POLICY GUIDELINES FOR SUSTAINABLE WATER RESOURCES MANAGEMENT IN AQABA GOVERNORATE CATCHMENT AREAS USING DECISION SUPPORT SYSTEM (DSS)

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DEDICATION

TO MY FAMILY

WITH LOVE

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AHP	Analytical Hierarchy Process.
ASEZ	Aqaba Special Economic Zone.
a	Anumm / year
amsl	Above Mean Sea Level.
ARA	Aqaba Regional Authority.
AS	Activated Sludge.
ASEZA	Aqaba Special Economic Zone Authority.
AWD	Aqaba Water Directorate.
BCM	Billion Cubic Meters.
d	Day
DBMS	Data Base Management System.
DI	Ductile iron.
DFMS	Demand Management System.
DMS	Demand Forecasting Management System.
DOS	Department of Statistics.
Dunum	Thousand square meters.
DSS	Decision Support System.
DPSIR	Pressure State Impacts Response.
EC	Electric Conductivity.
GAEAP	The Gulf of Aqaba Environmental Action Plane.
GDP	Gross Domestic Product.
GI	Galvanized iron.
GIS	Geographical Information System.
GNP	Goss National Product.
GPS	Geographic Position System.
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit (German Technical Cooperation Society).
GWP	Ground Water Pollution Model.
ha	Hectare (10,000 square meters).
hr	Hour
Indust.	Industrial
Irr.	Irrigation
JD	Jordanian Dinar.
JICA	Japan International Cooperation Agency.
JRV	Jordan Rift Valley.
JV	Jordan Valley.
Kg	Kilogram
Km	Kilometer
l	Liter
ICZM	Integrated Coastal Zone Management.
IPS	Image Processing Systems.
IWRM	Integrated Water Resources Management.
l/min	Liters per minute.
l/s	Liters per second.
lpcd	Liters per capita per day.
m	Meters
m/d	Meter per day.
m/s	Meter per second.

m/yr	Meters per year.
m3/d	Cubic meters per day.
m3/hr	Cubic meters per hour.
m3/s	Cubic meters per second.
Max	Maximum
MCA	Multi-Criteria Analysis.
MCDM	Multi-Criteria Decision-Making.
MCM	Million cubic meters.
MCM/ a	Million cubic meters per anumm.
MCM/yr	Million cubic meters per year.
Meq	Milliequivalent.
Meq/L	Milliequivalents per liter.
mg	Milligram
mg/L	Milligrams per liter.
Min	Minimum
mm	Millimeter
Mun.	Municipal
MIT	Municipal, Industrial, Touristic.
MOTA	Ministry of Tourism and Antiquities.
MWM	MedWater Model.
MWI	Ministry of Water and Irrigation.
N	Nitrogen
NCARTT	National Center for Agricultural Research and Technology Transfer.
NEAP	National Environmental Action Plan.
NWMP	National Water Master Plan.
NWAP	National Water Action Plan (GTZ Project).
O&M	Operation and Maintenance.
oC	Degree Celsius.
P	Phosphorus.
PE	Polyethylene.
ppm	Parts per million.
ICZM	Integrated Costal Zone Management.
IWRM	Integrated Water Resource Management.
Q	Rate of discharge, flow rate.
RO	Reverse Osmosis.
RSS	Reservoir Site Selection.
RS	Remote Sensing.
SWP	Surface Water Pollutant Model.
TDS	Total Dissolved Solids.
Tour	Touristic.
TP	Treatment Plant.
TWL	Top Water Level
TWW	Treated Wastewater.
UFW	Unaccounted for Water.
USAID	United State Agency for International Development.
USD or US $	United States Dollars.
WAJ	Water Authority of Jordan.
WSI	Water Stress Index.
dS/m	Decisiemons per meter.

v	Velocity
WDM	Water Demand Management.
WRA	Water Resources Assessment Module.
WRM	Water Resources Management Mode.l
WRMA	Water Resources Management Plan (JICA project)/
WWTP	Wastewater Treatment Plant.

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ABSTRACT

Aqaba city, being the only access to Jordan to the open seas and the only country's port, has been going under heavy development since 2000 after it has been declared as a special economical free zone area. Therefore, it is expected that the city will witness a sharp rise in population due to natural growth and internal migration attracted by the increased industrial and tourism investment as well as other economical development. These conditions will put high pressure on the water resources and will generate more waste thus affecting the environmental setting and the marine ecosystem. The city depends on its water supplies from the nearby non-renewable groundwater resources of Disi aquifers where an amount of 17.50 MCM has been allocated to the Aqaba. Therefore, this study was initiated at addressing the issues of future water supply and management for the next 20 years to realize their sustainability by considering all elements of economical development.

Aqaba and its catchments area (the Red Sea basin) was studied in term of geology, hydrology and physical environment. The demographic changes, the historical industrial

and tourism activities and the institutional setup development have been also reviewed since the establishment of the port of Aqaba. The study shows that tourism has increased significantly during the last thirty years and will be doubled in the next decade. The tourism sector consumes about 6 % of the total water demand. Industries in the city are the major water consuming activities where their consumption is about 43 % of total water demand. Services including the port activities consume about 20 % of the water demand while the domestic sector consumption reaches 33 %.

For the purpose of water allocation and city planning, land use changes for the last 15 years was evaluated by analyzing the satellite images and comparing them with existing land uses. It has been found that urbanization as well as areas allocated for industrial purpose and city services have increased by three folds. Land use changes associated with water consumption pattern were evaluated to project the increase in water demand. Also, demographic changes were analyzed for the last three decades and had showed that the first decade (1974-1984) witnessed a rise in population of 7.3 %. The rise in population was 5.3 % in the second decade (1984-1994) while it was 3.3 % for the last ten years. Future water demand for different water sectors has been estimated by projecting population growth and other water demanding activities such as industry and tourism under three growth models. By the year 2020, water demand could reach 24.3 MCM for the first growth model (3.3 % growth rate), 32.4 MCM for the medium growth model (5.3 % growth rate) and 43.0 MCM for the high growth model (7.3 % growth rate).

These growth models were evaluated using the Water Resources Management Model (WRM) under different management scenarios for the year 2020. A total of 13 runs were performed reflecting different management responses and were compared with the baseline scenario of the year 2003. The water resources management indicators reflecting the driving forces of demographic changes, industrial and tourism activities and technological changes have been concluded. These indicators are supply to demand ratio, system reliability, total shortfall and the unallocated water for the global water demand and sectoral water demand.

Under the low growth model, the supply to demand ratio was 71.92 % indicating a shortage of 4.47 MCM compared to 24.32 MCM of water demand; the shortage was 9.67 MCM and the demand was 32.42 MCM for the medium growth model; while for high growth model, the shortage reached 16.4 MCM against a total demand of 43.0 MCM. When the demand option was introduced by reducing the UFW to 25 %, the total demand for water had decreased to 20.75 MCM, 27.67 and 36.69 MCM, for the three growth model, respectively; whereas the shortage was reduced to 2.57 MCM, 7.77 MCM and 14.50 MCM for the three models, respectively.

Results showed that for better water management and in order to satisfy the future needs, the unaccounted for water should be reduced from 36 % at the present to 25 % by the year 2020. In addition to that, existing water supply has to be augmented by introducing desalination plants with a capacity of 20 MCM if the medium growth model is adopted. On the other hand, the generated wastewater can reach 6.88 MCM if all management responses are implemented by 2020. This amount can be reused for irrigation or recycled by industries on site.

The three growth models were evaluated using Decision Support System with different objectives under two constraints; quality and quantity. The multi-criteria analysis result has arranged the objective according to their priority. The first two objectives were allocating water to meet basic need and protecting the environment.

For the last ten years, the economical growth activities and the population growth were not up the expectation. Comparisons between the censuses of 1994 and 2004 have showed that only 3.3 % rise in population has been observed and little industrial expansion has been made for the last 10 years. Therefore, Aqaba special Economical Zone Authority (ASEZA) has to revisit its strategy and future plan by considering the results of this study.

Introduction

1.1 Importance of the Research

For the last two decades, research on water related issues has been focused on integrated resources management and policy oriented approaches instead of using the traditional approaches, which tend to be sectorally oriented and fragmented in character. The latter have failed to account for externalities inherited in many water activities and projects that overlooked threats to the environment, scarcity of resources, economical efficiency, social equity and sustainability. In arid coastal areas, like Aqaba, the problem is not limited to the scarcity of water resources but to the interaction between the natural resources and the related vulnerable ecosystem. As coastal areas are going under rapid development and increased population growth, the large scale multiple resources demand are causing unprecedented pressure on the limited and finite fresh water resources. Most of the coastal cities in arid areas are confronted with insufficient water supply or they are the most downstream users of the already exploited water resources. Thus, they have to obtain their water at very high cost by relying on water importation from other basin or using other expensive alternatives such desalination. On the other hand, the expansion of coastal cities are usually associated with high water demanding activities such as increased industrial and tourism development as well as other economic activities. The above conditions will result into immediate threats to the environment and marine ecosystem caused by upstream pollution, wastes generated by people, municipal and industrial effluent, oil spills, erosion, discharge from thermal power plants and air pollution. These problems and threats require an integrated coastal zone management (ICZM) and holistic water resources management approaches. According to Massoud et al. (2004), global efforts related to ICZM have shifted from a sectoral to a comprehensive approach and from protection of the marine environment and coastal resources to integrated resource management and sustainable development. Blair et al (1998) defined ICZM as a continuous, adaptive, day-to-day process which consists of a set of tasks, typically carried out by several or many public and private entities. The integrated water resources management (IWRM) is based on the perception of water as an integral part of the eco-system, a natural resource, and a social and economic good. (Kindler, 2000).

The city of Aqaba is no exception to that, water resources are imported from the non-renewable aquifer of Disi; industrial activities are increasing; tourism is expanding; transportation from and into the city is increasing; port loading and unloading is expanding; and finally, the population will grow at high rate. These are the expected results of policy oriented decision of converting Aqaba into a free zone area. The activities associated with that decision will put high pressure on the natural resources by affecting the environmental setting and the ecosystem. Therefore, an integrated approach is needed to take into consideration all challenges of maintaining a healthy ecosystem, improving the quality of water, associating land use in planning, shifting to demand oriented water resources management, and incorporation the socio-economical dimension into planning process.

This study addresses all these elements and translates them into policy guidelines that would realize a sustainable socio-economic development while considering the environmental dimension. Defining and introducing the problems as well as the research objectives are addressed in the first chapter. In chapter two, previous studies are reviewed while the description of the physical setting and natural resources are presented in chapter III. The social and economical dimensions as related to water demand are discussed in chapter IV. This chapter also discusses the institutional development and the governing legislation. The land use changes linked to water demand in the free zone area are evaluated over 10 years period in chapter V. Chapter VI presents analysis of the water supply and distribution system and evaluation of the future water supply and demand options according to population growth and economical activities using water resources management models. Finally, the policy guideline based on technical and social indicators are discussed in chapter VII.

1.2 Background

The Hashemite Kingdom of Jordan is located to the east of the Mediterranean Sea. It is bordered by Syria to the north, Iraq to the east, Saudi Arabia to the east and the south, and Palestine and Israel to the west. Jordan is located between 29° 11' N and 33° 22' N latitude and between 34° 19' E and 39° 18' E longitude with an area about 89,342 square kilometers (km^2) and a population of about 5.48 million (estimate of 2003). The estimated average population growth rate as of 2003 stands at about 2.8 % due to natural and non-voluntary migration (DOS, 2003). The statistics of last census (2004) shows that the total population has reached 5.35 million and the population growth rate has dropped to 2.5% (DOS).

The topographic features of the country are variable with approximately 80 % of the total area is steep mountainous or steppe arid land (Badia). The climate is a Semi-arid. Rainfall ranges from less than 50 mm in the desert region to about 600 mm in the north-western mountain. The average annual volume of rainfall occurred on Jordan is about 8.5 billion cubic meters of water of which about 92 % is lost by evaporation with remainder flowing into wadis and partially infiltrating into deep aquifer (MWI, 2001).

The expanding population and the climatic and topographical conditions of the country have exerted enormous pressure on the limited water resources and created a severe water supply-demand imbalance, where the renewable water resources are among the lowest in the world, and are declining with time. According to the water stress index (WSI), developed by Malin Falkenmalk (JICA 2001) to serve as an indicator of renewable water resources of a country, Jordan is classified in the category of "Absolute Water Scarcity" and the water resources is chronically short to demands due to the arid to semi-arid climate. Annual rainfall amounts are highly fluctuate year by year with 85 % of the total rainfall not being available for use due to high evaporation rates (JICA, 2001). Where the per capita basis available water from existing renewable sources are projected to fall from 165 m^3/capita/year in 2003 to 91 m^3/capita/year by the year 2025 (Shatanawi, 2002). The total available water resources are about (940) million cubic meters (MWI, 2001) broken down as follows: Irrigation water of 600 MCM, accounted for 64 %, Municipal water (including water for tourism industry) of 280 MCM accounted for 30 % and industrial water of 38.0 MCM accounted for 5 %. The remaining 1 % of about 9.40 MCM is used in remote areas for different uses. The unaccounted for water (UFW) is estimated to be 46 % of the water supply, the MWI maintain that about 30 % of water supplied at the water head is lost to leakage (MWI and GTZ, 2004). The per capital per day municipal water consumption over whole country decreased from 103 L/c/d in 1996 to 86 L/c/d in 2003 (MWI and GTZ, 2004).

