MINISTRY OF WATER AND IRRIGATION

Water Resource Policy Support

GROUNDWATER MANAGEMENT COMPONENT

Planning of Rapid Appraisal of Groundwater Use in the Amman-Zarqa Basin

18 April, 2000

The Water Resource Policy Support activity is supported by the
United States Agency for International Development (USAID) through a contract
with Associates in Rural Development Inc. (ARD):
USAID/ARD Contract No. LAG-I-00-99-00018-00

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PLANNING OF RAPID APPRAISAL OF GROUNDWATER USE IN AMMAN-ZARQA BASIN

1. INTRODUCTION

A key activity of the Water Resource Policy Support Task Order (TO) is the exploration of methods for curtailing groundwater use in the Amman Zarqa Basin. This includes the assessment of current groundwater use practices and ultimately the economic impact that changes in groundwater access will have on users. It will also address the impact continued overuse of groundwater will have on Jordan's economy.

As Municipal water supply has higher priority and has much higher value, it is assumed that the bulk of the reduction in groundwater use will have to come from irrigated agriculture in the uplands. One of the first activities involves a Rapid Appraisal (RA) of water users and uses in the agricultural area of Amman-Zarqa highlands. This document presents the objectives, methodology, planning, and GIS/Database of the RA.

2. RAPID APPRAISAL OBJECTIVES

The main objectives of the RA are to:

- Provide a profile of water users;
- Brief the users about origins and scarcity of groundwater resources in the area and explore options for reduction of agricultural water use in Amman Zarqa highlands;
- Collect information regarding quantity and quality of pumped water;
- Obtain information and assess on farm water use practices;
- Gather information about the economic value of different water uses;
- Obtain statistics about the social aspect of water use;
- Identify over-pumping impacts; and
- Explore ideas and suggestions from water users on the willingness to replace groundwater abstraction with recycled water.

3. SURVEY METHODOLOGY AND PLANNING

The following steps are followed in planning the RA:

- Gather existing information from the Ministry Database on irrigation production wells;
- Carry out a mini survey to clarify irrigation water use situation in the field and develop survey instrument;
- Identify the main questions to be answered by the survey;
- Select survey sample;
- Prepare interview forms and interview protocol; and
- Prepare field survey plan and implementation schedule.

3.1 Gathering of Existing Information

Data for each well are expected to come from: (1) the database; (2) the well license folders; and (3) the field survey itself. Additional information will be collected from key informants and, in some cases, from the electricity supplier in the area.

MWI Oracle data

A connection was made through the network to the new ARD office space and appropriate software installed to access the Oracle database. Access was granted to query the Oracle database quantity and quality information for wells in the Amman–Zarqa basin.

Andrew Alspach, with the help of Ibtisam Saleh, researched MWI Oracle database to extract pertinent information to be used in preparation for the survey. This information was compiled on a well basis from various Oracle tables and "Information Sheets".

Spatial Information

GIS was used to link to the Oracle database and display information spatially. MWI has an impressive amount of digital spatial information. A list of thematic layers available from the Ministry can be found in Annex 1. Using this information a sample frame was developed to select wells for the survey. Various thematic maps (Figures 1-2) were produced to assist team members in understanding the current and historic groundwater situation in the Amman Zarqa basin.

WAJ and Water Security folders

Some of the well license data such as history of well deepening, rehabilitation, well replacement, ownership transfer are available only in WAJ folders. In addition, farm area and irrigated areas are recorded in the Water Security Unit folders. These data will be copied to supplement RA and Oracle information.

Power Consumption Data

Attempts will be made to collect power consumption data from the Jordan Electricity Company to crosscheck the number of well pumping hours in a given year.

3.2 Mini Survey

In early and mid March mini-surveys were carried out. One objective of the mini-survey was to help clarify the situation in the field while a second objective was to determine how amenable users would be to participating in the survey. Results from this mini-survey were used to modify the survey instrument as well as the survey approach. Results of these mini-surveys were very informative. They immediately confirmed that farms in the uplands are relatively large, are very capital intensive, often have more than one well, have complex crop production mixes of fruits and vegetables, and an overall investment of more than $1 million is not unusual.

