MINISTRY OF WATER AND IRRIGATION

Water Resource Policy Support
Groundwater Management Component

STUDY OF GROUNDWATER USE AND USERS IN NORTHEASTERN AMMAN-ZARQA BASIN HIGHLANDS

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EXECUTIVE SUMMARY

This report describes groundwater development in the northeastern highlands of Amman-Zarqa Bazin (AZB) and presents the main findings of a Rapid Appraisal (RA) field survey of groundwater use and users, and related studies. The survey achieved its principle objectives, by defining the profile of the users, initiating discussions about management of groundwater resources in the area, exploring practical options for reduction of water use in irrigated agriculture, and gathering data for the assessment of socioeconomic impacts of these options.

Field interviews were completed for 155 farms and 170 wells. Groundwater management interviews were successfully completed for 80 owners and eight small group meetings with community leaders and farm owners. This high level of participation was considered unlikely at the beginning of the survey, and reflects the interest of farmers in future decisions related to groundwater management in the AZB highlands. The RA gave an opportunity to farmers to express their concerns and voice their opinions, as illustrated in the 35 short stories detailed in Appendix 3. The RA also presented valuable insight information to MWI decision makers, and opened doors to a collective effort in saving AZB groundwater resources.

The RA field visits revealed that farms in the uplands are relatively large and are very capital intensive. A very limited number of farmers are making a decent profit. Nearly 50% of interviewed farmers have marginal income, and therefore financial difficulties, and are willing to sell out. Few farmers have abandoned their properties.

Farm ownership started with mainly Bedouins, since irrigated agriculture was developed to provide them with a reliable source of income. Some of the bedouins sold their properties right after they got their well licenses. Others drilled their wells and sold their farms after failing to survive in the business. As a result, the pattern of farm ownership has shifted to private investors from outside the area, who own around 49% of surveyed Mafraq farms and 76% of those in Zarqa.

Bedouins, represented by their community leaders, have shown willingness to cooperate and be part of the management process. Most investors represent only themselves and may rally behind bedouin community leaders or influential well owners depending on their interests.

Trees cover around 60% and 70% of the cropped area in surveyed farms, respectively, in Mafraq and Zarqa. Olives are progressively replacing old fruit trees due to the fact that fruit trees are labor and capital intensive. As a result olives are becoming the predominant crop tree in the area, representing roughly 35% and 55% of total tree crops in Mafraq and Zarqa, respectively.

Most farmers would accept water use reductions based on reduction of cropped area. Reduction of cropped area is possible for vegetable farms, but more difficult for tree farms since they constitute a high investment, and removal of productive trees may engender significant financial losses.

One important element of the social aspects is that the irrigated agricultural sector in AZB highlands employs a fairly large number of local labors, especially females. Local females form the majority of seasonal working force. They represent around 54% and 74% of total irrigated farming labor in Zarqa and Mafraq, respectively. Female labor wages constitute in many cases a significant part of the income of thousands of families. As a result socio-economic impacts on local laborers should be a significant part of the AZB groundwater management equation.

Water charges are not accepted by around 85% and 91% of Mafraq and Zarqa well owners, respectively. On the other hand, 65% of Zarqa farmers are willing to exchange groundwater with recycled wastewater. However, preliminary analysis conducted by the Water Resource Policy Support (WRPS) groundwater reuse component shows that transfer of As Samra recycled wastewater to Dulayl and Mafraq is not economically viable.

Following the RA work the groundwater management team prepared recommendations for groundwater management in AZB highlands. These recommendations indicate that groundwater use reduction is achievable. Preliminary estimation suggests a potential average annual groundwater abstraction reduction from four proposed options ranging from around 35 MCM to 50 MCM, in addition to that of the option of exchange of groundwater with recycled wastewater, which is under study. The four recommended options are: 1) Irrigation Advisory Service (IAS), which is expected to save 5 MCM to 10 MCM by raising agricultural water use efficiency in AZB highlands' farms, based on results of the Jordan Valley IAS pilot study, 2) Well buy-out is expected to cut abstraction by 15 MCM to 20 MCM, 3) Implementation of abstraction quotas or gradual cropped area reduction, spread over 3 years for vegetables and 5 years for tree crops, would also result in saving around 10 to 15 MCM, and 4) Reduction of Municipal and Industrial Unaccounted for Water (UFW), via rehabilitation of the water supply network, should correspond to a minimum reduction of groundwater abstraction equivalent to 5 MCM. Priority, expected benefits, and implementation of these options are discussed. The above preliminary reduction figures will be fine-tuned in upcoming abstraction and groundwater modeling work. Mandatory cropping patterns are not recommended. Estimation of farm buy-out cost, identification of low water consumption/high value crops, assessment of current trends of progressive increase of olive plantations, analysis of current marketing, export, and impact of free trade on marketing will be addressed in the socioeconomic analysis of agricultural water use which will be conducted during January-April 2001. Groundwater use on the Syria side of Amman-Zarqa basin needs to be remotely monitored. A Groundwater management fund (GMF) is recommended. This fund can be generated from over-abstraction charges from private well owners, a water supply conservation fee from M & I water consumers, and other sources. This fund is intended to cover incentives related to implementation of IAS and reduction of abstraction/cropped area. The recommended groundwater management strategy is based on

participation of stakeholders and considers the basin as a management unit. The approach could be replicated to other groundwater basins in the Kingdom. A note on forming a groundwater management consultative committee has been prepared. ARD is currently analyzing the legal and regulatory aspects of these options. Upcoming activities will focus on social, economical, technical, and institutional aspects related to the implementation of each option and idea, including the management fund. These support activities form the basis for the development of the groundwater management implementation action plan.

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LIST OF ABBREVIATIONS

ACC	Agricultural Credit Corporation
ARD	Associates in Rural Development
AZB	Amman-Zarqa Basin
ECC	Economic Consultative Council
GMCC	Groundwater Management Consultative Committee
GMF	Groundwater Management Fund
GPS	Global Positioning System
IAS	Irrigation Advisory Service
JVA	Jordan Valley Authority
km^2	Square kilometers
KTR	King Talal Reservoir
LEMA	Lyonaise des Eaux Management-Amman
MCM	Million Cubic Meters
M&I	Municipal and Industrial
MOA	Ministry of Agriculture
MWI	Ministry of Water and Irrigation
NCARTT	National Center for Agricultural Research and Technology Transfer
NRA	Natural Resources Authority
RA	Rapid Appraisal
RS	Remote Sensing
TO	Task Order
UFW	Unaccounted for Water
USAID	United States Agency for International Development
WAJ	Water Authority of Jordan
WRPS	Water Resource Policy Support
WWTP	Wastewater Treatment Plant

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This report was prepared by Mohamed Chebaane, Team Leader of Groundwater Management Component, with significant input from ARD groundwater management team members: Lana Al Naber, Junior Engineer, Kamel Radeideh, Water Management Specialist, Ahmed Abu Hijleh, Water Resources Specialist, and Hani Al Rashid, Irrigation Specialist.

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1. INTRODUCTION

The main objectives of the groundwater management component of the Water Resource Policy Support (WRPS) Task Order (TO) are 1) the exploration of practical options for reducing groundwater use in irrigated agriculture in Amman Zarqa Basin (AZB) highlands and 2) the development of an action plan to implement these options. One of the important activities of WRPS involves a Rapid Appraisal (RA) of water use and users in the irrigated area of Amman-Zarqa highlands. The RA was conducted in April-June 2000 in selected parts of the basin. It provided a profile of different types of users and information regarding quantity and quality of water use, cropped area, well characteristics, pumping cost, labor force (permanent, seasonal, foreign/local, gender), and crop returns. The RA also initiated a participatory water management process by exploring water users' ideas and suggestions on options and practical actions for groundwater use reduction, and on the willingness to replace groundwater abstraction with recycled water.

The latter data form the basic information for technical, socio-economical, and water management analyses designed to support the formulation of AZB highlands' groundwater management action plan. This document gives a historical background of groundwater over-pumping and presents the methodology, planning, implementation, and findings of the RA and other related studies. It also includes recommendations on AZB highlands' groundwater management and a note on forming a groundwater management consultative committee.

2. BACKGROUND

2.1 Geography and Hydrogeology

Amman-Zarqa groundwater basin (AZB) extends from Jebel Arab in Syria in the northeast, to the Rift Side Wadis basin in the west, Yarmouk basin in the northwest, Azraq basin in the east and south, and Dead Sea basin in the southwest (Figure 1). It covers a total area of 4586 square kilometers (km^2), with about 4074 km^2 in Jordan and 512 km^2 in Syria, and includes the country's largest urban agglomeration and major industrial sites and irrigated areas (Figure 2). Annual average precipitation is around 600 mm in Jebel Arab, 400 mm in western Amman, and less than 100 mm towards the desert.

Amman Zarqa aquifers have the highest groundwater recharge (88 MCM/year) in Jordan, and represent about 30% of the nation's renewable groundwater resources (276 MCM/year). The main groundwater system in AZB is composed of the Basalt and the B2/A7 aquifers (Figure 3), which are located in the northeastern highlands extending north to the Syrian border and southwest to the outskirts of Amman. Note that hereafter, northeastern highlands are simply referred to as highlands. A significant part of the renewable recharge of these two aquifers originates from Jebel Arab and the rest from local rainfall. This recharge is estimated at around 70 MCM or 80% of the total AZB groundwater renewable resource, with 28 MCM for the Basalt and 42 MCM for B2/A7. These aquifers are relatively deep. Well depth ranges from 300 to 400 meters in North Badiya and from 50 to100 meters in Dulayl and Zarqa areas. This requires high drilling and pumping costs. For additional details refer to the AZB hydrogeology report (ARD, May 2000).

2.2 Historical Overview of Water Users and Water Use

In the early 1950s most of the inhabitants of AZB highlands were nomadic tribes. The major tribes represented in the area are Al Masai'd, Al Isa, and As- Sardieh, Al Shurafat, and Idhamat in the north and east part of Badiya; Bani Hassen in the area extending from Mafraq to the outskirts of Zarqa; and Bani Khaled and Bani Sakher in the Dulayl- Khaldiyya-Hallabat area.

Livestock was not the main source of income for the Bedouins. Herds are more of a form of wealth than a source of income. Their three major sources of income in 1970s were employment in the army, illegal trade, and government subsidies (Abu Jaber et al., 1987). In the early 1950s there was no water supply in north Badiya. One prominent chief of a local tribe stated (RA interview, April 2000) that the closet accessible source of water supply in the area was in Syria, at around 20 km from the border.

Development of AZB highlands aquifers system, for irrigated farming, began first in Dulayl in early 1960s because of its relatively shallower groundwater and its proximity to Amman. Figure 4 shows the history of groundwater development in the northeastern part of AZB

highlands, based on the MWI database and previous studies. This figure indicates that in 1965 there were only around 25 wells in Dulayl area. Fifteen years later (1980) the number of wells almost quadrupled.

In the late 1970s the government launched a full-scale development program in north Badia. The program included investment in domestic water supply, roads, schools, clinics, and other public services. The government also decided to encourage the development of irrigated agriculture as an additional reliable source of income with the objective of enhancing social welfare, stability, and security. This was done by granting licenses and soft loans through the Agricultural Credit Corporation (ACC) for drilling private wells. By mid 1980s AZB highlands became the land of orchard gardens and vegetable farms. Municipal town centers were established in Dulayl, Khaldiyah, Za'tari, Sabha, Um-Jimal, Bai'j , Dafiyaneh, and Um Al Quttayn. Mafraq became a large regional urban center in the Governorate. Roads, electricity, health centers and other services are now available in most towns and rural settlements. In addition to schools and cultural centers, one of the prominent Public Universities (Al Elbait) was established near Mafraq in the mid 1990s.

Favorable exports of agricultural produce to the Gulf market in early 1980 coupled with subsidized energy prices, construction of Mafraq Tomato-paste factory, and local market protection during harvesting season encouraged private investment in irrigated agriculture and resulted in rapid agricultural expansion in AZB highlands. Private investors include high government officials, high ranked Army officials, and farmers from other parts of Jordan, especially from the Jordan Valley, in addition to returnees from Gulf countries after 1990.

Figure 4 shows that extensive groundwater development in north Badiya, north of Al Khaldiyya, started between 1980 and 1990 where the number of wells increased tremendously from around 10 in 1980 to around 100 in 1990. Eight years later in 1998 the total number of production wells in the northeastern highlands was 445, knowing that during the same year the total number of productive wells in AZB groundwater basin reached 697 with 491 for irrigation.

Figure 5 indicates that in 1998 the total abstraction from AZB was 149.7 MCM (MWI Database) or 170% of the safe yield, with 72.2 MCM (48.2%) for domestic water supply, 69.3 MCM (46.3%) for irrigation, 6.1 MCM (4.1%) for industrial sector, and 2.1 MCM (1.4%) for pastoral uses. Figure 5 also shows that the bulk (83%) of groundwater pumping occurs in the highlands (124.2 MCM) with around 63.0 MCM for irrigation, 53.5 MCM for domestic, 5.7 MCM for industrial, and 2.0 MCM for pastoral purposes. Around 91% of total irrigation use in AZ basin is in the highlands. The highest irrigation water use (Figure 6) is in North Badia (17.8 MCM), North of Baghdad road and within the AZB surface water boundary, followed by Zatari area (10.8 MCM) between Baghdad road and AL khaldiya, Hallabat (10.8 MCM), As Samra-Balama (9.7 MCM), Dulayl (7.5 MCM), Northwest Azraq (3.9 MCM), and Zarqa (2.4 MCM). Over-pumping resulted in significant water level decline (Figure 7) and salinity increase in Dulayl area (Figure 8), drying up of springs near Sukhna, and reduced water level (Figure 9) and water quality in parts of North Badiya.

Continued over-pumping will likely further deplete the groundwater resources in the area and may induce a threat not only to domestic water supply in Zarqa and parts of Amman, but also to the socio-economic development and stability in the Badia area.

2.3 Groundwater Management Measures

The National Water groundwater management policy (MWI, 1997) stipulates that water is a state owned property. It also gives first priority to domestic water supply, second priority to industry and tourism and third priority to the agricultural sector. Abstraction quotas or upper limits of 50,000 m^3/year, 75,000 m^3/year, and 100,000 m^3/year are imposed on irrigation well licenses issued by the Water Authority of Jordan (WAJ) after 1984, but have not been enforced. For instance, the 1998 abstraction data shows (Figure 10) that:

- 97.6% in Amman Zarqa Basin have exceeded the 50,000 m^3/year limit,
- 94.9 % surpassed 75,000 m^3/year, and
- 91.7% pumped beyond 100,000 m^3/year

The average abstraction is estimated at 140,000 m^3/year. Older licenses issued by the Natural Resources Authority (NRA) have no abstraction limit. In addition well licenses in AZB highlands are subject to a rule, which restricts the distance between wells to 1 km. This rule is also not fully enforced. The majority of wells in the area have water meters. There is no groundwater abstraction charge for agriculture water use.

Groundwater management in the highlands has been based on instruments, which do not take into account the different costs for reducing water use incurred by individual water users. Water policy in Jordan is in the process of moving towards the introduction of new water management instruments with the assistance of the WRPS project (1999-2001).

3. RAPID APPRAISAL OBJECTIVES

The principal objectives of the RA are to 1) initiate a participatory water management process by involving well owners in the development and implementation of water management instruments, and 2) collect information related to well characteristics, pumping, water use, farming practices, and socio-economic aspects of irrigation water use.

3.1 Participatory Water Management

This deals with the participation of stakeholders in the management of groundwater use in AZB highlands. Stakeholders include the well owners, MWI, and other relevant institutions. The RA focuses on well owners' participation or bottom-up management approach, to achieve the following objectives:

- Develop a profile of water users,
- Explore practical options for reduction of agricultural water use in AZB highlands,
- Explore the willingness to replace groundwater abstraction with recycled water, and
- Explore participation of well owners with MWI and other stakeholders in AZB groundwater management.

3.2 On Farm Data Collection

This activity consists of collection of on farm information to supplement data obtained from MWI and other sources. This information includes:

- Quantity and quality of pumped water;
- On farm water use practices;
- Economic value of different water uses;
- Statistics about the social aspect of water use;

4. SURVEY METHODOLOGY AND PLANNING

4.1 Methodology

It is recognized that the reduction of agriculture water in AZB is a difficult and challenging task (WRPS scope of work). To face this challenge the RA methodology was developed around the following key elements:

- Selection of a team of field enumerators or surveyors from senior and well-respected professionals who are fully aware of the AZB water and social issues.
- Transparency in dealing with well owners.
- Confidentiality of sensitive information.
- Stress on water scarcity and its current and possible future effects on the agricultural activity in the area.
- Water is a national strategic resource.
- Advantage of well owners' participation in the management of the groundwater use in the area.

4.2 Planning

This activity extended from 18 February to 30 March 2000 and included the following steps:

- Gathering of existing information from the Ministry Database and other sources on irrigation water use;
- Conducting a mini survey to clarify the irrigation water use situation in the field and develop the survey instrument;
- Identifying the main questions to be answered by the survey;
- Selecting the survey sample;
- Preparing the interview forms and interview protocol;
- Developing a database for data recording and management;
- Preparing a field survey plan and implementation schedule.

The analysis of the current and historical groundwater use situation in AZB, which was presented in section 2.2 of this report, was used as a basis for conducting the mini-survey and preparing the interview protocol. Details about each of the above planning steps are illustrated in the RA planning report (MWI/ARD, April 2000). This section gives an overview of the important components of the survey planning such as selection of the survey questions and interview forms, survey sample, survey team, and interview protocol.

4.2.1 Survey Questions

Two field visits and a two-day mini-surveys were carried out respectively, in late September 1999 and in mid March 2000, to understand the situation in the field and determine how amenable users would be to participating in the survey. This preliminary field investigation immediately confirmed the following:

- Farms in the uplands are relatively large and are very capital intensive.
- Farm crops are vegetables, fruits or a mixture of both.
- Many owners are frequently not present on the farm.

Based on these observations, the RA objectives stated in section 3 of this report, existing data from MWI and previous studies, and discussions with farmers, it was decided to prepare two interview forms. One deals with water management and policy issues addressed to farm owners and one concerns on farm or field data collection addressed to the person in charge of the day-to-day farm operation. This person can be the farm owner, manager, or tenant. The water policy form covers farm and well investment, owner's feelings about the groundwater situation, his suggestions about groundwater management, his opinion about participatory groundwater management, and his willingness to replace groundwater abstraction with recycled water. The field form includes information on well status, water quality and water abstraction, cropped area, yield and returns, irrigation practices, and number and categories (temporary, seasonal, local/foreign, gender) of labor. Details of the survey questions are presented in the RA planning report (April 2000).

4.2.2 Survey Sample

The sample selection was based on the rate of annual pumping using the 1998 well production data, which were the latest data available in the Ministry database during the time of survey planning. The following six abstraction categories were chosen:

- Less than 50,000 m^3.
- 50,000-100,000 m^3.
- 100,000-200,000 m^3.
- 200,000-300,000 m^3.
- 300,000-500,000 m^3.
- Above 500,000 m^3.

Given that the most critical concern is with high pumping rates, the sample is designed to cover a large number of these wells. The sample also covers the lower abstraction wells but with a declining percentage of the total wells in the category. These wells are geographically disbursed throughout the sub-basin area in parts of Mafraq and Zarqa Governorates, as shown in Figure 11.

