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Survey and Planning of Landscape Irrigation Systems in Jordan

for

International Arid Lands Consortium

July 17-July 30

Final Report

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I. Introduction

Dr. Christopher Choi and I, representing the Technical Assistance Team of the IALC Sustainable Development of Drylands in Asia and the Middle East project traveled to Jordan to meet with representatives and officials of different institutions in this country to work out and initiate collaborative research and implementation activities that would benefit this country. We visited different areas of Jordan where they have wastewater facilities, demonstration sites, and laboratories that would be used during the length of this project. Power Point presentations were given at two sites to discuss wastewater reuse and bio-solids. We left Jordan on the 29th of July feeling that a lot had been accomplished in this first visit.

II. Aqaba

Upon arriving in Aqaba we attended a meeting set up by Dr. Akrum Tamimi with the Aqaba Special Economic Zone Authority (ASEZA). In attendance was Bilal Bashir, Head of the ASEZA economic zone; Salim M. Al-Moghrabi, Head of Permitting and EIA Division; Ismail S. Bazian, Physical Planning Director; Hani Habbab, Site Engineer, PA Consulting; Taiseer, Agronomist, PA Consulting; Robert J. Cardinalli, Ph.D, Technical Director and Head of Water Reuse Program at PA Consulting; Thair, Urban Planner and GIS Supervision for ASEZA; Dr. Choi, Dr. Tamimi and myself. At this meeting Dr. Tamimi discussed the purpose of the IALC in general and the overall goals of the IALC in different parts of Jordan. He described how the IALC can partner with USAID Jordan and with other agencies in Jordan.

Bilal Bashir described the reason Aqaba needs to have high landscape irrigation efficiency because inefficient practices will cause irrigated wastewater to reach the groundwater and eventually flow into the sea. As groundwater flows into the sea, it carries the contaminants with it. However, if the wastewater is treated to the same water Quality as the wastewater treatment plant in Wasi Mousa (2ppm N), then it may be possible to use wastewater in inefficient irrigation systems. **This question requires research**.

At this point I mentioned that landscape irrigation is usually very inefficient and that there is a high likelihood that irrigation systems in Aqaba will also be inefficient unless the city established codes and water conservation officers have legal authority. Also there should be a mandate to train people to use irrigation correctly. Otherwise, the irrigation practices will be similar to most other places in the world – inefficient and non-uniform. Bilal Bashir agreed with this assessment. ASEZA staff are anxious to move ahead quickly with implementation projects, but are not particularly interested in research.

Later that day at dinner Michael Crosby gave us the following information about the coral in the gulf. He said that coral is an animal that has a bacteria within each plant cell. These bacteria called dynoflagellum (they have two flagellums) provide essential processes to each coral cell. If nutrients are high, then the delicate balance between the coral and the dynoflagellum is disrupted. In addition, the nutrients encourage the growth of algae in the water. Algae removes oxygen from the water during the day and adds it at night. This disrupts the photosynthetic and respiration processes of the coral.

He went on to describe the situation at the Gulf of Aqaba. It is an inlet that extends from the Red Sea. There is a 6-mile wide entrance to the gulf that is 230 m deep. However, most of the entrance is occupied by islands so the actual entrance width is only one mile wide. This entrance supplies a very deep and wide gulf (it is an extension of the rift valley), and because it is a narrow inlet the residence time for water in the gulf is 30 years.

There are three aquifers in the valley that contains Aqaba and Elat. Fresh water aquifers flow to Aqaba and Elat from the mountains on the eastern and western sides of the valley, respectively. A brackish aquifer flows from the north along the rift. This water has a salinity of 2,000 ppm and is used by Al Haq farms to irrigate date palms. Al Haq farms are run by the Jordanian equivalent of the FBI.

While in Aqaba we stayed at the Movenpick Hotel. It has an excellent landscape that utilizes an inline drip emitter system that appeared to be manufactured by Rainbird (brown tubing). The tubing is wrapped around the planting area and pictures of the tubing are shown in Figures 1-3. There appeared to be a little bit of salt buildup around some of the emitters (Figure 2). The tubing is wrapped several times if more water is needed around a specific tree such as a palm tree (Figure 3). The hotel has the potential to be a good demonstration site, and is across the street from the demonstration garden.