A critical element of RRA has always been the fact that interviewers were speaking with the farmer-owners. By interacting directly with owners, RRA survey teams have been able to gain insight into the situation found in the field as well as in the village and surrounding region. However, in the Amman-Zarqa uplands owners are frequently not present on the farm. This suggested modifying the groundwater use survey into a two part approach. Technical production data are to be collected at the farm from the foreman in the absence of the owner and other more policy and investment oriented data are to be collected from the owner at his/her residence or place of work, often in Amman.

3. 3 Questions to be Answered

The mini survey and preliminary investigation of the Ministry data helped with identifying the main questions which can be answered, based on survey data collected during interviews with the foreman and managers as well as with the owners, supplemented by other data available from the Ministry. These questions are as follows.

1. What is the depth of pumping and has this depth changed over time?
2. How many hours are the wells operating annually?
3. What is the cost of pumping per cubic meter?
4. How many cubic meters are they pumping annually?
5. How much water is applied per ha for the different crops?
6. What is the efficiency of the irrigation system?
7. What is the area served by a well and what crops are being produced?
8. What yields and economic returns are farmers obtaining for their crops?
9. What are the returns per unit of water applied?
10. How much has the owner invested on his farm?
11. What is the potential for reduction in the use of irrigation water from groundwater wells in the uplands?
12. What would be the impact on the farm by a reduction, for example, of 30% of the current water supply?
13. Are farmers willing to accept water charges?
14. How much groundwater savings could result from the introduction of an irrigation information service?
15. Has the groundwater quality changed over time?
16. What are the impacts on agricultural production of changes in groundwater quality?
17. What would be the impact on local labor markets from a reduction in agricultural area in the uplands?
18. What would be the reaction of well owners to the introduction of treated wastewater for use as supplemental irrigation water in the uplands?
19. What solutions to the water problems in the uplands would the owners support?
20. What incentives would encourage owners to reduce ground water pumping for agriculture in the uplands?

3.4 Sampling

The north, northeast, and east parts of the AZB basin offer opportunities for abstracting municipal water supplies. It is also in this area where the competition for water with agriculture is most acute. Consequently, the sample for the groundwater survey is to be focused on the area in the basin that is north, northeast and east of Amman city. Figure 1 delineates the survey area.

The sample selection was based on the rate of annual pumping using the 1998 well production data, the latest data available in the Ministry database. Six abstraction categories were chosen, as shown in Table 1. Given that the most critical concern is with high pumping rates, the sample is designed to cover a large sample of these wells. The sample also covers the lower abstraction wells but with a declining percentage of the total wells in the category. To obtain a geographical spread throughout the area, a grid was placed over the survey area and wells of the different categories were selected at random throughout the grid squares. These wells are geographically disbursed throughout the sub-basin area, as shown in Figure 1.

Table 1. Number of Wells in Sample

Abstraction Category in cubic meters	Total Agricultural Wells-Abstraction Data from 1998	Number Proposed Sample Wells	Percentage of Total Number of Wells Sampled
Above 500,000 m3	11	10	91%
300,000-500,000 m3	31	27	87%
200,000-300,000 m3	67	40	60%
100,000-200,000 m3	143	54	38%
50,000-100,000 m3	90	29	32%
Less than 50,000 m3	118	24	20%
Total	460	184	40%

After collecting data from selected sample wells in the sub-basin, a decision will be made relative to collecting data from a small sample of wells in the east and northeast parts of the basin.

3.5 Sample ID

An official Sample ID is assigned to each farm, covering all wells located on the propriety. Sample ID numbers will be:

(1) the governerate (A=Amman, Z=Zarqa, and F=Mafraq),
(2) a unique four digit number taken from one of the wells located on the farm, and
(3) an indicator of the annual abstraction amount (Q1=less than 50,000 m3, Q2=50,000-100,000 m3, Q3=100,000-200,000 m3, Q4=200,000-300,000 m3, and Q5=300,000-500,000 m3, and Q6=greater than 500,000 m3).

As an example: Z2456Q5 is a farm with a high abstraction well number 2456 in Zarqa governerate. The sample ID will be entered on all the folders as well as on the survey forms.