The recurrent drought conditions and decreasing tendency of rainfall exasperated the availability of surface water in the country. More than half of the total water resources depend on the ground water resources of which the nonrenewable groundwater occupies 14 %. The regional groundwater level decline and ground water quality deterioration have taken place because of the over abstraction of the renewable groundwater. Therefore, it is of the most importance to utilize the restricted water resources efficiently and to allocate the water resources properly (JICA, 2001).

The above mentioned problems are most pronounced in the coastal region of the country where Aqaba area lies. This area is characterized by severe aridity with an average rainfall of less than 35 mm/year. The climate is mostly warm in the winter with an average temperature of 16^{o} C and very hot in summer with a mean temperature of 32^{o} C. The city of Aqaba stands at coast of the Gulf of Aqaba of the Red Sea which represents the only access for Jordan to the open waters. Aqaba is a residential city in Jordan, an important industrial complex for several heavy industries, a tourism attraction city in terms of its unique natural property specially that of its marine life.

Aqaba city is located 343 km south of the capital Amman at longitudes of $34^{o}57'$ and $35^{o}09'$ E, and latitudes $29^{o}19'$ and $29^{o}43'$ N. Administratively, Aqaba city belongs to Aqaba Governorate which host few towns and rural settlements. In the year 2000, the Government of Jordan has declared Aqaba area (about 375 km^2) as a special economical zone and has established Aqaba Special Economical Zone Authority (ASEZA) to manage and operate this area.

The main objectives of the new authority were to develop Aqaba as a center for commerce, a destination for tourism, and an incubator for technology. As a result of that, the number of inhabitants is expected to increase, and the tourist, economical and industrial activity will also increase. This expansion in activities and population will exert high pressure on nearby water resources and would result in a sharp competition between various demands against very limited water resources. Water demand will therefore exceed the supply in the future making water as the strong limiting factor to this ambitious planning (Dweiri and Badran, 2002). Therefore it is of prime important to study the scarcity water resources in the area in order to establish measures to effectively utilize the limited water resources as much as possible, relying not only on the development of new water resources, but also on appropriate sustainable optimal management measures.

The main water supply sources of Aqaba are the well fields in Disi and Wadi al-Yutum (Wilbur Smith *et al.,* 2001*).* It was deduced that the potential non-renewable groundwater of Disi Aquifers can withstand annual withdrawals at a rate of 100-110 MCM/year (JICA, 2001). Other groundwater sources within the boundaries of the Aqaba Governorate are in Wadi Araba (Wilbur Smith *et al.,* 2001). Surface water resources in the Governorate are very rare it would not exceed 1.00 MCM/year, with no potential utilization (JICA, 2001). An additional potential water supply source could be made available through treated wastewater and desalination of seawater and brackish water from beach wells or shallow aquifers (Dweiri and Badran, 2002; Wilbur Smith *et al.,* 2001*).* The conventional allocated water resources that can be utilized to satisfy the increasing water demand will reach the maximum sustainable yield in less than 5 years (Dweiri and Badran, 2001). According to DOS (2004), the population of Aqaba Governorate is 110,000 people. The development of Aqaba as a duty free area will increase demand for water for the growing population and future industrial activities. This development will lead to a potentially dramatic rise in water demand, but also wastewater generation. The total amount of water allocated to Aqaba Governorate in 1999 was 17.30 MCM of which 13.90 MCM was for ASEZA and the remaining was for rural and agricultural supplies in the Governorate (Montgomery-Watson *et al.,* 1999). In 1998 water production from the Disi for different consumers was 13.80 MCM broken down as follows: 5.00 MCM for industry, 2.20 MCM for domestic, 1.10 MCM for services, irrigation and landscaping, 0.70 for commercial, 0.30 for tourism and 4.50 as uncounted for water (Wilbur Smith *et al.,* 2001). According to the final Master Plan of the ASEZA, the total consumption is expected to increase by about 5.00 MCM/y by this year 2005, 11.00 MCM/y in the following 5 years, and about 30.00 MCM/y by the end of 20 years (Dweiri and Badran, 2002). The water demand is affected by the leakage in the system. Leakage is the main component of the unaccounted for water which has reached 38 % in 1999. (Wilbur Smith *et al.*, 2001).

From the previous background information, it is clear that Aqaba Governorate is a water-deficit area, and water is the most important natural constraint to economic growth. Developing new water sources to meet the increasing demand is not only an economic and environmental challenge, but it is a requirement for sound and sustainable development to meet future growth. Also there is an urgent need to improve the efficiency of the water supply system. The research in water resources management, allocation between regions, the timing of the allocation, as well as the quality and quantity should aim at understanding different ways of managing water effectively.

1.3 Research Objectives

The general objective of this research is to develop management options in order to optimize the use of water resources of the Gulf of Aqaba and integrate the environmental components of coastal zone development through:

a. Evaluating the socio-economic status and the institutional development in Aqaba.

b. Studying the land use changes with respect to urban and industrial development.

c. Analyzing water use and evaluating water management efficiency.

d. Evaluating different scenarios of sectoral demand using water management models.

The study aims also at the integration of physical, economic, and policy elements in one integrated approach, that directly derives the policy guidelines from the existing data and modeling results. This necessarily leads to a multi-objective, multi–criteria decision problem. The study will demonstrate how to reconcile conflicting interests and development objective through the proper choices and trade-offs in terms of feasible and non-dominated scenarios of water use efficiency, allocation efficiency, economic efficiency, social compatibility, and environmental compatibility, given the policy instruments of: zoning, pricing, economic incentives and direct regulation.

Literature Review

The importance of the Gulf of Aqaba to Jordan and at the international level has attracted many researches and consulting agencies to carry out different studies about Aqaba, concentrating on integrated resources development and regional planning. This is also coupled by the declaration of Aqaba as a special economical zone free of taxes. Most of these studies were carried out through cooperation between national and international agencies or through bilateral cooperation.

Bennet (2001) reported that the coastal areas are some of the biological most productive areas in the world and are extremely important for world food production. About 60 % of the world population lives within 100 km of the coast and are dependent on the coast for survival. At the same time these areas are subject to a number of threats. Since population are increasing there is a continuous struggle for space and resources, serious problems of pollution and waste treatment, loss of biodiversity, depletion of non-renewable resources and over-exploitation of renewable resources, loss of attractively and access, and reduction of the coast's ability to protect people and property from the sea. These problems are both complex and challenging. Challenges facing management and planning are divided into two interrelated groups: problems of substance, and problems arising from the organization and procedures management. Their solution demands new knowledge, new awareness, and development of competency and management skills, new political approaches, new institutional and organizational arrangements, and new management routines.

2.1 Environmental Aspects

The Government of Jordan with GEF and World Bank assistance (1996) prepared the Gulf of Aqaba Environmental Action Plan (GAEAP). The primary objective of the GAEAP was to contain existing damage and to prevent further environmental degradation of the Gulf of Aqaba's coast, coral reefs and marine ecosystems through the implementation of environmental management activities accompanied by required investment.

Badran and Foster (1998) studied the environmental quality of the Jordanian coastal waters of the Gulf of Aqaba/Red Sea. They reported that the sandy beach-sea grass bed habitat had significantly positive modifications in chlorophyll a concentration. A coral reef exhibited positive modifications of nitrogen and dissolved oxygen concentrations and percent oxygen saturation during summer. An industrial site had consistently positive modifications in phosphate concentration, but not in nitrogen or chlorophyll a concentrations. In addition to these sites, specific modifications, ammonia and silicate concentrations were positively modified at all the coastal station.

Twite (1998) reported that there was a rapid development in the Gulf of Aqaba and there is widespread anxiety about the future of the Gulf, especially for tourism. Plans exist to increase the number of hotel rooms from about 8000 in the Israeli portion of the Gulf to 12000 or more (all on a mere 7 kilometers of shoreline). In Egypt, approximately 40000 rooms are planned to be added to the 15000 or so currently available, while in Aqaba itself the number of rooms will increase from 700 to 5000 and this will lead to overuse of energy and water resources and increase wastewater discharge.

Farajat (2001) carried out a study for his Ph.D. on the hydrogeo-ecosystem of the Gulf of Aqaba by modeling surface water balance for a period of 20 years . The hydrodynamic fresh water/seawater interface was investigated by applying Geoelectrical Vertical Modeling of several methods to confirm its coincidence with the aquifers flow amounts where human impacts in term of over pumping allowed more encroachment of seawater into land, and unintended recharge which led to seaward interface migration. Also a ground water balance and solute transport were approached by developing a flow model from the hydro-geological and hydro-chemical data. The nature of soil cover and aquifer whose physical properties enhance human impacts indicated the vulnerability of groundwater to pollution. This certainly threatens the marine ecology which forms the sink where the in-excess flow ends. The constructed digital background was exported into GIS to sub-zone the study area in terms of the aquifer's vulnerability to pollution risks using DRASTIC index. A comprehensive index-SALUFT- was developed which allow suggesting the suitable land use units for each zone in the light of vulnerability grades aiming at protecting the available groundwater resources.

2.2 Water Resources Management

Water resources are the heart of sustainable development in many regions of the world. Water of sufficient quantity and quality is an essential resource for agriculture, industry, and tourism, but most importantly for everyday life in cities and villages. A growing population and a growing economy not only lead to increasing demand for water, they also cause increasing pollution that may threaten the very water resources which their growth depends on and thus threaten the sustainability of development. Water resources are distributed in time and space, and their availability may vary greatly from time to time and place to place. This variability causes problems that require innovative tools for their solution (Fedra, 2002).

The availability of water is classified by a term called the Water Stress Index, which indicates the degree of water shortage. Countries with less than 1,700 m^3/capita/year are regarded as countries with "existing stress", while countries with less than 1,000 m^3/capita/year are regarded as having "scarcity" and countries with less than 500 m^3/capita/year are regarded as having "absolute scarcity' according to this index. With 167 m^3/capita/year Jordan falls into the category of "absolute scarcity" (Abdel Khaleq and Dziegielewski, 2004).

Water Demand Management (WDM) was embraced as a means to achieve a more sustainable water resources management and can be defined as an object-oriented approach to influence water consumption so as to achieve a more efficient and cost effective water use (Magiera *et al.*, 2004). Several studies have been conducted that address the water resources management analysis assessment and modeling.

Ministry of Water and Irrigation and the GTZ (2004) conducted a study for the formulation of the National Water Master Plan (NWMP) for Jordan by developing two customized software programmers, the Pre-Processing Module and the Irrigation Module in order to have structured tools to forecast developments of the municipal, industrial, touristic and irrigation demands and the associated losses as well as the development of anthropogenic water resources. The outputs of the Pre-Processing Module were monthly water demands. While the outputs of the irrigation module were monthly irrigation water demand per irrigation centre. The estimated demand projection for Aqaba for the years 2005, 2010, 2015 and 2020 for municipal uses were expected to reach 9.60, 10.50, 11.50, and 13.20 MCM/year; for touristic uses the demand would be 1.27, 1.76, 2.24 and 2.92 MCM/year; and for the Industrial uses it would reach 10.96, 13.34, 16.56, and 21.33 MCM/year while the physical losses percentage were expected to be 28 %, 20 %, 15 %, and 15 % for the above years respectively.

Japan International Cooperation Agency (JICA) (2001) conducted a comprehensive study for the formulation of the water resources management master plan with the Ministry of Water and Irrigation as a counter part agency. The study aimed at establishing "Unified, comprehensive and sustainable management of the water resources", and "Strategic development of remaining scarce water resources" while having in mind the future goal of "shift to water re-cycling society". The study took into consideration special aspects in the country; global climatic change and characteristic of climatic change of the arid region, and cooperation for regional peace water development. As a result of that, a comprehensive water resources management master plan for the twelve Governorates has been formulated covering the period until year 2020. They considered conventional and non-conventional water resources. (Conventional water resource comprised of surface water, peace water, renewable groundwater and fossil fresh groundwater while, the non-conventional water resources which were desalinated brackish groundwater, desalinated sea water and treated wastewater). Also in the course of the formulation of the water resources management master plan, the municipal, industrial, touristic demands as well as the agricultural demand for water were balanced with the restricted water supply as much as possible. Within the main policies for conservation of water environment and recycling of water resources desalination of sea water and the desalination of brackish water was allocated only for the MIT purposes, while international and treated wastewater reuse would be limited to the vicinities of the treated plants.

For Aqaba Governorate, JICA study has dealt with the present conditions of water resources management and presented the master plan for water resources management with the target year of 2020. Three scenarios were considered for demand projections. In the first scenario, the municipal, Industrial and touristic demand projection were 11.37, 8.05, and 0.69 MCM for the year 2005; 12.90, 9.38, and 0.83 MCM for the year 2010; 12.67, 10.41 and 0.94 MCM for the year 2015 and 11.01, 10.99, and 1.06 MCM for the year 2020 for the above three sectors respectively. The demand projection for the second scenario for municipal, industrial and tourism were 11.37, 8.82, and 0.86 MCM for the year 2005; 12.90, 9.81, and 1.21 MCM for the year 2010; 14.09, 14.10, and 1.80 MCM for the year 2015; 12.89, 17.83, and 2.69 MCM for the year 2020 for MIT respectively. Similarly the demand projection for the third scenario for the municipal, Industrial and touristic (MIT) were 10.86, 7.38, and 0.71 MCM for the year 2005; 11.95, 8.51, and 0.83 MCM for the year 2010; 12.67, 9.82, and 0.98 MCM for the year 2015; 11.19, 11.33, and 1.14 MCM for the year 2020 for MIT respectively. The leakage percentage for the three scenarios is 20 %, 10 %, 10 % and 10 % respectively.

