OPTIMIZING THE WATER ALLOCATION SYSTEM AT JORDAN VALLEY THROUGH ADOPTING WATER EVALUATION AND PLANNING SYSTEM MODEL (WEAP)

Dr. Iyad Hussein[1] and Dr. Radwan Al - Weshah[2]

[1]Consultant in Water and Environment
E-mail: dr.iyad@index.com.jo
[2] Regional Hydrologist/ UNESCO Regional Office in Cairo, Egypt
E-mail: weshah11@yahoo.com

ABSTRACT

The Jordan Valley Basin is considered as the backbone of Jordan Development sectors and has remarkable activities in terms of water demand and supply; the demands which comprised Agricultural and domestic uses.

The current status of the Jordan Valley is the sufferance of enough and affordable water for the different uses, which invite the essentiality of adopting a water allocation and management model to develop a number of water demand/supply scenarios which will be considered as a lateral thinking towards bridging the deficiency.

Water Evaluation and planning system Model (WEAP) is considered as one of the effective management tools in allocating the water resources under increasing competitiveness and shortage of water for the different uses.

The model was tested and adopted for the current status of the valley. Future scenarios were considered in running the model and testing the water demand/supply system. These scenarios were focused on reuse of treated wastewater in the North regions for irrigation practices; raising the efficiency in the irrigation practices mainly in the middle Ghors and using 50 MCM from the Unity Dam to cover part of Amman city domestic demand.

Results of the WEAP were in the form of:

- Stream flow (below node or reach listed)
- Inflows and Outflow to Area
- Reservoir Inflows and Outflows
- Transmission Link Flow
- Costs of delivering the water to the targeted demand
- Expected revenues
- Return Link Inflows and Outflows
- Surface Water Quality (TDS, BOD, and pH)
- Unmet Demand

- Water Demand (not including loss, reuse and DSM)
- Demand Site Coverage (% of requirement met)T

Water Quality constraints were considered in the system (pH, BOD, and TDS) where three types of water were considered; fresh water (without any treated wastewater), blended water (fresh and treated wastewater) and (only treated wastewater). The capital and operation cost of each resource were considered in running the model to check the most optimal allocation from the financial point of view. Expected revenues out of allocation of the water for the different purposes were considered in the selection exercise of the model.

It was proved that optimizing the water supply system in the Jordan valley should consider the technical as essential as the financial aspects to fulfill the integrated management of the available resources.

This paper will assist the decision makers in the field of water resources planning and management in Jordan and similar countries in the region to use WEAP model to better manage the water demand / supply cases and forecast for the future. It is worth mentioning that certain parts of the research were conducted at water and research center at Jordan University.

I. WATER IN JORDAN

Water problems in Jordan are diverse and changing as the gap between supply and demand widens. Water issues are linked to scarcity, mal-distribution, and sharing. The development and management of water resources in Jordan presents a challenge for water managers and experts.

The adoption of new water allocation policies in Jordan is crucial for sustainable water development. This strategy should focus both on demand management and development of non-conventional water resources. With the same trends in population growth and water use, the gap between water supply and demand will continue to widen. The objective of this paper is to present the adaptation of " Water Evaluation and Planning Model" named WEAP for analyzing the available water resources and demands for the different purposes and best manage the water demand and supply under the most technical and financial conditions. The model was applied in the Jordan Valley Basin which is considered as the backbone of the agricultural sector in Jordan and one of the main surface water resources for domestic purposes in Amman.

Water Supply and demand in Jordan

In Jordan, the gap between available water supply and demand was first observed in the domestic sector. The gap is more likely to widen further in the municipal, agricultural and industrial sectors unless adequate measures are taken.

Jordan's water resources are composed of surface water, groundwater and reclaimed wastewater. Total available water amounts to 1050 million cubic meters (MCM) in 1998 (MWI, 2006). Surface water contributes 470 MCM and reclaimed wastewater amounts to 70 MCM. Groundwater makes the largest contribution of 510 MCM/yr. Groundwater abstraction is 450 MCM from renewable aquifers and 60 MCM from non-renewable basins. The safe annual yield from the renewable aquifers is estimated to be 280 MCM, which means that about 170 MCM are being over pumped (i.e. the annual abstraction is 161% of the safe yield). This over exploitation of ground water resources imposes a major constraint on sustainable water development.

Municipal uses represent around 21% of the total consumption and irrigation uses represent around 69% of the total consumption. Ground water is considered the main source for irrigation and municipal uses followed by surface water. With the current trend in water use, it is anticipated that within the next decade, Jordan will have utilized all the potentially available conventional water resources. By 2020, the population of Jordan is projected to become 10 million. The demand in the municipal sector will be about 700 MCM and in industry about 150 MCM. Based on projections of water supply and demand, Jordan is likely to face a potable water crisis by 2010.

Table (1): Current Water Uses in Jordan in 2006 (Unit: MCM/year)

Resource Uses	**Surface water**	**Groundwater**	**Reclaimed Wastewater**	**Total**
Municipal	65	170	-	235
Irrigation	350	313	60	723
Industrial	3	22	10	35
Others	52	5	-	57
Total	**470**	**510**	**70**	**1050**

Table (2): Water Demand, Supply and Deficit of Jordan for the period (1995-2020)

Item	**1995**	**2000**	**2005**	**2010**	**2020**
Population (millions)	4.4	5.2	6.1	7.0	10.0
Water resources (MCM/yr)	832	902	1042	1092	1150
Water demand (MCM/yr)	930	1050	1375	1570	1800
Deficit (MCM/yr)	**98**	**148**	**333**	**478**	**650**

Available Water Resources in Jordan

Groundwater Resources

Jordan's water resources, surface and groundwater, depend mainly on rainfall which is estimated at a long term average value of 8532 MCM/year (MWI). Moreover, the former figure is subject to substantial variations with the nature of rainfall patterns in the country. Variation may fluctuate at ± 4 averages as will be described later.

Groundwater constitutes the most important available resource that can be tapped in over 80% of the country in varying quantities and qualities, and at varying depths ranging from a few meters to more than 1000 meters. Groundwater in Jordan is of two types, renewable and fossil. The latter constitutes 5% of the total groundwater storage of most hydro-geological regimes in Jordan. Estimates of the groundwater safe yield are around 280 MCM/year.

For the fossil water quantities, found in the south eastern part of the country, estimates depend on the exploitable depth and other hydro-geological factors, however this reserve is estimated at 90 MCM/year for a period of 100 years. Quality of groundwater varies from one aquifer to another; salinity ranges from 170 ppm to 3000 ppm in some places.

Surface Water Resources

Surface water resources in Jordan comprise two principal parts; base flow and flood flow. Base flow is derived from groundwater drainage through springs. Surface water is developed through 13 water basins distributed all over the country. In 1998 the actual supply of surface water was 470 MCM/year (MWI) and this number is expected to increase to 550 MCM/year by the year 2010. This increase is due to the construction of Unity Dam at Yarmouk River and other side Wadis reservoirs.

The main surface resource is the Yarmouk basin in the north which contributes almost 45% of base flow and flood flow waters in Jordan. Eleven dams with a total safe yield of 130 MCM/year have been constructed along the main rivers and streams of the Jordan valley.

Non-conventional Water Resources

Different non-conventional water resources are considered as potential water resources. These include reclaimed waste water, ground recharge, water harvesting, desalination of brackish and sea water and importation of water across national boundaries. A brief description of these resources follows:

A. Reclaimed Waste Water

Reclaimed wastewater is an important non-conventional source in Jordan. Currently, there are 21 operating plants of which Khirbit Al Samra is the largest with effluent volume corresponds to about 75% of the effluent volume nation wide. Plans are underway to construct 23 more treatment plants to serve an additional 34 towns and villages in Jordan. These plants will have a combined treatment capacity of 90 MCM in the year 2007 and 110 MCM in the year 2010 (MWI).

Extensive plans and studies are underway to assess the feasibility of using reclaimed water for irrigation in areas adjacent to the treatment plants. The current policy of Water Authority is to consider the reclaimed wastewater as a valuable commodity and should be utilized efficiently close to the treatment plants or at the potential areas. About 70 MCM/year is used currently for restricted irrigation purposes.

Recent studies at Water Authority showed that the average unit cost of treating one cubic meter of wastewater in Jordan is 0.52 $.

B. Water Harvesting

Two types of water harvesting applications are considered for the case of Jordan; urban water harvesting such as the roof harvesting, and the agricultural water harvesting such as the cases of artificial recharges at potential catchment areas.