4.2.3 Survey Team

A MWI/ARD rapid appraisal multidisciplinary survey team was formed from senior professionals who are very well versed in both technical and public relation skills. Five out of the seven-team members have witnessed the historical development of groundwater use in AZB and the socio-economic development in the Badia since the early 1950s. The team included:

- Salameh Al Khreisheh, Head of Groundwater Studies, MWI
- Kamel Radeidah, Water Management Specialist.
- Hani AL Rashid, Irrigation Specialist
- Mohammed Abu Ajamiyeh, Hydrogeologist
- Ahmed Abu Hijleh, Water Resources Specialist
- Khalil Na'im, Senior Technician

In addition to Mohamed Chebaane, Groundwater Management Team leader, and Lana Al Naber, junior engineer in charge of RA data management, checking and analysis.

4.2.4 Interview Protocol

This team was subdivided into two groups, each composed of a group leader and two enumerators. The group leader was responsible for the water management interviews and for arranging meetings with owners, who were not on farm. The enumerators were in charge of on-farm data gathering. The group leader started the discussion by introducing the objective of the visit and the rapid appraisal activity, and presented an overview of water resources and water scarcity in the area. Then, he offered to measure water quality and explained results with emphasis on impacts of over-abstraction on water quantity and quality. Examples of water quality and/or quality deterioration in other farms in the vicinity were given to illustrate the negative impacts of over-pumping in the AZB. The benefits of better management of the limited groundwater resources were explained. The owner was invited to suggest practical actions to reduce over-pumping and to voice his opinion about the implementation of these actions. The discussions were conducted in a courteous and cordial interview style.

The team leader of the groundwater management component participated and conducted discussions with farm owners, and kept the team focus on the interview protocol. All information regarding water users is kept confidential.

The survey team was trained on field survey methods, use of GPS units, and data management. On March 28, the team started preparing the field activity program and field road maps, which included all the sample wells.

5. SURVEY IMPLEMENTATION AND FINDINGS

The RA field survey began on 02 April 2000 and ended mid-June 2000. From the first week, the team adjusted well to the interview procedures and field conditions. Daily and weekly coordination meetings where held to discuss matters relevant to work progress. The interview forms were adjusted and questions such as those related to irrigation efficiency and gender were added. Final versions of the policy form and field form are shown in Appendices 1 and 2, respectively. This section describes the interaction of the RA team with the well owners and tenants or farm managers throughout the survey. It also gives an overview of the RA data analysis, and presents the RA findings and the opinions and suggestions of water users.

5.1 Water Users' Participation

During the first two weeks, the RA team concentrated on explaining the objective of the survey, promoting the participatory management approach, and gathering farm data. For owners who were not present at their farm, field interviews were conducted with managers, tenants or sharecroppers, and separate meetings were held at the owners' convenience to complete the policy interview. Once farmers understood the objectives of the survey the water policy/management interviews witnessed significant progress. Farmers frequently expressed their appreciation for being asked to voice their opinion about water management. This helped easing discussions and opened doors to meetings with farming community leaders and small groups of owners (Picture 1).

Field interviews were completed for 155 farms and 170 wells, with policy interviews successfully completed for 80 owners and eight small group meetings with community leaders and farm owners. This high level of participation was considered unlikely at the beginning of the survey, and reflects the interest of farmers in future decisions related to groundwater management in AZB highlands. Besides the structured information recorded in the farm interview form and policy form, 35 short stories are reported in Appendix 3. These stories represent a snapshot of the RA discussions and reflect the interest, concerns, and opinions of well owners, tenants, sharecroppers and community leaders.

5.2 Data Management, Checking, and Analysis

The RA team members spent one day per week in completing data transfer from field notes to farm and policy interview forms, and in checking the accuracy of and completeness of the records. These data are entered in the RA database (Figure 12). An official Sample ID is assigned to each farm, covering all wells located on the propriety. Sample ID numbers includes:

- Two Characters representing the Governorate (MF=Mafraq, and ZA=Zarqa),
- A unique four digit number taken from one of the wells located on the farm, and

- An indicator of the annual abstraction amount (Q1=less than 50,000 m^3, Q2=50,000-100,000 m^3, Q3=100,000-200,000 m^3, Q4=200,000-300,000 m^3, and Q5=300,000-500,000 m^3, and Q6=greater than 500,000 m^3).

As an example: ZA2456Q5 is a farm in Zarqa Governorate. The farm's well number is AL2456 with a high abstraction level. The sample ID was entered on all the folders as well as on the survey forms. Note that hereafter Zarqa and Mafraq Governorates are referred to as Zarqa and Mafraq. Additional details are found in the RA planning report (MWI/ARD, April 2000).

Part of the data such as the type and area of irrigated crops will be validated using Remote Sensing (activity I3.2, Annual Work Plan, 2000-2001). The validated cropped area and the RA socio-economic information will be analyzed and presented in the socio-economic studies (activities I-4 and I-5, Annual Work Plan, 2000-2001). Activities I-6 to I-8 of the groundwater management component will draw most of their basic information from the RA Database. This report presents the analysis of information related to the water user's profile, labor, energy cost, irrigation practices, and water charges. It also describes farmers concerns, opinions, and suggested practical actions for groundwater management in AZB highlands.

5.3 Findings

5.3.1 Farm Types

As stated earlier the majority of farms in the area are large. A few farms are modern and tend to be highly profitable. The rest are traditional farms. Hobby farms are extremely limited in number. Based on the field visits, farms may be classified as follows:

- **Seasonal Crops Farms:** They cover 25.6% of the surveyed farms in Zarqa and 27.6% of those in Mafraq (Figure 13 and Table 1). Dulayl WAJ project farms are included in this category. Seasonal crop farmers prefer to use virgin land for its high productivity and its tolerance to low water quality. As a result most of the seasonal crop farms have extended their operations progressively to neighboring virgin lands, which may be a few kilometers away from the water source (Picture 2).

- **Tree Farms:** They represent 30.2% of surveyed farms in Zarqa and 28.6% of those in Mafraq (Figure 13). These include modern farms run by owners and/or skilled managers (Picture 3), who have good command of crop production, farm management, and marketing (stories 1 and 2). Some of these farms are comparable to modern farms in the U.S. or Europe.

- **Seasonal Crops / Tree Farms:** They represent the majority of the surveyed farms in the study area; 44.2% of them are in Zarqa and 43.8% are in Mafraq (Figure 13).

- **Water Sale farms:** There are two categories of water sale farms. The first, predominantly sells water to tankers for domestic water supply and/or irrigation (Picture 4). Most of

these farms are located in the outskirts of Zarqa, and some of them are illegal (story 3). The second category consists of those selling bottled groundwater while maintaining most of their irrigated farming activity.

- **Dairy farms:** Two large dairy farms were visited. Both claim that they do not grow fodder grass or any other animal feed in their farm. All animal feed is bought from Saudi Arabia and other Jordanian farms. Abstracted groundwater in these farms is for livestock drinking and other dairy operations.

- **Abandoned Farms:** Only 3 out of the 155 surveyed farms are abandoned due to marginal production (story 20). Picture 5 shows the remains of an abandoned tree farm. This indicates that even olive trees can't survive in AZB highlands without irrigation, due to scarcity of rainfall in the area.

5.3.2 Water Users' Profile

The high level of participation of the water users in the RA interviews, and their willingness to express their concerns and opinions, helped the survey team to better define their profile and assess the potential of their future contribution in the management of AZB groundwater use.

- **Farmers' Background**

- **Bedouins:** They are at the origin of and the reason for irrigated agriculture in AZB highlands as described earlier in the background section. A number of bedouins sold their farms to investors. As a result only 20% of owners of surveyed farms in Zarqa and 46.2% of those in Mafraq are bedouins (Figure 14 and Table 2). The higher percentage in Mafraq is due to the fact that communities in North Badia are attached to their lands. The majority of the bedouins' farms are classified as seasonal crop farms. A handful of these farmers have decent returns, but the majority have marginal returns and large debts. The bedouins have strong opinions (stories 33 and 35), and strong ties with their community leaders. The survey team met with all community leaders in the study area and with a large number of bedouin farmers.

- **Private investors:** They include professional farmers from other parts of Jordan, especially from the Jordan Valley, and returnees from abroad (stories 10, 22 and 28) particularly from Gulf countries after 1990. Most of these farmers own modern tree farms or seasonal crops/tree farms. These farmers often represent only themselves. They may rally behind bedouin community leaders to protect their interests. Private investors form the vast majority (76%) of owners of surveyed farms in Zarqa and 49.1% of those in Mafraq (Figure 14 and Table 2).

- **Other farmers:** Farming is not generally the main source of their income. This category includes ex. Government officials and employees, Senior Army retirees, and private sector employees. They are only 4.7% of the owners of surveyed farms in Mafraq and

about 4.0% of those in Zarqa (Figure 14 and Table 2). These farmers often represent only themselves. Other farmers generally accused them of being less compliant to regulation. The RA has found that this category of well owners have also strong opinions, but they claim that they will be the first to comply with government water policy.

One important element to mention is that most farmers have a fairly good education standard. A significant number have university and post high school degrees (stories 1, 2, 21, 26, and 29-35).

- **Ownership and management**

Surveyed farms included those run by owners/tenants; supervised remotely by owners/tenants and managed by professional managers, laborers or sharecroppers.

- **Tenants and sharecroppers:** Around 18.1% of the farms in Mafraq and 6.4% of those in Zarqa are leased (Figure 15). On the other hand, only 2.9% of Mafraq farms and 12.8% of those in Zarqa farms are run in total by sharecroppers. In addition, a significant number of farm owners have only part of their farms sharecropped. Tenants and sharecroppers are mainly seasonal crop growers. They practice extensive farming (story 12) and over-irrigation with the objective of achieving short-term profits, which are often marginal.

- **Owners/managers:** There are two types of owner's farm management: 1) on farm management and 2) remote management. Agricultural engineers often manage modern farms, which are remotely controlled by owners. While foreign laborers often manage remotely controlled traditional farms. Around 55.2% of Mafraq farms and 42.6% of those in Zarqa are on farm managed (Figure 16 and Table 2). The higher percentage for Mafraq is due to the fact that local Bedouins own nearly half of the farms in the northern Badia while the majority of farm owners in Zarqa Governorate live in Amman. This also explains the lower percentage of remotely managed farms in Mafraq, which is 26.7% versus 51% in Zarqa (Figure 16 and Table 2).

- **Hallabat Cooperative Society:** This society operates as a water users association. It owns a farm with a total area of 400 dunums and a 150 m deep groundwater well. There are ten farmers in the society; each one owns a share of 40 Dunums. Well and pump operation and maintenance costs are shared according to the size of cropped area. Members of the society have the right to lease their farm shares or water right either to another shareholder or any outsider.

5.3.3 Labor Statistics

Agricultural sector in the highlands employs a fairly large number of local laborers, especially female (Table 3). Local females form the majority of the seasonal working force and their wages constitute in many cases a significant part of the income of thousands of families. On the other hand, the majority of permanent labors are foreign, draining hard

currency (story 5). Statistics of farming laborers in AZ highlands surveyed farms are as follows:

- 4479 laborers with 1182 in Zarqa and 3297 in Mafraq. Around 26.6% of total laborers in Zarqa area are permanent and 73.4% temporary or seasonal, while in Mafraq 18% are permanent and 82% temporary (Figure 17).
- 67% of Zarqa and 72.2% of Mafraq permanent labor is foreign.
- 60.7% of Zarqa and 93% of Mafraq temporary labor is local.

Most of the permanent laborers are male whereas females constitute the majority of the temporary labor. Females represent around 53.7% of Zarqa and 74.1% of Mafraq agricultural total labor force.

5.3.4 Cropping Patterns

Preliminary 1999 crop data (Table 4) obtained from this survey indicates that olives are by far the most predominant crop in AZB highlands. Figure 18 shows that olives cover 35.5% and 54.5% of the total crops (seasonal and permanent) in Mafraq and Zarqa, respectively. While figure 19 indicates that tomatoes are the second predominant crop in Mafraq (18.1%), followed by melon (9.1%), apple (8.4%), peaches (7.2%), and cauliflower/cabbage (5.7%). On the hand, the second important crop in Zarqa is apple (7.3%), then peaches (4.8%), tomatoes (4.6%), Alfalfa (4.5%), barley (4.1%), and cauliflower (3.2%). Tree crops represent 58.6% of total crops in Mafraq and 69.7% in Zarqa, versus 38.7% in Mafraq and 20.8% in Zarqa for vegetables, including melon. Cereals and fodder grass cover, respectively, only 2.6% and 0.1% in Mafraq versus 5.0% and 4.5% in Zarqa. Note that except for olive trees, most nut and deciduous trees in AZB highlands begin to significantly lose productivity at the age of seven to ten years.

5.3.5 Water Metering and Estimation of Irrigation Water Use

The majority of wells, 94% in Zarqa and 85% in Mafraq, are metered. Only 60.8% and 53.8% of the meters are working in Zarqa and Mafraq, respectively (Figure 20 and Table 5). This indicates that water meters data need to be supplemented by other water abstraction estimation methods.

Two alternative methods for estimation of irrigation water use are used in this survey. The first based on pumping rate in m^3/hour and total hours of irrigation for each month, and the second based on number of hours of irrigation for each crop and pumping rate. A third alternative, for the electrical-pumped wells, is based on electrical energy consumption data from National Electricity Company, lifting head, and pump characteristics.

Data from the three alternative methods will be analyzed and validated using crop water requirement and cropped area to:

- Obtain reliable estimates of irrigation water use,
- Monitor groundwater use at each farm and possible for each crop, and
- Assess the reliability of water meters.

5.3.6 Pumping cost

Preliminary findings from field data indicate that pumping cost varies from 35 to 130 fils/m^3 with an average of 78 fils/m^3 for diesel and from 30 to around 100 fils/m^3 for electricity with an average of 62 fils/m^3 (Table 6). These figures will be finalized once reliable estimates of groundwater pumping are obtained. Around 58% of farmers are using electrical pumps with 70.6% in Mafraq and 42.6% in Zarqa (Figure 21).

As stated earlier the high pumping cost is mainly due to high depth of water table. The energy bill for most farms exceeds JD 12,000 and reaches up to JD 30,000.

5.3.7 Irrigation Methods and Irrigation efficiency

Drip irrigation (Picture 6) for vegetables and trees and mini-basin irrigation (Picture 7), exclusively for trees, are the main irrigation methods used in AZB highlands. Other irrigation techniques such as flood and furrow are used in a very limited number of farms. In an effort to reduce pumping cost, by reducing water consumption, some modern farms started using a local water saving method, based on reduction of soil evaporation by covering tree bases with a mulch of volcanic tuff (Picture 8). However, RA field visits revealed that despite the widespread use of drip irrigation most farmers are not using adequately this modern irrigation method. Once the drip irrigation system is installed by vendors, most farmers are left alone with little knowledge (story 11) about its efficient use. Agricultural extension services are absent in AZB highlands. As a result, irrigation water loss is expected to be high. Farmers are willing to be better informed about water conservation methods (stories 1, 11, 13, and 14). Nearly all of them, 97.9% in Mafraq and 100% in Zarqa (Figure 22 and Table 8), are in favor of the establishment of an Irrigation Advisory Service.

An international irrigation extension specialist conducted an evaluation of the potential of an IAS program in the Highlands of AZB in August 2000, to assist farmers in improving irrigation water efficiency. Data on groundwater pumping and field observation suggest that in many cases, considerable over-irrigation is occurring (Picture 9 and stories 12 and 23). The evaluation activity has confirmed that farmers have little knowledge about the performance characteristics of their irrigation systems (IAS report, August 2000), and recommended that a pilot extension scheme be initiated in a limited area, to test the feasibility of establishing an irrigation advisory service. The August field visit was also an opportunity to involve farm owners in the evaluation of their irrigation systems (Picture 10), as part of the participatory management of AZB groundwater. Farmers were very much interested in the outcome of the

evaluation, five (5) of them volunteered to offer experimental sites for a potential IAS pilot program.

5.3.8 Farmers Ideas and Suggestions

The main farmers' ideas and suggestions, related to AZB groundwater management, are summarized and classified in four categories:

- **Management options**

- Stop illegal drilling and illegal water sale
- Metering is not an effective management tool
- Water charges are not generally accepted
- Restrict cropping area to licensed farm area
- Gradual reduction of cropping areas, proportional to current well yield
- Develop and implement a restricted cropping patterns program, under conditions of more restructured marketing
- Start negotiation with Syria about the management of AZB shared groundwater system

- **Incentives and Compensations**

- Groundwater management incentives, including IAS
- Fair compensation to farmers willing to sell out

- **Management Instrument and considerations**

- Form stakeholder groundwater management committee
- Consider socio-economic aspects of any management action
- Actions should be implemented by all users

- **Alternative Resources**

- Recycled water is accepted by a majority of Zarqa farmers, if its quality complies with international standards, but generally rejected in North Badia
- Develop water harvesting

Management options

Illegal drilling and Illegal water sale

According to MWI sources, illegal wells represent around only one percent (1%) of total irrigation wells. The low rate is mainly due to risk of losing (high capital cost) deep highlands' wells as a result of well closure. Both illegal drilling and illegal water sale are being monitored and enforced by the newly established MWI water security unit. The total illegally drilled wells, in other basins, exceeds 500. This issue has been a major concern of MWI, the parliament, and the irrigation committee of the Economic Consultative Council.

Metering and water use charges

Most farmers claim that water metering is not a reliable tool for monitoring and control of groundwater pumping, especially when water charges are applied (story 6). Due to high pumping costs, only 8.7% of Zarqa farmers and 14.7% of Mafraq farmers accept water abstraction charges (Figure 22 and Table 7). Some farmers think that water charges are a form of taxation rather than a groundwater pumping reduction tool (story 33). Others state that water charges will have negative impacts on the agricultural sector (story 21).

The higher rate of water charge acceptance in Mafraq is due to high water use return due to the availability of good quality water in the area. One farmer in this area, who is enjoying this luxury, is ready to pay up to 200 Fils/ m^3 (story 25).

Reduction of Cropping Area

Most farmers agree with the reduction of cropping area as a measure for groundwater pumping curtailment. They suggested first restricting cropping area to the licensed farm area. Then, apply a reduction to licensed areas. This reduction should be proportional to current well yield. Reduction of cropped area is easier for vegetable farms. For trees, the reduction should be gradual due to high investment in starting tree farms and losses incurred in removing productive trees.

Monitoring of cropped area can be done on a seasonal basis via remote sensing. The preliminary results of the August 1999 classification also indicated that remote sensing could be used as a monitoring tool for irrigated crop area and, therefore groundwater abstraction changes (Remote Sensing report, October 2000). These results will be verified and validated after classification of 1998 scenes.

Cropping Patterns and Marketing

Cropping patterns and marketing are some of the major concerns of all farmers. The current cropping system was developed around exporting a large part of the vegetable and fruits to Gulf countries. Farmers claim that significant reductions of exports to the latter countries, coupled with inadequate local marketing resulted in high financial losses. They suggest the

application of a restricted cropping patterns program in accordance with local demand and export needs, under conditions of more structured marketing.

An analysis of current cropping patterns and marketing will be tackled in the socio-economical analysis of agricultural use, activity I.4 of the groundwater management work plan.