Different consultants (Wilbur Smith and others, 2001) submitted their final report on Aqaba, Jordan Special Economic Zone Master Plan for the United States Agency for

International Development and ASEZA. The objective of this activity was to provide a clear vision on the physical development at the newly formed Aqaba Special Economic Zone. The plan could be the key reference for the use of the current physical assets within the ASEZ and the port for the development of Aqaba. The plan had several components prepared in there volumes. In section 5 (the water system) of volume III (port, land transport and utility Master Plan), they reported that the per capita water production in Aqaba was around 500 l/d. which is the highest in Jordan. Also the industrial water use in Aqaba was the largest among all Jordan's Governorates representing to around 60 % of Jordan's industrial water use. The industrial water use in Aqaba is expected to increase rapidly in the next few years. By far the biggest consumer is the fertilizer factory, with current requirements of about 3.70 MCM/yr followed by the thermal Power Plant at 0.90 MCM/yr, The Ministry of Water and Irrigation has committed another 2.00 MCM/yr for industrial use for the area surrounding the airport.

Water resources and demand assessment for Aqaba Governorate were investigated by Montgomery Watson in association with Arabtech-Jardaneh (1999) for the technical and economic feasibility study and final design of the upgrading and expansion of the water and wastewater facilities at Aqaba using modeling tools. These models were used to estimate the water demand for the target years under two scenarios based on the projected population, projected per capita per day water supply and leakage.

By the year 2004, water demand for Aqaba will reach 17.50 MCM/yr and beyond that, the allocation of water from Disi aquifer will not satisfy the water demand of Aqaba. Therefore they have suggested exploiting the following options to bridge the gab between supply and demand:

- ? Groundwater Disi aquifer: The maximum allowable rate of abstraction is about 17.50 MCM/yr (555 l/s)
- ? Groundwater (Wadi al-Yutum): A conservative extraction value of 2.50 MCM/yr (79 l/s) is used herein.
- ? Seawater Desalination: A large component of desalinated seawater will be required to realize the water balances for the target years. Two desalination plants are recommended to be built producing a total of 15 MCM/yr.
- ? Reclaimed Water: The reclaimed water of the municipal and tourism sectors should be used for landscape irrigation (roads, parks, golf courses…) and restricted agriculture of palm trees and fodder crops while the industrial reclaimed water should be used on site.

Shatanawi and Al-Jayyousi (2001) reported that the crisis management solution to water issues in Jordan proved to be in adequate and water resources in Jordan required clear allocation water policies if demands are to be satisfied. Therefore, in their study of analysis of management options for the water sector in Jordan, they projected the water supply and demand during the years (1995-2025). The estimated water supply projection for the year 1995, 2000, 2005, 2010, 2020, 2025 is expected to reach 995, 1286, 1297, 1390, 1448, 1500 and 1557 MCM for the above years, respectively. Also they examined different scenarios for managing future water policies; constrained future irrigation use scenario; constant per capita allocation by sector scenario; and sectoral allocation priority policy scenario. They analyzed the three scenarios by using multi-criteria evaluation, namely Analytic Hierarchy Process (AHP) and they found that the third scenario has the highest weight.

Al-Jayyousi and Shatanawi (1995) analyses the future water policies in Jordan using decision support systems. They evaluated and synthesized Jordan's water plans, current and future water strategies, they defined objectives, constraints, scenarios and policies. They used an Analytical Hierarchy process (AHP) to break policies into components parts, then synthesize and analyze them in the context of constraints and scenarios in Jordan for the year 2010 and assess future water polices. The study recommended to give priority to the efficient management of water resources at the regional level. This includes institutional restructuring, new water pricing strategies, strengthening public services and encouraging the private sector, importation of water and water desalination.

Hussein (2002) conducted a research on water management and policy analysis in Jordan; he reported that in 1990, the per capita availability of water from existing national sources in Jordan was 260 m^3 /yr and about 500 m^3 /yr of water are needed by each person for an adequate existence, However, he concluded that 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, and will be face a potable water crisis by 2010. Therefore, he recommended the adaptation of new strategy for water planning in Jordan for sustainable water development. This strategy should focus on demand management, development of non-conventional water resources, privatization and efficiency enhancement in distribution system.

Dweiri and Badran (2002) studied the water resources, demand and supply in Aqaba they reported that the desalination of the seawater and brackish water is an immanent solution for the provision of extra water supply for the ASEZA to support the growth in investments and population.

Waller and Tamimi (2004) analyzed water allocation in Aqaba; they reported that Aqaba is growing fast. Irrigated areas, industrial capacity, and tourist facilities were expanding at the same rate as the City of Aqaba. As a result, water demand will increase, and new sources of water must be found. At the present time Aqaba's water use is divided as follows: 45 % to industry, 35 % to residential, and 20 % to Aqaba Special Economic Zone Authority, hotels, and the tourist industry. The largest industrial user of water is the phosphate plants in Aqaba. Allocating new water resources between users should incorporate both economic and environmental criteria. In their study they addressed three water allocation decisions from both an environmental and economic perspectives: using treated wastewater for irrigation of municipal landscapes within the City of Aqaba, using treated wastewater for irrigation of proposed golf course in Aqaba, and, finally the construction of new phosphate plants with planned use of treated wastewater.

Taha *et al.* (2004) prepared a report for projection of municipal, industrial, touristic and irrigation demands in Jordan. Software tools were developed to project the current consumption into the future. They indicated that irrigated agriculture in Jordan is the largest consumer constituting around 64 % of the overall uses compared to only 36 % for municipal, industrial and tourism purposes. They reported also that the decrease of municipal consumption from 103 l/s/d in 1996 to 86 l/s/d in the year 2001 clearly indicates the increasing pressure of growing population on limited water supply and resources. The touristic consumption in the governorate of Aqaba has been increasing both in absolute and relative terms, from a total of 0.44 MCM/a (22 %) of touristic consumption in 1996, to about 0.74 MCM/a (41 %) in the year 2001 whilst the share of Amman governorate has been falling from 74 % to 46 % during the respective years due to the progressive touristic expansion in Aqaba city. The major water consumers in Jordan's industrial sector are limited to nine big industries (Table 1), which consumed about 87 % of the total water used by industries.

Table 1. Industrial Water Consumption of the Big Industries in 2001 (MCM/year)

Industry	**Water consumption**	**% of Total**
Aqaba Thermal Power Station	0.70	2.00
Jordan Phosphate Mines (fertilizer)	3.20	10.00
Arab Potash Company	10.60	33.50
Cement Industries	0.40	1.40
Jordan Phosphate Mines (Wadi al-Abyad)	1.10	3.60
Jordan Phosphate Mines (Shediya)	6.00	18.90
Jordan Phosphate Mines (Hassa)	2.50	7.90
Jordan Petroleum Refinery Company	2.30	7.30
Al-Hussein Thermal Power Plant	0.50	1.40
TOTAL	**31.60**	**86.40**

About 12 % of the total water consumed by industries is fossil groundwater (Disi aqifer) supplied to the Thermal Power Plant and the Fertilizer Company through the public network in Aqaba.

According to Magiera *et al.* (2004), it has been reported that with the available water resources in the water demand management in the Middle East and North Africa (MENF) Countries, still the agriculture is the largest consumer of water, consuming an average of 75 % in the Mediterranean Countries. Municipal uses consume 22 %, the insignificant rest is shared by industrial and tourism uses. Focus needs to be put on how to balance the increasing drinking water demands in most countries with irrigation demands, they accentuated that steps towards a shift from irrigation to domestic uses have to be undertaken especially in countries overusing their renewable water resources.

Saidam *et al.* (2004) studied the competition between the sectors of agriculture and tourism in the Dead Sea Region to develop a strategy for overcoming possible water conflict between the sectors using a computer-based MedWater Model (MWM) for Integrated Water Planning. The MedWater Model is a highly flexible analytical tool for water management. It can help planners and decision makers evade possible inter-sectoral competition emanating from growing demands placed on water resources. It is user-friendly as it is based on the widely available and PC-based MS Excel software. Computations of present and future water balances for any specified region can be made. The model is an appropriate tool for scenario testing and sensitivity analysis. They suggested three policy targets for the Dead Sea; cultivation of water modest crops, implementation of additional inland brackish water desalination and protection of the Dead Sea ecosystem.

Abdel Khaleq and Dziegielewski (2004) emphasized the importance of water demand management in Jordan. They reported that the water demand in Jordan already exceeds the capacity of available water resources. Therefore, careful consideration and control of water demand is an important component of the integrated water resources management in the Kingdom. Water demand management includes planning and controlling water uses using social, economic and technical measures in an attempt to reach equilibrium between limited water resources and demand. The current and future water demand management activities in Jordan represent a serious attempt at reducing the demand on fresh water resources to match it with the available water before embarking on the development of additional supplies. In their research study they described the water demand Management Policy and concluded the need to bring greater efficiency to all sectors, including municipal, tourism, industrial and agricultural users of water.

Abdalla *et al.* (2004) accentuated that the supply management is becoming unsustainable due to environmental, hydrological, and financial reasons. Therefore, stronger emphasis on water demand management is essential. Water demand management seeks to provide incentives and mechanisms to promote water conservation and its efficient use, and thus induces treating water more like a commodity and not like an entitled free public service. In their study entitled "Pricing as a tool for water demand management in water scarcity," they discussed the economic characteristic of water as a natural resource and look into the market and non-market based incentives required to optimize water demand management. Their paper presents water pricing as an example of regulated incentive in water demand management across the various water users. It provides an overview of the development of pricing as a tool in water demand management in Jordan and they concluded that pricing is one of the most important tools to lower demand.

Abu Shams and Dahiyat (2004) agreed that proper water management techniques can reduce misallocation and misuse of water, promote efficient use, reduce water quality degradation and improve the financial situation of governmental agencies as well as services delivery to the users and accentuated that the Private Sector Participation in water utilities management is a better tool for effective management through improved practices and service delivery in Jordan. While Feas *et al.* (2004) reported that there is no doubt that public participation has become a major issue in integrated water resources management (IWRM). This was agreed by Bruen (2002) when he said that the scoping and public consultation activities are important and essential features of decision making in many decisions relating to large scale activities or infrastructure related to water resources and he accentuated that the involvement of the stakeholders must be as early as possible in the analysis and on refining objectives and criteria rather than on adjusting a proposed solution.

2.3 Modeling Tools

Management of natural resources requires the integration of often very large volumes of disparate information from numerous sources, the coupling of this information with efficient tools for assessment and evaluation that allow broad, interactive participation in the planning, assessment, and decision making process, and effective methods of communicating results and findings to a broad audience.

Information technology, and in particular the integration of the database management systems, Geographic Information Systems (GIS), remote sensing and image processing, simulation and multi-criteria optimization models, expert systems, and computer graphics provide some of the tools for effective decision support in natural resources management (Fedra and Feoli, 1998).

Mysiak *et al.* (2002) emphasis the contribution of geographic information to environmental decision-making to improve the quality of decision making and to achieve a truly integrated approach to river basin management, and to assist water authorities in the management of water resources by developing a decision support system (DSS) through the integration of environmental models with GIS functions and multi-criteria decision methods.

Kachel (2004) provided evidence that using the computerized integrated information management systems on the basis of GIS can remove internal inefficiencies in all kind of business processes and a short-term efficiency gains can be realized particularly in water loss reduction, customer management and operations control. According to Kachel(2004), When a set of integrated, GIS based water management tools were applied in the regular business processes to address in particular the customer management and relationships, the efficiency of water distribution and water loss reduction. Striking results were achieved, the non revenue water was reduced by more than 20 % within a year; the response time for maintenance and repair services were reduced from 2.2 days to less than 6 hours; when it applied in its hydraulic modeling and design process considerable time were saved in the preparation of bill of quantities for the tender documents; reduced paper maps for design purposes by more than 50 % and tendering process will start much earlier than planned.

Abu Taleb *et al.* (1992) reported that in Jordan, water management problem can be characterized by water shortage, environmental quality issues and supply distribution concerns. To solve these problems, four broad categories solutions were recommended. These includes: (1) measures to increase supply from conventional sources, (2) measures to increase supply from non-conventional sources, (3) measures to promote greater efficiency and conservation, and (4) development of an integrated comprehensive planning and management framework. The fourth category solution represents an important approach to solving complex water resources. In their study, they described the development of a decision-support system (DSS) that incorporated a data management component and multi-criteria decision-making (MCDM) component. The DSS is based upon an integrated multiple objective approach, and was used to assist policy-makers in analyzing the economic, social, and environmental ramifications of development strategies in the water sector to optimize water resources planning in Jordan.

Fortes and Fazi (http://www.unesco.org/csi/act/ulugan5.htm) accentuated that high quality information and data obtained through scientific research are crucial for the correct coastal zone management practices. They indicated that successful development depends on strengthening the capacity of local community participation in coastal environment conservation. Coastal habitats can best be managed and protected by the local communities as they possess profound knowledge of the environment and are the key users of its resources.

Windevoxhel *et al*. (http://www.nwindevo/uicn.icr.co.cr) reported that the integrated coastal zone management (ICZM) in the Central America has been limited by information gaps, restricted technical and financial capacity, strong sectoralism and Laws and their regulation. The most important general weakness in regional laws with regard to achieving ICZM is: fragmentation of institutional responsibilities, absence of a clear-cut definition of the rights of common property, absence of a definition of ICZM. The incorporation of non-governmental society in MCZ management has not been defined effectively, obsolete sectoral laws, dispersed and unstructured legislation, and general lack of knowledge about legislation.