C. Desalination

Desalination of brackish and sea water seems to offer a sound alternative to arid lands bordering seas or salt lakes; desalination plants producing up to several million gallons per day are commercially available and already used for domestic and industrial purposes in some arid regions.

Figures show that a total desalination capacity of 15 million m^3/day is expected to be installed within the Arab World during the next 25 years. With present capital required for erecting desalination units ranging between $ 1000-2000 per (m^3/day) installed capacity, it is estimated that 15-30 billion US$ would be needed for such a purpose.

In Jordan, two main sources are available to be desalted: the red sea at the Gulf of Aqaba and brackish groundwater in Jordan Valley basins. Preliminary studies show that by the year 2010 more than 20 MCM/year could be developed in the Central Jordan Valley. This figure may reach 70 MCM/year by the year 2040 (JICA, 1995).

For the case of seawater desalination at Aqaba, the transportation cost of fresh water from Aqaba to the capital Amman may add big burden on the total unit cost.

D. Importation of Water

Preliminary studies have been conducted to assess possibilities for importing water to Jordan, and sources have been identified in Turkey, Lebanon and Iraq (GTZ, 1999). Conditions which are necessary for the success of such options are (a) the enforcement of regional monitoring of water resources and uses and (b) the establishment of a regional water commission to ensure sustainable water management.

E. Mega-scale projects

Two mega-scale projects are considered in the Jordan water sector investment plan. These projects are the Red-Dead project and Disi-Amman project. The first project is a multi-purpose scheme that entail a conduit that convey the water from the Dead sea towards a desalination plant using the difference in elevations that will generate electricity, and then to the Dead Sea. The desalinated water will be conveyed again to Amman and other potential demand centers. The second project, Disi-Amman project entails a conduit that conveys the fossil groundwater from Disi aquifer towards the north up to Amman city.

II. FUTURE SCENARIOS FOR SUSTAINABLE WATER DEVELOPMENT

The approaches for dealing with water issues in Jordan are characterized by challenging management. This was evident in three major areas of water management:

1. Rationing and interruptions of water supply for many users during summer times.
2. Water quality deterioration for both domestic and irrigation.
3. Delays of tariff adjustment after opposition from farmers are voiced.

Dealing with management of water resources under severe shortages created an overburden over the responsibilities of the decision makers in Jordan. The following issues in water management have been identified. These include problems related to fluctuations of supply, water pricing, water quality and user's participation.

Uncertainty and Fluctuations in Water Supply

Surface water resources depend on base flow and flood flow. Due to the erratic distribution of rainfall from one year to another, potential water supply in Jordan is uncertain and the range of fluctuations from year to another are high (above 25%) of the average annual figure. During the period of (1998-2000), rainfall experienced about 35% reduction in comparison to the long term average. This was repeated in the years 2004/2005 with less reduction ratio.

Subsequently, rationing of domestic water supply has been practiced. In addition, during the second Gulf war, an emergency plan was implemented to supply water for the domestic users especially after receiving more than 700,000 Iraqi residents to live in the country.

Over-exploitation of ground water in the Jordan Valley basin is taking place. In 2003, the extraction rate was about 42 MCM while the safe yield was only 21 MCM/year. As a result, water quality deteriorated and moreover some aquifers faced mining. Therefore, preventive measures must be taken to ensure the sustainability of water development in Jordan.

Water Pricing

A tariff of 0.2 cents per m^3 of irrigation water in the Jordan Valley was first introduced in 1961. In 1966, this rate was raised to 0.4 cents for water consumption exceeding 1800 m^3 per 1000 m^2 of irrigated land. This rate was increased again to 0.6 cents per m^3 with no limit of water consumption in 1974 and to 1.2 cents per m^3 in 1989.
Tariffs are usually opposed by users, especially farmers. The ability and willingness-to-pay for water are usually evaluated prior to any increase in water pricing.

Water quality

One major environmental problem in Jordan is related to water pollution. Such a problem is caused by water resources contamination with inadequately treated waste water, cess pools and other environmentally-hostile practices. Deterioration of the quality of Zarqa river water course and King Talal Reservoir water is a representative example as of the above causes.

User's participation

Efficient and sustainable development in the Jordan Valley requires participatory irrigation management. This means joint involvement and shared responsibility by both the Jordan Valley Authority (JVA) and the users in the operation of an irrigation system. This requires a revision of relationships and involvement of users in the decision-making process.

The JVA is in the process of modifying its law to open the door for private sector participation in operation and management of irrigation activities.

III. NATIONAL WATER POLICY FORMULATION IN JORDAN

The formulation of coherent water policies would help guide strategic decisions regarding water priority allocation, water rights, efficiency of service, and environmental protection.

Recently, a national water program was developed. The overall objective of the program was to formulate water policies for the sustainable development of water resources in Jordan. Moreover, the program aimed to build consensus within the water sector and stakeholders. The program was characterized as a participatory approach where various groups (public officials, private sector consultants, and NGO's) were involved in the entire process.

A summary of the major water policy issues and their corresponding policy components is presented in Table (3). Critical policy issues include allocation priorities, investment options, conservation and efficiency measures, and privatization.

To achieve the above proposed water policies, a coherent institutional framework is needed to ensure access and accountability. Such institutions should be characterized by a distinct separation between the management of water resources (regulatory functions) and the delivery of water services (functional activities). The introduction of a mathematical and management model was essential to achieve the transformation from the traditional thinking into the lateral thinking and adopting a coherent model that will consider the different water resources at the Jordan Valley and the demand centers for the different uses followed by simulating and optimizing these resources to be best allocate for the demand centers. The following sections will elaborate more about the conceptual framework of the model "(WEAP) which stands for "Water Evaluation and Planning System Model".

Table (3): Summary of water policy issues and their components

Water policy issues	Water policy components
Water resources assessment and monitoring	- national monitoring program - central entity for integrated management - water sustainability
Rehabilitation versus new investments	- criteria for project priorities
Regional and shared water resources	- principles to reach agreements - mechanisms for cooperation and trust
Standards and guidelines	- quality control program - standardized procedures
Water rights and water markets	- define water rights - examine possibilities of water markets
Water pricing and cost recovery	- coverage of O&M cost - differential water pricing
Intersectional allocation	- highest priority to domestic uses - adopt water productivity criteria, employment generation and socioeconomic development
Waste water management and reuses	- treatment and reuse of effluent in accordance to standards
Pollution prevention	- integrated environmental management program
Conservation and efficiency measures	- measures to improve efficiency
Privatization and private sector participation	- private sector participation should be pursued to improve efficiency and accountability

Stakeholder Participation and public awareness	- promote participation at planning and operation levels - educate the public about water issues
Research and Development	- encourage research in all related water issues

IV. PREFACE OF JORDAN VALLEY BASIN

As discussed in the previous chapters, Jordan Valley Basin has remarkable activities in terms of water demand and supply and is currently witnessing a shortage of fresh water resources. The demand which comprised Agricultural activities in the valley and Domestic uses in the main cities. The following sections describe the building steps of WEAP over the JV basin model, testing and running the model for the current status and future scenarios. Results were presented after each of the proposed scenario.