Management of Shared Water Resources

Well owners near the Syrian border state that groundwater development is recent, but has been increasing in the Syrian side with participation of some Jordanian sharecroppers, who moved their operation to the Syrian side after the deterioration of water quality and ban on drilling in the Jordanian side. Jordanian well owners call for negotiation with Syria about the management of the AZB shared groundwater system.

Incentives and Compensations

Many owners of traditional farms have financial difficulties due to low returns, inadequate marketing system, and inability to pay debts. Around half of interviewed owners have suggested selling their wells to the government and are asking for fair compensation. Farmers are also suggesting rescheduling of farm loans and minimizing interests as groundwater management incentives. It is worth mentioning that a limited number of owners have already sold their farms to modern local farmers or foreign investors.

Irrigation Advisory Services would also be an incentive to assist farmers in improving water efficiency and increasing profitability.

Management Instruments and considerations

Groundwater Management Committee

The RA achieved one of its main objectives by initiating and supporting participation of well owners in groundwater management discussions. During group meetings community leaders were fully convinced that reduction of groundwater over-pumping needs to be tackled in a participatory manner. One of these leaders stated that " A committee representing all concerned stakeholders should be formed and solutions need to be sought before it is too late"(story 33). Another leader mentioned that "Now we have negotiating cards, but later we may have nothing and we will loose everything, if the aquifer is depleted".

The survey indicates that around 65.2% of Zarqa farm owners and 89.7% of those in Mafraq (Figure 22 and Table 7) accepted the idea of a groundwater management committee and many volunteered to be part of it. These owners stressed that the committee should be representative of the farming community.

Socio-Economical Aspects

The government development program and private sector investments in AZB highlands are built mainly around irrigated agriculture, as mentioned in the background section. Groundwater management has a direct impact on the social and economical development in the area. Farmers stressed that any groundwater management option should consider the socio-economical impacts. RA team explained to well owners that socio-economic data collected during the survey will be complemented by additional data from other sources to carry out socio-economic analysis of groundwater management options. Results of this analysis will assist the selection of appropriate management actions.

Alternative Resources

Water Quality and Recycled Wastewater Use

Water quantity decline and quality deterioration, as shown in Figures 7 to 9, is becoming a worry for farmers in the southeast part of the basin. Almost all farms (95.7%) in Zarqa and 38.2% of those in Mafraq area have water quality and/or quantity problems (Figure 22 and Table 7). As a result around 65.2% of Zarqa farms are willing to use recycled wastewater instead of groundwater, but only if the quality of recycled water complies with the international standards, fits for major crops and will not result in reduction of yield and farm revenue. On the other hand, the majority (88.2%) of farmers in the North Badia are against exchanging groundwater with recycled water. They claim that the use of AS Samra recycled water in the western part of AZB, downstream of As Samra WWTP, is the one of the main reasons for loosing the Gulf Market in early 1990s (story 32). Note the 33.8% shown in figure 22 concerns all surveyed wells in AZB and located within Mafraq Governorate, which includes farms north and east of As-Samra. These wells have low water quality, and the majority of their owners are in favor of using recycled water, under the same conditions stated above by Zarqa farmers. Analysis of alternative options, for recycled water reuse in the AZB highlands, is being conducted by the Water Reuse component team, as part of the WRPS Task Order.

Water Harvesting

Water harvesting came up during discussions with well owners. Some went back to the Nebatian era where rainfall and runoff harvesting were successfully practiced in desert areas such as the Badia (story 30). A farmer showed us his own private small recharge dam (Picture 11). Many farmers think that the construction of harvesting and recharge schemes are the solution to water over-abstraction in the area. The RA team answer is that those schemes may increase local direct recharge in the vicinity of the recharge structures by 5 %, which is insignificant when compared to an over-abstraction over the whole AZB basin approaching 100%. In addition runoff and flood flow retention in the highlands will reduce downstream surface storage at King Talal Reservoir (KTR). Current water harvesting research work at Al Beit University and the Dutch proposed recharge pilot program in Wadi Madona would assist in evaluating the feasibility of water harvesting in the area.

6. SUMMARY AND RECOMMENDATIONS

6.1 Summary

This report described groundwater development in the northeastern highlands of Amman-Zarqa Bazin (AZB) and presents the main findings of the Rapid Appraisal (RA) field survey of groundwater use and users, and related studies. The survey achieved its principle objectives, by defining the profile of the users, initiating discussions about management of groundwater resources in the area, exploring practical options for reduction of water use in irrigated agriculture, and gathering data for the assessment of socioeconomic impacts of these options.

Field interviews were completed for 155 farms and 170 wells. Groundwater management interviews were successfully completed for 80 owners and eight small group meetings with community leaders and farm owners. This high level of participation was considered unlikely at the beginning of the survey, and reflects the interest of farmers in future decisions related to groundwater management in the AZB highlands. The RA gave an opportunity to farmers to express their concerns and voice their opinions, as illustrated in the 35 short stories detailed in Appendix 3. The RA also presented valuable insight information to MWI decision makers, and opened doors to a collective effort in saving AZB groundwater resources.

The RA field visits revealed that farms in the uplands are relatively large and are very capital intensive. A very limited number of farmers are making a decent profit. Nearly 50% of interviewed farmers have marginal income, and therefore financial difficulties, and are willing to sell out. Few farmers have abandoned their properties.

Farm ownership started with mainly Bedouins, since irrigated agriculture was developed to provide them with a reliable source of income. Some of the bedouins sold their properties right after they got their well licenses. Others drilled their wells and sold their farms after failing to survive in the business. As a result, the pattern of farm ownership has shifted to private investors from outside the area, who own around 49% of surveyed Mafraq farms and 76% of those in Zarqa.

Bedouins, represented by their community leaders, have shown willingness to cooperate and be part of the management process. Most investors represent only themselves and may rally behind bedouin community leaders or influential well owners depending on their interests.

Trees cover around 60% and 70% of the cropped area in surveyed farms, respectively, in Mafraq and Zarqa. Olives are progressively replacing old fruit trees due to the fact that fruit trees are labor and capital intensive. As a result olives are becoming the predominant crop tree in the area, representing roughly 35% and 55% of total tree crops in Mafraq and Zarqa, respectively.

Most farmers would accept water use reductions based on reduction of cropped area. Reduction of cropped area is possible for vegetable farms, but more difficult for tree farms since they constitute a high investment, and removal of productive trees may engender significant financial losses.

One important element of the social aspects is that the irrigated agricultural sector in AZB highlands employs a fairly large number of local labors, especially females. Local females form the majority of seasonal working force. They represent around 54% and 74% of total irrigated farming labor in Zarqa and Mafraq, respectively. Female labor wages constitute in many cases a significant part of the income of thousands of families. As a result socio-economic impacts on local laborers should be a significant part of the AZB groundwater management equation.

Water charges are not accepted by around 85% and 91% of Mafraq and Zarqa well owners, respectively. On the other hand, 65% of Zarqa farmers are willing to exchange groundwater with recycled wastewater. However, preliminary analysis conducted by the Water Resource Policy Support (WRPS) groundwater reuse component shows that transfer of As Samra recycled wastewater to Dulayl and Mafraq is not economically viable.

Following the RA work the groundwater management team has been working on technical and legal assessment activities and is starting two socio-economic analyses in January 2001 to evaluate impacts of irrigation water use and over-pumping, to support screening of groundwater management options. The technical and legal activities include:

- Field evaluation of irrigation practices was conducted in August 2000 by Dr. Blane Hanson, irrigation extension specialist at the University of California Davis. It has confirmed over-irrigation in AZB highlands and found that farmers have little knowledge about the performance characteristics of their irrigation systems. As a result irrigation advisory services are highly recommended.

- Groundwater Modeling is underway to evaluate impacts of various management scenarios on groundwater level and salinity in AZB highland groundwater aquifers. Results of this model will be used to evaluate the socio-economical effects of over-pumping and other management options.

- Estimation of cropped area via remote sensing (RS) and quantification of applied water in AZB highlands agricultural sector to quantify abstraction and irrigation efficiency. This work started October 2000 and will be completed March 2001.

- Evaluation of compatibility of proposed actions with water use regulations, which started in November 2000, is near completion.

In addition to MWI/ARD groundwater management efforts, it is worth mentioning that 24 parliament deputies decided in September 2000 to hand a petition to the House speaker asking the government to take decisive measures against private water well abusers. On the

other hand, the Economic Consultative Council's (ECC) irrigated agriculture committee is discussing ways to stop illegal drilling and reducing groundwater over-pumping, but admits problems in implementation some of the measures.

6.2 AZB Highlands Groundwater Management Recommendations

This section presents ARD groundwater management team's ideas and recommendations about reduction of groundwater use in AZB highlands, which include:

- Groundwater use reduction options
- Illegal drilling and Illegal Water Sale
- Crop patterns and marketing
- Management of AZB shared groundwater system
- Creation of AZB Groundwater Management Fund
- Formation of Groundwater Management Committee
- Monitoring support

6.2.1 Groundwater use reduction options

The following practical actions are discussed:

- Irrigation Advisory
- Wells buy-out
- Reduction of abstraction by limiting annual abstraction or limiting cropped area
- Exchange of groundwater with recycled water
- M&I pumping reduction

Irrigation Advisory

- Priority: Irrigation advisory is a first priority option. It is intended to increase irrigation efficiency by reducing over-irrigation, and therefore reducing over-pumping.

- Estimated reduction: Jordan Valley Irrigation Advisory Service (IAS) results indicate that water consumption at the farm level can be reduced by an average of 20% (JVA/USAID, 2000). Based on these results, the potential reduction of applied irrigation water in AZB highlands may reach 12 MCM, considering 63 MCM irrigation water use in AZB highlands (1998 MWI, Database). Preliminary assessment of metering data indicates a higher value of irrigation water abstraction in AZB highlands, and therefore higher potential irrigation water saving which may reach 15 MCM, assuming no well buy out and no crop area reduction. However, despite the IAS request by almost all farmers, it is expected that few farmers won't apply IAS recommendations. A 10 MCM reduction via IAS seems to be more realistic. If 25% to 30% of irrigation wells are bought out and 30% of remaining cropped area reduction is achieved, the IAS saving will be limited to around 5 MCM.

- Expected Benefits: For an average pumping of 140,000 m^3/year/irrigation well, as per 1998 MWI abstraction data, and an average pumping energy cost of 70 Fils/m^3, 20% reduction corresponds to an energy saving cost of approximately JD2,000/well/year. In addition, reduction of over-irrigation may increase yield. Thus, IAS is a viable incentive based groundwater management tool, which assists farmers in reducing energy cost and increasing profitability.

- Implementation: IAS or irrigation extension is not specifically stated in WAJ or Ministry of Agriculture (MOA) Laws or regulations. Note that the MOA role in highlands agriculture extension is quasi-absent; this makes it difficult to conduct other extension services such as IAS. It is therefore recommended that IAS should be developed with the support of the private sector in association with water users. Discussions with drip irrigation equipment vendors in the highlands indicate that they are interested in being part of the IAS activity.

- Proposed actions: A note on development of IAS pilot project in AZB highlands will be prepared in February 2001.

Wells buy-out

- Priority: This is a high priority option since around 50% of interviewed irrigation well owners suggested selling out their wells. This offers a tangible groundwater use reduction option.

- Reduction: Assuming only around 25% to 33% of well owners will sell out, which corresponds roughly to a reduction of around 15 MCM to 20 MCM.

- Expected Benefits: Since current Municipal and Industrial (M&I) abstraction is already approaching the safe yield of AZB highlands aquifers, it is recommended that wells buy-out should not be used as a mean of transferring irrigation water use to Municipal and Industrial (M&I) water supply. This reduction is intended to conserve and protect AZB highlands' aquifers, and assist durability of Municipal and Industrial (M&I) water supply from groundwater from these aquifers. Buy-out cost should be added to current cost of M&I supply from AZB basalt/B2-A7 aquifers.

- Implementation: According to groundwater bylaw WAJ has the authority to buy-out private wells, based on the fact that water resources conservation is a national priority that serves the public interest.

- Proposed actions: Economic Feasibility and estimation of compensation for irrigation wells buy-out will be addressed in the socio-economic study, which starts in January 2001.

Reduction of abstraction by limiting annual abstraction or limiting cropped area

- ***Limiting annual abstraction***

- Priority: This is a first priority option and also a highly political option.
- Current situation: Abstraction quotas or upper limits of 50,000 m^3/year, 75,000 m^3/year, and 100,000 m^3/year are imposed on irrigation well licenses issued by the Water Authority of Jordan (WAJ) after 1984, but have not been enforced. Older licenses issued by the Natural Resources Authority (NRA) have no abstraction limit.

- Reduction: The enforcement of an abstraction limit of 75,000 m^3/year/well would correspond to 46% reduction of total irrigation water use, given that current mean abstraction is around 140,000 m^3/year as stated earlier. Similarly, the enforcement of an upper abstraction quota of 100,000 m^3/year/well would lead to a 30% reduction of total irrigation water use. The 30% and 46% reductions would be equivalent to a reduction of around 20 MCM to 30 MCM in AZB highlands irrigation water use, which is currently around 63 MCM/year. If 25% to 30% of farms are bought out and a 5 MCM reduction is achieved via IAS the total reduction due to limitations of well abstraction will decrease to12-18 MCM. This will further decrease to 10-15 MCM if 20% of farmers surpass abstraction limits and pay extra water charges. The latter percentage is expected to decrease with increases of water charges.

- Expected benefits: Conserve and protect AZB highlands' aquifers, and assist durability of Municipal and Industrial (M&I) water supply from groundwater from these aquifers. This relatively significant reduction of abstraction will lead to a decrease of cropped areas and therefore a decrease of agricultural production, which in turn may increase the price of produce, especially at the local market.

- Implementation: Gradual reduction, spread over a period of three (3) years for seasonal crop farms and five (5) years for tree farms, is recommended. The enforcement of limitation of abstraction quota Incentives based on well metering is a challenging task. Recommendations about monitoring of abstraction are described hereafter. Incentives should be provided to those who comply with the regulated abstraction quota and extra charges or penalties should be applied to those who do not respect the quota. Ideas about generation of financial incentives are described hereafter.

- Proposed actions: Feasibility and socio-economic impacts of abstraction reduction and water charge scenarios will be addressed in the socio-economic study, which starts in January 2001. Results of various scenarios will be presented to AZB Groundwater Management Consultative Committee (GMCC), which is described hereafter in section 6.2.6 and Appendix 4, to support practical and informed decisions toward implementing abstraction reduction.

- ***Limiting cropped area***

Farmers have suggested this option as an alternative to limitation of abstraction quota. Abstraction reduction in this case is based on reduction of cropped area.

- Priority: This is a first priority option and also a highly political option.
- Reduction: 100 and 200 dunums are acceptable upper size limits of seasonal crop farm and tree farm, respectively. This corresponds to 50% reduction of cropped area, given that current average size farm in highlands is around 200 and 400 dunums for vegetable and tree farms, respectively. Only around 20% to 35% crop area reduction, from those 70% of farms remaining after buy-out, corresponds to a 15% to 25% reduction of current total cropped area, and therefore an abstraction reduction of around 10 MCM to 15 MCM.

- Expected benefits: Conserve and protect AZB highlands' aquifers, and assist durability of Municipal and Industrial (M&I) water supply from groundwater from these aquifers. This level of cropped area reduction, ranging between 15% and 25% of total irrigated area, will lead to a decrease of agricultural production, which in turn may increase the price of these produce, especially at the local market.

- Implementation: Gradual reduction, spread over a period of three (3) years for seasonal crop farms and five (5) years for tree farms, is recommended. Crop area reduction has been added as a water management option in the recently drafted MWI groundwater bylaw. More details about the legal aspects of crop water reduction will be presented in the study consisting of legal evaluation of groundwater management recommendations, which is near completion. Incentives should be provided to insure implementation of this option and charges/penalties should be applied to those who do not comply. Ideas about generation of financial incentives are described hereafter.

- Proposed actions: Feasibility and socio-economic impacts of various scenarios of cropped area reduction will be addressed in the socio-economic study, which starts in January 2001. Results of various scenarios will be presented to AZB Groundwater Management Consultative Committee to support practical and informed decisions toward implementing crop area reduction.

Exchange Groundwater with Recycled Water

- Priority: Exchange of part of groundwater use in highlands irrigated agriculture with recycled water from As Samra is a high priority option, which is being addressed by the Water Reuse Component of the WRPS project.

- Reduction: Three highland irrigation project options have been considered totaling around 20 MCM, which could potentially replace 20 MCM of currently pumped groundwater.

- Expected benefits: Provide highlands irrigated agriculture with an alternative water supply, conserve AZB highlands' aquifers, and assist durability of Municipal and Industrial (M&I) water supply from groundwater from these aquifers.

- Preliminary Results: The preliminary economic feasibility study carried out by Dr. Willis Shaner (Water Reuse Component, Dec. 2000) shows that it would not be economically viable to use recycled water from As Samra in AZB highlands if farmers pay for capital or operating costs of water conveyance. However, economic viability would also depend upon both the value placed on conserved groundwater in the highlands and upon the costs of disposing of the effluent downstream.

- Proposed actions: 1) If other additional recycled water reuse irrigation areas, outside the highland area, are found to be economically viable, we recommend moving part of the seasonal crop activity from highlands to these areas. Note that most seasonal crop farms in the highlands have no significant infrastructure and are mainly run by sharecroppers who move from one farm to another. Their move will be analyzed in the socio-economic study, which starts in January 2001. 2) Results of the above highlands irrigation options will also be compared to the value placed on groundwater conservation in highlands.

M&I pumping reduction

- Priority: This is a second priority option

- Reduction: Current efforts by WAJ and LEMA to reduce leakage, the physical component of Unaccounted for Water (UFW), should be reflected in reduction of abstraction in highly over-exploited groundwater basins such as Amman Zarqa. According to specialists of the UFW project, UFW due to leakage or physical losses is approximately 30% in Greater Amman and 35% in Zarqa (WAJ/JICA, 2001). M&I groundwater abstraction from AZB basalt/ B2-A7 system is around 58.5 MCM. The reduction of physical losses to the 15% target, via rehabilitation of the water supply network, as indicated in JICA water resources management study (October, 2000) would correspond to saving an equivalent of 10 MCM from the current basalt/B2-A7 abstraction. A reduction of 5 MCM is an expected minimum. Additional reduction might be possible with construction of Al Wehda dam and Disi projects.

- Expected benefits: Conserve and protect AZB highlands' aquifers, and assist durability of Municipal and Industrial (M&I) water supply from groundwater from these aquifers.

- Implementation: Gradual reduction, spread over a period of five (5) to ten (10) years, according to achievement of reduction of UFW. Full reduction of 5 MCM to10 MCM should be achieved by 2010.

- Proposed actions: Feasibility of other scenarios of M&I reduction will be addressed in the groundwater modeling and socio-economic studies, which starts in January 2001. Results

of various scenarios will be presented to AZB Groundwater Management Consultative Committee (GMCC) to support practical and informed decisions toward implementing M&I pumping reduction.

6.2.2 Illegal drilling and Illegal Water Sale

- Priority: This is a first priority option

- Current situation: Illegal drilling in AZB is very limited, for the reason indicated in section 5.3.8; however illegal water sale was noticed during RA field visit.

- Proposed Actions: Illegal drilling should be enforced. Illegal water sale needs to be identified and also stopped. Private water sale for irrigated agriculture need to disallowed. The ban on new well permits for irrigated agriculture should be enforced. Further details about these actions will be presented in the legal aspects activity, which is near completion, as stated earlier.