Isobe (1998) examined the three functional aspects for coastal zone: provision of ecological services, disaster prevention, and human utilization. Then he introduced a basic theoretical framework scheme for integrated Coastal Zone Management (ICZM). Such a scheme seeks will to integrate the ecological, disaster prevention, and human utilization function of coastal zones. He concluded that the ICZM is absolutely essential to solve Japan's development-related coastal zone problems, and ICZM seeks to think of coastal management with a long-term and broad-based perspective.

2.4 Land Use

Land use is a major driving force for water demand. For better management and planning of the natural resources land use maps are required, and precise information about recent and current land use changes is needed to know the available resources of land and the utilized areas and to evaluate future trends. Determining the trend and the rate of land conversions is very necessary for development planners in order to build up land use policy. Land use change affect the water demand distribution through human activities (Smart, 2004). Al-Bakri *et al.* (2001) indicated the potential of remote sensing and GIS in providing and analyzing land use changes with different models at different scales. In Jordan, land use changes were mainly attributed to the high population growth rate, socio-economic change and the environmental factors.

Rajan and Shibasaki (2001) reported that the land cover/use is an important component in understanding the interaction of the human activities with the environment. Therefore, a natural scale, integrated, dynamic time-series simulation model 'Anthropogenically Engineered Transformation of Land Use and Land Cover' was developed to simulate agricultural and urban land uses. The study concluded that land use transformations were mainly attributed to biophysical and human divers.

Furthermore, land resources data can be incorporated into GIS for planning rural and industrial explanation (Theocharopoulos *et al.* 1995).

2.5 Decision Support System (DSS).

Fedra (2003) reported that water resources management requires potentially large volumes of data of different nature, ranging from long term historical time series to large-scale spatially distributed data and to real time monitoring and telemetry. The acquisition and processing of these data and turning them into useful information for policy and decision making pose a number of challenges. He discussed the transfer of data collected into decision relevant information available to a large and divers group of distributed stakeholder and actors participatory decision making processes by using information technology. Also he analyzed the role of data for modeling and the role of models, GIS, and expert system in decision support. He said that the basis principles behind these simulation models are the conservation laws, Geographic information systems provides the tools for spatial analysis, Rule-based expert systems use symbolic logic for deductive inference and can express qualitative concepts and conditional relationships that are difficult to formulate in purely numerical terms. Expert systems are empirical and heuristic systems, based on a more or less explicit and usually qualitative. The integration of these different tools, models, GIS and expert systems provides the basis for a new generation of powerful information and decision support systems. Decision Support System is based on information management and model-based decision support.

Fedra and Feoli (1998) reviewed methods and tools of spatial analysis, their integration and application to coastal zone management. They reported that to face problems of protected areas, ecosystem management, impact assessment, economic evaluation and to solve conflicts and find optimal solutions the integration of recent tools such as Geographic information system (GIS), Image processing systems (IPS), remote sensing (RS), with data management, data analysis and modeling, seems to be a promising exercise.

Frookh (2000) reported that the decision system of domestic demand management (DMS) forms part of a highly integrated decision supply system for river basin management (WaterWare). The DMS is part of the Demand Forecasting and Management System (DFMS). The core components of DMS are Geographic Information System, database management system, expert system, Multi-criteria decision, prediction models, user-interface, and hypertext files. The system provides water resources planners with the facilities for management of domestic water demand for any demand region and time period. It allows for computing conservation effectiveness due to the implementation of various demand-management measures such as metering, pricing, pressure reduction, saving devices, awareness, plumping codes and water use regulations. The system is generic and can be used for any region since the information used gives the user several options based on the existing conditions.

2.6 WaterWare Model

Fedra and Jamiesan (1996) described the Water Ware system as an object oriented information and decision support system for river basin management. The basic data framework combines a hybrid GIS as the overall structure with classes of objects, including river basin elements, models and model scenarios, and tasks or decision problems. The system is based on a modular framework of GIS and databases that allows linking of various simulation and optimization models into this framework. WaterWare describes a river basin by set of interacting objects which are spatially referenced. River basin objects represent real world entities. Network objects represent a different layer of abstraction, including nodes and reaches of network representation of the surface water system. Scenario objects represent model oriented collections of instantiations of network objects that are partially derived from and linked to the river basin objects.

GIS is used to capture, analyze and display spatial data. The GIS can provide a common framework of reference for the various tools and models addressing a range of problems in river basin management. In a multi-media framework, it can also provide a common interface to various functions of integrated river basin information and decision support system, this interface has to translate the data and model functionality available into information that can directly support decision making processes.

Jamieson and Fedra (1996 a) defined the river basin in its broadest terms and were deemed to include all aspects such as water supply, land drainage, hydropower generation, effluent disposal, recreation and amenity. They reported that while resource utilization remains small; interactions between these different interests are largely absorbed by the natural buffering within the physical system. However, as demands increase, it soon becomes necessary to co-ordinate activities. Eventually, there comes a time when, to realize the full potential, the only sensible way of proceeding is to consider the whole basin as one complex integrated system. River basin management can be characterized as an exercise in conflict resolution. Although water is a renewable resource, it is also finite and has to be allocated between competing interests. The need for additional resources implies an increase in the level of economic activity, which inevitably generates more pollution, whether from agriculture or industrial sources or both. This together with the corresponding increase in domestic pollution can cause environmental and water-quality degradation, which in turn constrains further development. Clearly, there is a need to achieve a better balance between economic activity and environment quality; this has led to the quest for 'sustainable' river-basin development policies. They used the WaterWare programme to develop a comprehensive, easy-to-use decision support system for river basin planning to assist government agencies in decision making for the efficient management of water resources in terms of both quantity and quality by combining the capabilities of geographical information systems (GIS), database technology, modeling techniques, optimization procedures, expert systems, user interface and hyperlink facility, the aim is to improve the quality of decision-making in what is becoming an increasingly complex area.

Fedra (2002) applied WaterWare (GIS and Simulation Models) for water resources management in Kelantan River Malaysia where a serious problem had accrued. A catchment of about 12,000 km^2 and an altitude difference of more than 2100 m generate an average runoff of about 500 m^3/sec, with the variations of the local climate. The variability of rainfall with extreme monthly values between 0 and 1750 mm in dry and wet months, respectively, reliability of water resources for the rice paddies that supply about 12 % of national production, drought and floods that affect the efficiency of the irrigation system, continuing changes in land use, and the potential of water pollution from intensive agriculture pose a range of problems. In his study historical data of rainfall, river flow, and air temperature as well as water quality are stored for the various monitoring stations into the data base in real time to provide an accurate and up to data picture of the situation. Hydrographic catchment, network of draining channels, the river network that collects and conveys surfaces water, river reaches, dams and reservoirs, diversion and pumping stations water works and secondary distribution network are all spatially distributed. GIS is used to capture, analyze, and display this spatial data, and data base as well as other model interface (expert systems, simulation and optimization models) are thus fully integrated and present a unified graphical and symbolic representation of a river basin to the user. The results was that prolong periods of below average rainfall that lead to low soil moistures, lowering of the groundwater table, and most importantly, low flow in the river. This in turn, leads to a combination of increased water demand for irrigation and a low availability of irrigation water: below a certain low -flow level, pumping water out of the river in fact becomes impossible , also by using the water resources management model he computed the daily water budget for all nodes in the river network, and by adding a simple simulation routine for the net economic benefit for different types of water use he got an overall economic optimization of the water allocation.

Fedra and Jamieson (1996) described the analytical components both existing and intended of the WareWare decision-support system for river-basin planning, they reported that the Waterware consists of a central information systems component with GIS and databases as well as the multi-media hypertext system that provides background information and describes a specific river basin. Linked to this data layer are a set of models that can perform scenario analysis, i.e./answer WHAT-IF and HOW-TO questions for various water quantity and quality issues, as well as related engineering, environmental, and economic aspects. Also they reported that one of the major uses of WaterWare is for planning future water resources. In essence, this requires decisions to be made about which sources should be developed, when the investment should be made and where their resources-contribution should be allocated. However, because a river-basin is a highly integrated system, these decisions cannot be taken in isolation from the context of existing resources. Therefore, there is a need to consider the basin as a whole, as well as the possibility of inter-basin transfers.

Jamieson and Fedra (1996 b) described the application of WaterWare to the River Thames basin in England and Rio Lerma in Mexico, The main problem in the Thames basin is to meet the continuing increasing in demand without adversely affecting the environment. The demand is increasing as a result of improved living standards rather than population growth the aim of applying WaterWare system was to augment existing resources. In Rio Lerma the problem was pollution control. Most major cities in the Rio Lerma basin are located in the headwaters and had inadequate municipal wastewater treatment facilities. Moreover, many of these cities contain heavy industries and most industrial wastes were discharged directly to the river without treatment. Application of the WaterWare system in Rio Lerma was to reduce abstractions and planning the basic waste-water infrastructure. WaterWare organizes the date describing a river basin in terms of spatial objects. They include elements such as monitoring station and the associated time series of measurements, sub-catchments and irrigation districts, the river network with it nodes and connecting reaches as well as the various simulations models and their scenarios. They applied Water resources assessment module (WRA), reservoir site selection (RSS), Surface-water flow and pollutant transport model (SWP), ground water pollution control model (GWP) to the Thames basin. The WRA was run to asses how frequently restrictions on supply have to be imposed, using past records to reflect the variability in weather patterns. The present capability of the system can be assessed and any temporary surpluses redeployed as the first stage of the water resources development strategy. RSS model using WaterWare's expert system can help in search for the best reservoir site selection. The surface-water flow and pollutant transport model can also help in predicting the effects of abstraction or release on river-water quality for reservoir development. GWP estimates the scale of the contamination by predicting where the pollutant is moving and in what concentrations, under the prevailing ground water-flow regime to determine the optimal number and location of scavenger boreholes.

In Rio Lerma, they used the base system of WaterWare (GIS database, water resources planning and surface water pollution control components) to determine a more realistic allocation of available water resources, and to determine where improvements to effluent treatment should be directed to achieve a maximum benefit.

Description of the Study Area

3.1 Geography

Aqaba Governorate is located at the most south-western part of Jordan at 360 kilometers from Amman encompassing about 6904.7 km^2 (7.8 %) of Jordan's land mass, at longitudes 34°57' and 35°09' E and latitudes 29°19' and 29°43' N. It has two regional borders; with Saudi Arabia from the south and with Israel (city of Eilat) from the west. Approximately 7 % of the Gulf of Aqaba is coastline, which totals about 367 kilometers, of which 27 km belong to Jordan. The remaining portion is divided between Egypt 200 km (53%), Saudi Arabia 130 km (35 %), and Israel 14 km (4 %) (Adam and Al-Khoshman, 1993; Montgomery-Watson *et al.*, 1999). Prior to 1996 Aqaba belonged to the Ma'an Governorate. According to the administrative division by-law No. 46 article 120 of the year 2000, Aqaba Governorate comprises of Aqaba District which contain Aqaba Sub-District with an area of about 2018 km^2 and a population of about 87,040 person (2003); Wadi Araba Sub-District with an area about 2322 km^2 and population of about 4,480 person ; Quwayrah District with an area 2,560 km^2 which contain Quwayrah Sub-District with a population of about 14,270 person and Disi Sub-District with a population of about 4,210 person. Aqaba is Jordan's only sea port as it occupies a strategic location close at the cross roads of Europe, Asia and Africa. The Gulf of Aqaba is a small semi enclosed north-western branch of the Red Sea, 180 km long and 5 to 26 km wide and reaches a maximum depth of 1828 m and an average depth of 800 m and is connected to the Red Sea at the narrow (6 km) strait of Tiran. These unusual geographic features are due to the Gulf being situated within the Syro-African Rift Valley, which stretches from East Africa to Turkey.

3.2 Climate

The climate in the Red Sea Basin is considered as arid with the exception of brief but intense precipitation where the average annual rainfall of 35 millimeters. Mean daily air temperature ranges from 14°C in January to a mean maximum of 32°C in August. The mean maximum monthly temperature varies from 21°C in January to around 40°C in the summer month of July. Sunshine is prevalent throughout the year. Prevailing winds are from the north, with occasional winter storm winds blowing from the south. Relative humidity ranges from 30 to 55 percent. Potential evaporation rate is about 4000 mm/year. Marine water temperature in the gulf remains at a constant 21.5°C below a depth of 200 meters and varies from 20.5°C in February to 27.3°C in September at the surface. Salinity of the Gulf waters ranges from 40.3 to 41.6 parts per thousand. Tides are semidiurnal, with a tidal range of 30-100 cm. (World Bank, 1996; Montgomery-Watson, 1999).

3.3 Geology

The area of Aqaba Governomate has an irregular shapes topography; it varies in elevation from sea level on the western borders to an elevation over 1200 m above sea level on the eastern side. This is represented by the relief between mountain top and wadi areas, with steep to vertical slopes developed in granitic rocks and separated by flat wadis.

According to the information cited by Wilbur Smith Associates, *et al.* (2000) the rock in the Aqaba area, are igneous, metamorphic and sedimentary in origin. Description of the outcropping ground materials covering the area (starting consequently from the oldest rocks) is as follow :

Igneous Rrock: Granitc Mountains of different composition running from the east side of the area towards the west side and it is extended to reach the beach of Aqaba at the middle part of the area only.

***Sabil Granodiorite (S)*:** Sabil Granodiorite of Rumman Suite is the oldest rock outcropped at the site. It is characterized by distinctive green-gray color, ubiquitous dykes, hornblende and variable biotite. The Sabil Unit is a medium-grained granodiorite with a typical, granular to hypidiomorphic, granitoid texture. It characteristically takes the form of variably weathered, friable, undulating ridges crossed by numerous dykes.