IDs need to be assigned to Unlicensed Wells using the following steps:

- Use a prefix UL (Un-Licensed)
- Take the Numeric portion of the Sample ID and add it to UL. (e.g. UL1234)
- For more than one well add an Under score and sequential numbers. (e.g. UL1234_1, UL1234_2)

3.6 Survey Team

The team started with four members split into two teams. The first team includes Dr. Kamel Radaideh, senior hydrogeologist and water law specialist; Dr. Hani Al Rashid, senior irrigation specialist, Mr. Mohammed Abu Ajamiyeh, senior hydrogeologist; and Mr. Ahmad Abu Hijleh, environmental hydrogeologist. A fifth person, Mr. Kalil Na'im, a senior field technician who is

very familiar the survey area, was added to help both teams coordinate meeting with owners and assist them in gathering data.

The team was briefed on interview protocol. They were trained on field surveys, use of GPS units to read well site coordinates, and data management. The team also participated in the review and update of the field interview forms.

3.7 Interview Forms

Two interview forms were prepared. A field interview form, shown in Appendix 1, is designed for farmer, water abstraction, and irrigation practices. A policy form, illustrated in Appendix 2, is designed for the owner and deals with investment and groundwater management.

The field interview form includes data concerning: farm information, well status initially and current, water quality, agricultural production, and over-pumping impacts for farmers affected by water shortage and/or water quality. The policy form covers well and farm investment, and owners' feelings about groundwater management and use of treated wastewater.

Farmer Information

(a) name of owner
(b) name of respondent
(c) farm size
(d) irrigated area
(e) licensed irrigated area
(f) leased area, if any
(g) sharecropped area, if any

Initial Well Data

(a) year of initial operation
(b) well type-electric or diesel
(c) engine/motor size
(d) original pumping capacity
(e) original well depth
(f) original water table depth
(g) original well costs
(h) aquifer tapped

Current Well Data

(i) well type-electric or diesel
(a) present pumping capacity
(b) present well depth
(c) increase in well depth
(d) costs of increase
(e) decline in water table depth
(f) annual pumping-1999
(g) annual energy use
(h) annual energy costs
(i) water sales
(j) water sales revenue
(k) monthly hours pumped

Water Quality
(a) initial quality of water
(b) present quality of water
(c) quality change since installing well
(d) reason for change
(e) crop yield decline due to quality changes
(f) impacts on soil quality

Agricultural production
(a) crops grown
(b) irrigation method
(c) irrigation efficiency
(d) labor use
(e) yields
(f) gross return
(g) water cost/m3

Over-pumping Impacts
(a) crops grown
(b) irrigation method
(c) irrigation efficiency
(d) labor use
(e) yields
(f) gross return
(g) water cost/m3

Investment
(a) total investment on farm and irrigation system
(b) number of co-owners
(c) type of financing
(d) sources of farm labor

In addition the survey will initiate groundwater policy discussions with the owners. These discussions will explore options for addressing groundwater problems in the uplands. Data collected during the policy discussions will include:

Groundwater Policy
(a) long-term expectations on groundwater quality and quantity
(b) impacts of water shortages on uplands
(c) suggested solutions for uplands water problems
(d) changes to compensate for 30% decline in groundwater quantity
(e) acceptance of water use charges
(f) need for Irrigation Advisory Service
(g) actions and incentives to reduce groundwater abstraction
(h) willingness to participate in groundwater management committee
(i) acceptance of supplementing groundwater with treated wastewater

3.8 Interview Protocol

The team leader will start discussion by introducing the objective of the visit and the rapid appraisal activity, stressing on the benefits of better management of the limited groundwater

resources. Then, he offers to measure water quality and explain results with emphasis on relationship between abstraction and water quality, and impacts of water quality on crop returns. One of the team members will focus on water abstraction issues and the second on farming practices and agricultural production. The survey team leader is responsible for the water policy interviews and for arranging meeting with owners, who are not on farm.

The team leader of the groundwater management component will participate and conduct discussions with farm owners, and will keep the team focus on the interview protocol. The discussion will be conducted in a courteous and cordial interview style. All information regarding water users will be kept confidential.

3.9 Survey completion

Once a sample well has been selected and a Sample ID assigned, the survey team put the sample well locations on 1/25,000 topographic and road maps, and prepared a weekly schedule for the field visits. Four days a week are planned for field visits, with the fifth day for data review and preparation of the weekly field visits schedule.

In most cases it should take around 2 to 3 hours to complete the field survey and collect all the data. Including travel time and other unexpected delays, it is should be possible to complete three surveys per day as long as they are in the same area.