6.2.3 Crop patterns and marketing

- Current situation: More than 60% of crops are trees with around 40% olives. Vegetable crops are limited to a few traditional crops such as tomatoes, water melon, and cabbage/coliflowers. Vegetable production, especially tomatoes, is in surplus and therefore often sold at noneconomical prices. There is a clear tendency towards replacing fruit trees with olives. The local marketing system is traditional and the export market is limited, especially after reduction of export to Gulf region. Export of high water consumption and marginal value crops such as tomatoes means noneconomical export of virtual water.

- Responsibility: MOA, NCARTT for cropping patterns; MOA and private sector for marketing

- Recommendations and proposed actions: The effectiveness of mandatory cropping patterns is questionable and their implementation is difficult, and therefore it is not to be recommended as a groundwater management instrument. Both socioeconomic studies, planned during January-April 2001 will tackle the following aspects: Identification of low water consumption/high value crops, assessment current trends on moving towards olives, analysis of current marketing, export, and impact of free trade on marketing.

6.2.4 Management of AZB shared groundwater system

- Current situation: Groundwater development in the Syrian side of AZB is recent and has been increasing with participation of Jordanian sharecroppers , who moved their operation to the Syrian side, as indicated in section 5.3.8

- Proposed Actions: monitor groundwater development in the Syrian side and prepare for negotiotiation with Syrian, before a critical level of groundwater development is reached. Remote sensing is recommended as a monitoring tool for current and future groundwater development.

6.2.5 Creation of AZB Groundwater Management Fund

A groundwater management fund (GMF) is recommended to cover incentives related to implementation of an IAS and reduction of cropped area. This fund can be generated from the following sources:

- Charges applied to those surpassing the allowed cropping area: A charge of JD250 for every additional dunum beyond the allowed cropping area. This charge is equivalent to 250 fils/ m3 or water charge for industrial sector.

- Water conservation fee: this fee should be applied to M&I water consumers as part of their contribution to conserve their main source of supply, AZB groundwater. A proposed amount of this fee is 3% of the water bill for domestic water supply and 5% of the bill for Industries and tourism. This corresponds to around JD240,000/year for domestic water supply and JD50,000/year for industrial water use, assuming 40 MCM billed out of the 72 MCM produced for domestic water supply and 4 MCM billed out of 6 MCM produced for industrial, and 200 fils/ m3 for domestic use versus 250 fils/ m3 for industrial use. These figures will be verified and validated during the upcoming socio-economic studies.

6.2.6 Formation of Groundwater Management Consultative Committee

A groundwater management consultative committee (GMCC) is recommended to review the above suggestions to identify and support groundwater management actions. A note on forming a GMCC is shown in Appendix 4. The recommended groundwater management strategy is based on participation of stakeholders and considers the basin as a management unit. The approach could be replicated to other groundwater basins in the Kingdom. Work on the institutional framework of the recommended groundwater approach is underway. It will be discussed with MWI and stakeholders, and presented in the action plan.

6.2.7 Monitoring of abstraction and monitoring of implementation of groundwater management options

- Current Status: Current monitoring is based on well meter readings and estimation based on crop area and rough applied water per dunum. As stated earlier, the RA field survey has shown that nearly half of meters are malfunctioning and most farmers think that meters are not an adequate method for monitoring because existing meters may be manipulated. Remote sensing has been introduced by the WRPS project as a new technology to monitor cropped area, and therefore monitor abstraction.

- Recommendation: Continue use of well meter readings, to obtain actual measurement of applied water, and supplement well meter readings with remote sensing and electricity data. Remote sensing is recommended for monitoring cropped area and well buy-out, and therefore as a support tool for monitoring the implementation of groundwater management options.

Ongoing and Planned Actions: Work is being conducted on analyzing well metering data for working meters. A field evaluation of well metering system is planned for January-February 2001.

7. CONCLUSION

The Rapid appraisal survey and subsequent assessment work completed so far indicate that groundwater use reduction in Amman Zarqa basin highlands is achievable. Preliminary estimation suggests a potential average annual groundwater abstraction reduction from four proposed options ranging from around 35 MCM to 50 MCM, in addition to that of the option of exchange of groundwater with recycled wastewater, which is under study. The four recommended options are: 1) Irrigation Advisory Service (IAS), which is expected to save 5 MCM to 10 MCM by raising agricultural water use efficiency in AZB highlands' farms, based on results of the Jordan Valley IAS pilot study, 2) Well buy-out is expected to cut abstraction by 15 MCM to 20 MCM, 3) Implementation of abstraction quotas or gradual cropped area reduction, spread over 3 years for vegetables and 5 years for tree crops, would also result in saving around 10 to 15 MCM, and 4) Reduction of Municipal and Industrial Unaccounted for Water (UFW), via rehabilitation of the water supply network, should correspond to a minimum reduction of groundwater abstraction equivalent to 5 MCM. Priority, expected benefits, and implementation of these options are discussed. The above preliminary reduction figures will be fine-tuned in upcoming abstraction and groundwater modeling work. Mandatory cropping patterns are not recommended. Estimation of farm buy-out cost, identification of low water consumption/high value crops, assessment of current trends of progressive increase of olive plantations, analysis of current marketing, export, and impact of free trade on marketing will be addressed in the socioeconomic analysis of agricultural water use which will be conducted during January-April 2001. Groundwater use on the Syria side of Amman-Zarqa basin needs to be remotely monitored. A Groundwater management fund (GMF) is recommended. This fund can be generated from over-abstraction charges from private well owners, a water supply conservation fee from M & I water consumers, and other sources. This fund is intended to cover incentives related to implementation of IAS and reduction of abstraction/cropped area. The recommended groundwater management strategy is based on participation of stakeholders and considers the basin as a management unit. The approach could be replicated to other groundwater basins in the Kingdom. A note on forming a groundwater management consultative committee has been prepared. ARD is currently analyzing the legal and regulatory aspects of these options. Upcoming activities will focus on social, economical, technical, and institutional aspects related to the implementation of each option and idea, including the management fund. These support activities form the basis for the development of the groundwater management implementation action plan.

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3. Hanson R. Blane, Technical Report: Development of Irrigation Advisory Service Program in the Highlands Area, Groundwater Management Component, MWI/ARD WRPS task Order, August 2000
4. MWI/ARD, Hydrogeology of Amman-Zarqa Basin, Draft report, May 2000
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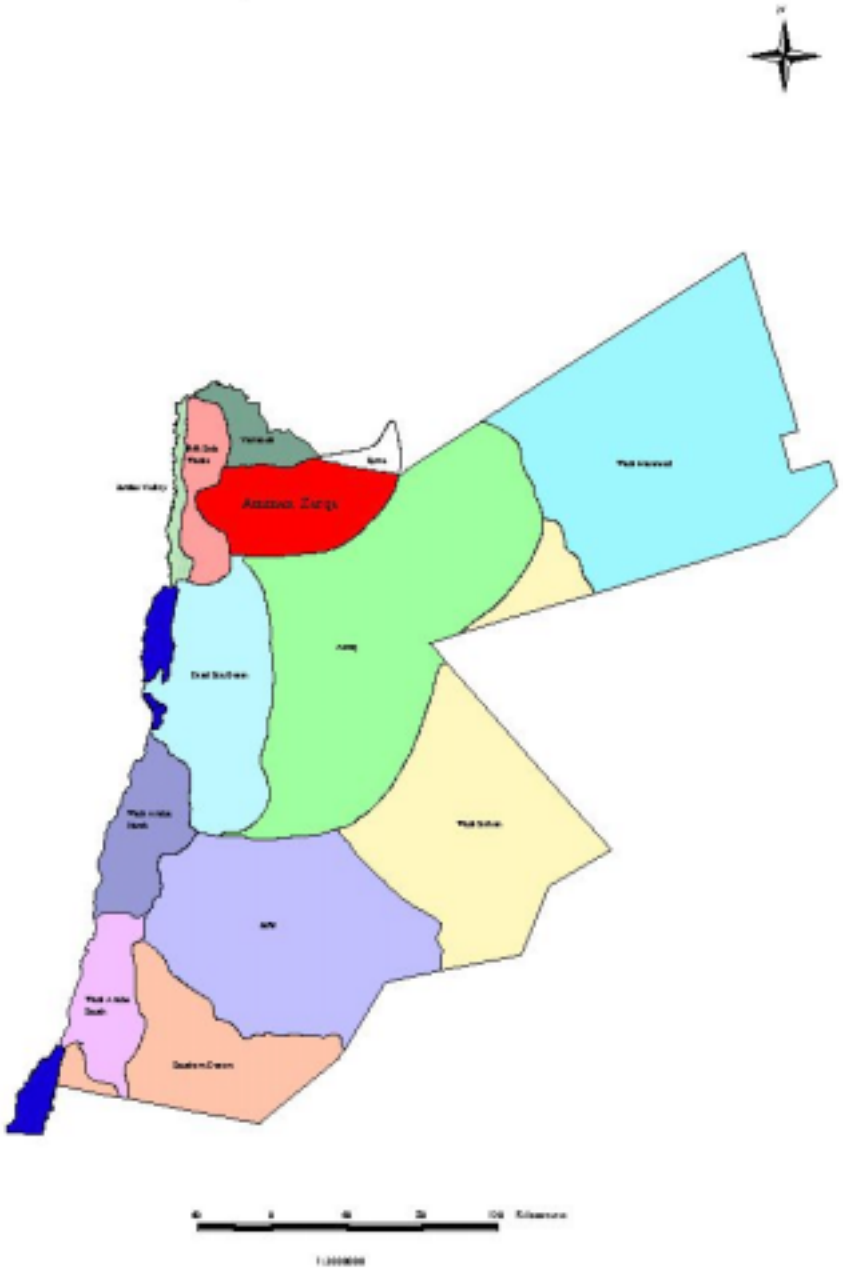
9. Wood Lynnette, Remote Sensing Training and Landsat Image Classification, Groundwater Management Component, MWI/ARD Water Resource Policy Support, October 2000

Figures

Figure 1 : Groundwater Basins in Jordan



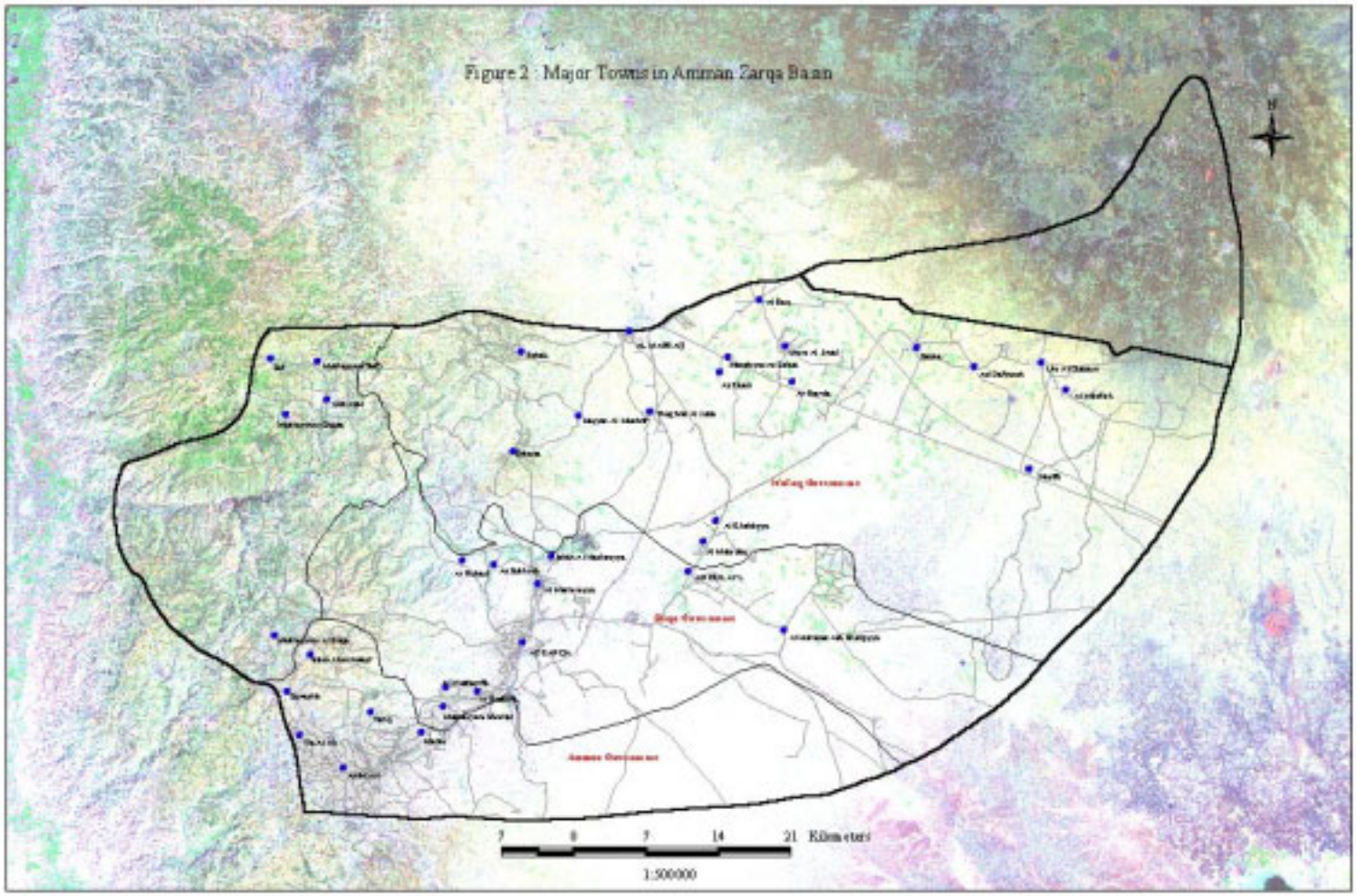


Figure 2 : Major Towns in Amman Zarqa Basin
N
7 0 7 14 21 Kilometers
1:500000

[redacted]

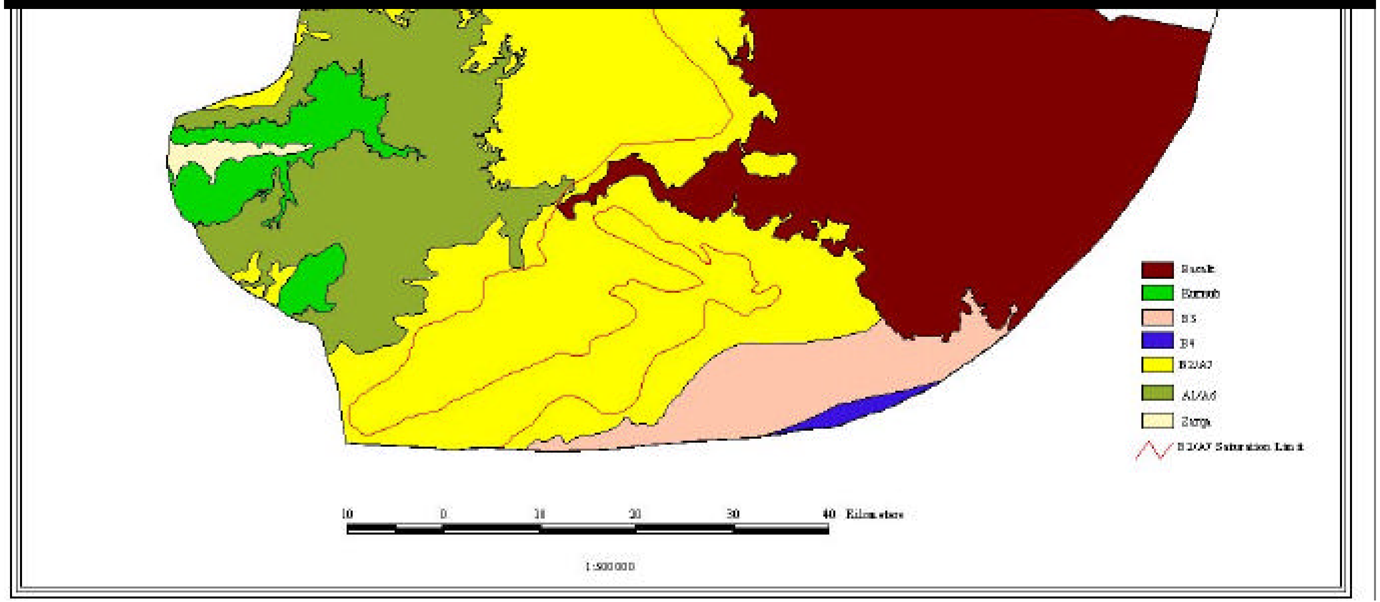

Basalt
B5
B4
B2/A7
A1/A6
Zarqa
B2/A7 Saturation Limit
10 0 10 20 30 40 Kilometers
1:500000

Figure 4: Historical and Spatial Distribution of Production Wells in the Northeastern AZB Highlands 1965-1998