***Sahaqi Granodiorite (SI)*:** The Sahaqi Unit is only found in contact with the Abu Jadda and Imran Units of the Yutum Suite. It is a medium grained black and white rock, with abundant biotite commonly found in shiny subhedral crystal aggregates, and grey-white plagioclase, Sahaqi Granodiorite is characteristically mafic rich, conspicuous metasomatic pink k-feldspar weakly foliated, highly weathered, common minor mafic clots or xenoliths dykes. It forms a relatively rugged topography with steep talus, covered slopes, dominated by angular blocks, rising up to sub-vertical massive crags at outcrop, although the bedrock is often deeply weathered and friable.

***Imran Monzogranite (I)*:** The Imran Monzogranite is a medium to coarse grained with a characteristic high color index and with distinctive coarse pink K-feldspars. Biotite is found in association with subordinate amount of hornblende accounting for the high color index of the unit.

The majority of the outcrop of Imran unit is characterized by low relief, sub-rounded hills and ridges often highly weathered and extensively dyked.

Abu Jadda Granite (AJ)**:** The most igneous rock outcrops at the area is Abu Jadda Unit. It typically forms high rugged mountainous terrain with a sub-rounded massive outcrop pattern, often with a cavernous weathering aspect.

Abu Jadda Granite is relatively homogeneous plutons medium to coarse grained, pink, common biotite with lower color index corresponding to the lack of hornblende. It is characterized by moderate numbers of dykes but numerous along reional fracture zones and few xenoliths.

Humrat Granite (HT)**:** Humrat Granite Unit outcrops as distinctive brick-red colored ridges and craggy hills with an irregular topography cross-cut by minor, few, thin, green weathering basic dykes. Humrat Granite is generally composed of two types. They are:

? A fine grained, pink-red, equigranular syenogranite to alklifeldspar granite with isolated subhedral biotite.

? Orange-red mafic poor alkali-feldspar granite, locally varying to alaskite, with distinctive wormy quartz which produces a granophyric texture.

Mubark Granite Unit**:** This unit tends to develop an outcrop pattern very similar to that of the Abu jadda granite except for the characteristic lighter colours of the latter.

This rock in hand specimen, is a coarse to very coarse-grained, equigranular, holo-leucocratic, pinkish white to red granite that differs from the similar Abu jadda Granite in having a coarser grain size, lower colour index, higher amounts of quartz, and the absence of hornblende. The perthite occurs as coarse–grained, anheddral crystals with prominent kaolinitization, mainly along albeit twinning lamella. Quartz displays clear, fractured crystals with consertal texture, clustered in groups. The plagioclase, which is mostly completely sericitized, forms medium to coarse, subhedral, tabular to rectangular crystals with a well develop poikilitic texture. The anhedral biotites are partially altered to chlorite and iron oxide. The Mubark granite is found in gradational, not well defined and very poorly exposed, contact with the very similar Abu jadda Granite.

The most impressive geological features of the area are the abundance of dyke rocks which dramatically cross-cut at all granite units.

***Sedimentary Rocks*:** Sedimentary rocks outcrops at the area in scattered positions only and it is mainly setting unconformable with Abu Jadda Unit.

***Salib Arkosic Sandstone Formation*:** This formation crop out at the northern part of the study area and it consists of up to 0.55 m yellow–brown, pebbely conglpmerate, to very coarse–and coarse-, rarely medium–grained arkosic to subarkosic sandstone. Grain size decreases upwards, but lenses and/or beds of pebbely conglomeratic sandstone can be seen through out the formation.

***Kurnub Sandstone Group*:** The Kurnub sandstone has been divided into two parts, the lower consists of white coarse sandstone and the upper variegated sandstone. The lithology typical for the lower part of the kurnub sandstone, consist of gray–white, fine–to coarse–grained, massive to thickly bedded sandstone with scattered granules and quartz pebbles. Trough and cross–bedding with pebbly forests are common.

***Pleistocene Deposits*:** Different facies of pleistocene sediments cover the most west side of the project area which is adjacent to the Aqaba beach and the rift valley, also several wadi of these sediments cross the granitic rocks from the east side of the area.

Alluvium (AL) consists of sub-rounded matrix of weathered granited and clast-supported gravel ranging in size from pebbles to cobbles. Alluvial terrace wadis, particularly the meandering streams on the plateau area. Most of the alluvial terraces comprise ageneral fining–upward sequence from gravel at the base to fine grained sand with scattered pebbles above.

Alluvial fans (Alf) composed of angular debris (rock fragments) from the adjacent hillsides were developed peripheral to the upstanding granitic maintains.

3.4 Hydrology

3.4.1 Surface Hydrology

The surface water system in the area of Aqaba (Red Sea Basins) is very complex system as it consists of two main catchments that are completely different in their hydrological characteristics. These catchments are Wadi al-Yatum and Wadi Araba South. In addition to that, there are other small catchments that originate from the eastern step rocky mountain facing the southern coast that may present flood hazard to the urban and industrial areas in the south coast. Figure 1 shows the catchments of the Red Sea Basins.

Actually, there is very little information about these catchments that are not enough to describe their extents, areas and characteristics. In an attempt to provide basic data needed for analysis, satellite images of 30 m resolution and topographic maps of 1:50,000 scales were acquired for Aqaba area and its surrounding.

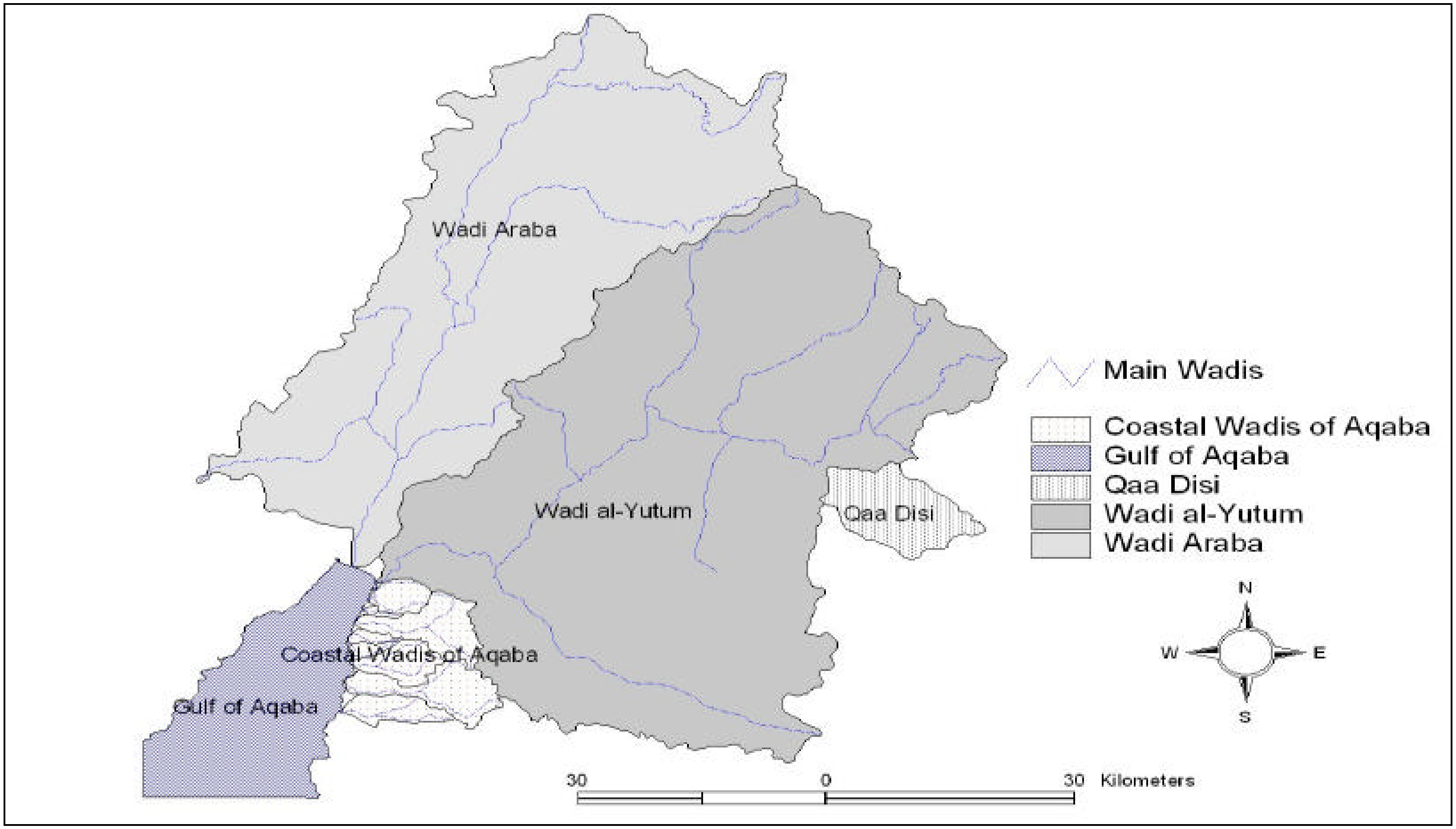


Figure 1: Catchments of the Red Sea Surface Basins.

The images and the maps were processed at the GIS unit of the University of Jordan to delineate the boundaries of the catchments and to determine their area, extend and hydrological characteristics. There process involved visual interpretation and Arc-GIS analysis which has identified the following features:

1. Wadi al-Yutum Catchement

The area of Wadi al-Yutum basin is about 2840 km^2 which represents about 42 % of the total area of the Red Sea Basin (Figure 2). The basin has a polygon shape with a length of its main stream of 75 km. The elevation varies from 1417 m (asml) near Wadi Rum to almost sea level at its outlet in Aqaba near the Royal Diving Club. Rainfall on this basin is scarce which averages about 35 mm/yr, but rainfall can vary in some years to have very high intensity causing severe floods. Wadi Yutum constitutes the major risk to Aqaba City. No real study on the hydrology of Wadi al-Yutum has been done to determine the frequency and magnitude of the flood. In 1982, a reconnaissance study was carried out to determine the return period and magnitude of these floods but rainfall intensity data were not enough. However, during the last 50 years, two major floods has occurred causing series damages to the existing infrastructure. To avoid the risk of flood, some retention dams were constructed aiming at lowering the peak of the flood using the principle of channel routing. The Wadi has two main tributaries; Wadi Imran and Wadi Hafir. The catchments area can be divided into 3 sub-basins. The upper sub-basin having an area of 1420 km^2, the lower sub-basin with an area of 480 km^2, and the wadi Imran sub-basin that has an area of 940 km^2. Wadi al-Yutum passes trough mountainous terrain and mudflat areas before it finally ends with a huge alluvial fan extending from the northern port of the urban area to the airport in the north.

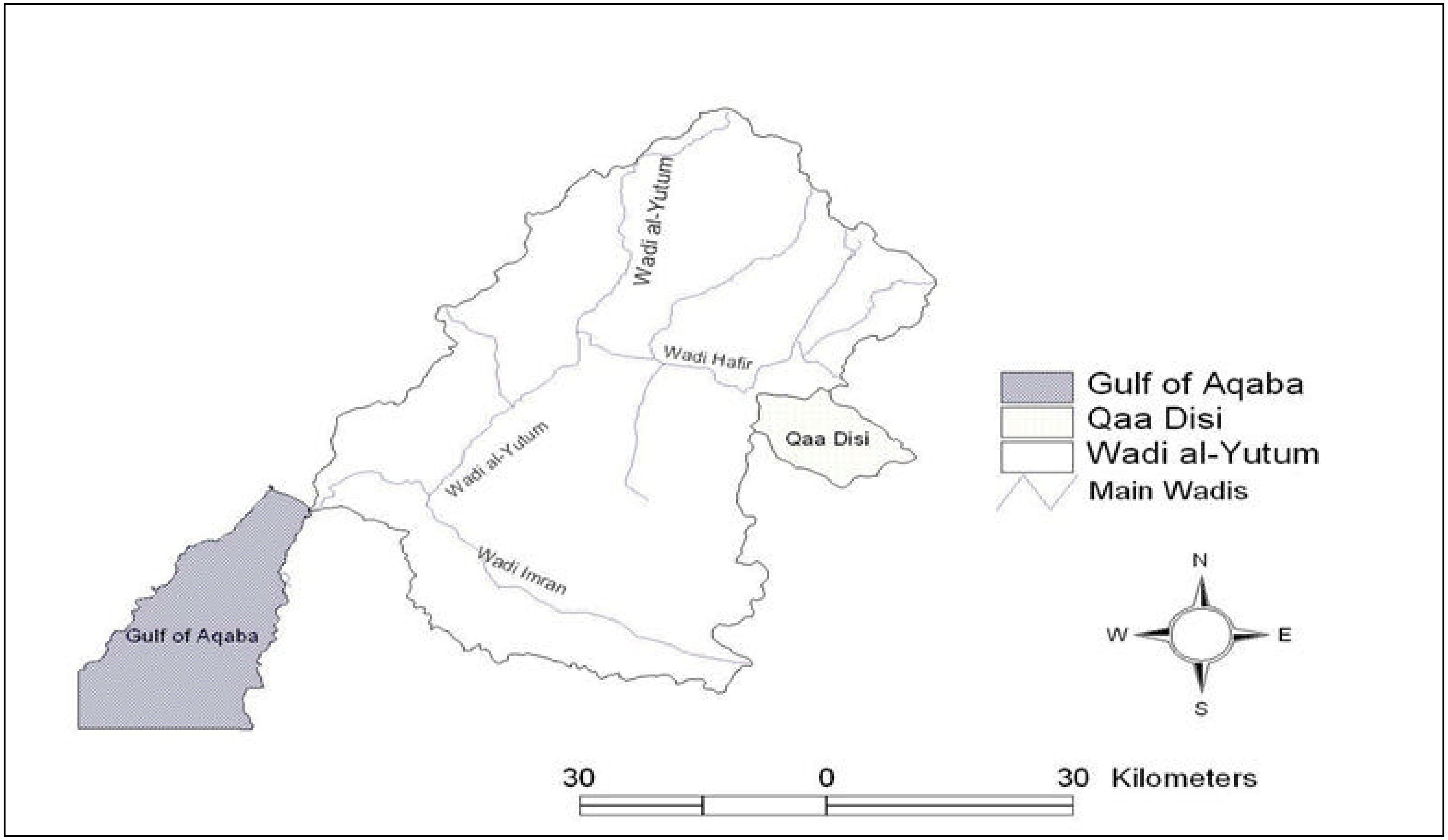


Figure 2: Wadi al-Yutum Catchments.