Hose irrigation is used to water the medians and parks in Aqaba. Even in a new park with a drip irrigation system, the maintenance personnel leave the drip system off and irrigate with hoses. There are small basins around each plant. Pipes (aluminum and polyethylene) often run along the surface of the medians (Figure 4). Spigots attached to the surface mainlines supply water for hose irrigation. The major plant type in the medians are palms (Figure 5). Turning circles and parks often include palms, turf, and hedges and are irrigated with sprinklers (Figure 6).

Figure 1. Tubing wrapped around fire hydrant.

Figure 2. Salt buildup around emitters.

Figure 3. Tubing wrapped around a palm tree.

Figure 4. Water supply line along the median.

Figure 5. Palms planted along medians.

Figure 6. Turning circle with palms hedges and sprinklers.

The Farouq Shrer (Farouq Street) has several types of plantings along the medians. This street is on the outer edge of the community, but within the city limits on the north side of town near the wastewater treatment plant. New plantings are irrigated by hand with hoses although there are drip lines running along the southern side of the street (Figure 7). The irrigation is utilizing the wastewater from the old wastewater treatment plant. This is a very low-quality water and does not meet minimal acceptable standards for irrigation.

Figure 7. Southern side of Farouq Shrer Street with drip line surfacing within wells.

On Farouq Shrer, the drippers were plug-in type adjustable flow emitters. Although the system is not in use, we examined three drippers. One was missing (Figure 8), one was broken, and one was intact.

Plants along the center median on Farouq Shrer were irrigated with hoses attached to a polyethylene line that ran along the center of the median (Figure 9). Parts of the ground surface looked green and other parts looked light brown from the water. Other parts did not have any residue from the sewage.

On the north side of the street, trees were arranged in rows four deep and were irrigated by hoses also that were attached to a polyethylene line. This planting was much more mature (Figure 10).

Figure 8. Tubing with missing emitter.

Figure 9. Center median along Farouq Shrer.

Figure 10. Plants along north side of Farouq Shrer.

The wastewater reuse site is near the wastewater treatment plant and Farouq Shrer on the north side of town (Figure 11). Currently, the wastewater reuse site is undeveloped. The site is 100 dunnums (10 ha), and PA Consulting plans to put 1/3 of the site in a landscape plant nursery, 1/3 in fodder, and 1/3 in fruit trees. A view of the wastewater reuse site looking northwest is shown in Figure 12.

Figure 11. Wastewater reuse site in Aqaba looking southeast.

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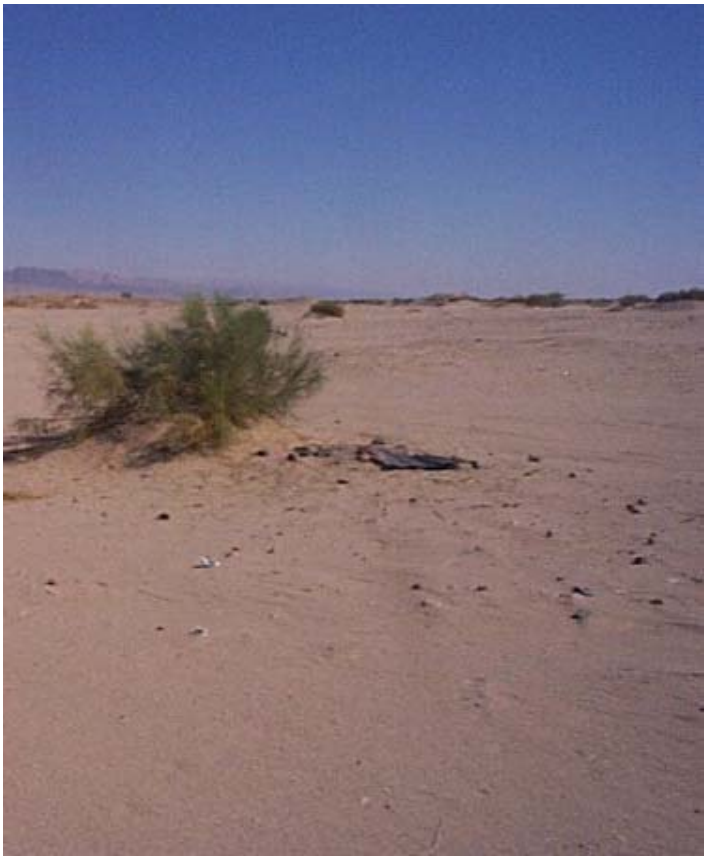

Figure 12. View of the wastewater reuse site looking northwest.