Interviews with owners are used to collect investment and groundwater policy information. In many cases this data will be collected in Amman with interviews held at the owner's place of work or elsewhere, depending upon which location is most convenient. Although there is a limited amount of the technical data to collect, it is expected that this interview will take around one hour.

With a sample of 184 wells (and a smaller sample of farms due to the fact that some farms have multiple wells) it should take two survey teams slightly more than two months to complete data collection for the sample of wells, as shown in Table 2.

As each interview is completed, data entry will be supervised by survey team members. It is expected that within two weeks of the completion of the field data collection effort, all the data will be entered in an Excel database. This database has been designed to be self-explanatory and easy to enter the data. The format can be exported to Access or any statistical package.

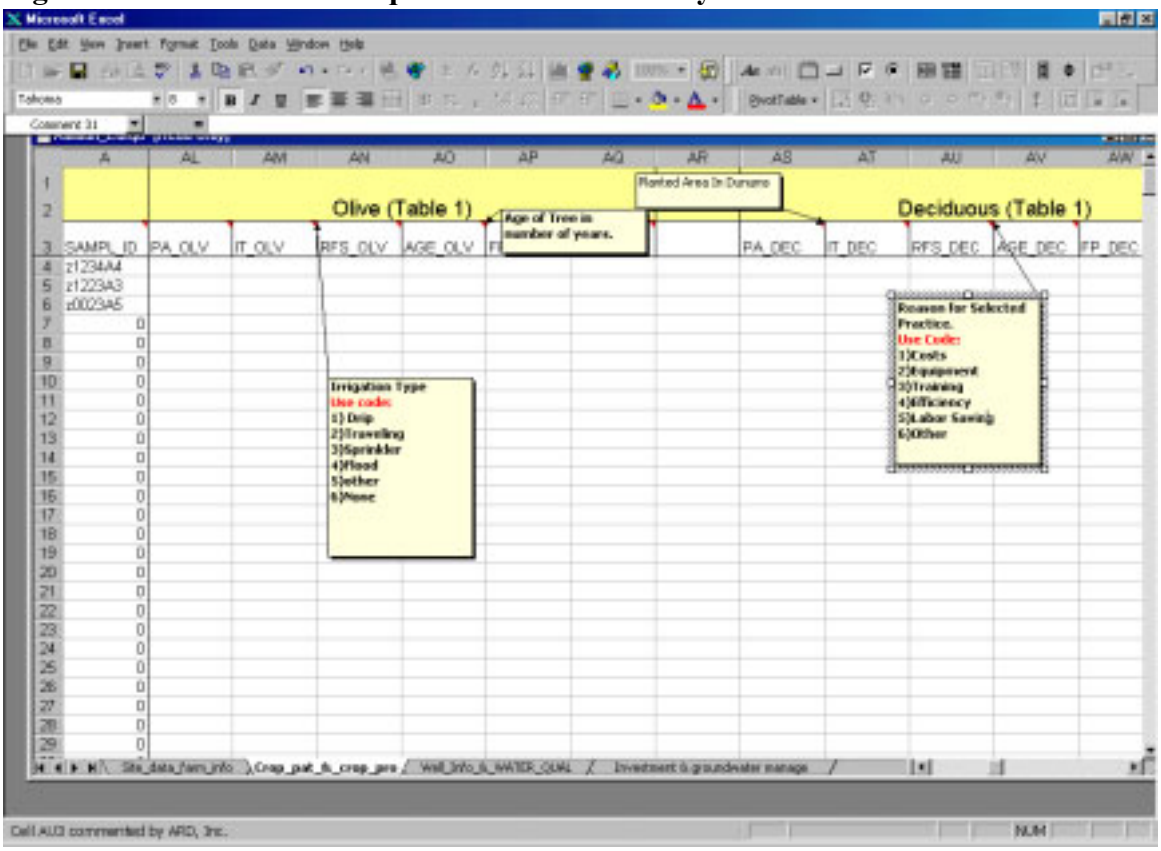
Table 2. Rapid Appraisal Survey Schedule

Activities	**March**				**April**				**May**				**June**				**July**	
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**
Mini-Survey		X	X	X														
Field Survey					X	X	X	X	X	X	X	X	X	X				
Data Entry							X	X	X	X	X	X	X	X	X			
Data Check														X	X	X		

4. PROCEDURES AND FORMATS FOR DATA RECORDING

The development of the survey forms paralleled the creation of a database in which to store and later analyze survey data. It is important to maintain the connection between the database and field survey instrument. As revisions are made to the survey forms, the database must be updated. Excel was chosen for the format of the database because of its ease of use by project staff. The database can later be exported to formats compatible with the Oracle database and statistical packages. To help standardize data entry, the database was customized with pull-down windows that explain the information that should be entered, and with an elaboration of the codes and units of data to be entered (See Figure 3).