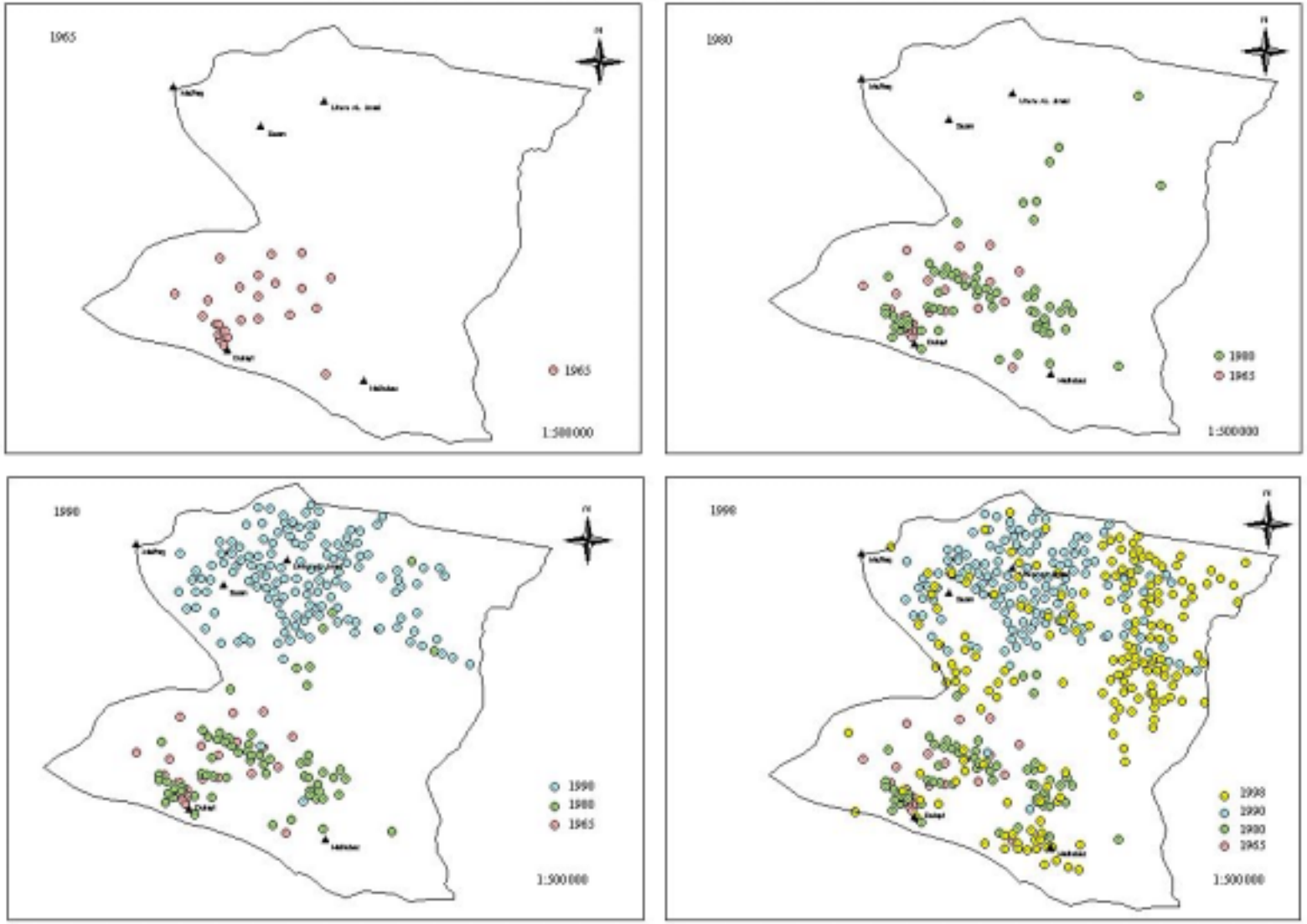
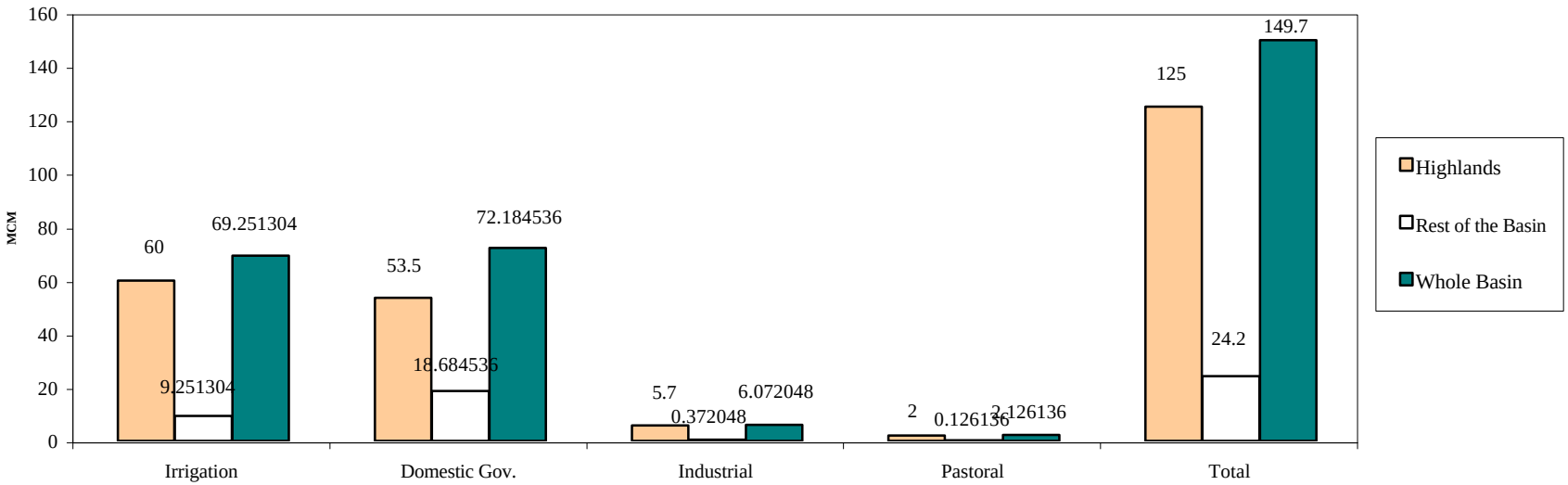
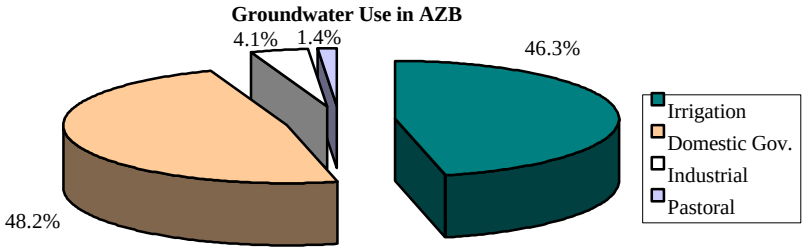
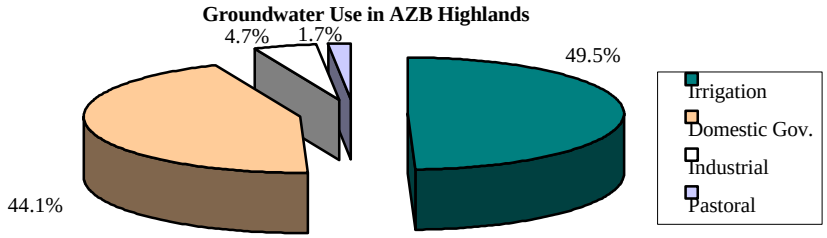


Figure 5 : Groundwater Use in Amman Zarqa Basin in 1998







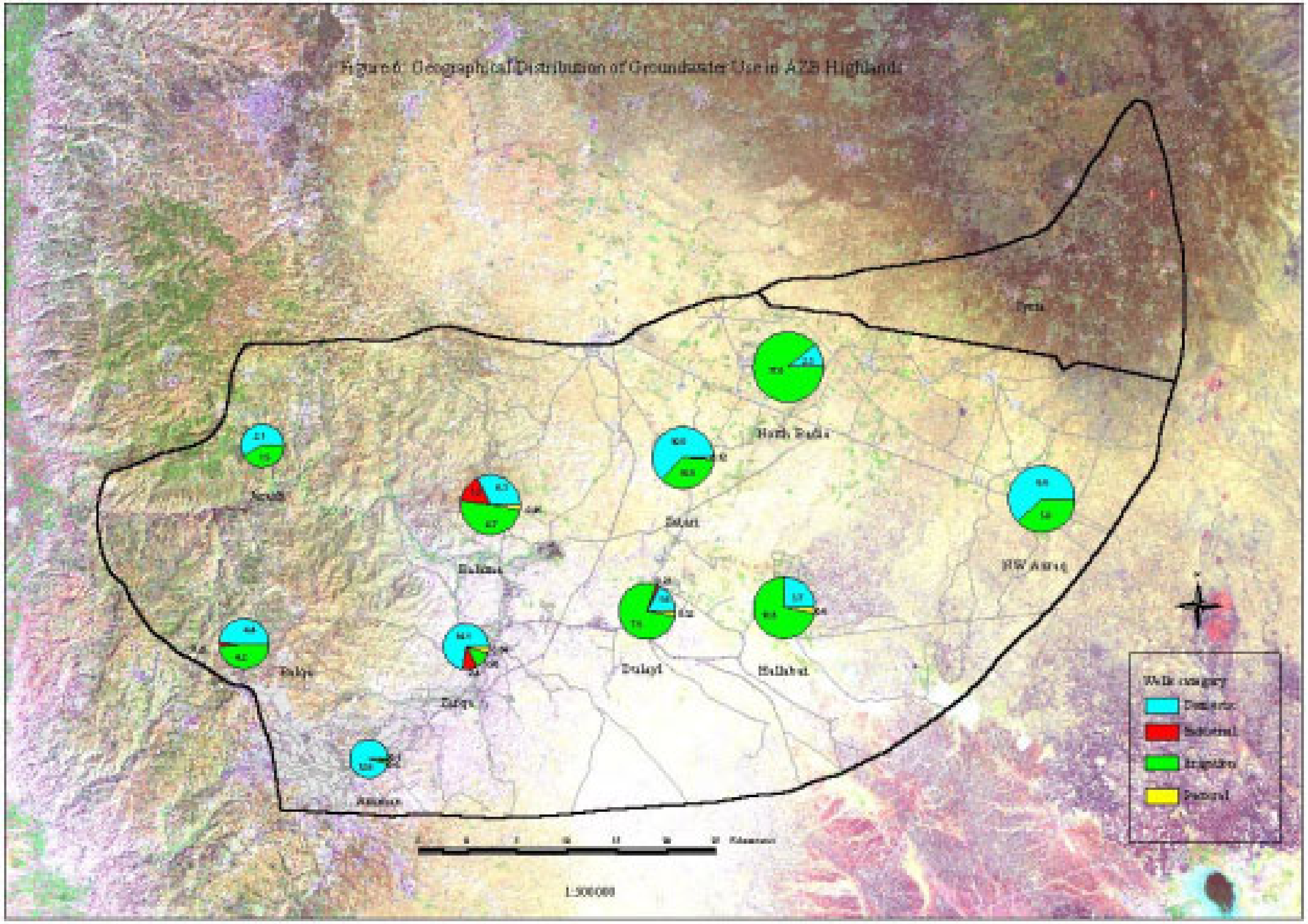


Figure 6: Geographical Distribution of Groundwater Use in AZB Highlands

Figure 7: Static Water Level Dulayl Area, Well AL1041

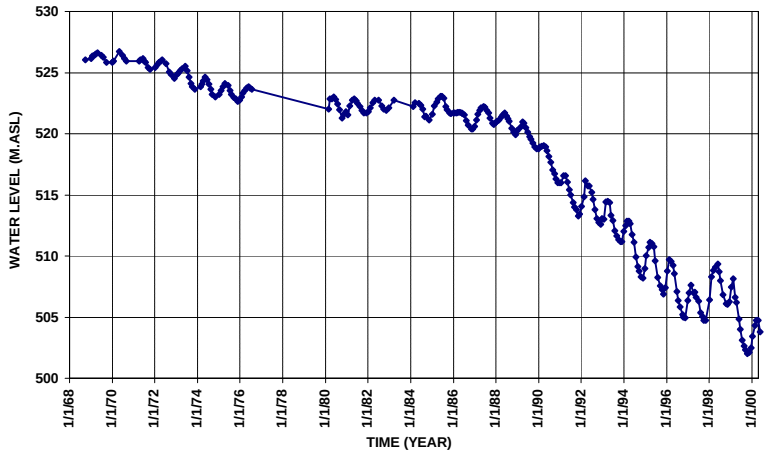


Figure 8: Water Quality Dulayl Area, Well AL1076

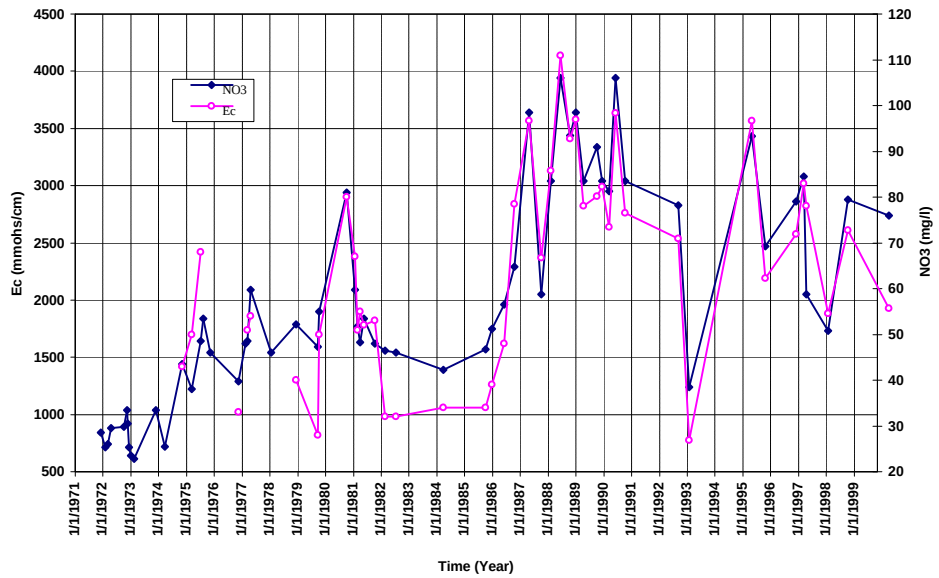


Figure 9: Static Water Level Umm Jimal, North Badia, Well AL1521

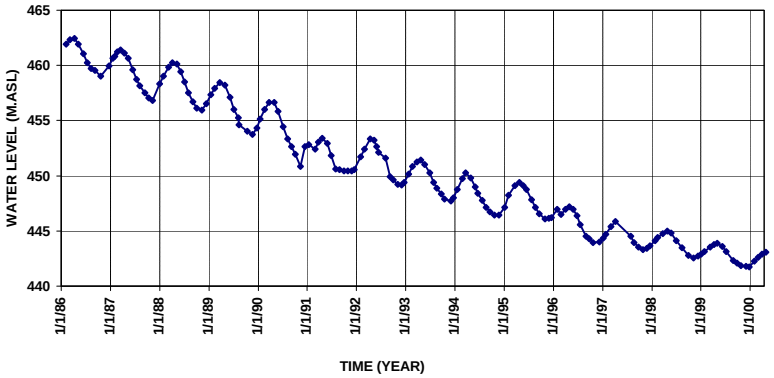
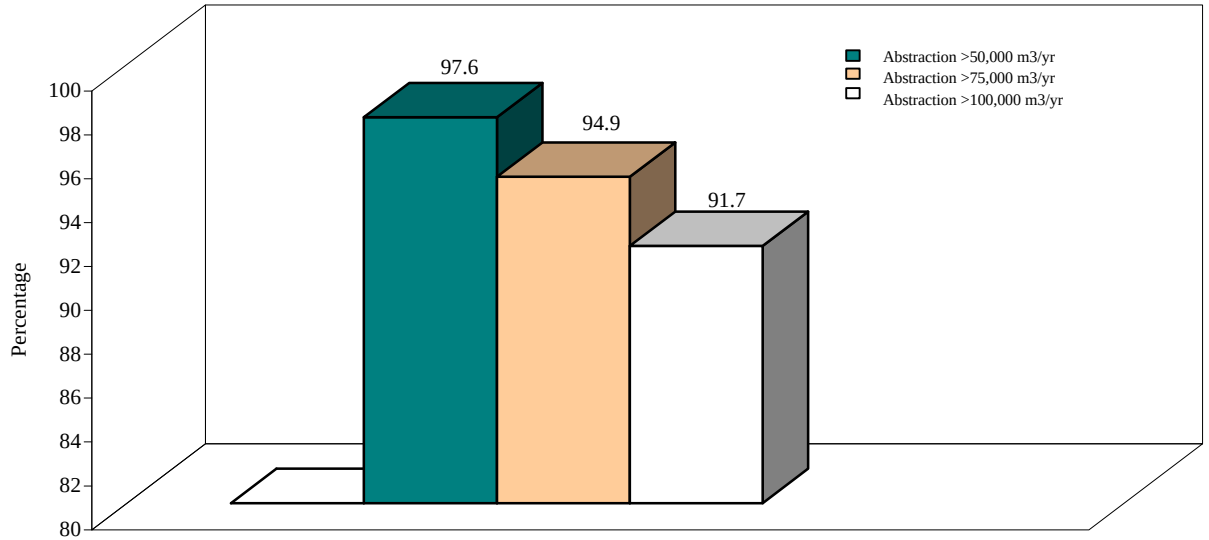


Figure10: Percentage of Wells Exceeding AbstractionLimits



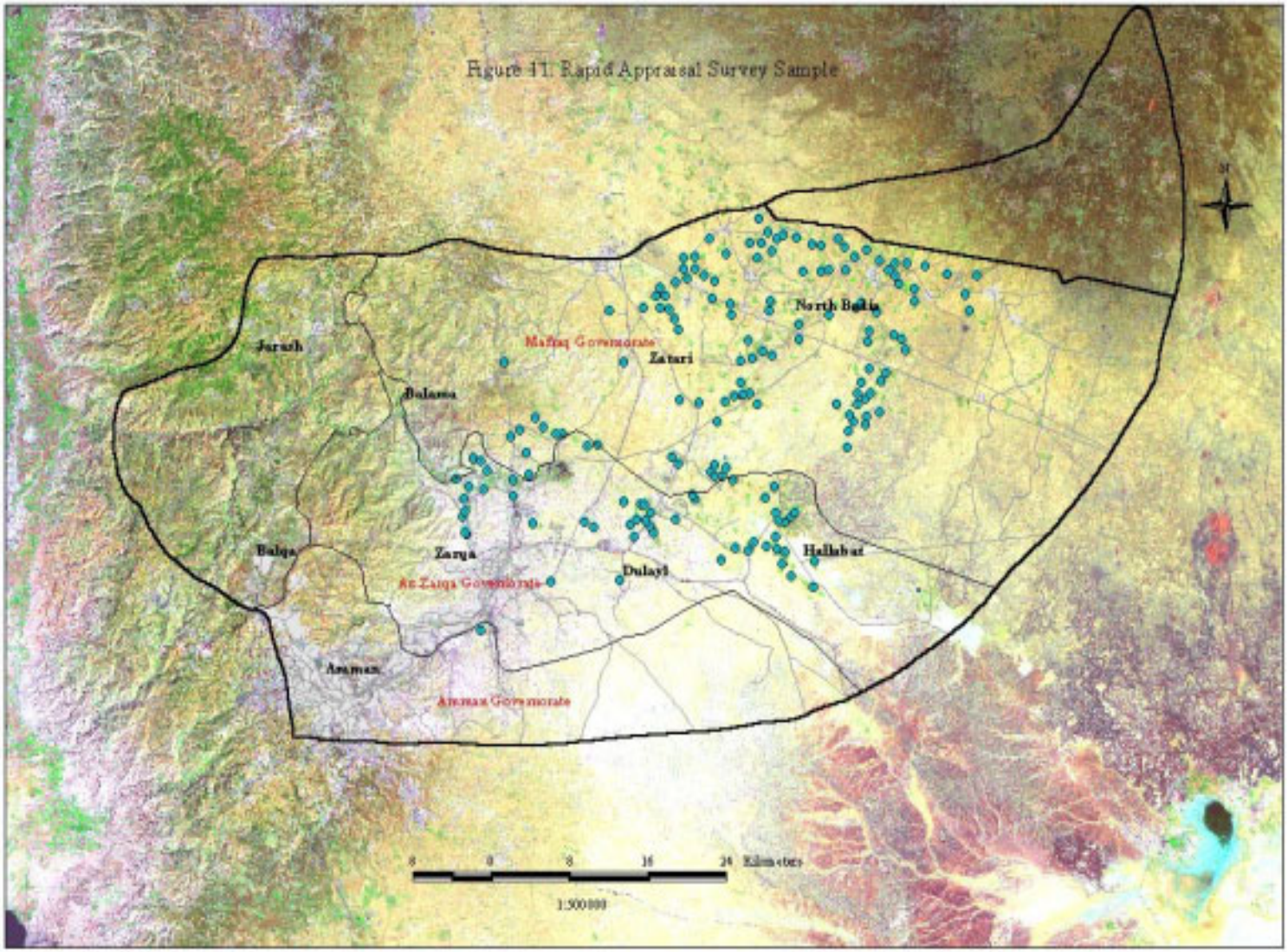


Figure 11: Rapid Appraisal Survey Sample
N
North Balqa
Mafraq Governorate
Zatari
Jerash
Balama
Balqa
Zarqa
Az Zarqa Governorate
Dulayl
Hallabat
Amman
Amman Governorate
0 4 8 16 24 Kilometer
1:500000