The wastewater treatment plant is a completely passive system with two facultative ponds (Figure 13) and two maturation ponds in parallel (Figure 14). Both ponds are 9 m deep. There is a 17-day design detention time; however, the ponds are currently overloaded. The flow rate into the wastewater treatment plant is 9,000 m^3/day. The loss to seepage and ET is 1,500 m^3/day. Approximately 1/3 of the wastewater irrigates a date palm farm. The farm treats the wastewater before application to the palm trees.

Figure 13. Facultative pond in Aqaba.

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Figure 14. Maturation ponds in Aqaba.

The next stop on the irrigation tour in Aqaba was the planned landscape irrigation demonstration site. The demonstration site is currently shaped as shown in Figure 15.

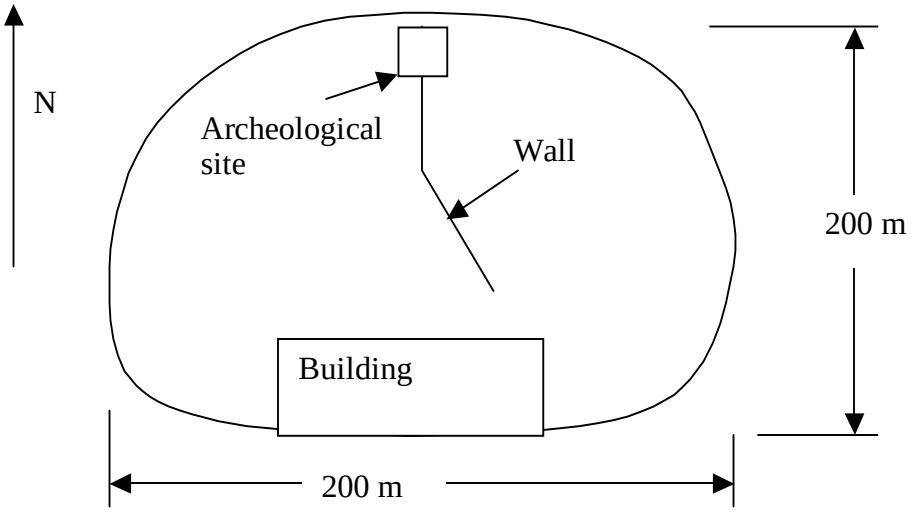

Figure 15. Demonstration site in Aqaba (dimensions are guessed).

It is possible that the building will be removed. The demonstration site is in an ideal location between all of the most expensive hotels in town and down by the waterfront. Figure 16 was taken from my room in the Movenpick Hotel. The large dirt area is the demonstration site. The white all on the south end of the site surrounds a building.

Figure 16. View of the demonstration garden from the Movenpik hotel.

The demonstration site soil is a type of sand. There appears to be very few rocks, and it would seem to be easy to trench or dig. Much of Aqaba has similar soil. One advantage of the sand is that many low water use plants require good drainage, and this site would certainly have good drainage. A view of the demonstration site from the northwest side looking southeast is shown in Figure 17. The large hole is an archeological pit where nothing was found.

Archeologists found ancient buildings at the north end of the demonstration site and the ruins appear to extend southward along the wall that runs N-S along the center of the property (Figure 15). A view of the archeological site looking toward the east is shown in Figure 19. There appears to be quite an extensive network of rooms. It seems that these features could be integrated into the demonstration garden. The white wall in the background surrounds a rather unattractive government building. There was some indication that it could be removed or changed if necessary. The archeological ste continues onto the north side of the street surrounding the demonstration garden. The view of the north side excavation is shown in Figure 20. A view of the east side of the demonstration garden is shown in Figure 21. A view of the demonstration garden looking southwest is shown in Figure 22.

Figure 17. Demonstration site in Aqaba with archeological pit.

Figure 18. Archeological excavation along the road north of the property.

Figure 19. Demonstration site with view south along wall.

Figure 20. North side excavation (not part of demonstration garden).

Figure 21. East side of demonstration garden.

I think it is important for Margaret Livingston to contact the people who are in charge of the archeological diggings so that discussions can begin on the best way to integrate the demonstration garden and the digs.

Figure 22. A view of the demonstration garden looking southwest.