The mudflat areas store return water resulting from medium intensity and thus reducing the magnitude of the flood reaching Aqaba.

2. Southern Wadi Araba Basin

The southern Wadi Araba Basin has a total area of about 1860 km^2. The basin has a narrow shape of length that extends about 75 km north of the Gulf. The average width of the basin is about 30 km from west to east. The Wadi buttom almost represents the political boundaries between Jordan and Israel (Figure 3). The average precipitation above the basin is less than 50 mm; it can reach 150 mm at high altitude of the eastern mountain. The potential evapotranspiration is about 4100 mm/year. The total discharge from different tributaries feeding Wadi Araba can reach a non-significant amount of 1 MCM. Most of this water percolates during its downstream movement into wadi beds and finally into the alluvial fans at the end of these wadis. Due to that, flood rarely reaches the Gulf of Aqaba as it percolate into the ground during its course of travel.

3. Coastal Side Wadis

Through the delineation, several side wadis have been identified (Figure 4) which were originating from the eastern escarpment facing the Gulf of Aqaba. Some of these wadis represent some risks during periods of flash floods. No real studies concerning flood hazard risk assessment were carried out. However, some diversion structures and protection levees were constructed to divert the flow to the highway culverts ending into specific location of the shore.

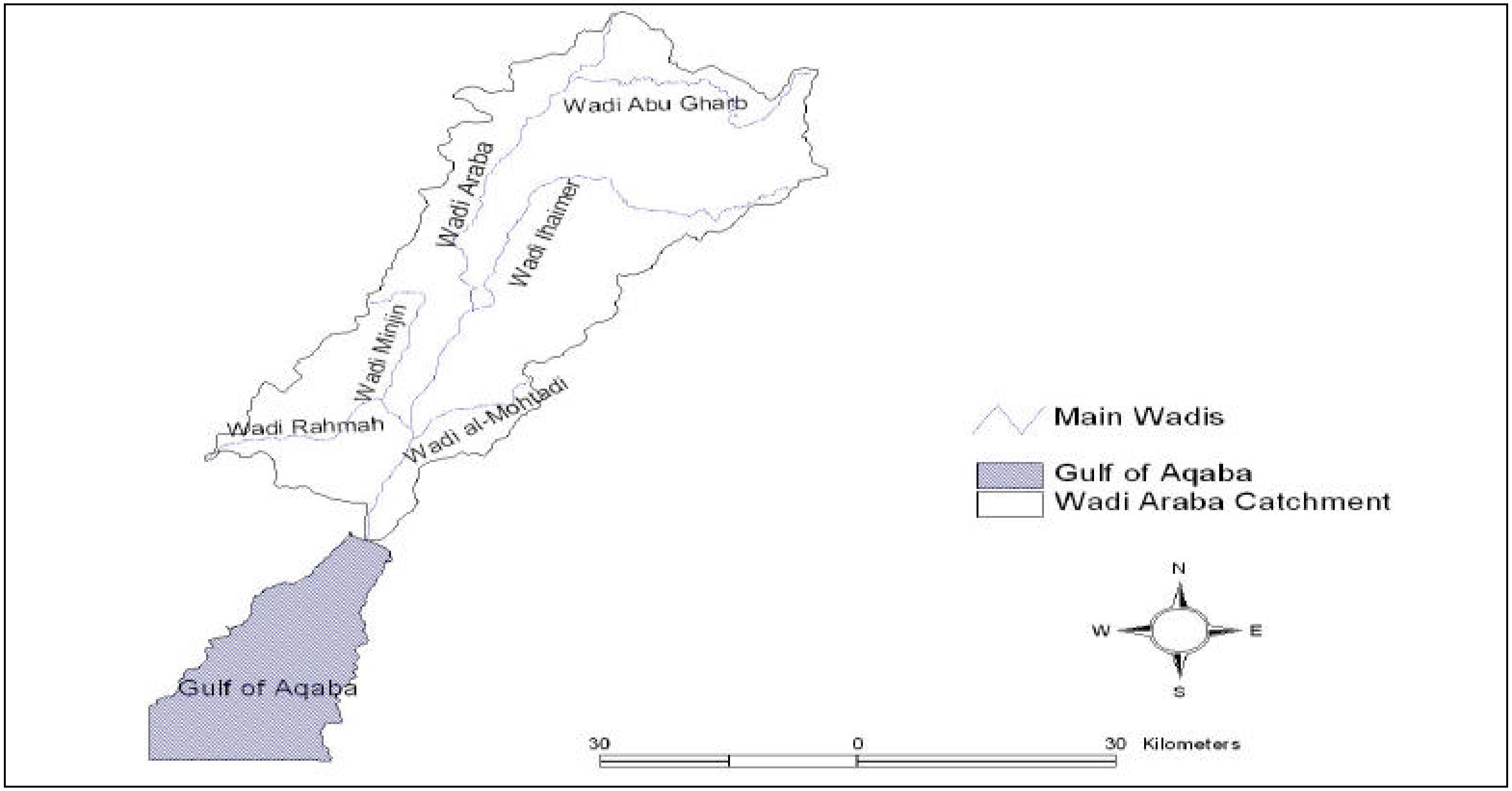


Figure 3: Wadi Araba Catchments.

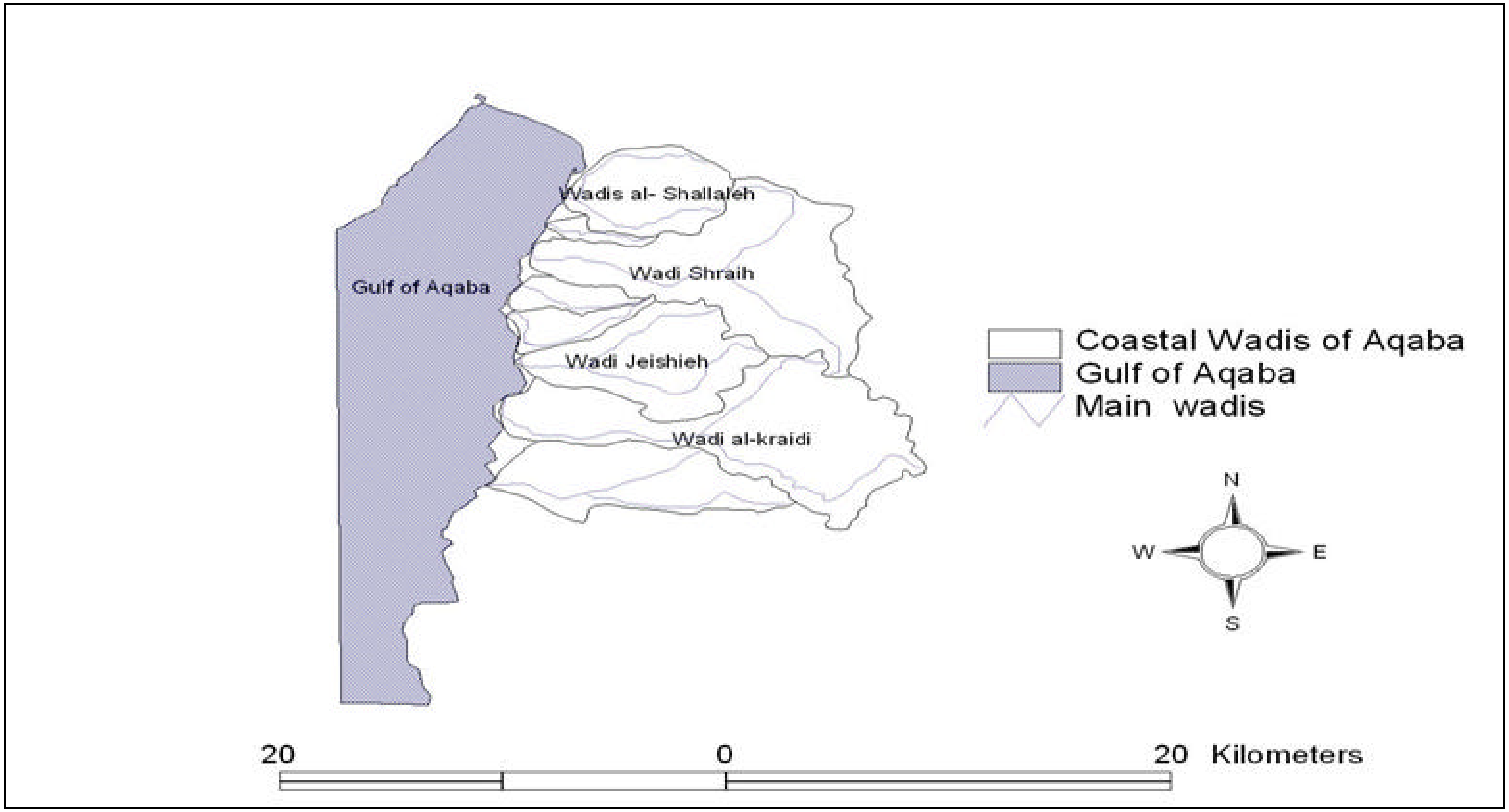


Figure 4: Coastal Wadis Catchments.

The identified major wadis of the East Coast are:

***Wadi T*:** Has a northwest orientation and a catchments area of 10 km^2. It drains into an area close to the intersection of Amman Aqaba highway and the Wadi Araba highway.

***Wadi Shallaleh*:** Wadi Shallaleh catchment has an area of about 11 km^2, and flows to the west into the southern residential area.

***Wadi Jeshieh*:** The main wadi which flows into the main port. It has a catchments area of 10.5 km^2.

***Wadi Mubruk*:** Amajor wadi that drains to the north of the container Port. Wadi Mubruk has a history flooding due to the high slope of the wadi bed that causes supercritical flow and severe erosion

***Wadi 9*:** The largest wadi in the Coral Coast with an area of 28 km^2.

***Wadi 2*:** The major wadi that drains into the industrial area. The wadi catchment has an area of 62 km^2.

3.4.2 Groundwater Hydrology.

The groundwater resources represents the major water resources for Aqaba area since surface resources in the Red Sea Basin are very small (about 1 MCM) and are not reliable for any development except if certain measures are taken to utilize them for artificial recharge of groundwater. The underground hydrology of the Red Sea Basin falls under the following categories:

1. Southern Wadi Araba Aquifers.
2. Disi-Mudawwarah Aquifers.
3. The Aquifers of Wadi al-Yutum.
4. Local Aquifers in the vicinity of Aqaba Coast.

***Southern Wadi Araba*:** Wadi Araba floor is composed of alluvial sediments brought from the surrounding mountains in the east and west. The thickness of the sediment fill is measured in kilometers, but the fresh and brackish groundwater is found in the uppermost portions of the aquifer. The groundwater flow is directed from the north to the Red Sea in the south. Recharge comes from precipitation falling on the surrounding mountains in the east, and infiltrates there in the barren rocks and flows laterally into the fluviatile and alluvial deposits covering the wadi floor. Part of the recharge takes place along the wadi courses of the side wadis and Wadi Araba itself. The throughput of the aquifer is around 10 MCM/ year composed mostly of brackish water

***Disi-Mudawwarah area*:** the Disi-Mudawwarah aquifer system crops out in south Jordan and extends into Saudi Arabia and the underground of Jordan, where it overlies the Basement Complex, which consist of intrusive igneous rocks functioning as an aquiclude. The system is part of the sandstone group (SAG) which extends from Ma'an in Jordan to Tabouk in Saudi Arabia. The Disi aquifer consists of medium-to fine-grained sandstones with a total thickness of about 1000 meters. The average precipitation over the area ranges from 20 mm/yr in the east to about 50 mm/yr in the west, with an average potential evaporation of 4000 mm/year. The ground water in the

Disi area occurs under phreatic conditions and considered unconfined and lies at a depth of around 80 meters below the surface. The aquifer has been penetrated by some 80 wells; about 15 wells are governmental and used for supplying water to Aqaba city and Quwayrah and Disi sub districts. About 2 MCM are used for irrigation in Disi village. There are also five wells that are used as observation wells. The rest of the wells are private and operated by six agricultural companies for irrigation. These companies have released the land in Disi-Mudawwarah area and the right to exploit the groundwater of the aquifer. The estimated amount of water abstraction by these companies is about 50-55 MCM/year. The governmental plan is to pump Disi water to middle governorates of Amman, Zerqa and Madaba to alleviate the water shortages. The Qa Disi sandstone aquifer produces high quality water with total dissolved salt (TDS) every where is less than 450 mg/l and at some location less than 250 mg/l. The Jordan water quality classification for this aquifer water is good to very good (Montgomery-Watson, 1999; Wilbur Smith *et al.*, 2001). The ground water in the Disi has a very low salinity and is free of pollution signs of any type. Table 2 illustrates the excellent quality of that water.