Figure 12: Rapid Appraisal Database Sample

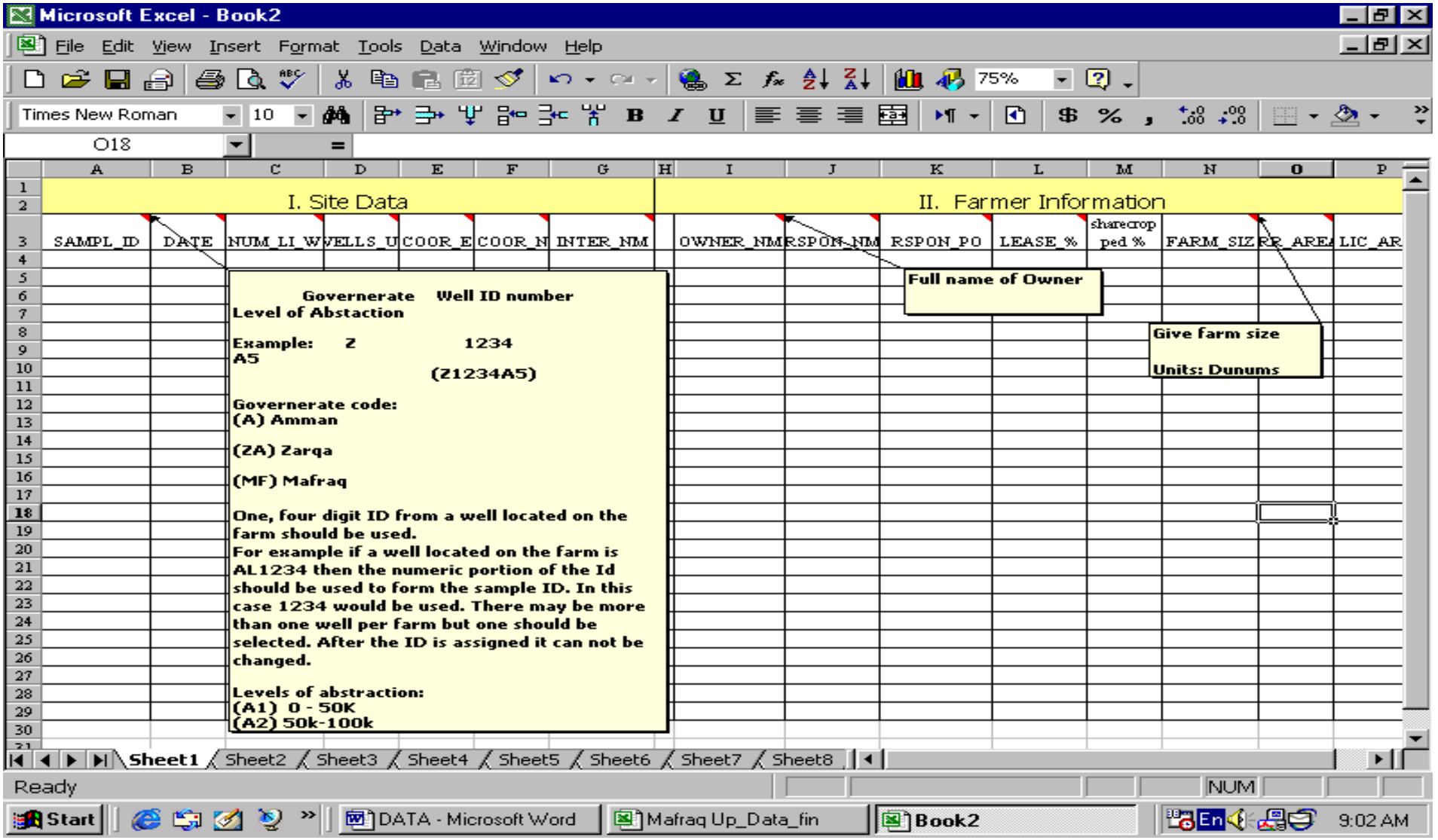


Figure 13: Farm Types in AZB Highlands

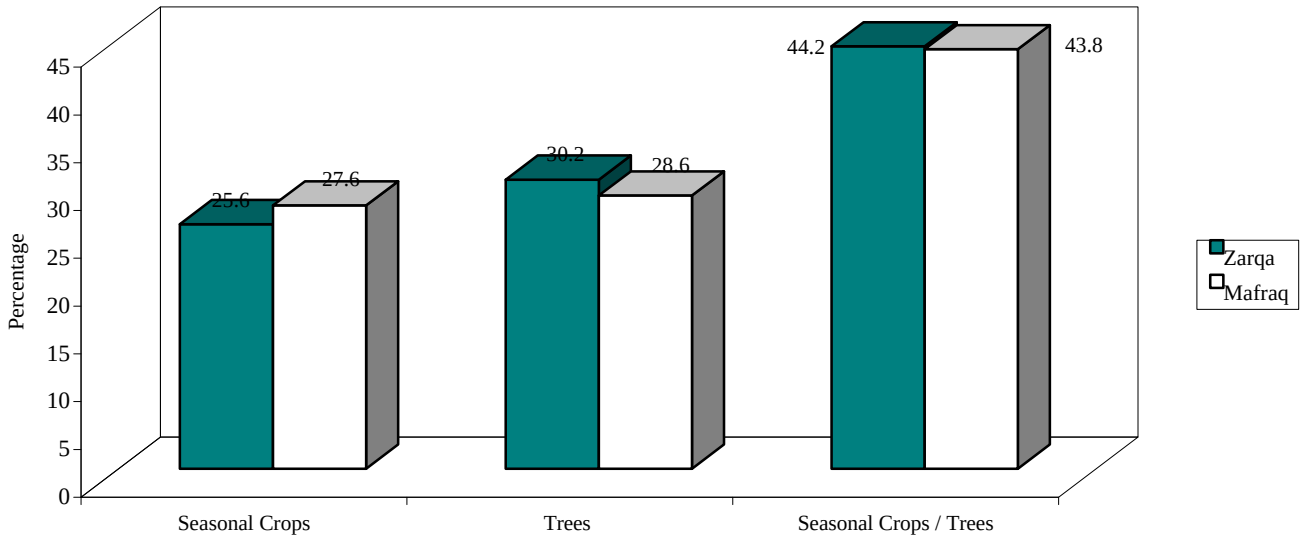


Figure 14: Farm Owners' Profile in AZB Highlands

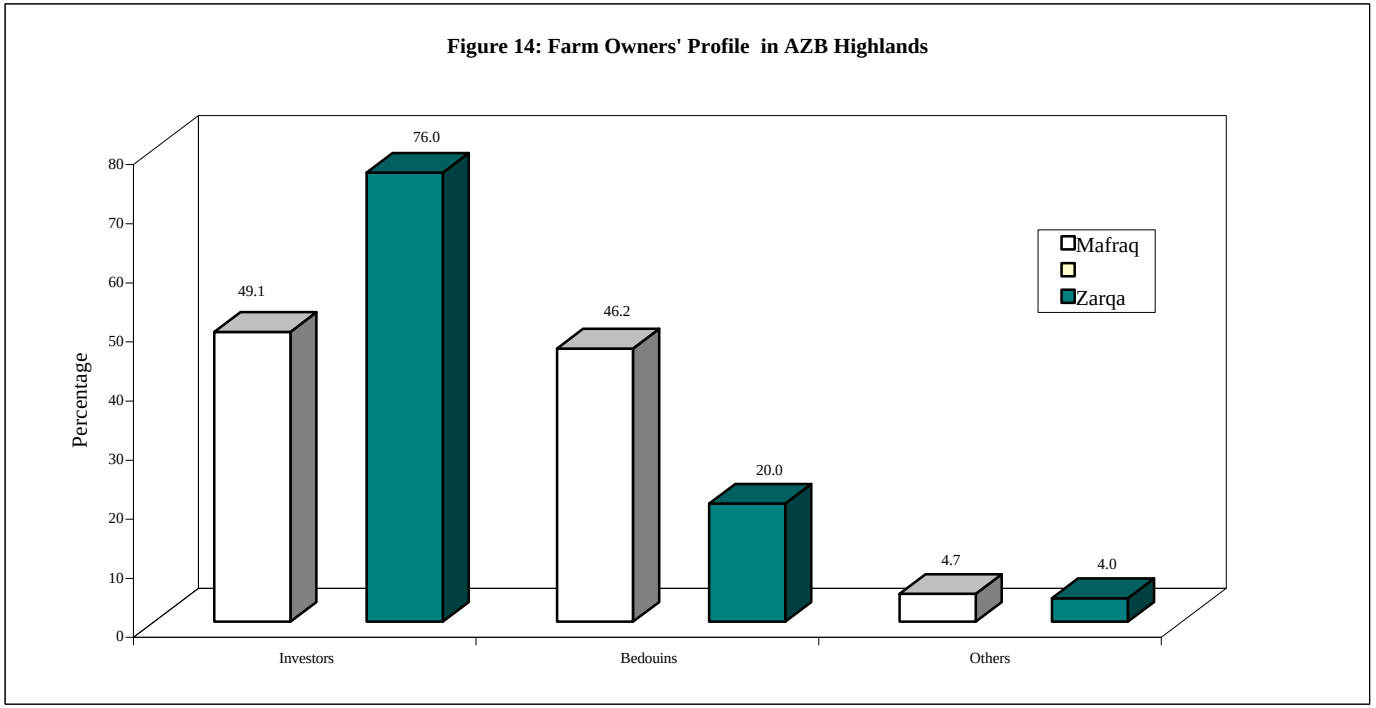


Figure 15: Farm Status in AZB Highlands

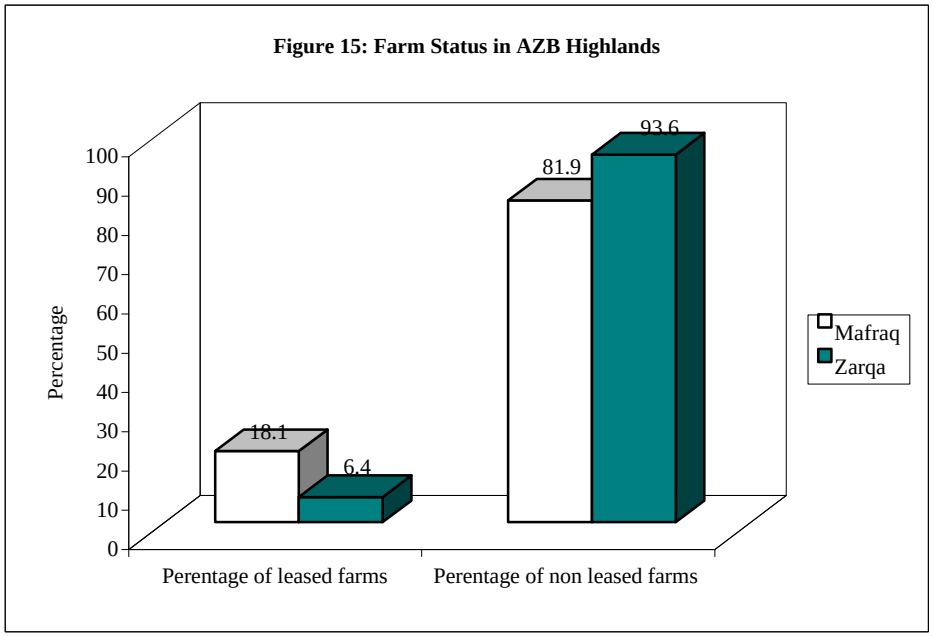


Figure16: Farm Management in AZB Highlands

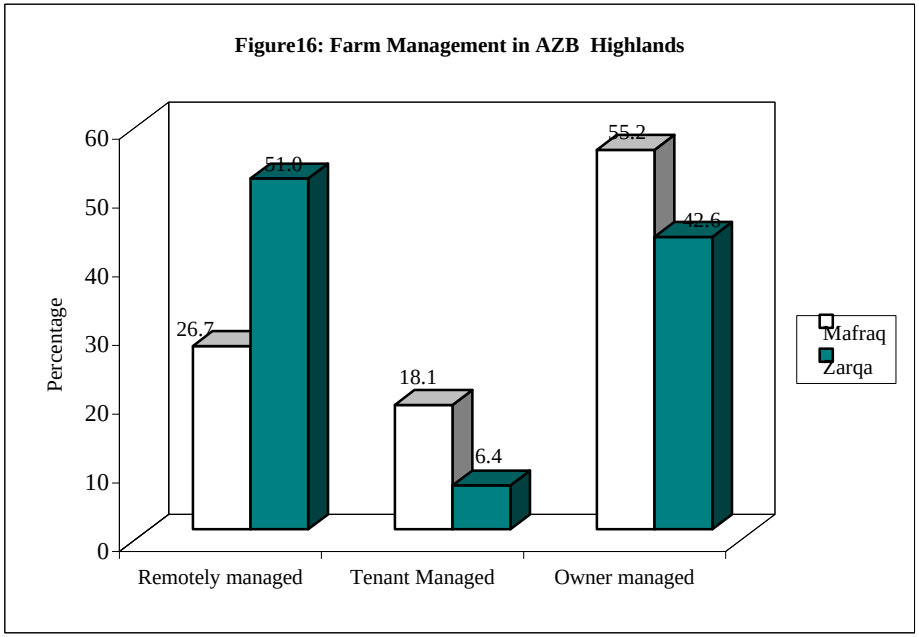


Figure 17: Labor Statistics in AZB Highlands

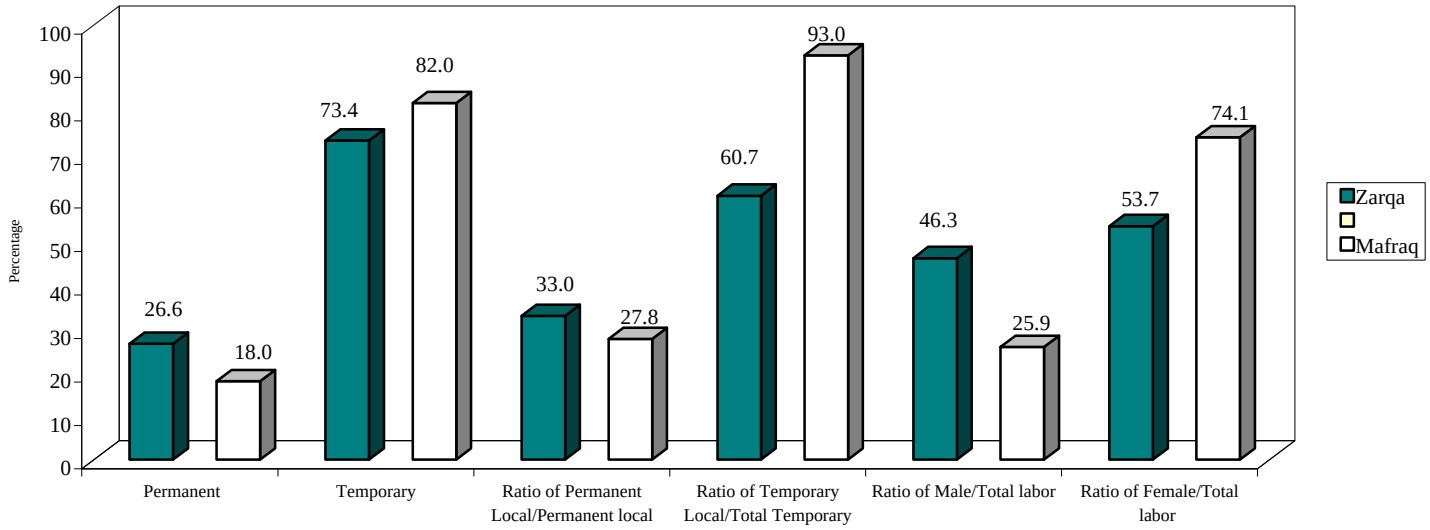


Figure 18: Tree Crops in AZB Highlands, 1999

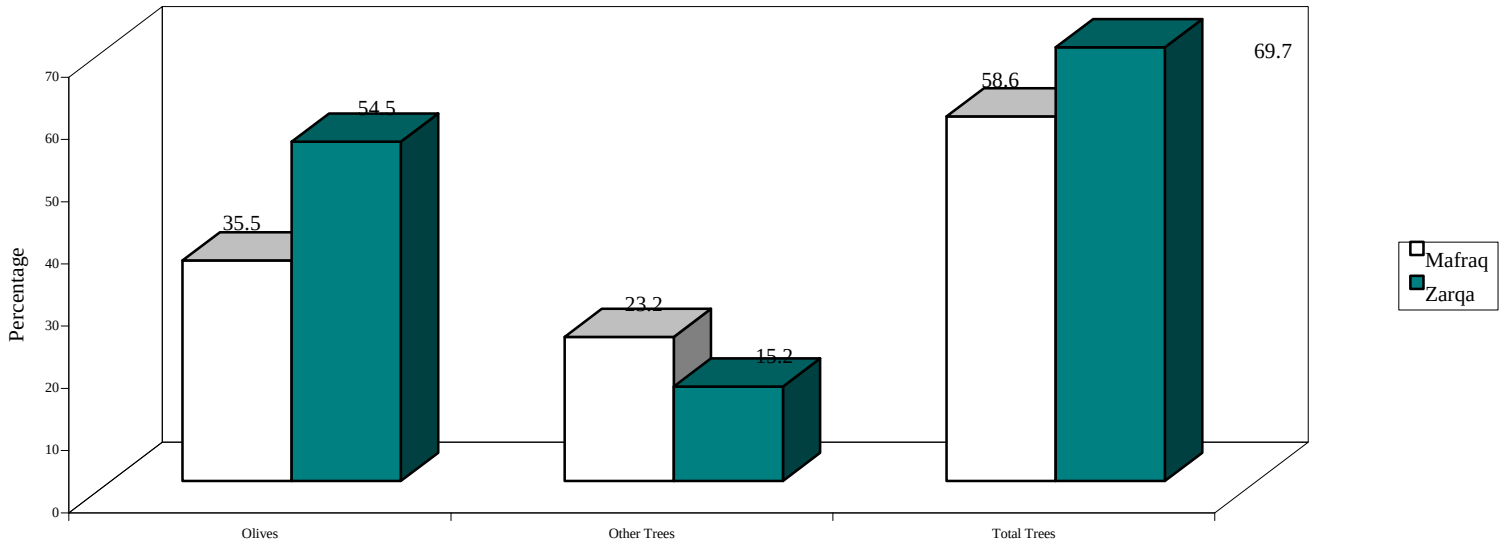


Figure19: Seasocal Crops in AZB Highlands, 1999

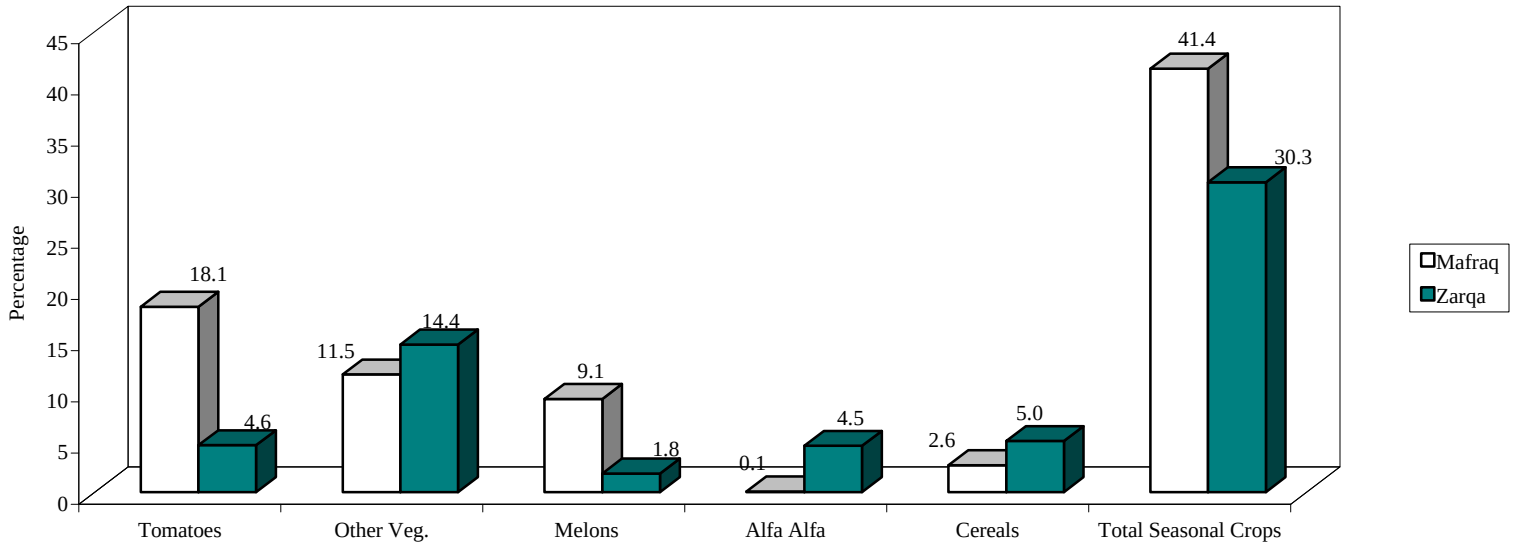


Figure 20: Percentage of Working Meters in AZB Highlands

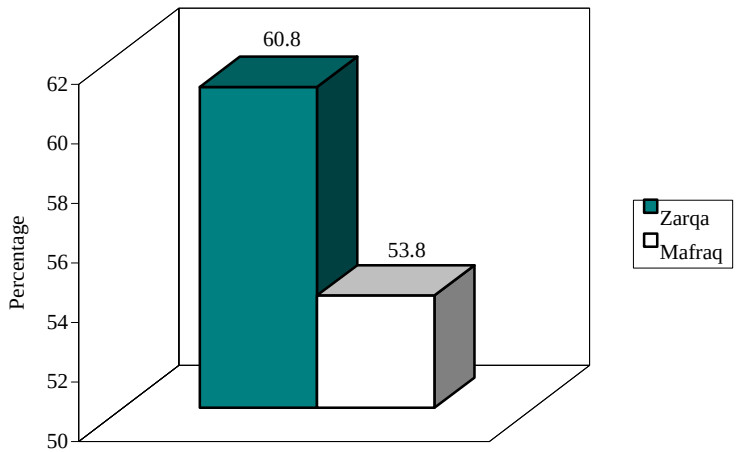


Figure21: Electrical versus Diesel Pumps in AZB Highlands

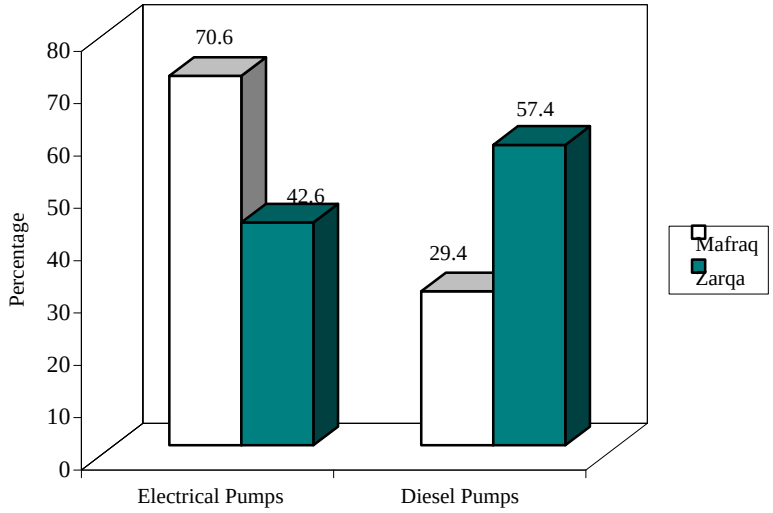
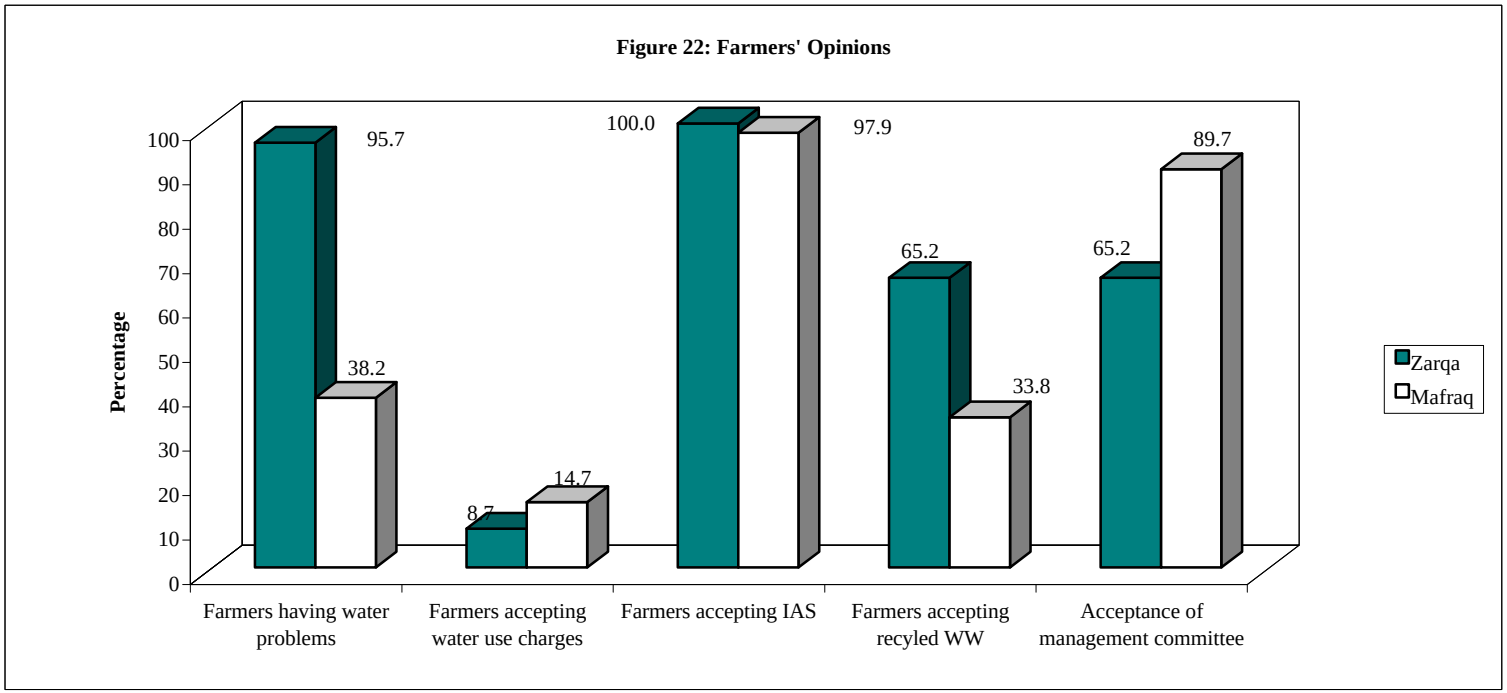


Figure 22: Farmers' Opinions



Pictures

Picture 1: Group meeting at Sabha Municipality, Mafraq area

Picture 2: Seasonal crop farms extending to neighboring virgin lands

Picture 3: MWI/ARD team and owner of modern farm

Picture 4: Private water sale facility

Picture 5: Abandoned tree farm

Picture 6: Drip irrigation at Sabha farm, Mafraq area

Picture 7: Mini basin irrigation at Dulayl farm, Zarqa area

Picture 8: Volcanic tuff, South of Rawda, Mafraq area

Picture 9: Algae, sign of over irrigation in North Badia farm

Picture 10: Evaluation of drip irrigation system with participation of farm owner

Picture 11: Private Recharge Dam

Tables

Appendix 1: Field Interview Form

Field Interview Form

Water Resource Policy Support
Farmer, Water Abstraction, and Water Use Practices

I. Site Data

Sample ID ……. Date of Visit……
Number of licensed wells…… Number of unlicensed wells……
Coordinates . Jordan East…… Interviewer……
Jordan North……..

II. Farmer Information

Name of Owner……...Name of Respondent……..
Respondent Position (1) Owner……..(2) Tenant…….(3) Manager……
(4) Sharecropper ..……(5) Laborer…….(6) Other……..
If lease, % of farm leased..…..……..
If sharecropper, % of farm sharecropped …….
Farm Size (Dunums)……..Irrigated Area (dunums)……..
Licensed Area (Dunums)…….

III. Irrigation Wells

Characteristics of Well at Installation

Table 1

Well ID No.	Year Initial Operation	Initial Type 1)Elec. or 2)Diesl	Initial Elec. motor Size (KWh)	Initial Diesl. Motor Size (Hp)	Initial Pumping Capacity (m3/hr)	Initial Well Depth (m)	Well Outlet Size (inches)	Initial Water Table Depth (m)	Initial Well Total Cost (JDs)	Flow Meter Installed (code)	Flow Meter Installed (Year)	Aquifer Tapped (code)
AL												
AL												
AL												
AL												
AL												
AL												
UL												
UL												
UL												

Aquifers: (1) A7, (2) B2 (3) B2/A7, (4) Basalt (5) B4, (6) A4, (7) A1/A2, (8) K, (9) Other

Flow meter : (1) Yes, (0) No

Question 1) 1998 Abstraction from database_____(m3)

Question 2) Is meter working?

1) Yes ☐ 0) No ☐

Question 3) If No, when meter stopped operating? ……

Well Changes From Initial Well Installation

Table 2

Well ID No.	Present Type 1)Elec. or 2)Diesl	*Present Pumping Capacity (m3/hr)	Present Well Depth (m)	Present Water Table Depth (m)	Increase Depth of Well? (m)	If yes, costs of Increase (JD)	Decline Water Table? (m/yr)	Year Start to Decline	Aquifer Tapped (code)
AL									
AL									
AL									
AL									
AL									
AL									
UL									
UL									
UL									

*** Use Pumping Capacity worksheet to calculate pumping capacity for each well.**

Well Usage (1999 data)

Table 3

Well ID No.	Annual Pumping in 1999 (m3)	Annual Elec Use (KWh)	Annual Elec. Cost (JD's)	Annual Diesel Use (liters)	Annual diesel cost (JD's)	Sell Water? (code)	Initial year of Water Sale	Sold Water (m3/yr)	Sales Revenue From Water (JD/yr)	Use of Sold Water (code)	Annual Pumping in 1998 (m3)
AL											
AL											
AL											
AL											
AL											
AL											
UL											
UL											
UL											

Sold Water: (1) irrigation, (2) domestic, (3) industrial
Sell Water : (1) Yes, (0) No

Well Hours (hours pumped/month)-1999

Table 4

Month	**AL**	**AL**	**AL**	**AL**	**AL**	**AL**	**UL**	**UL**	**UL**
Jan									
Feb									
Mar									
Apr									
May									
June									
July									
Aug									
Sept									
Oct									
Nov									
Dec									
Total (hrs)									

Water Quality

Table 5

Well ID No.	Initial Quality in PPM	Quality of Present Water (code)	Quality Changed (1)Yes (0)No	Year Start Change (year)	Reason for Change (code)	Present Quality in PPM	Impacts on Soil Quality (1)Yes (0)No
AL							
AL							
AL							
AL							
AL							
AL							
AL							
UL							
UL							
UL							

Quality: (1) Very good, (2) Average, (3) Below Average, (4)Brackish,…(5) Unusable..
Reasons: (1) Decline in Water table, (2) Mixed aquifers, (3) Both (1) & (2) (4) Surface Pollution, (5)Other

IV.

Cropping Patterns (1998/1999)

Table 6

Crop	Planted Area (dunums)		Irrigtn Type (code)		Farming Practice (code)		No of Irrigation Units		No of Irrigation hours (hr/unit)		No of Irrigatns per month (day)		Cropping Season (month)		Total Irrigatn Time (hrs)		Age of Trees (Years)		Reason for select (code)		Future Plans
	98	99	98	99	98	99	98	99	98	99	98	99	98	99	98	99	98	99	98	99	
Barley																					
Wheat																					
Tomatoes																					
Potatoes																					
Cauliflower																					
Squash																					
Other Vegetables																					
Water Melon																					
Apple																					
Peaches																					
Grapes																					
Olive Trees																					
Other Deciduous																					
Other Nuts																					
TOTAL																					

Irrigation types: (1) drip, (2) furrow, (3) sprinkler, (4) flood, (5) other, (6) none