A slide show was presented to Bilal Bashir and others from ASEZA (10 people) at the Marina. I discussed the need for irrigation efficiency. There is a lack of irrigation efficiency and uniformity in most landscape irrigations systems in general, and I used my study of landscape irrigation systems in Phoenix as an example. I mentioned the critical need for irrigation efficiency in Aqaba because the ground water flows directly into the g Gulf of Aqaba where a nutrient excess threatens the coral. I discussed the need for water conservation officers in Aqaba and of the possibility of giving the officers some legal authority. I stated that I would like to see bubblers and in-line drip emitters incorporated into the demonstration garden. Also the possibility of linking the demonstration garden in Aqaba to the Desert Irrigation Research and Training Center in Tucson was approached. The slide show given in Aqaba is included as appendix A. Because of the danger of wastewater treatment inconsistencies, I emphasized that the wastewater should not be used for vegetable production (I mentioned this somewhere, maybe not here, but they agreed and decided that they would emphasize that people shouldn't grow vegetables, but they would have to leave it up to the citizens to make their own decisions).

III. Wadi Mousa

We left the hotel in Aqaba and drove to the Wadi Mousa (Petra) Wastewater Treatment Plant (WWTP). The WWTP was very impressive. The odor control system is shown in Figure 23. The activated sludge system is shown in Figure 24. The clarity of the effluent discharged into the ponds is shown in Figure 25. It discharges a very high quality wastewater. The nitrogen in the effluent is in the range of 2 ppm according to the representative from the wastewater treatment plant. However, the treatment plant is dramatically under loaded (1/3 capacity) due to the lack of tourism in the area, and wastewater quality may decrease with increased tourism. Drying beds and bio-solids are shown in Figure 26. Treatment plant operators said that the trees in Figure 27 were planted a little over one year ago, and have grown very fast because of the bio-solids. Much of the bio-solids have been removed by plant employees and they claim they have tremendous yields because of the use of bio-solids in their orchards. The final stabilization pond is shown in Figure 28.

Figure 23. Odor control system at Wadi Mousa wastewater treatment plant.

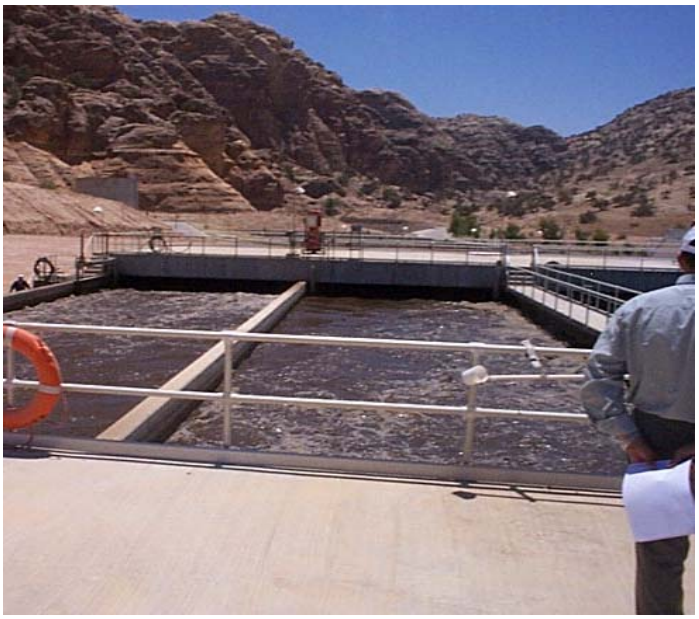

Figure 24. Activated sludge system at Wadi Mousa wastewater treatment plant.

Figure 25. Effluent discharged from final clarifiers.

Figure 26. Drying beds and bio-solids at Wadi Mousa wastewater treatment plant.

Figure 27. Trees fertilized with bio-solids after one year.

Figure 28. Final stabilization pond at Wadi Mousa

We toured the demonstration gardens and there were mixed results. Landscape plants and trees appeared to be doing Ok (Figure 29-31), and they were all being watered by hand. Agronomic crops such as sunflowers, alfalfa, and corn were not doing as well. The drip irrigation system is not in use yet so they are being watered with hoses. There is some difficulty in getting the manual laborers to be responsible to water the plants consistently. PA Consulting specified that they wanted to use purple tubing (Figure 32) because of the use of reclaimed wastewater. They tried to work with one manufacturer, but that company could not get the purple dye into the polyethylene. Another manufacturer was able to include the purple dye. The tubing felt very thin and is probably not designed to last beyond one or two years. Another problem with the irrigation system was the fact that the contractor installed the pump on pallets rather than concrete and wiring was done incorrectly.

Figure 29. Landscape plants at Wadi Mousa demonstration site.

Figure 30. Landscape plants at Wadi Mousa demonstration site.

Figure 31. Landscape plants at Wadi Mousa demonstration site.