Table 2. Aqaba Water Quality (sample date 18 January 1998)

No.	Source & Date Parameter	Qa Disi Well	Aqaba Terminal Reservoir	High Level Reservoir
1	**E.C (*dS*/m)**	0.452	0.368	0.367
2	**pH (unit less)**	7.98	8.1	8.11
3	**Ca (meq/l)**	2.63	2.09	2.05
4	**Mg (meq/l)**	0.67	0.60	0.45
5	**Na (meq/l)**	1.25	0.97	0.9
6	**K (meq/l)**	0.07	0.06	0.05
7	**Cl (meq/l)**	1.45	0.93	0.85
8	**SO_4 (meq/l)**	0.86	0.59	0.29
9	**CO_3 (meq/l)**	0	0	0
10	**HCO_3 (meq/l)**	2.03	1.96	1.96
11	**NO_3 (meq/l)**	15.38	11.20	10.84

Source: Montgomery-Watson.

3.5 Marine Life

The semi enclosed characteristic of the Gulf of the Aqaba has led to its rich biodiversity. The Gulf of Aqaba hosts an extraordinary diversity of coral and related marine life, where about 50 % of the Gulf's shoreline is fringed with coral reefs over 120 scleractinian coral species and 10 species of soft coral have been observed. Twelve percent (80 known species) of mollusks and a similar proportion of echinodermata occurring in the Gulf may be endemic. Fifteen percent of the Gulf is amphipod species. The reefs which fringe the Gulf of Aqaba coastline host more than 1000 species of fish, making the Gulf one of the world's most popular places for scuba diving and snorkeling. Sea grasses exist in the immediate vicinity of coral reefs, providing an important nursery for fish, shrimp and other invertebrates and serving as host organisms for many species of micro-and macro algae. Marine mammals in the Gulf include sea cows observed in small numbers on sea grasses. Spotted and bottle-nosed dolphin also inhabits the Gulf's waters. Sea turtles observed in the Gulf include the green, hawksbill and leatherback turtles, (Adam and Al-Khoshman, 1993; Farajat, 2001; Smart, 2004; World Bank, 1996). Corals depend on two principal environmental elements: clear water free from sediments, and steady, slow currents to carry off waste and provide nutrients. In this regard, The Gulf of Aqaba is exceptionally well suited for mature coral reef ecosystem. This deep, still water of the Gulf allow sediment to settle, and the bright sunshine penetrates the water as far as 100 meters. As a result, coral formation-both reef building and soft coral is extensive and unusually deep in the Gulf. The slow, circular currents of the Gulf of Aqaba provide abundant nourishment without endangering coral polyps, and the high levels of dissolved oxygen in the warm waters allow luxuriant coral growth (Adam, and Al-Khoshman, 1993; Farajat, 2001; World Bank, 1996).

The semi enclosed characteristic of the Gulf results in limited water exchange with the Red Sea and Indian Ocean. The residence time for shallow water is one to two years, while the lower mass of water experiences a three year average residence time. Also the semi enclosed nature of the environment of the Gulf of Aqaba causes the sea to be particularly susceptible to pollution. Marine pollution sources include urbanization, industrialization, aquatic tourism, oil spills, solid waste, waste oil contamination, phosphate dust, air pollution from land transportation, chemical pollution from industries, thermal pollution from power plant, return flow from irrigation, pollution of the shallow brackish water aquifer and sewage from the municipal sewage treatment ponds. If these activities are not controlled in an environmentally sound and sustainable manner, environmental degradation will worsen (World Bank, 1996).

3.6 Terrestrial Ecology

Aqaba is an important bird area, which lies on a major migration route; it has two very distinct biogeographic zones that combine typical Afro and Arabian species. Millions of birds migrating from Europe and Asia to Africa and back. Aqab's terrestrial biodiversity is of global, regional, and local significance, with the presence of various habitats and ecosystems. Over 200 bird species have been observed traveling this route, among them white and black stork and several species of birds of prey, the latter passing through the Aqaba region and Wadi Araba particularly on their springtime northward migration. Many migrants also rest and feed in the Aqaba area. The Gulf-fringing highlands may be inhabited by rare predators such as Lammergeier and Sooty Falcon while the lower wadis contain typical desert and tropical species including rarities such as Little Green Beater, hooded Wheatear and Arabian Warbler.

3.7 Plant Cover and Vegetation

Plant cover in the area has special characteristics due to dryness, wind and salty soil dominant in the area. These factors make the soil very poor without organic matter content and rich with salts. Accordingly, this is reflected on the plant cover making it spares and of less diversity. The plant cover of the city composed of some desert plants, some grazing plants in wadi beds, palm trees and special gardening activities in the surrounding of residential areas. The largest plantation in Aqaba is the palm plantation project, initiated by the Aqaba Regional Authority in the northern part of the town to serve two reasons; to utilize the treated wastewater of the Aqaba Wastewater Treatment Plant, and to create a barrier against the wind borne sand coming from Wadi Araba. The second large one is the private plantations called (Al Hafair) located to the north-east of the Gulf of Aqaba which is planted by the inhabitants of the city; where about 20 randomly distributed very shallow wells (1-3 meter depth) were dug to supply irrigation water. These plantations are overlooking the coastal area at about 50-100 meter away from the shore. Palm and some other seasonal plants are planted.

3.8 Demography

Aqaba's economical growth over the past two decades has been accompanied by a parallel growth in population. Since 1972, Aqaba has expanded from a small town of 10,000 to a city of 110,000 inhabitants today. By the year 2005, Aqaba is predicted to reach population of 113,369. Beyond the year 2000, the region's planners anticipated a doubling of the coastal population to approximately 172,224 by the year 2020, taking into account current plans for resort hotels and vacation community development as well as the new development in the upland area of southern Jordan.

3.9 Institutional Development

The following is a brief description of the institution succession in Aqaba Governorate.

3.9.1 Port Corporation

The Port of Aqaba started in 1939 with one berth as a supply base for the British Army in the World War II. In 1952 Jordan took an economical decision in converting the base into Aqaba port to receive the imports, cargo the exports and to employee the local workforce and established Aqaba Port Authority. In 1958, the name of Aqaba Port Authority changed to Aqaba Port Department. In 1968, the Sea Organization was established to take care of cargo handling beside the Aqaba Port Department supervision. In 1978 the Aqaba Port Department and the Sea Organization were joint together under the name of the Port Corporation to take the responsibility for the construction, operation and maintenance of Aqaba port facilities, which currently occupy nearly 30 % of the Jordanian Gulf of Aqaba shoreline. Given the economic importance of port activities, the Port Corporation joined efforts with Aqaba Region Authority (ARA) to address priority environmental protection concerns in the region, and bearing responsibility for ensuring the health and safety of the largest workforce in Aqaba Region (World Bank, 1996; The Port of Aqaba, 2002/2003).

3.9.2 Aqaba Region Authority (ARA)

The Aqaba Region Authority was established in 1984 under the authority of the Prime Minister in order to ensure coordination and integration of all development taking place in the Aqaba region. In order to enable ARA to perform its mandate for overseeing the integrated development of the region, the Government issued a special law (Law of the Aqaba Region Authority No. 7 for the year 1987) which identified the organization's goals and guided its activities. The law states that the ARA is responsible for the coordination of social and economic development of the region and the formulation of necessary policies, plans, regulations and programs in collaboration with the concerned public and private agencies. This law also enabled ARA to introduce rapidly, and enforce, environmental regulations for the Aqaba region.

The President of the ARA, who has ministerial authority in running the authority is appointed by the Cabinet of Ministers and is subject to approval by Royal Decree. The President chairs a 12-member ARA Board of Directors which includes representatives of key ministries (Municipal and Rural Affairs and Environment; Planning; Industry and Trade; Tourism; Interior) as well as the Port Corporation, the Army, the Department of Lands and Survey, Mayor of Aqaba and two other local representatives. In April 2001, the ARA was replaced by Aqaba Special Economic Zone Authority (ASEZA)

3.9.3 Aqaba Special Economic Zone Authority (ASEZA)

Under ASEZ Low No. 32 of the year 2000, a special economic development zone has been established in the city of Aqaba and was called Aqaba Special Economic Zone (ASEZ). The zone will be developed under the control of the Aqaba Special Economic Zone Authority (ASEZA). ASEZA associated to the Prime Minister and administered and supervised by a Board known as the "Board of Commissioners", which composed of six full-time members, including the Chief Commissioner and the Vice-Chief Commissioner who appointed by a decision of the Council of Ministers upon the recommendation of the Prime Minister for a renewable four-years term, provided that such decision shall be endorsed by a Royal Decree. The Authority has a juridical personality with financial and administrative autonomy. The Authority becomes the legal and factual successor of the Aqaba region Authority and the Municipality of

Aqaba. All rights and obligations of the Aqaba Region Authority and the Municipality of Aqaba transferred to the Authority. It is assumed that ASEZ is Jordan's gateway to global commerce and a premier tourist destination. The Aqaba Special Economic Zone is emerging as a major duty-free economic development node for tourism, recreation services, professional services, multi-modal transportation and value-added industries in the Middle East. The ASEZ is strategically located at the crossroads of four countries and three continents. Situated on the northern tip of the Red Sea on the Gulf of Aqaba, the ASEZ covers approximately 375 square kilometers, and extends to the land borders of Saudi Arabia, and Israel and the territorial waters of Egypt (Figure 5). Aqaba offers global business opportunities in a competitive location with a high-quality lifestyle. Businesses in Aqaba can benefit from the many incentives and facilitation offered by the ASEZA such as: streamlined and simplifies business registration and licensing; simplified foreign work permits and visa regime; no Social Services tax; Exemption from sales tax on the final consumption of all goods, except for a 7 % sales tax in certain items; no annual land and building taxes on utilized property; exemption from custom duties on all imports to the ASEZ except cars; no restriction on foreign currency and no repatriation of capital and profits and much more. The Qualified Industrial Zone within the ASEZ allows products manufactured therein to benefit from duty-free and quota-free access to the United States. Other trade agreements with the United States, European Union and some Arab countries bring similar benefits to industries manufactured in Jordan.

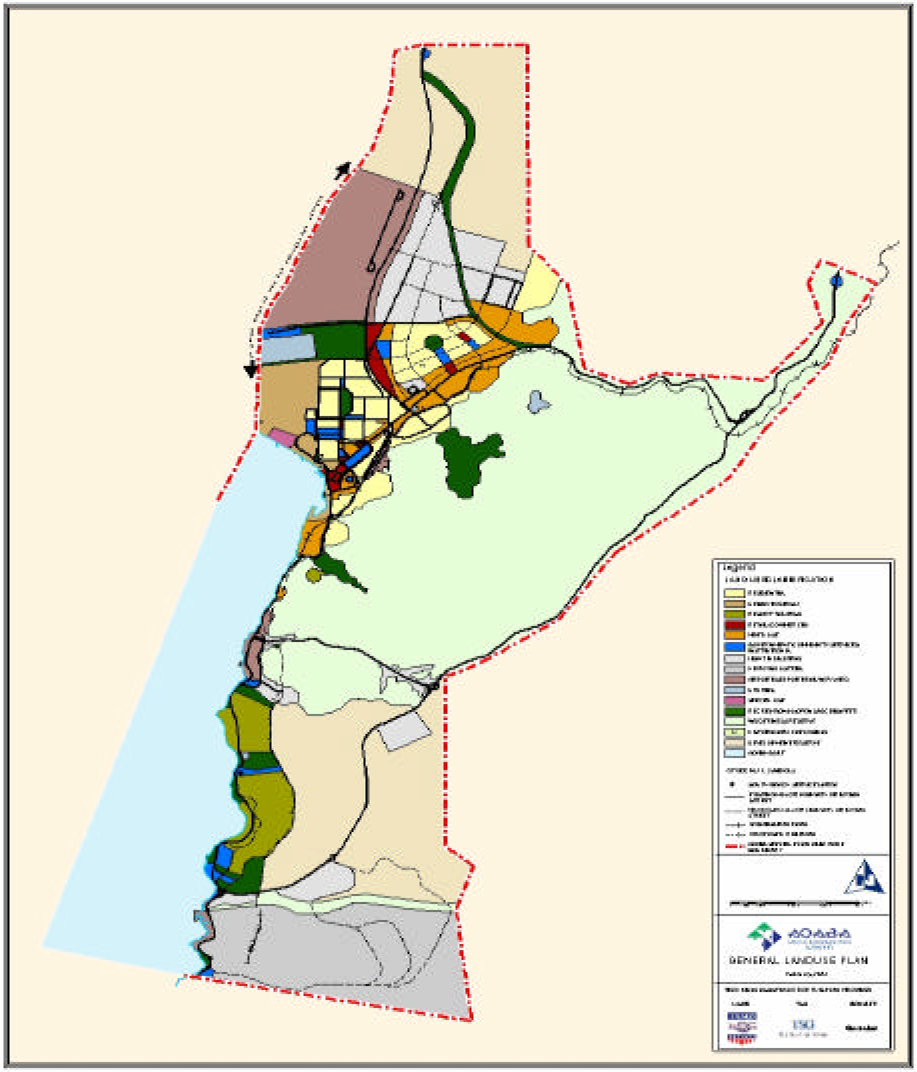


Figure 5: A Map Showing the Boundaries of ASEZA

3.10 Aqaba Wastewater Treatment Plant

The rapid growth of coastal cities and associated human activities create multiple, significant sources of pollution in the Gulf of Aqaba. Urbanization, industrialization, tourism and shipping are the main causes of pollution and environmental degradation. The number of tourists coming to the city of Aqaba for recreation is increasing rapidly and this would increase wastewater generation. Until June 1987, untreated sewage was discharged directly into the Gulf in the vicinity of the port of Aqaba. Today discharge of sewage into the Gulf is no longer occurring. (personal communication with WAJ officials). The Aqaba wastewater treatment plant (WWTP) which was established in 1987 as a waste water stabilization pond with a design capacity of 9,000 cubic meters of raw sewage per day and the BOD_5 loading of about 3510 kg/day. But in 2001, the operating capacity has exceeded 9310 m^3/day (MWI, 2001). The plant includes a seepage receiving station, inlet works, two facultative ponds, two maturation ponds and four percolation basins. Chlorination, recirculation and bypass facilities were also provided. The two facultative ponds have a surface area of 13.5 ha. The existing ponds have reached their full design capacity. The treatment plant for Aqaba city will be upgraded to reduce evaporation and seepage losses and to improve effluent quality. The government is building another highly efficient wastewater treatment plant with capacity (18000 m^3/day) using Activated Sludge (AS) treatment process (MWI, 2001).