Reasons: (1) costs, (2) equipment, (3) efficiency, (4) labor saving, (5) other
Farming Practices: (1) Open field, (2) Tunnels, (3) Greenhouse, (4) Both

Question 4) Irrigation Efficiency: 1)very poor, 2) poor, 3) moderate, 4) good, 5) very good

Question 5) Do you need Irrigation Advisory service to improve irrigation efficiency

1) Yes ☐ 0) No ☐

Question 6) Indicate your top two soil problems.
(Circle 1st and 2nd next to your choice or check no problem)

1) Salinity , 2) Poor Drainage, 3) Heavy soils, 4) Low fertility, No problem ☐

Question 7) Annual person-months of permanent labor used on farm._____(person-months/yr)

Question 8) Annual person-months of temporary labor used on farm. _____(person-months/yr)

Question 9) Number of seasonal labor _____

Question 10) Percentage of permanent foreign labor _____ %

Question 11) Percentage of temporary foreign labor _____ %

Question 12) Percentage of male labor _____%

Question 13) Percentage of Female labor _____%

Crop Production (1998/1999)

Table 7

Crop	Harvested Area (dunums)		Production (t/dunum)		Price (JD/ton)		Gross Returns (JD/dunum)		Total Returns (JD)		Water Cost JD/m^3	
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Barley												
Wheat												
Tomatoes												
Potatoes												
Cauliflower												
Squash												
Other Vegetables												
Water Melon												
Apple												
Peaches												
Grapes												
Olive Trees												
Other Deciduous												
Other Nuts												
Total Area												

V. Over Pumping Impacts In Case of Water Quality and/or Water Quality Changes

Over Pumping Impacts On Cropped Area and Yield

Table 8

Crop	Cropped Area Prior to Change (dunums)		Present Cropped Area		Cropped Area Middle Year*		Yield Prior to Change (t/dunum)		Present Yield (t/dunum)	
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Barley										
Wheat										
Fodder										
Tomatoes										
Potatoes										
Cauliflower										
Other Vegetables										
Water Melon										
Apple										
Peaches										
Grapes										
Other Deciduous										
Other Nuts										
TOTAL										

* Middle Year, between first year of Water Quality change and 1999.

Question 11) If you have experienced declines in yields when did this start?

1) 1 year ☐ 3) 3 years ☐ 5) 5 years ☐ 7) 7 years ☐ 10) 10 years ☐ 11) 10+ years ☐ 0) No decline ☐

Pumping Capacity Worksheet

Timed meter reading **Well ID………………………..**

Beginning time ……………… **Beginning Quantity…………………(m3)**

End time………………. **End Quantity………………….(m3)**

(Begin time) – (End time)………… **(Begin Quantity) – (End Quantity)………….**

Total elapse time…………..(hr) **Total quantity………..(m3)**

Pumping rate………….(m3/hr)

Timed meter reading **Well ID………………………..**

Beginning time ……………… **Beginning Quantity…………………(m3)**

End time………………. **End Quantity………………….(m3)**

(Begin time) – (End time)………… **(Begin Quantity) – (End Quantity)………….**

Total elapse time…………..(hr) **Total quantity………..(m3)**

Pumping rate………….(m3/hr)

Timed meter reading **Well ID………………………..**

Beginning time ……………… **Beginning Quantity…………………(m3)**

End time………………. **End Quantity………………….(m3)**

(Begin time) – (End time)………… **(Begin Quantity) – (End Quantity)………….**

Total elapse time…………..(hr) **Total quantity………..(m3)**

Pumping rate………….(m3/hr)

Timed meter reading **Well ID………………………..**

Beginning time ……………… **Beginning Quantity…………………(m3)**

End time………………. **End Quantity………………….(m3)**

(Begin time) – (End time)………… **(Begin Quantity) – (End Quantity)………….**

Total elapse time…………..(hr) **Total quantity………..(m3)**

Pumping rate………….(m3/hr)

Appendix 2: Policy Interview Form

Policy Interview Form

Water Resource Policy Support
Investment and Groundwater Management

Sample ID…….(Must be the same ID as Field Interview form)

I. Farm Finance

(1) Approximate size of total investment on farm, including land, wells, buildings, equipment, etc…….(JD)
(2) Number of farm co-owners or investors ……
(3) Type of finance: (A) self……(%), (B) Loans……(%), (C) Other……(%).
(4) If (B) estimated loan ……. (JD)
(5) If sharecroppers ……..
(A) Number of local …….,……. (B) Number of Migrant ……..

II. Groundwater Management Policies

(1) Do you experience water quantity and quality problems

1)Yes ☐ 0)No ☐

(2) If No,
(A) Do you expect your well(s) to produce the same quality and quantity of water in the future.

1)Yes ☐ 0)No ☐

Explain:_____
_____
_____
_____

(B) Do you believe your children will have enough water to continue to cultivate the same farm land in the future?

1)Yes ☐ 0)No ☐

Explain:_____
_____
_____
_____

(3) If Answer 1) is Yes

A) water shortage, (B) water quality problem, (C) both

(4) If (A) or (C) and if you plan to deepen or replace well, how much will it cost …....(JD)

(5) If (B) or (C),
(A) Approximate losses due water quality deterioration….……(JD)
(B) How are you planning to overcome this problem?

Explain:_____
_____
_____
_____
_____

(6) What long-term impacts do you expect to result from the water quantity and quality deterioration in the Uplands?
Impacts:_____
_____
_____
_____
_____

(7) What solutions would you suggest for the water problems in the Uplands?
_____
_____
_____
_____
_____

(8) If there was a reduction in availability of groundwater, for example by 30%, what changes would you make in agricultural and irrigation practices?

_____
_____
_____
_____
_____

(9) Would you accept water use charges?

1)Yes ☐ 0)No ☐

Explain:_____
_____
_____
_____
_____
_____
_____

(10) If Yes, Maximum accepted charge per cubic meter…….(JD)

(11) If water charges are applied, what changes would you make in agricultural and irrigation practices?

_____
_____
_____
_____
_____

(12) Would you use Irrigation Advisory Service to improve irrigation efficiency

1)Yes ☐ 0)No ☐

(13) Would you supplement current groundwater irrigation water with treated wastewater.