WEAP Structure: Building Steps over JV Basin Model

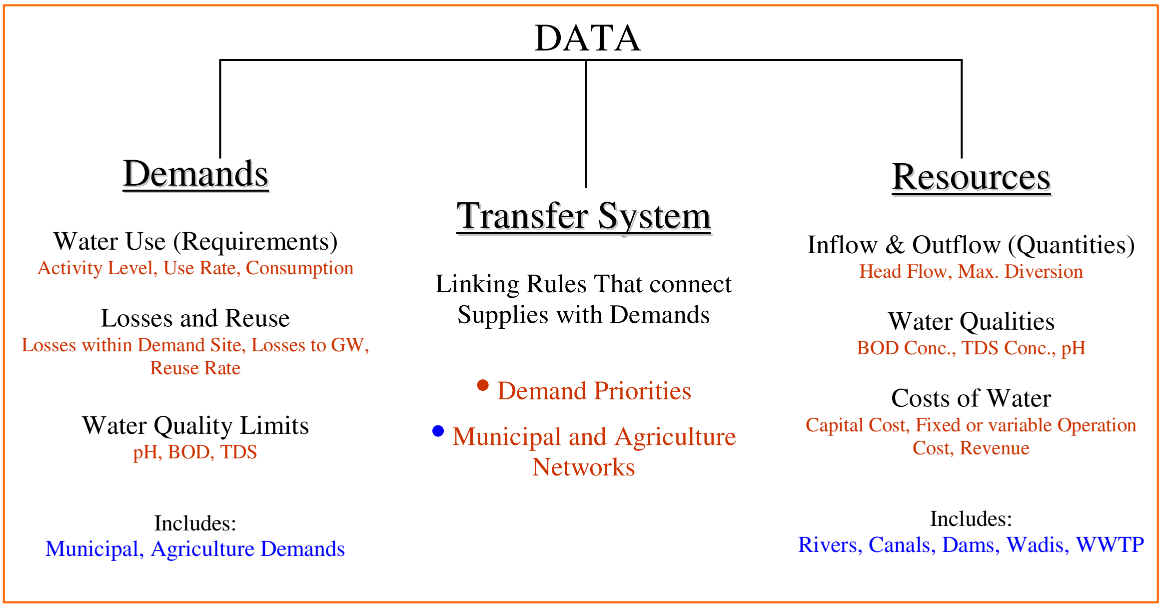
WEAP consists of three subsystems: namely, data, model and dialogue. The first sub-system of WEAP is the Data part which need to be provided to the model:

Input Data to the Model:

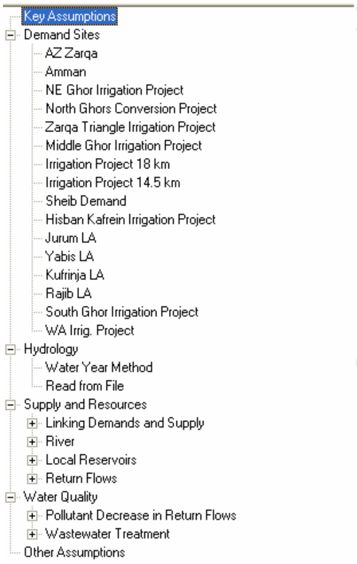
The data that were considered in the model can be classified into:

- Demand Data
- Transfer System
- Water Resources

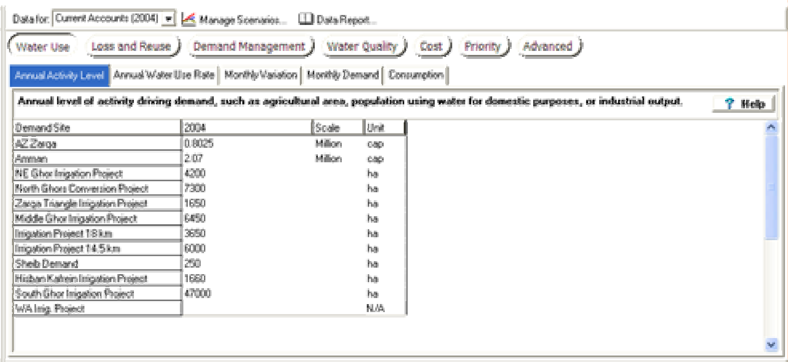
Details of the data that were considered in the WEAP can be shown in the following box.



Figures Represent the input data on the system



Tree View



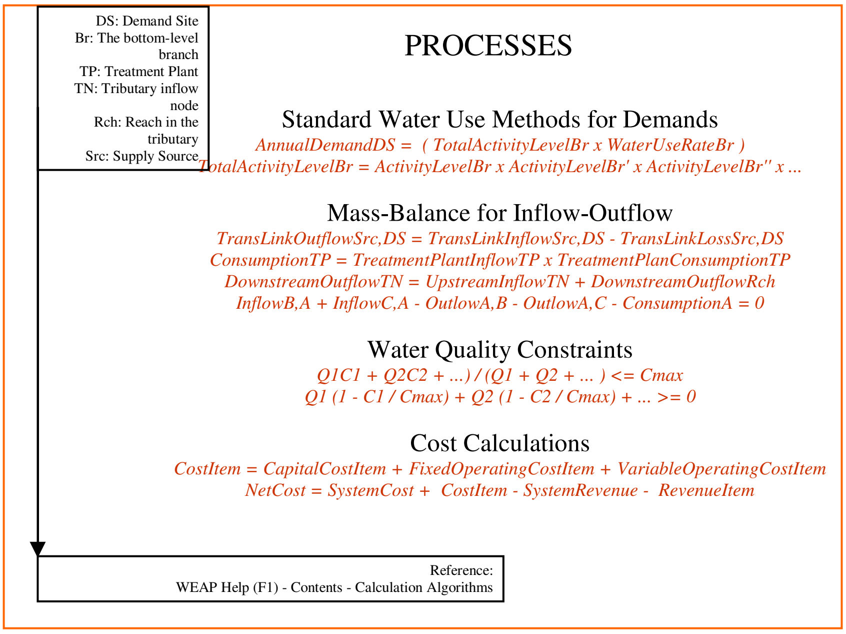
Database View (Tables)

Model Subsystem

The second subsystem is the model subsystem which entails all the mathematical processes that will take care of all the necessary calculations.

Processes of WEAP

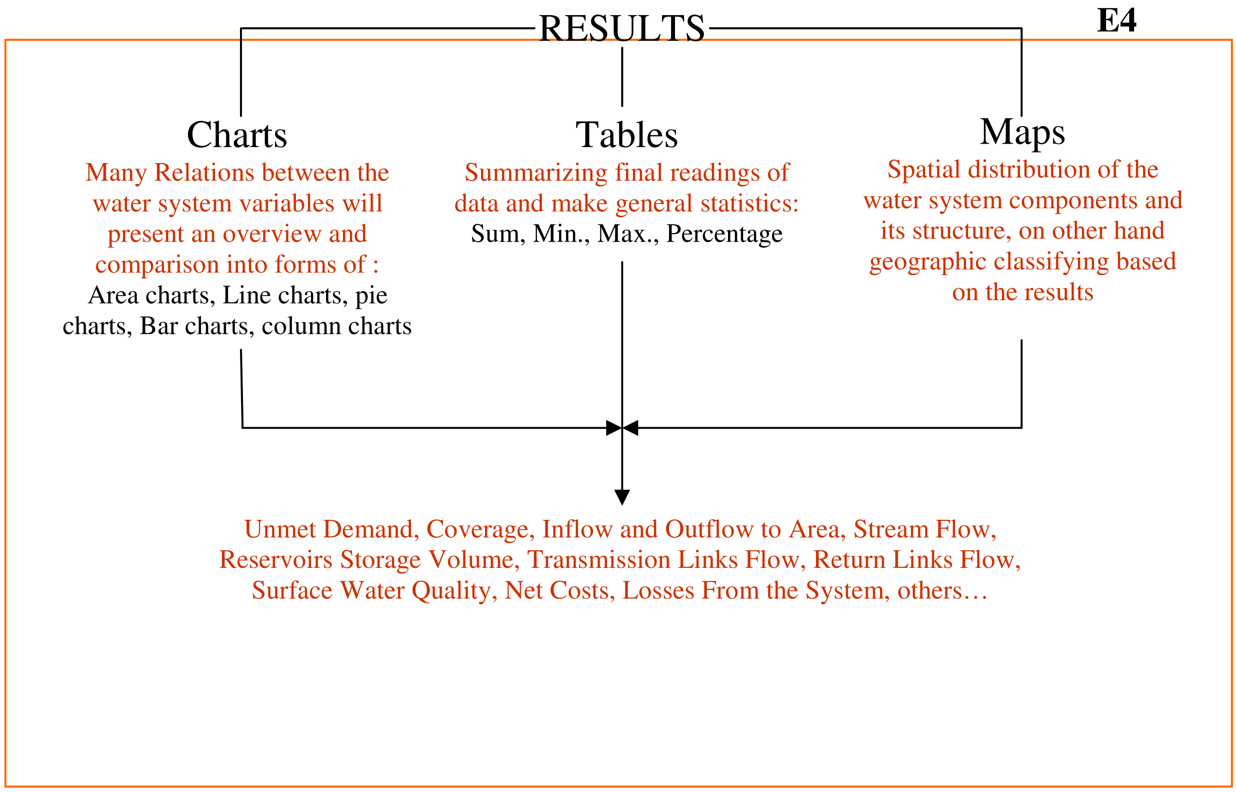
The processes that are embedded in WEAP which will enable the model to do the necessary calculations such as mass balance and water allocation. Processes entails water qualities, quantities and financial aspects in terms of capital and operation cost of the available resources.