Figure 32. Drip irrigation system with pressure regulator at Wadi Mousa.

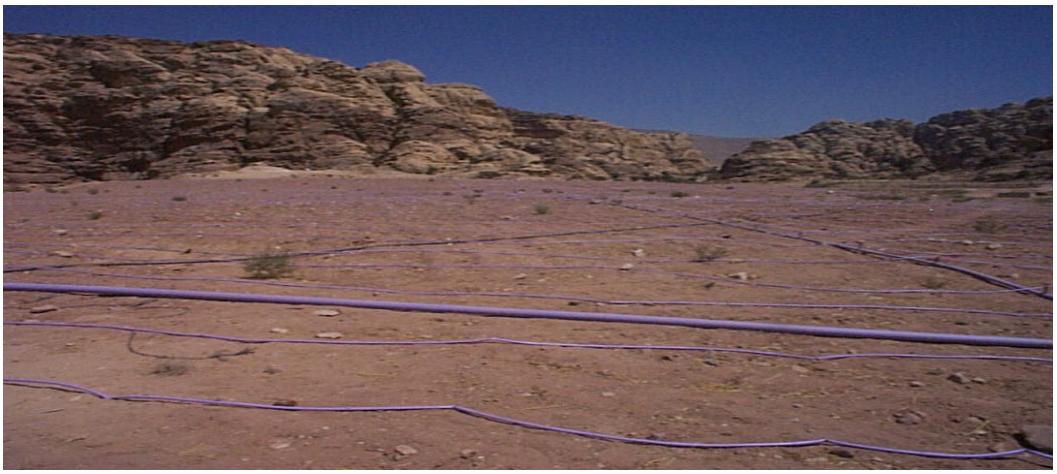

Figure 33. Drip irrigation system at unplanted ground at Wadi Mousa.

We met with PA Consulting and discussed the issue of the demonstration garden around the visitor's center and that Margaret Livingston, from the U of A, might be able to help with this project. PA Consulting said they only have $20,000 budgeted for the visitor's center and, consequently will have to be a simple design. They will start building the center in September because they need to complete their contract. There was some discussion because the Badia feels the visitor's center should be more extensive. I think the visitor's center is in the right location; however, more money than what is budgeted will probably be needed to make it an effective outreach tool. Most of the landscape plants are already planted so a minimal amount of work will be needed by Margaret Livingston at this site.

The slopes at this site are very steep which makes the design of the drip system difficult. I think that the drip design should be modified to include telescoping pipes in order to reduce the energy due to elevation gain. There was a pressure regulator on the system (Figures 33 and 34), but there should be some method of keeping pressure constant on the slope unless the emitters are pressure compensating, and it is my understanding that they are not. The main lines were above-ground polyethylene (this may be a common practice in Jordan), but I would prefer to see buried mainlines. I recommend approving the design if the system has a distribution uniformity (DU) of 80% while it is running.

Figure 34. View of the hill where the visitor's center will be located.

The proposed visitors center at Wadi Mousa is located on a high point (Figure 34) and looks out over the wastewater treatment plant, the demonstration site, and proposed farms. There is an existing structure (Figure 34) that will be torn down and replaced by a 1,000 square foot structure with two rooms. It seems that a very attractive demonstration garden could be designed on this hill with a wetlands project and other landscape features. The view from the hill is shown in Figure 35 with a view of the demonstration gardens and the proposed farm area in the background.

Figure 35. View from the proposed visitor's center.

The next day two groups were formed to write proposals. One group – Akrum Tamimi, Pete Waller, Dr. Hani Saoub, and Dr. Jamal Sawwan from the University of Jordan - wrote an outline of a proposal to build a demonstration garden at Aqaba. The other group – Dr. Choi, Wael Suleiman, and Dr. Bassam Hayek from RSS – wrote a bio-solids proposal. The outline for the Aqaba demonstration garden proposal is included below. Dr. Tamimi will finish writing the proposal and coordinate with the cooperating institutions. The only change to the proposal so far is that RSS will act as the contractor.