1)Yes ☐ 0)No ☐

Explain:_____
_____
_____
_____

(14) What actions and incentives would encourage farmers to reduce groundwater abstraction?

Explain:_____
_____
_____
_____
_____
_____

(15) Do you think a groundwater management committee could be formed to organize agricultural groundwater users to protect your groundwater resources?

1)Yes 0)No

☐ ☐

(16) Would you participate in a groundwater management committee?

1)Yes 0)No

☐ ☐

Appendix 3: Short Stories

SHORT STORIES

Modern Farmers

1. The owner and sons own four modern tree farms in the area. He has close contacts with European agricultural institutions where he got most of the flourishing fruit varieties. His farm is practically weedless. He provides incentives for his workers for keeping his insect population down.

   He rents cold storage for his produce. Together with high quality fruit, he enjoys the highest prices on the market every year. However, recent evaluation of his irrigation system revealed deficiencies, which could be rectified through appropriate irrigation advice. He is readily receptive to water saving methods and can be an ideal location for future IAS and pilot project activities.

   He suggests that the Government should compensate wells owners who reduce irrigated areas or sell their wells, and rearrange agricultural water uses in the basin according to returns. He thinks that public awareness programs should be also targeted to farmers to inform and educate them about water conservation.

2. This farmer is shifting to flower production mainly in plastic houses using good European varieties and aiming at the special seasons of national and international feasts. He believes it is only rational to use our scarce water supplies efficiently. He enjoys high incomes that are rarely obtained by the ordinary farmer.

   He suggests that the government should supervise water abstraction. Farmers should be compensated for losses and should participate in groundwater management decisions.

Water Sale Farms

3. This well owner is selling water to tankers and other farmers through yearly lease agreements, where water is pumped to other farms and conveyed at distances ranging between 1 to 3 km. He claims that water sale earnings help him cover his marginal crop production losses.

Marginal Income

4. The owner of this farm is also an owner of a big food processing company in Jordan. This farm is considered as an old family heritage since 1964. According to him the total investment since 1993 is about 250,000 JD, while the income doesn't exceed 75% of the expenses. He is convinced that farming practice is a wrong investment. This well owner thinks that restricted cropping patterns programs should be applied, local marketing system should be improved, and local products should be custom protected.

5. This farmer has an average size tree farm, predominately olives, in addition to a poultry and dairy unit. His farm income is relatively marginal. He stated that the agricultural sector is one of the major depleting sources of water. The sector also drains a large

amount of foreign currency since most of the required inputs such as labor; materials and equipment are imported.

He suggests that the government should impose restricted cropping patterns programs and reduce cropped areas according to the licensed farm size. Priority should be given to domestic water supply.

6. At the end of the day and when the season is over, farmers end up with nothing, whereas everybody else (e.g. workers, merchants… etc.) get something in their pockets, a problem worth working out. This well owner believes that water metering is not a recommended tool for control of pumping especially when water charges are applied. On the other hand limitation of cropped areas can be a means to reduce water use. He as well suggests that government should buy wells and compensate farmers for their losses and this should be equally applied on all farmers.

7. This is a hobby farm. It is the smallest farm on record, about 30 dunums of olives and vegetables. The owner is well off; he claims that the farm barely sustains its sharecroppers. Limitation of cropped areas and applying cropping patterns programs could be a successful measure for water pumping reduction. He suggested rescheduling loans and reducing interest rates as tools to convince farmers to reduce abstraction.

Salinity

8. This is a case of a model farm that flourished in the 1980's. But, due to the increasing level of salinity in the well and ineffective farm management, the farm is losing a major part of its fruit tree productivity. More sensitive varieties are suffering due to the high salt content of irrigation water, winter frosts, and improper fertigation.

   This is a clear example of what could happen to any farm in the area in the future as long as control measures continue to be lacking.

9. This is an example of good management of a fruit trees farm under relatively highly saline irrigation water. It is much better off than a neighboring farm having good water quality. This farm has been suffering from salinity during the last five seasons.

10. This farmer has his farming business under his control, especially after his return from the Gulf States. Being a wealthy businessman, he could easily afford the high cost of production of his large fruit tree plantation. He complains about the increasing water salinity. He is also keen to introduce new plant varieties that are more salt tolerant and produce higher yield revenues. He has five wells, the latest was drilled last year. Four wells are used for irrigation and one well supplies a new water bottling company established earlier this year. He supports reduction of cropped area and suggests that vegetable farmers should stop extending their operation outside their licensed area.

Farming is a tradition that should be kept

11. A wealthy farmer believes that agriculture is a tradition that should be kept. He states that irrigated farming provides a large portion of poor sectors of our nation with cheap

agricultural products. Also we have all sorts of natural hazards to overcome, such as drought, plant diseases, and soil salinity.

This farmer was able to buy the surrounding areas to his farm and is wondering if he can get a new license to drill a new well. He is unaware of current developments in irrigation technology and would like to be better informed in methods of water conservation. His suggestion for groundwater water management is to limit vegetable areas, under condition that farmers are compensated for any reduction. He stresses that water management measures should be equally applied to all farmers.

12. This tenant of a vegetable farm also believes that farming is a blessing to the poor majority of the nation who otherwise may not find anything cheap to eat. He over-irrigates and practices extensive farming. He thinks that he is a small farmer and abides by the rules. Influential farmers should be consulted first. He stated that influential farmers constitute the major obstacle to any solution. If they don't abide by the rules, our efforts are deemed fruitless.

Irrigation Advisory Service

13. This is fruit trees farm, owned by a wealthy man. It has two major problems; some of the fruit trees bear no fruits at all due to a failure in varieties of some apples, cherries, and nut fruits. The well is not well located in the farm and needs rehabilitation or preferably a change of location. He is also worried about the next generation, as they are not interested in farming. He thinks that modern irrigation and agriculture techniques should be introduced through demonstrations in pilot projects.

14. The manager of a large tree farm, mainly olives, is an agriculture engineer who is well aware about water problems in the area. He feels that most farmers are not reacting to these problems, but they will start complaining when they will face disaster. He started managing the farm in mid 1990 and turned it from a deficient operation to a modern and profitable activity. He suggests gradual reduction of cropped area. Reduction is easier for vegetable farms and for young and aging trees, but would not be accepted for productive trees. He supports the idea of selective cropping patterns, but does not agree with mandatory cropping since mistakes were made in its application. He calls for introduction of new water saving methods, and he is ready to allocate a lot for a pilot irrigation advisory program.

Buy out

15. This farm owner has two wells; one of them has high water salinity. He has a fairly large olives and vegetable farm. His income is marginal. He is staying in this business because he fears that his family and neighbors will blame him for giving up this activity. He believes that around 75% of the farmers are facing the same situation and are willing to sell out.

16. The owner of the farm says that every year special teams conduct different studies; they all ask the same questions without any benefit. He suggests that marketing systems should be restructured and cropped areas should be limited to 100 dunums per farm.

Government should buy wells from farmers suffering from financial problems and support those exporting their produce.

Exchange of Groundwater with Recycled Wastewater

17. Dulayl Agricultural Project: It is a Badia development project to encourage Bedouins to settle and practice irrigated farming as a sustainable source of income. This project started irrigating 5500 dunums in 1969. The irrigated area increased to 6300 by the early 1970s. Water is pumped from government wells and delivered to farms at 10 Fils/m3. Due to problems of water shortage and increasing water salinity, only 2,000 dunums are presently irrigated, mainly for fodder. Farmers in the area are desperate for new sources of water and indicated their willingness to exchange groundwater for recycled water to save their livestock.

Marketing

18. During our visit, the owner was in the process of rehabilitating his well, a costly operation that might cost around 5000 JD, at this early time of the season.
    He stated that farmers are left in the open without any government support. Our conditions are worsening because we might be forced to sell our farms at a low cost. Quality of our groundwater resources is very good but we are still suffering from loss of the foreign markets of Saudi Arabia and the gulf region due to the adverse effects of Khirbet As-Samra. He doesn't believe that a groundwater management committee would solve problems.

19. The farm is presently managed by eight sharecroppers, three of them are bothers, and the rest are relatives. The farm enjoys a good quality, highly productive well that is the least liable to experience any deterioration of water quality and quantity in the foreseen future. He thinks that better marketing policies are needed, and tomato paste factories should be better managed to cope with the actual yield conditions.

Miscellaneous

20. This farmer's property is in Yarmouk basin. He is a prominent chief of a tribe, which extends from Yarmouk to the northwestern AZB highlands. This is a good example of a perseverant tomato grower who cultivates up to 1000 dunums every year. He constructed his own recharge dam to enhance groundwater recharge for his wells. He stated that few farmers in the eastern Yarmouk basin are deserting the profession due to financial difficulties. He admits that agricultural production using groundwater is very costly. Both agricultural materials and energy costs are very high. Farmers can only survive under mass production of larger areas. This farmer has good control over the vegetable markets. He is also extending his operation to virgin lands located at around 9 km from his well (picture 1).

    This farm owner thinks that the flow meter is not an effective solution for water overuse control. It encourages mismanagement, fraud, and corruption. A proper marketing system should be established to secure adequate incomes. Imports of agricultural products must be stopped during high season. Wastewater use should be for only wood and fodder production as a measure for restricted use of As Samra recycled water. He also suggests

that any management solution should consider the socio-economic implications and should be implemented by all farmers.

21. A well educated pharmacist who believes that his well location is suitable geographically and geologically. Therefore, he does not foresee quality and quantity problems. He wonders for what purpose and for whom the present study is being done. Clear agricultural policies, proper cropping patterns that guarantee better structured marketing are the solution to most of the problems in the area.

    Only studies can dictate reduction in availability of water. He believes that water charges and taxation will affect negatively the only vital sector of our economy, agriculture. Fair and realistic solutions are needed.

22. This farmer used to run a profitable business in Germany. When he decided to invest in Jordan for family reasons, he established a farm of his own. It consists of plastic houses and open field vegetables plus a fruit tree orchard. The farm represents a good example of farmer persistence and good management. He believes that controlling the marketing system and compensating farmers for any reduction in cropped areas could enhance water demand management.

23. This farm is considered one of the most prominent farms in the area. It is run by a young wealthy farmer. His father thinks that his son over-irrigates. The high water consumption was confirmed in August 2000 during the irrigation evaluation activity. He thinks that the Government should help farmers in marketing their agricultural produce overseas. For farmers who have financial problems government should buy their wells and fairly compensate them.

24. A tenant farmer runs a family farming business. He makes good profits. To control groundwater overuse he suggests reducing cropped areas especially those planted with vegetables, control prices of agricultural produce such that reasonable returns are guaranteed, and enhance agriculture extension services.

25. This farmer is one of the rare ones, who accepts water charges, up to 200 fils/m^3. His farm enjoys the best record of water quality together with a high well yield of 120m3/hr. Tomato is the predominant crop in the farm. He thinks that better marketing policies are considered necessary for water demand management in the basin. Also there should be control over imported agricultural produce during the high cropping season.

Competing Demands

26. The owner's son is currently managing this farm. He is a young engineer who believes that excessive WAJ extraction contributes greatly to the problem. Al-Za'atari pumping station has the capacity of 3200m3/hr or 28 million cubic meters/yr. He stated that Amman users and not only us should pay for the consequences of over abstraction. He suggested that farmers should be fairly compensated for any reduction in cropped areas.

Future Generation

27. A large farm of more than 600,000 JD of investment in vines, olives, and other fruit trees. The owner rehabilitated an old Roman pool, which he uses as a storage reservoir to supply his fruit trees with irrigation water by booster pumps. Being an old man, he is worried about the future of his farm since his sons practice other professions away from agriculture. One of the surrounding farms is already losing its trees and the farm owner is too old to look after it. He thinks that better marketing policies and reduction of production costs could be an effective instrument to convince farmers reduce groundwater abstraction.

Worries

28. The owner bought the 350 dunums farm after a long banking career in Saudi Arabia, for a total cost of 400,000 US$, including farm and well rehabilitation. He runs the farm with the help of two young sons and a team of monthly paid permanent and temporary Egyptian workers. This farm is well recommended for any future pilot project activity in the area. Zeolite mix is already used as mulch, which is expected to reduce irrigation by 10-20%. Currently, this farmer is doing fine. The danger is if and when water conditions worsen.

Ex-Governmental Official

29. An ex-army officer and farm owner, who supports reduction of cropped area and suggests a series of incentives for the implementation of this option. Among the proposed incentives rescheduling loans and interests rates, reduction of energy cost, and improvement of marketing. He suggests reduction of government abstractions, closure of illegal wells, use of desalinated water for domestic water supply, and negotiation with Syria about the management of the shared groundwater in Amman Zarqa Basin.

30. An ex. High official at the Ministry of Agriculture and agriculture engineer, a co-owner of two vegetable/tree farms in Hallabat area. He is a strong believer in water harvesting. He stated that the highlands was a successful dry farming and grazing area during earlier civilizations, especially the Nabateans, who were masters of water harvesting. He is aware that over-abstraction has caused salinity increase in parts of the basin. He calls for stringent enforcement measures to reduce over-abstraction, before it is too late. However, he suggests that the government should discuss pumping reduction measures with well owners. He supports the idea of a groundwater management committee. He is against water charges, recommends a reduction of cropped area, based on well yield i.e. higher well production rate would correspond to lower reduction of cropped area, and thinks that the government should promote exports and improve the local marketing system.

31. An ex. High Government official and senior advisor to King Hussain, he owns one well in a large tree farm. After suffering from low farming productivity and the poor marketing system, he started a water bottling company, which uses part of the pumped groundwater, while maintaining most of his irrigated farming. He foresees no major change in his high quality water since his well is located in a major flow recharge path originating from the Syrian mountains. He is not in favor of water charges and exchange of groundwater for recycled water. He also thinks that the government should have a more active role in

regulating water abstraction in the basin. He does not object to the idea of stakeholder participation in groundwater management.

32. The owner of this farm is an ex-parliament member. He believes that government wells aggravated over-abstraction in the basin. Neighboring countries like Saudi Arabia and Syria have also their contribution to the water decline. Water sale should be stopped and illegal wells should be closed down. He suggests setting maximum limits for cropped area, applying restricted cropping patterns program, reducing energy cost, rescheduling loans and interest rates, and opening foreign markets.
    On the other hand he suggested importing water from other regions to cover the increasing water demand for domestic purposes.

    He also thinks that studies and researches are lacking in the irrigated agricultural field. Use of recycled wastewater in the As Samra area is one of the main reasons for loosing the Gulf market in the early 1990s. Thus, recycled wastewater should be used in areas far away from the highlands to produce timber and forages only.

Potential Committee Members

33. The owner of the farm is one of the most influential people in the area. He is a mayor and chief of a major tribe. He arranged a group meeting in his office. His sons and relatives work on his farm. Tomato is the predominant crop in the farm, in addition to other seasonal crops. He stated that the government encouraged irrigated agriculture as part of the development of the Badia area. This study should have been conducted 25 years ago as part of the planning of agricultural development in the basin. He believes that water charges are a form of taxation and not conservation.

    He thinks that artificial recharge and water harvesting should be used to increase available water resources in the area. He suggested that cropped area reduction should be tied to well production rate. In other words, high yield wells should have high limit of cropped area. He also urged that a committee representing all concerned parts must be formed and solutions to the problem need to be sought before it is too late.

34. This farm owner is a representative of the farmers union in the area. He has a traditional olive tree farm. He participated in the Dafianeh and Sabha meetings. He believes that water conservation could be enhanced by incentives such as rescheduling of farm loans and minimizing or waving interests. He suggests limitation of cropped areas and imposing restricted cropping patterns. These measures should be equally applied to all. Farmers who are willing to sell their farms due to financial difficulties should be fairly compensated. He also thinks that metering is not an effective tool to control abstraction. A delegation must be sent to other countries, to get acquainted with foreign expertise in cropping patterns and marketing. A committee representing all concerned parties with active participation of farmers should tackle management of the basin water use.

35. A young farmer, who comes from a famous tribe in the area. He is a government employee of the ministry of interior who knows the rules by heart. He is convinced that groundwater management is urgently needed. He stated that farmers have now various negotiation cards, but later on when water conditions worsen they will have no options and they will lose all their investment. He stresses on considering social and economical

impacts of any management options. He is not receptive to the use of recycled wastewater in North Badia. He also thinks that effective marketing policies are missing, energy costs should be reduced, pilot studies for water saving and public awareness should be enhanced. This farmer helped us to organize the largest group meeting, which included other community leaders and farmers.

Appendix 4: Note on Groundwater Management Consultative Committee

MINISTRY OF WATER AND IRRIGATION

Water Resource Policy Support
Groundwater Management Component

NOTE ON GROUNDWATER MANAGEMENT CONSULTATIVE COMMITTEE

December 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, Delivery Order No. 800

Note on Groundwater Management Consultative Committee

Background

The AZB highlands groundwater management recommendations include ideas about groundwater use reduction options, illegal drilling and illegal water sale, crop patterns and marketing, management of shared groundwater system, creation of groundwater management fund, formation of groundwater management consultative committee, and monitoring of abstraction. Analysis of legal aspects of these suggestions revealed that beside MWI other institutions, especially WAJ and the Ministry of Agriculture (MOA) would be legally responsible for the implementation of some of the groundwater reduction options. In addition water users and other stakeholders would play an instrumental role in the implementation of these management options. The recommended implementation approach is based on participation of stakeholders, and considers the basin as a water management unit. MWI/ARD team has successfully initiated participatory groundwater management by exploring farmers' opinions about reduction of groundwater use in irrigated agriculture in AZB highlands. This note proposes the formation of a Groundwater Management Consultative Committee (GMCC) chaired by the Ministry of Water and Irrigation to discuss, screen, and support groundwater management actions.

Consultative Committee Roles

The main roles of the committee are:

1. Discuss and screen practical groundwater management options with assistance of ARD's groundwater management team.
2. Discuss and approve action plan for implementation of the selected groundwater management options, with assistance of ARD's groundwater management team.
3. Assist the implementation of the approved action plan.

Potential Committee Members

1. MWI – Water Authority
2. Ministry of Agriculture
3. Farm Owners' representatives
4. Representatives of Mafraq and Zarqa Governorates
5. Representative of Economic Consultative Council (ECC) irrigation committee

Forming the Committee

The committee can be formed through consultation with MWI Secretary General/Assistant Secretary General.

Proposed Schedule of Activities

Meetings	Objective	Date
1. Farm Owners-MWI/ARD Meeting	1. Present Rapid Appraisal results and groundwater management recommendations to a of group farm owners. 2. Selection of farm owners' representatives	22 January 2001
2. Individual (Informal) Meetings with potential Committee members	1. Discuss AZB groundwater management options 2. Discuss results of compatibility of options with groundwater bylaw and agricultural law. 3. Discuss progress of socio-economic studies	24 to 31 January
3. First Meeting of Groundwater Management Consultative Committee (GMCC)	1. Define Role of each member 2. Define objectives and Targets to finalize list of groundwater management actions 3. Prepare Work Agenda	8 February 2001
4. Second Meeting of GMCC	1. Discuss Preliminary Results of Socio-economic analyses 2. Discuss Groundwater management action plan framework	12 March 2001
5. Third GMCC Meeting	Discuss draft of Groundwater management Action Plan	30 April 2001
6. Fourth GMCC Meeting	Discuss final version of Groundwater management Action Plan	30 May 2001