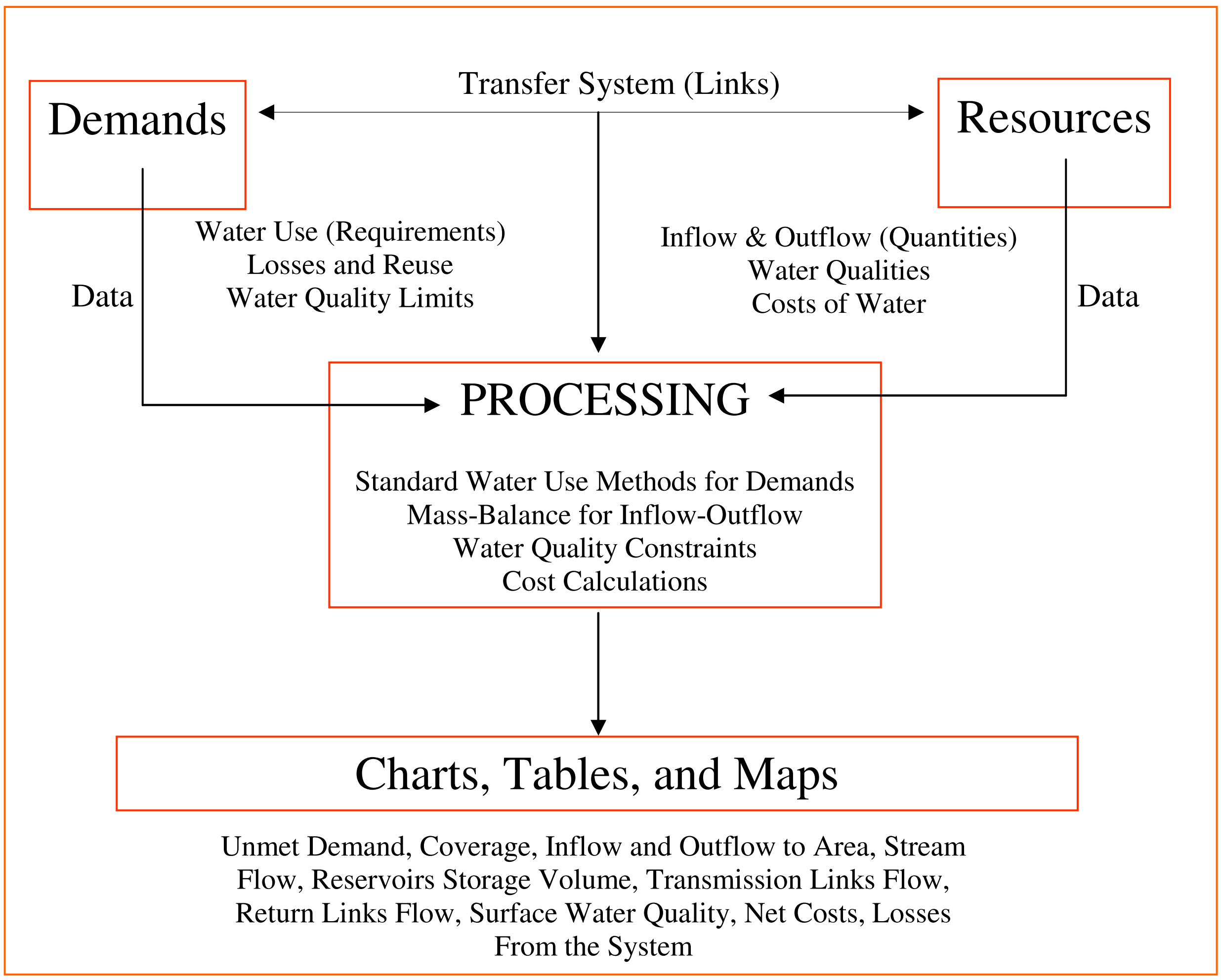


Dialogue Subsystem

Dialogue subsystem is the third part and was presented through simulating the results and changing in the input data.

Results of the model can be presented in the form of Charts, tables and maps. Description of such results can be shown in the following box.


E4
RESULTS
Charts
Many Relations between the water system variables will present an overview and comparison into forms of :
Area charts, Line charts, pie charts, Bar charts, column charts
Tables
Summarizing final readings of data and make general statistics:
Sum, Min., Max., Percentage
Maps
Spatial distribution of the water system components and its structure, on other hand geographic classifying based on the results
Unmet Demand, Coverage, Inflow and Outflow to Area, Stream Flow, Reservoirs Storage Volume, Transmission Links Flow, Return Links Flow, Surface Water Quality, Net Costs, Losses From the System, others…


Demands
Transfer System (Links)
Resources
Data
Water Use (Requirements)
Losses and Reuse
Water Quality Limits
Inflow & Outflow (Quantities)
Water Qualities
Costs of Water
Data
PROCESSING
Standard Water Use Methods for Demands
Mass-Balance for Inflow-Outflow
Water Quality Constraints
Cost Calculations
Charts, Tables, and Maps
Unmet Demand, Coverage, Inflow and Outflow to Area, Stream Flow, Reservoirs Storage Volume, Transmission Links Flow, Return Links Flow, Surface Water Quality, Net Costs, Losses From the System

V. ACTUAL IMPLEMENTATION OF THE MODEL

Used Data for the Water Resources:

The following data were considered as an input data for the available water resources in the JV:

- Three Rivers (Yarmouk, Zarqa, and Jordan River)
- One Canal (King Abdullah Canal)
- Eleven Wadi (Valley) (Wadi Arab, Wadi Taibeh, Wadi Ziglab, Wadi Abu Ziad, Wadi Jurum, Wadi Yabis, Wadi Kufrinja, Wadi Rajeb, Wadi Shueib, Wadi Kafrein, and Wadi Hisban)
- Eight Surface Water Reservoirs (Unity Dam, Lake Taiberia, Arab Dam, Shurabil Dam, KTD, Karameh Dam, Shueib Dam, and Kafrein Dam)
- One Groundwater Reservoir (Azraq GW)

Used Data for the Demand Areas:

The following demand areas were identified in the model, based on the real conditions in the JV:

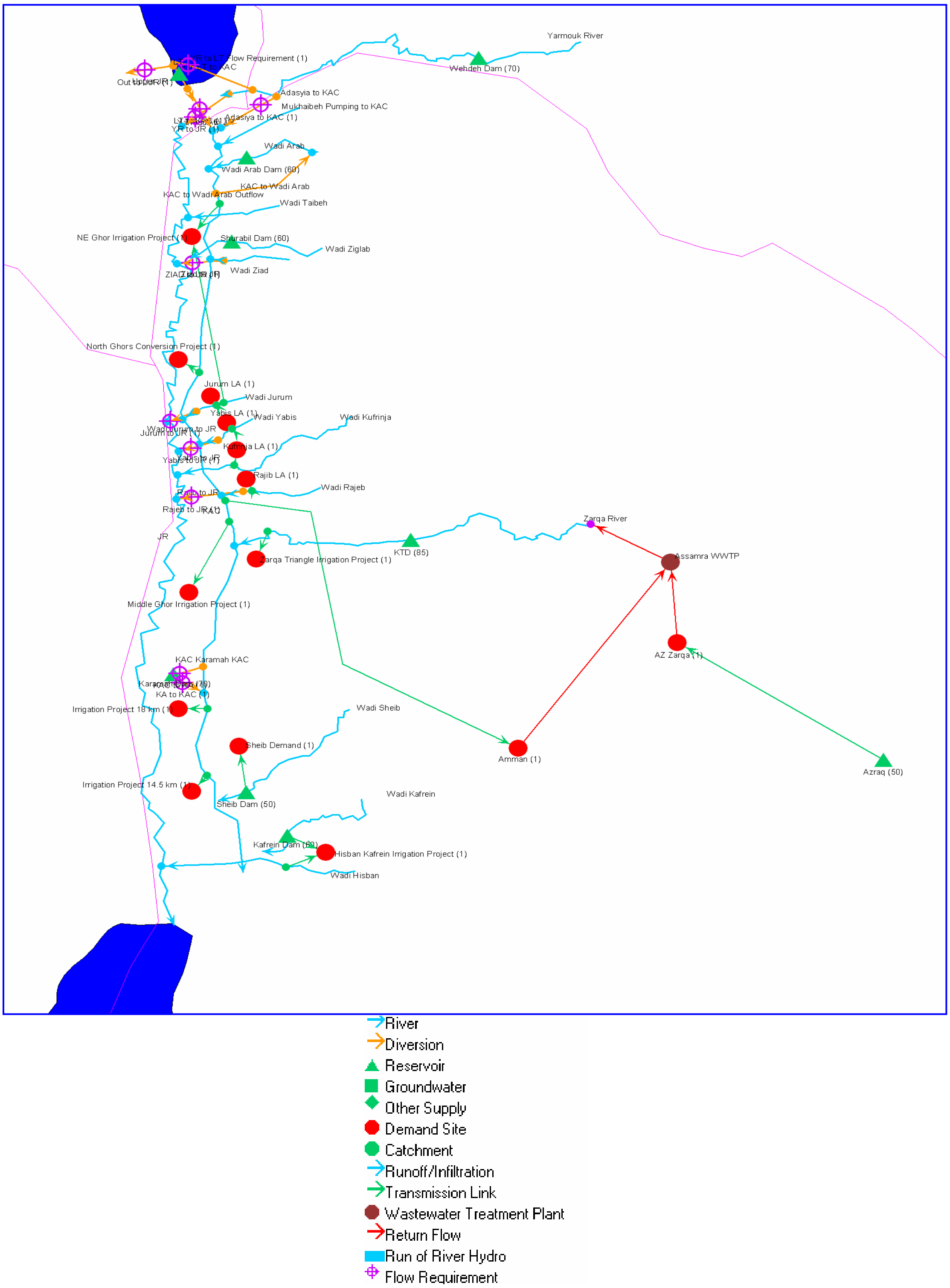
- Agriculture Demands (NE Ghor Irrigation Project, Wadi Arab Irrigation Project, N Ghor Irrigation Project, M Ghor Irrigation Project, Zarqa Triangle Irrigation Project, Irrigation Project 18.5 km, Irrigation Project 14.5 km, South Ghor Irrigation Project, and Hisban-Kafrein Irrigation Projects)
- Domestic Demands (AZ Zarqa, and Amman)
- Local Areas and Rights (Jurum LA, Yabis LA, Kufrinja LA, Rajeb LA, and Shueib Demand)

