……



Water Equipment Maintenance Dept

- Surface pumps Section
- Water Electrical Equipment
- Motors wiring section
- Lath section
- Chlorine section
- Generators Section
- Steel workshop and welding

Wells preparations and maintenance Dept.

- Submersible pumps maintenan
- Pumps installation groups

Administrative and Financial Affairs

- Administration Section
- Personnel Section
- Accounting Section
- Fuel Section
- Stores Section
- Services Section
- Computer Section
- Accidents & Insurance Section

Follow up, Inspection, and Transportation

- Follow up Section
- Inspection Section
- Transportation Section

Equipment Maintenance Dept

- Equipment Mechanics Section
- Car wash and grease section

Vehicles Maintenance Dept.

- Vehicles Mechanics
- Vehicles electrical
- Vehicles body shop