Draft Proposal

Literature Review
Literature review of landscape irrigation and plants.
Demonstration sites
Irrigation systems
Reclaimed water and SDI
Technology from Arizona

Background
IALC – Sustainable Development of Drylands in Asia and the Middle East.
Pipe network in Aqaba
Degradation of the coral reef
Ground water movement toward ocean with treated wastewater
ASEZA and the development of tourism and greening the city of Aqaba

The lack of uniformity and efficiency of landscape irrigation

Partners

University of Arizona
- Peter Waller
- Margaret Livingston
- Akrum Tamimi
- Don Slack

University of Jordan
- Jamal Sawwan
- Hani Saoub

WEPPIA
- Mona Greiser

Xeriscape committee

ASEZA
- Bilal Bashir

IALC
- Bob Freitas (education)
- Ed Martin (extension)

Objectives

To promote efficient and proper use of reclaimed water in residential and public landscapes
To protect the coral reef
To promote and test use of landscape plants in Phoenix
To evaluate different irrigation strategies for landscapes in Aqaba
To demonstrate use of bio-solids in landscapes
To promote use of landscape rocks in Aqaba.

Activities

Adopting a design and plans of the IALC project.
Select a student
Hire an agronomist
Develop a management system based on individual plants
Set up demonstration garden
- Development of bidding materials
- Hire and company to install the landscape and irrigation system
- Company to install for the first year
- Transfer to ASEZA for maintenance

Set up weather station and sensors in garden
Student will conduct statistical analysis of the treatments
Extension and education (signage, publications, and workshops)

Plant types
Pine trees
Bougainvillea
Mesquite
Acacia
Palm
Lantana
Cassia
Ponciana (red flowered tree)
Jacaranda (blue flowered tree)
Cactus and Agave
Annual flowers

Landscape types
Home gardens – 5 m wide samples of gardens
Park gardens
School gardens
Hotel gardens
Line the periphery as a median garden
Turf area (bio-solids for the turf)

Irrigation types
Bubblers
Adjustable
Pressure compensating
Drip
In-line drip emitters (purple should be covered with rocks)
Multiple outlet emitters
Flag emitters

Division of responsibilities
Pete – bill of quantities for irrigation system
Margaret – bill of quantities for plants and materials
RSS – Act as contractor for installation (this is a change made during visit to Amman)
ASEZA – cost share on weather station maintenance and hire an agronomist.
Cost share – Bob take one trip, Pete take 2 trips, Slack take 1 trip, Ed Martin take one trip, Margaret take one trip.

Budget (Proposed)

Task	IALC requested	Jordan	U of A
Design the IALC project.	Cost – share		20,000
Recruit a student	$200		
Hire a student	$10,000 for 2 years		
Hire an agronomist (ASEZA)		$14,000 for 1.5 year (0.5 years to 2 years)	
Develop a management system based on individual plants			Travel – salary accomodations $7,000

Development of bidding materials and bidding	$300 * 10 * 3 = $9,000		
Hire RSS to install the landscape and irrigation system	$35,000	$5,000	
Contracting Company to manage for 6 months	$10,000		
Laborers		$5,000 is 2 for one year.	
Set up weather station and sensors in garden		$27,000	
Student will conduct statistical analysis of the treatments – computer and supplies	$2,000		
Extension and education (signage, publications, and workshops)	$1,000 signage + $2,000 literature + $2,000 brochures + technical (20 people with lunch $500) + public (100 people with lunch $1,000) workshop personnel $1,500 * 2 days. **=$7,500**		

IV. Amman

We left Wadi Mousa and drove to Amman. There we gave a seminar to the RSS and University of Jordan personnel in Amman. The Badia was supposed to be there, but there was a miscommunication due to the change in plans after the British Airways delay. Dr. Choi talked about bio- solids and wastewater irrigation. I talked about irrigation, chemigation, and remote sensing. The irrigation lecture was similar to the Aqaba lecture on irrigation, and the chemigation and remote sensing lectures were taken from my class lectures which are available online at:

http://ag.arizona.edu/classes/ABE456/ and

http://ag.arizona.edu/classes/ABE455/.

V. General Observations

After the lectures we toured the RSS labs. It is very clear that the RSS has a high level of expertise and would be an excellent partner to work with. Bassam and Wael also discussed other areas of possible collaboration such as water harvesting. I discussed the possible writing of a proposal on water harvesting with RSS representatives. Meetings were held with the president of RSS, the head of the Badia (Mohammed Shahbaz) and the head of the USAID Mission in Jordan (Amal Hijazi).

The Badia has an excellent program. They are assessing ground water basins from a holistic point of view and developing maps for possible land use planning. Input parameters to the model include energy resources, water resources, soil resources, and other considerations.

Amal Hijazi met with us and seemed to have an excellent grasp of the proposed wastewater treatment plants and other needs in Jordan.

In general was very impressed with the level of expertise in Jordan and hope to have cooperative research with the Badia, RSS, and the University of Jordan.