Building the Scheme for JV Basin

This process was based on the WEAP capabilities to simulate and draw the Water System Features through the legend tools and its functionality, thus the following assumptions were considered:

1. King Abdulla Canal (KAC), All Wadis, and the official Rivers drawn as Rivers in the Scheme at WEAP Model.
2. Lake Taiberia (LT) and all Dams in the Basin will be Surface Water Reservoirs.
3. Mukhaibeh Ground Water (GW) is simulated as River to transfer water to KAC.
4. One GW source (Azraq GW Reservoir)
5. Some connection points between the resources are simulated by Diversion tool (Wadis to Jordan River (JR), Pump water from Yarmouk to LT then Pump Water from LT to KAC, Pump Water from KAC to Karameh Dam then Pump Water from Karameh Dam to KAC)

6. Other connections are built directly like Wadis to KAC (River connects to other)
7. One Wastewater Treatment Plant (WWTP).
8. Transmission and Return Links for Amman city, Zarqa city, and Assamra WWTP
9. Transmission links to cover the irrigation projects.



Main Schematic: contains all the water system features

Filling out the Data gap:

In order to bridge the gap related to the availability of data, some of the parameters were considered to ensure the functionality of the model, there parameters that were performed are as follows:

1. Mass Balance Requirements (inflow-outflow) and water volumes
2. Percent of reuse and consumption for Demand Nodes
3. Losses at each Demand and Supply Node
4. Water Demand Requirements for agriculture and domestic use.
5. Water Amounts that returns to WWTP.
6. Water Quality constituents in the system (pH, BOD, and TDS). Where three types of water were considered; fresh water (without any treated wastewater), blended water (fresh and treated wastewater) and (only treated wastewater).

Other parameters which are related with the unit cost of water were considered such as (Capital cost, Variable and fixed cost, and revenues). These financial parameters were essential to decide on the most financially and economically resource that could be allocated to the defined demand center.

Financial Data:

The financial implications of delivering certain resource to a demand area were based on the unit cost of delivering the water to the target. This unit cost is calculated based on the capital, operation and maintenance costs of the said resource. The capital cost is the investment cost which entails

- Equipment
- Construction costs (civil, electromechanical and others)
- Labor costs
- Interests on debts
- Contingencies

The financial cost for the existing resources are the true values, where the investment costs of the future projects / resources should be the discounted costs based on the starting year of construction. The operational and maintenance costs of the existing resource will be based on the actual monthly or yearly spending on delivering the water to the targeted demand centers. The operational costs which may range from 2-5% of the capital costs may entail the following:

- Labor costs
- Energy sources
- Spare parts
- Maintenance costs
- Consumables such as chemicals and others.

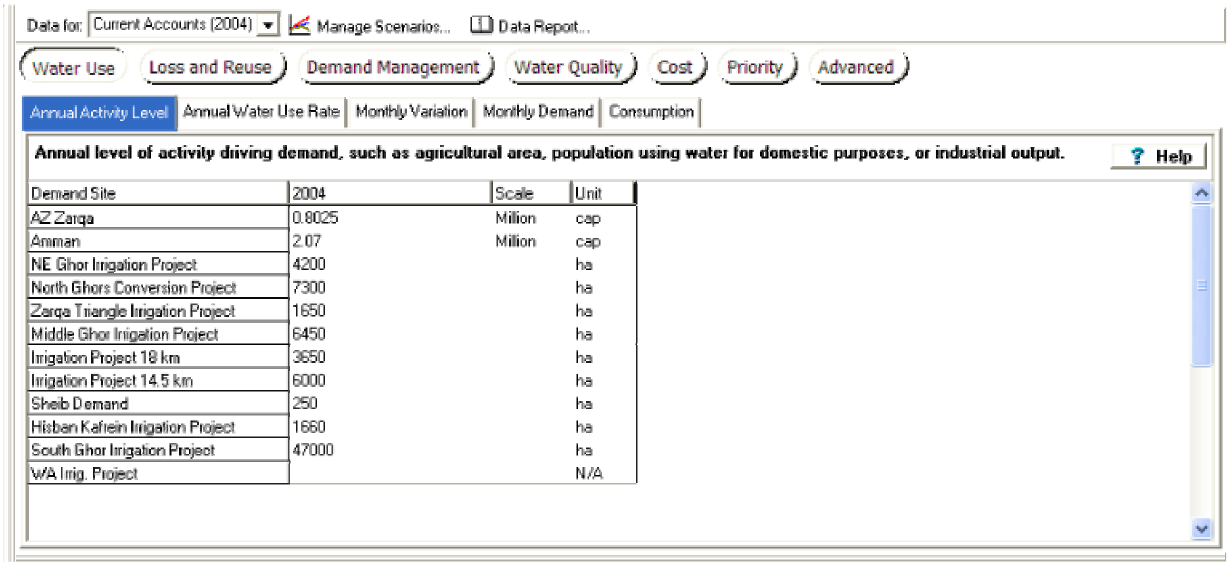
For the projects which are under construction or that will be constructed in the future, the expected O&M costs will be adopted.

In order to calculate the unit cost of the resource, both capital and O&M costs need to be considered. Each project should have a life period and the discount rate should be defined. Life spans of the water projects ranges from 10-15 years for the case of pipe works up to 25 years for the case of pumps up to 50 years for the case of dams and reservoirs. The investment cost will be divided all over the operational period (life span of the project) with application of a defined discount rate which can range from 5% up to 15% for the cases in poor and developing countries. The yearly share of the investment cost will be added to the O&M in order to get the total yearly cost per resource. This total yearly cost will be divided by the total generated quantity of water per the said year; the result will be the unit cost of water for that resource at that year.

Each resource with its related unit cost can be added to the WEAP model on yearly basis to encounter the financial and economical aspects of allocating certain resource to defined demand center.

The other part of the financial implications is the calculation of the expected revenues out of the project. Revenues of water supply project for municipal uses will be calculated based on the current water tariff and the expected billed quantities during one year. The same is applied for the industrial uses. For the case of the irrigation projects, it will be more difficult. The cropping patterns need to be defined with the areas, expected market prices for each product with the expected production per defined period such as one year. For the existing projects, real financial data can be collected, where for the new projects; an anticipation of the expected income can be calculated. The income of selling the water to the farmers needs to be considered accordingly. The revenues for the future projects need to be discounted like the case for the capital and O&M costs.