Figure 3: Amman –Zarqa Groundwater Survey Database



This should eliminate some of the confusion that often arises during data entry, when units or codes are confused. The Help Desk Administrator was trained to modify and update the database and will train data entry staff. For the Policy Form questions a short narrative is required. Each question will have a separate MS Word file, and narratives will be entered with a corresponding Sample ID number.

Finally, as the survey team completes the survey, all of the originals of the completed survey forms will be stored in folders according to the Sample ID.

5. RECOMMENDATIONS FOR GIS AND REMOTE SENSING ACTIVITIES RELATED TO RAPID APPRAISAL

Currently MWI has a composite TM image of the Amman-Zarqa basin. Figure 2, taken from a 1995 Landsat image, illustrates how easy it will be to locate the wells since nothing is green and

growing in the area without a well to provide water. This satellite image is very useful as a backdrop for thematic layers in the GIS, but further processing can not be performed unless the raw bands are acquired. MWI does not have Image processing software in house at this time. With the Oracle database and current GIS layers, no spatial data gaps were identified for the purpose of the Amman–Zarqa appraisal. It is important to research the availability of satellite imagery in Jordan.

There is great potential for time series analysis of satellite imagery to ascertain the extent of irrigated area expansion in the basin. Mr. Alspach recommends that research be first conducted to see if this analysis has been done previously. The Ministry of Natural Resources, Ministry of Agriculture and the Royal Jordanian Geographic Society should be contacted to see if this type of analysis has been done. If not, building this capacity in MWI would benefit activities related to the monitoring and evaluation of irrigated areas.

Spatial Database Engine (SDE)

ESRI provides a database access tool that allows seamless integration of an Oracle database and GIS. It is recommended that a feasibility study be conducted for the use of SDE in MWI.

Digital Elevation Model (DEM)

MWI does not have a high resolution DEM. It is recommended that a high resolution DEM be purchased from a local source for future use in the project.

MWI GIS Staff

There is a high level of GIS technical expertise in MWI. It is recommended that a GIS working group be formed and the possibility of a GIS lab be investigated. This would facilitate a closer working relationship among GIS users and foster collaboration on analysis and projects. Potential members of the team could include an ARD GIS specialist, Susan Taha, Ibtisam Saleh, Mazen Rayen, and Ali Subah.

Additional GIS Analysis

A GIS specialist will scheduled to be hired by ARD in the near future. It is recommended that this individual utilize the data developed to date to assist the assessment team. Linking Oracle database information with spatial layers should continue. The maps produced should be "working maps" that can be brought to the field and address specific needs of the team. In most cases these should be produced in Black and White to allow for photocopying if necessary.

Future GIS Analysis

The wastewater component of the project and future groundwater modeling will require additional high level spatial analysis. Possible collaboration with MWI modelers and external consultants may be necessary during the development stages of this analysis.

Future Survey Analysis

Possible collaboration with MWI and external consultants to assist in the groundwater survey analysis should be considered as an option.

Appendix 1

GIS Layers and Location

Location of MWI spatial layers: N:\WIS\spatial-data
Administration boundaries
Agricultural zones
Contour lines 50 meters
Districts
Evapotranspiration
Governerate
Groundwater
Gauge station
JTM Grid (10km)
Lakes, Dams, Sea, Pools
Land-use
Pipes
Pmp & Res
Rainfall
Roads
Surface hydrology
Soils MoA
Soils RJGC
Spot Heights
Spread Wadis
Springs
Surface water basins
Surface water basins and sub basins
Towns
Villages
Wadis, canals, Pipelines
Wells
Wellsjtm

TM 1995 Composite
Geologic layers of outcrops
Well location

Appendix 2

Field Interview Form

Appendix 3

Policy Interview Form