The following chart shows the page of the data entry where the different data bases can be established. Cost is one of the bases for running the model.



Demand Site	2004	Scale	Unit
AZ Zarqa	0.8025	Million	cap
Amman	2.07	Million	cap
NE Ghor Irrigation Project	4200		ha
North Ghors Conversion Project	7300		ha
Zarqa Triangle Irrigation Project	1650		ha
Middle Ghor Irrigation Project	6450		ha
Irrigation Project 18 km	3650		ha
Irrigation Project 14.5 km	6000		ha
Sheib Demand	250		ha
Hisban Kafrein Irrigation Project	1660		ha
South Ghor Irrigation Project	47000		ha
WA Irrig. Project			N/A

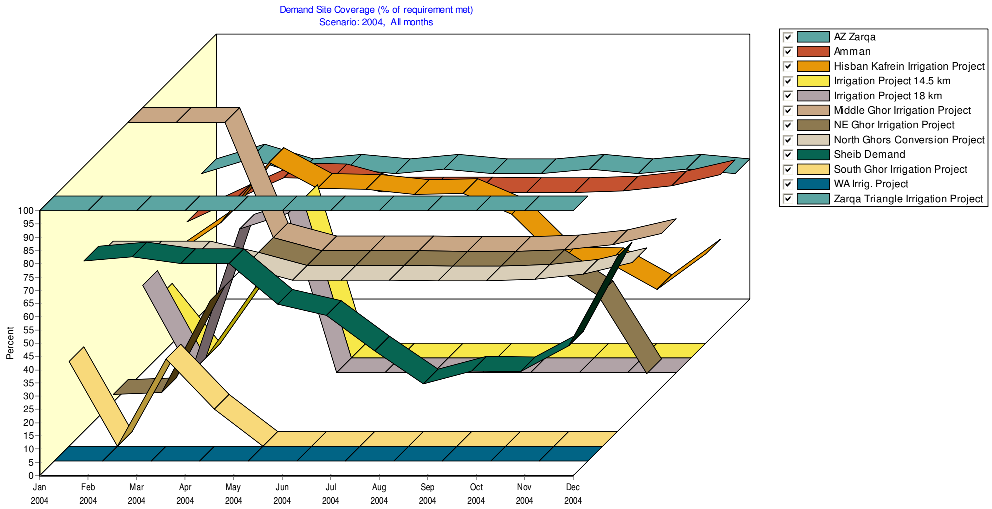
The data entry tables are used to enter expressions that define Current Accounts and Scenario values of variables.

Running the model and conceived Results

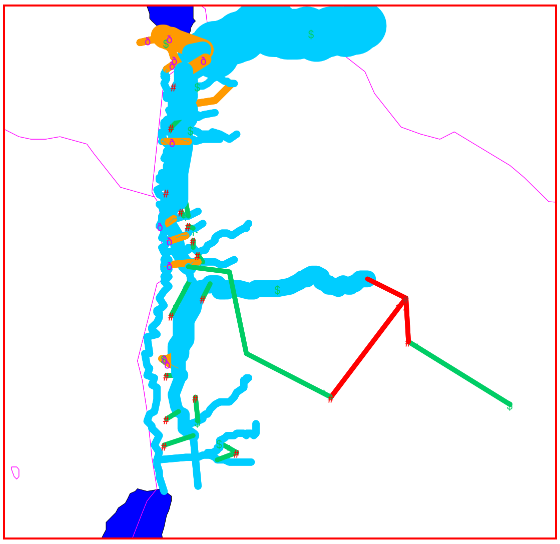
After running the model with the previous assumptions in terms of water balance, water quality and related unit costs, the following results were noted:

A. Good Views and summaries over the basin as a whole system.

- Stream flow (below node or reach listed)
- Inflows and Outflow to Area
- Reservoir Inflows and Outflows
- Transmission Link Flow
- Return Link Inflows and Outflows
- Surface Water Quality (TDS, BOD, and pH)
- Unmet Demand
- Water Demand (not including loss, reuse and DSM)
- Demand Site Coverage (% of requirement met)
- Cost of delivery for each selection



Demand Site Coverage (% of requirement met)

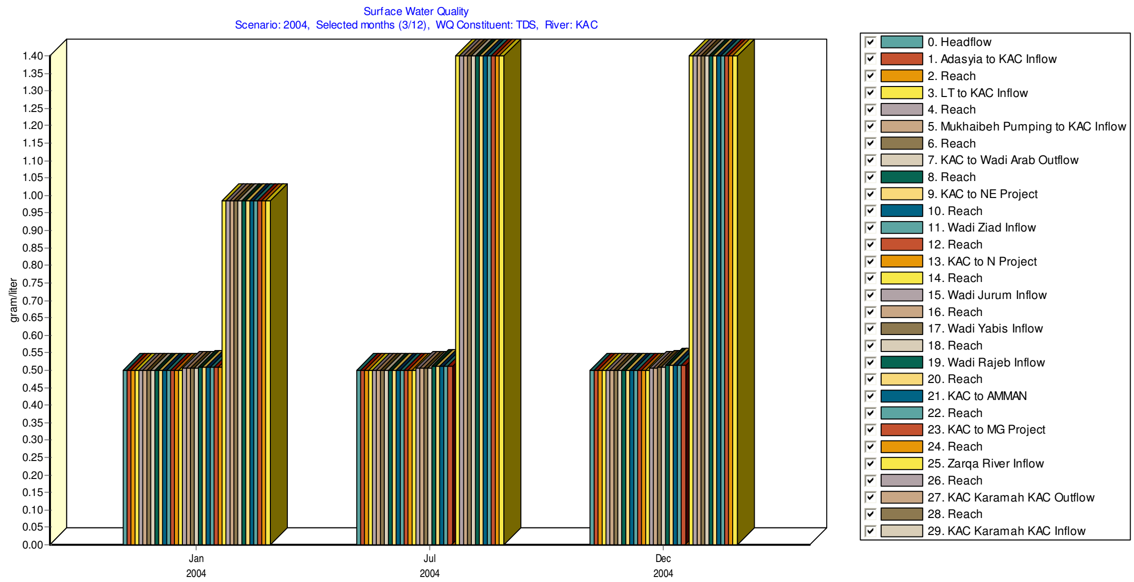


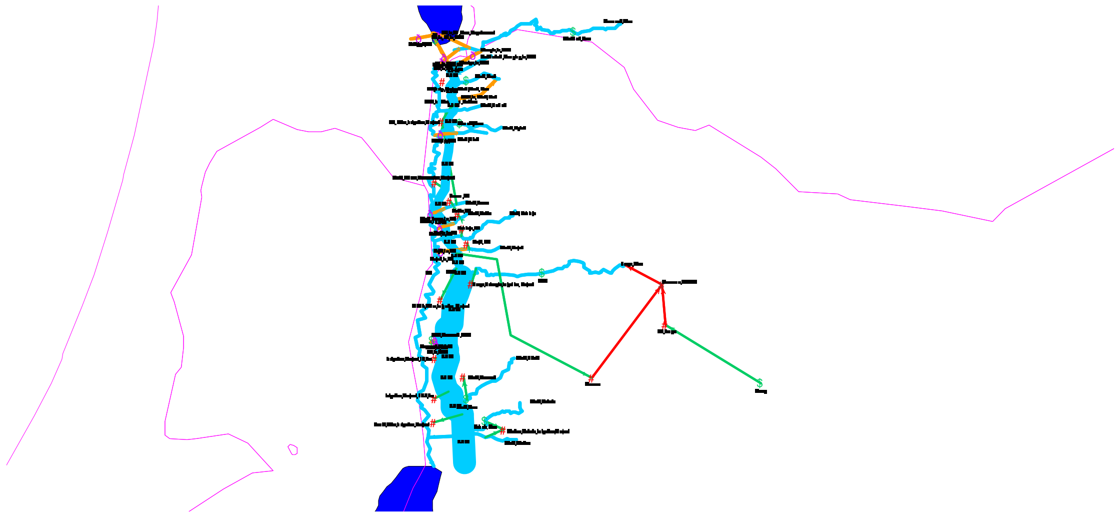
Stream flow (below node or reach listed)

Surface Water Quality
milligram/liter

	Jan-04	Feb-04	Jun-04	Jul-04	Nov-04	Dec-04	**Min**	**Max**
0. Headflow	60	60	60	60	60	60	60	60
1. From Assamra to Zarqa River	95	99	121	119	95	110	95	121
2. Reach	95	99	121	119	95	110	95	121
3. KTD	50	50	50	50	50	50	50	50
4. Reach	50	50	50	50	50	50	50	50
5. Zarqa River to Zarqa Triangle	50	50	50	50	50	50	50	50
6. Reach	50	50	50	50	50	50	50	50
Min	50	50	50	50	50	50	0	0
Max	95	99	121	119	95	110	0	0

Surface Water BOD at Zarqa River





Surface Water Quality (TDS) Declination at KAC in Jan, July, and December

Running the model using the actual data shows that the water qualities will not sufficient to cover all the purposes for irrigation at the Jordan Valley. Around 70% of the actual water demand was met with the available resources. This will be reflected on scaling down the production of agricultural sector. For the domestic uses in Amman, the anticipated quantities that could be pumped were 90 MCM/year. The current supply is 45 MCM/year which is around 50% of the planned figures.

Results shows that the cost for delivering fresh water to the middle and south Ghor areas will cost much more what the farmer is already paying for each cubic meter.

In order to bridge the gap of the water demand/supply deficiency, three different scenarios were proposed. The following sections will present these scenarios and their impacts on the allocation system.

IV. Managing the Deficit and considering Future Scenarios

The actual status of the Jordan Valley is suffered from the scarcity of water that could be allocated for irrigation and domestic purposes and this situation is expected to continue; therefore a number of conventional and non conventional water supply scenarios were considered as suggestions for bridging the deficiency, these are:

1. The treated wastewater of three treatment plants in the North regions (Irbid, Duqarra, and Wadi Hassan) to be used in the future for irrigation practices
2. Raise the efficiency in the irrigation practices in the Jordan Valley by 10%.
3. Using 50 MCM from the Unity Dam to cover Amman city domestic demand.

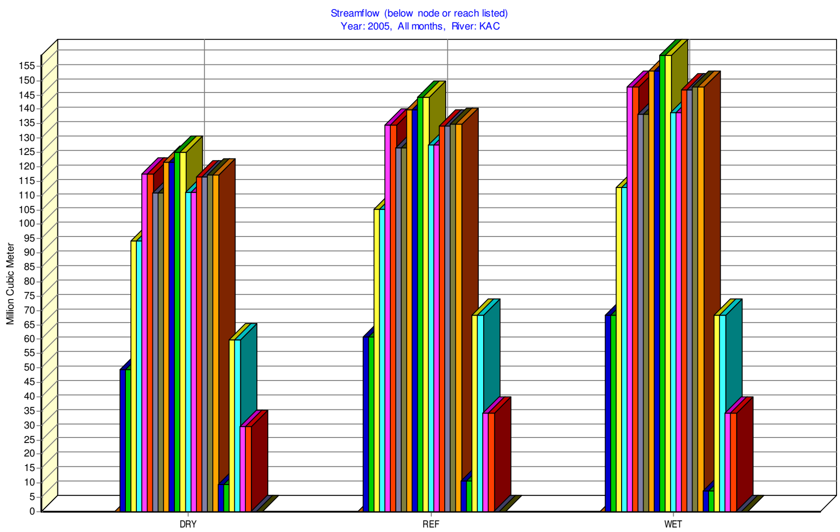
In order to run the model with respect to the different scenarios, the following assumptions were considered:

- In terms of climatic conditions and rainfall changes, three cases were adopted to simulate lower JR Basin:

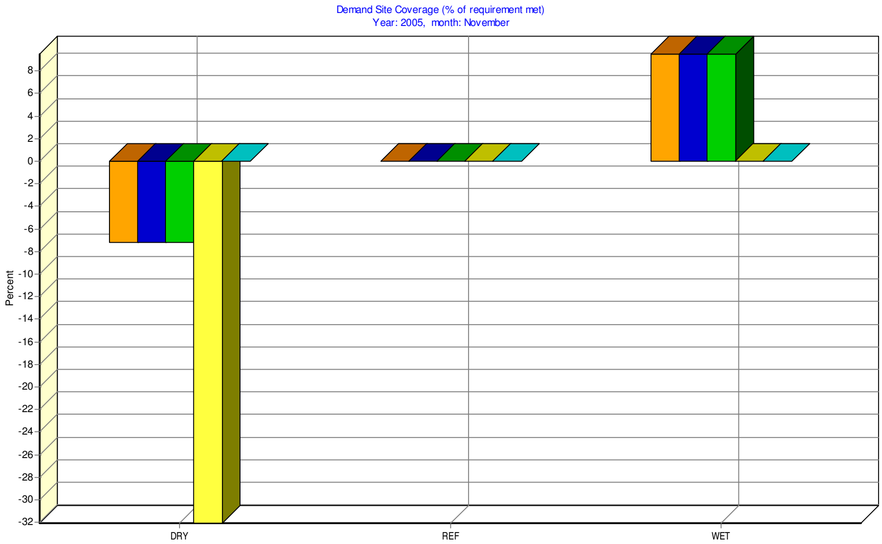
❑ Base Year (Current Account)
Average year of 2004 reflects normal distribution of water budget

❑ Wet Year
A prediction of increasing 20% of water income

❑ Dry Year
A prediction of decreasing 20% of water income

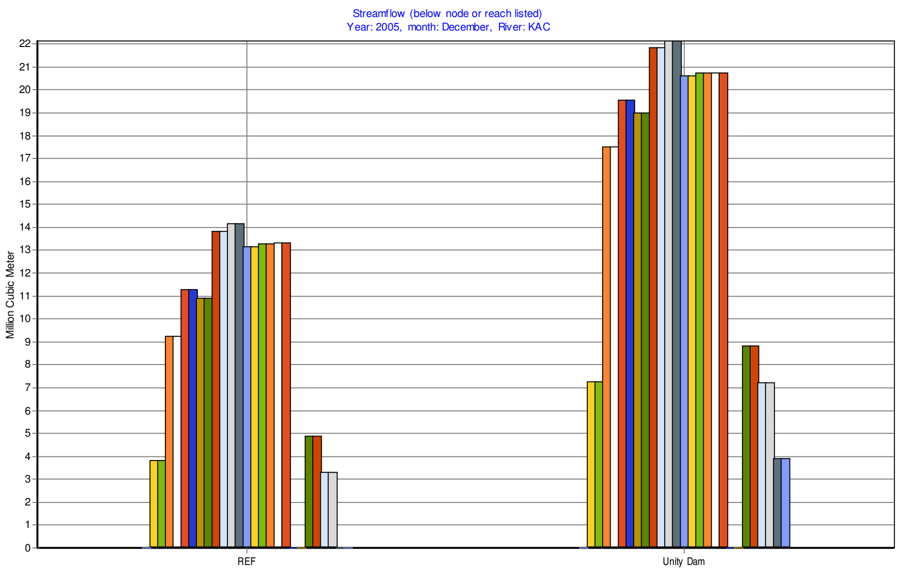


Stream-flow distribution in KAC through three cases of water budget, (it is clear to distinguish that wet account has maximum water abundant in KAC as well as in all stream along JV system).

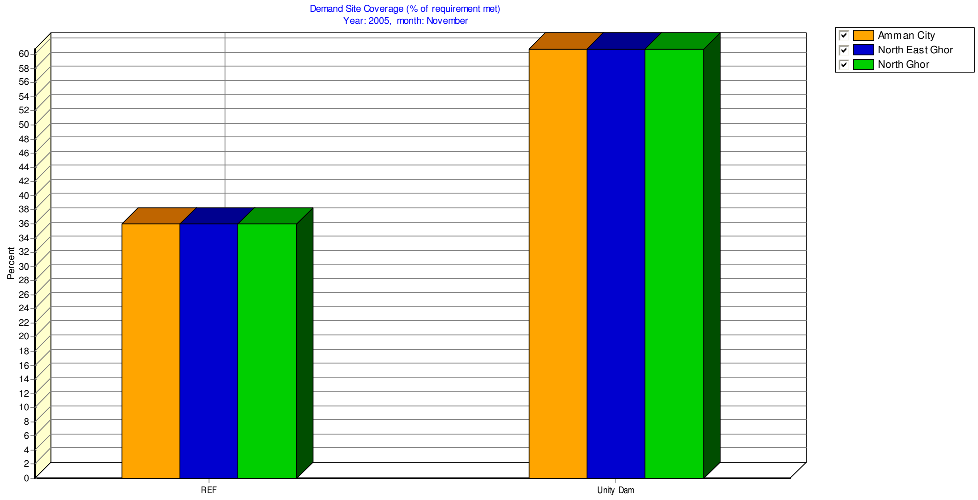


Demand Site Coverage (% of requirement met) the middle bar in this chart shows the base values in the normal water account, in the right hand the bars represents raising of coverage weights in positive trend and the opposite is observed in dry account in the left hand.

<u>Water Balance after considering the Unity Dam scenario:</u>

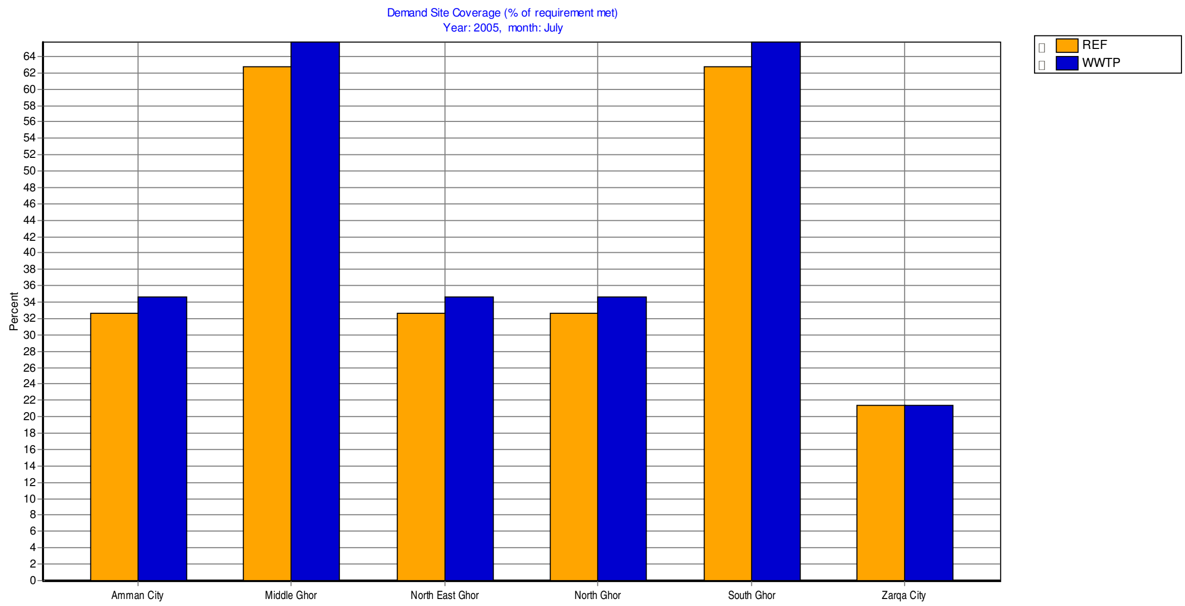


Stream-flow in KAC in comparison with unity Dam scenario (these amounts of water that increase in the right bar of figure will be allocated to Amman city and to north irrigation projects as 50% equally likely)

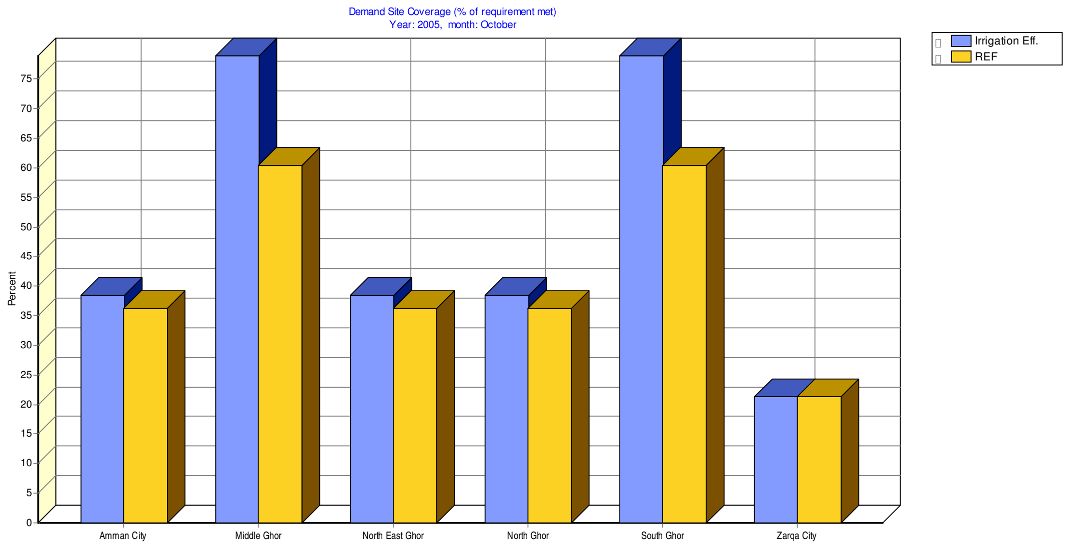


Demand Site Coverage (% of requirement met), notice that coverage for north irrigation projects and for Amman city is going to be better in Unity Dam Scenario.

<u>Results of water balance after considering the reuse of the three wastewater treatment plants in the North.</u>



Raising the Coverage% (Water Reuse-WWTP Scenario) this is reflected as a result of finding new water source and ready to serve the north irrigation projects and so raising the coverage percentage.



<u>Results of raising the Coverage% (Irrigation Efficiency), by using new techniques in irrigation method</u>

BOD parameter as a key element to determine the water quality in the JV. Three different types were considered for the different sources:

- Blended water (Fresh and treated)
- Fresh only.
- Treated wastewater only.
- The area which is northern the middle Ghor is considered as Fresh (before reaching Zarqa River). The area below Zarqa River is considered as blended or pure treated wastewater.

Results show that without an introduction of fresh water in the system, TDS will increase along the valley from north down to south. The same is applied for the BOD concentration which originates due to the existence of the Zarqa River. Without fresh water to blend the treated wastewater, the water quality that will be used for irrigation will deteriorate year after year.

In terms of financial implications, results show that treated wastewater is the most feasible option (scenario) that could be adopted for irrigation in the northern irrigation projects. The adaptation of reuse option with 15 MCM/a will relief the same quantity of fresh water that is currently used from the KAC. This fresh water can be used for domestic purposes in Amman and the Dead Sea development projects. Without the consideration of the financial parameters, it was not possible to rank the different future scenarios in terms of priorities. The first impression will be the adaptation of Unity Dam because of the generated fresh water, but looking deeply into the financial and economical sides, this option is not prior than the reuse of treated wastewater option.

RESULTS AND CONCLUSIONS

As a result of adopting three different future scenarios and running the model on these scenarios, it can be concluded that **WEAP** has the ability to represent the actual status of the water systems and able to be supplied by new sources (quantity, quality and cost).

With respect to relevance for future water use and/or availability in the Jordan River region; WEAP examined to apply three Scenarios, to carry and calculate options which assist Decision Makers in finding alternative or enhancing water plans. Results were promising and prove that WEAP can be used efficiently and effectively for the case of JV and other similar cases in the region. From the purely technical aspects (quantity and quality), adaptation of supplying the system with 50 MCM of fresh water from the Unity Dam proved to be the best scenario. Raising the efficiency at the irrigation facilities will increase the available water and scale down the unmet fraction by 10% was the second option. Utilization of the treated wastewater in the north will add 15-20 MCM/year to the system but certain but ranked technically as the third. With the application of the unit costs only, the reuse of treated wastewater was selected as the first, raising the efficiency is the second and the Unity Dam is the third. With considering the necessary precautions to avoid any blending of the treated water with the fresh water before reaching the point of pumping the KAC fresh water to Amman for domestic uses, the reuse option is the first option. A separate water irrigation system can be introduced to separate the fresh from treated wastewater.

Looking into the three options from the economical point of view and the fact that the 50 MCM/a from the Unity Dam is fresh water that can be used directly for municipal purposes in Greater Amman, and the expected revenues out of that in comparing with the irrigation option. The Decision maker will select the Unity Dam as the preferred option from the technical and economical points of view.

It can be seen that WEAP was able to consider the financial implications of the different scenarios in parallel with the technical aspects. This is necessary in the water management of the Jordan Valley to satisfy the integration of utilizing the available water sources.

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