Socio-Economical Development in Aqaba

Water is essential for the Socio-economic development of every society. The importance of water is thus under-scored by the fact that many great civilizations in the past sprang up along or near bodies of water. The Coastal Zone shows a highly population density with a large number of urban conglomerations, and in consequence, in most countries a fast population growth and a high concentration of economic and in particular industrial activities, with all the resulting problems of resource consumption. High level of population and industrial activities cause high resources requirements, water being the most obvious. Aqaba has been facing a chronic imbalance in its population and water resources. Water resources development and management are essential for sustainable effective water use. In this chapter, the social and economical development in Aqaba and their link to water consumption, in particular, the water resources-population formula will be used for projection of water demand using different scenarios of population increase.

4.1 Economical Activities

4.1.1 Economic Development in Jordan's Aqaba Coastal Region

During the past two decades, the Jordanian Gulf of Aqaba coastline has been transformed by a variety of development associated with economic growth. These include the construction of the port and storage facilities, power generation station, fertilizer production industries, hotels, restaurants, beachside concessions and roads.

Industrial production is the largest revenue generator in the Aqaba region, with annual revenues from fertilizer and mineral processing currently exceeding JD 200 million.

While cargo handling activities in the port generate more modest revenues totaling JD 66 million (2003). Every ton of goods generates approximately 25 US dollar for Jordan national economy (The Port of Aqaba, 2002/2003).

The port is the largest employer in the region with over 5000 workers on the payroll as compared to1700 workers in the industry. The changes in the manpower during the periods 1990-2003 ranges from 4996-5064 persons. The port of Aqaba has emerged in the last two decades, pending political circumstance, as a major regional shipping center, now ranking as the third largest Red Sea port after Suez in Egypt and Jeddah in Saudi Arabia. Between 1990 and 2003, the port of Aqaba received an annual average of 2332 vessels handling 15 to 17.8 million tons of cargo each year. Total port revenues during this period ranged from 32.7 to 66 million JD (The Port Corporation, 2003). The preceding year (2002), traffic volume of 14.2 million tons was handled and a revenue of 52 million JD were made (The Port of Aqaba, 2002/2003). Number of Ships increased from 12 to 2694 during the periods from 1952-2003 (The Port Corporation, 2003).

Exports through the port of Aqaba in 1952 were 84 tons while during the 1990-2003 periods they ranged from 8.8 to 8.2 million tons. Of these exports is phosphate, which has been the leading commodity in terms of overall tonnage, ranging from 4.8 to 3.6 million tons (approximately 1.3 percent of world exports). Potash exports were 1.3 to 1.9 million ton ranges; cement exports ranged from 1.3 to 0.12 million tons; and fertilizer exports were 0.7 to 1.0 million tons (The Port Corporation, 2003).

Imports through the Port of Aqaba during the 1990-2003 periods ranged from 6.2 to 9.6 million tons. Leading imports included grains 1.5 to 2.8 million ton; sugar 0.2 to 0.56

million tons; steel and iron 0.16 to 0.33 million tons; ammonia 0.15 to 0.25 million ton; and vegetable oils 0.11 to 0.19 million tons (The Port Corporation, 2003).

Along with industrial and port activities. Tourism is a key driving force in Aqaba's growing economy. Tourism in the region generates estimated revenues of 40 million JD and employs about 800-person workforce. The city of Aqaba hosts 40 hotels, with some 3600 beds with an estimated total of 300,000 hotel bed nights annually. Significant expansion of the Aqaba tourism sector is envisioned by the ASEZA, which serves as the chief planning agency for the Jordanian coastal region. According to current ASEZA plans, up to 10 new four to five star resort hotels will be built in Aqaba's South Coast Tourism Zone, an undeveloped stretch of shoreline between the southern end of the Aqaba port complex and the South Coast Industrial Zone, bordering Saudi Arabia. Also some 2000 hotel beds and 1000 vacation villas are slated for development along five km stretch of shoreline.

Commercial fishing is modest though important feature of Jordan's Aqaba region economy. The Aqaba fishermen Cooperative catch approximately 105 tons of fish annually. The fish, primarily sold to local restaurants and hotels, is caught in shallow water 5 to 15 m with baited cage traps, hand- drawn gill and seine nets, and hand lining with baited hooks and lures

4.1.2 Data Acquisition

The data used in this study were obtained from the Department of Statistics (DOS), Ministry of Tourism and Antiquities (MOTA), Hotels, Ministry of Water and Irrigation (MWI), Water Authority of Jordan (WAJ), Aqaba Water Directorate (AWD) and the Port Corporation. The data have been documented for several decades. The data included population, industrial activities monthly water supply from Disi line during the period 1998-2003, water consumption by sector, economic activities, and hotels number and occupancy. Direct interviews with WAJ-Aqaba officials, and MWI, WAJ- Amman and ASEZA officials were carried out during several visits to Aqaba. In addition, field surveys of main economical activities were made to obtain their water consumption pattern, handling of their wastewater and their contribution to the protection of the environment.

4.1.3 Review of Previous Studies

A substantial part of this work was concerned with forecasting the change in water demand and analyzing of sectorial water demand associated with the expected changes of socio-economic. So, the first step in calculating daily water budget for a given area and studying water supply and water demand over time and space from a multidisciplinary perspective was to analyse the socio-economic aspect. In developing the socio-economic review, the following primary studies were revised and evaluated:-

1. Ministry of Water and Irrigation and German Technical Cooperation (GTZ) (2004): National Water Master Plane (NWMP) Volume 3 Water Uses and Demands; MWI and GTZ. Amman
2. "Upgrade and expansion of Aqaba water facilities design report" Prepared by Montgomery-Watson in association with Arabtech-Jardaneh, October, 2002.
3. "Technical and economic feasibility study and final design of the upgrading and expansion of the water and wastewater facilities at Aqaba". Contract package number 4, distribution network design report; prepared by Montgomery-Watson in association with Arabtech-Jardaneh, July, 2001.

4. "Feasibility Study- Wastewater" draft report Prepared by Montgomery-Watson in association with Arabtech-Jardaneh and EnviroConsult Office , March, 2000.

5. "Hydraulic Network Analysis and Rehabilitation Measures" Water sector final report. Prepared by Montgomery-Watson in association with Arabtech-Jardaneh, April, 2000.

6. "Technical and economic feasibility study and final design of the upgrading and expansion of the water and wastewater facilities at Aqaba". Feasibility study, final report Water volume I. Prepared by Montgomery-Watson in association with Arabtech-Jardaneh, June, 2000.

7. "Technical and economic feasibility study and final design of the upgrading and expansion of the water and wastewater facilities at Aqaba". Water resources and demand assessment water sector final report. Prepared by Montgomery-Watson in association with Arabtech-Jardaneh. August 1999.

8. Aqaba, Jordan Special Economic Zone Master Plane. Volume 3: Port, Land Transportation and Utilities. Prepared by Wilbur Smith Associates, in association with Moffatt and Nichol, Gensler Consolidated Consultants October 2001.

9. Ministry of Water and Irrigation & Japan International Cooperation Agency (JICA). Water resources Management Master Plane in the Hashemite Kingdom of Jordan, final report Volume 1 Main Report Part-A. Prepared by Yachiyo Engineering Co., LTD. December 2001.

4.2 Social-Economical Prospective

This section presents a review and discussion of existing population, settlement patterns, water used by domestic, commercial, tourism and industrial Also, the growth trends and projection of water needs necessary to serve the community throughout the coming 20 years period; from 2003 to 2020.

4.2.1 Population and Demography

Aqaba has always stood at the crossroads of culture and trade. Human habitation of the city dates back to 4000 BC. Until 1960's, The Gulf of Aqaba was relatively unaffected by development with its coastline, Aqaba was not more than a small village consisting of the old town only sparsely populated by Bedouins (Farajat, 2001; World Bank, 1996). Then as a result of the city's strategic location of the junction of trading routes between Asia, Europe and Africa. The Gulf has become a strategic international center, with major industrial facilities, shipping activities and rapidly expanding tourism.

In 1960, an agreement between the Government of Jordan and the Saudi Government on adjusting borders was reached resulting in expanding the shore line of Aqaba by 17 km south along the coast line to reach a 27 km stretch of coastline. Jordan's Gulf coastline has been modified by a variety of developments which accompanied the nation's economic growth from the mid 1970's to mid 1980's. The port of Aqaba gives Jordan it's only outlet to the Red Sea and is of crucial importance to the Jordanian economy. Since the 1970's the port has changed from a modest complex serving Jordan's local needs to a regional transportation hub. The increase in shipping activities through Aqaba over the past three decade has made it in times of political stability the busiest Red Sea port.

Table 3 and the illustration in Figure 6 show the historical population growth of Aqaba over the last 10 years. Aqaba has grown from small city of 10,000 inhabitants in 1972 to a big city of about 110,000 people according to the last census of 1994. The population of Aqaba was recorded as 27,000 by the 1979 census. By the time the 1994 census was undertaken, the population of Aqaba had increased at an average annual rate of 7.1 %. Prior the Gulf War the average annual increase was 5 % for the period 1979 to 1990. By the end of the year 2005 Aqaba is predicted to reach a population of 113,369. Beyond the year 2005, the region's planers anticipate a doubling of the coastal population to approximately 186,000 by the year 2025 (Montgomery-Watson, 2000).

Table 3. The Population Growth of Aqaba Governorate and Aqaba City from 1994 to 2004.

Year	Aqaba Governorate	Aqaba Town
1994	79,839	63,804
1995	85,800	68,574
1996	85,700	68,500
1997	88,780	70,955
1998	95,355	76,205
1999	98,490	78,680
2000	101,285	80,915
2001	104,160	83,195
2002	107,115	85,555
2003	109,230	87,980
2004	110,460	88,278

Sources: DOS

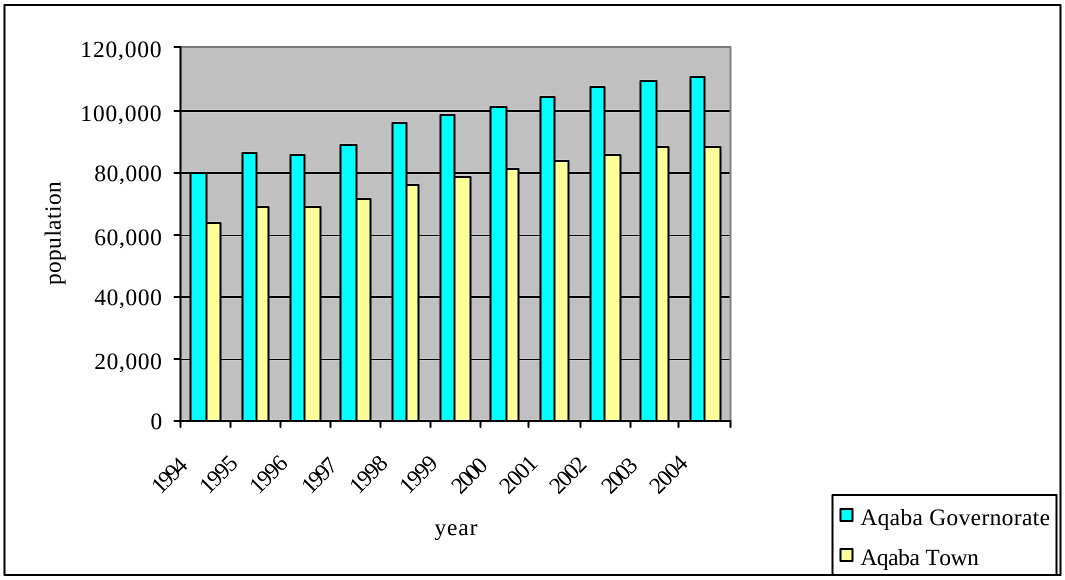


Figure 6: Diagram Showing the Growth of Population in Aqaba during the Last 10 Years (1994-2004).

The projected populations of Aqaba town in accordance with various studies are shown in (Table 4) (Montgomery-Watson, 2000, 2001). Results of 2004 census show that the total population has reached 110,000 people and the population growth rate has dropped to 2.5 %. The law population growth is contradicting ASEZA ambitious plan to have Aqaba as an attracting place for people to immigrate. No real explanation can be given to why after five years of huge investment in Aqaba, the situation is like that.

4.2.2 Settlement Patterns

Aqaba City occupies almost 6 km^2, and a further 3.7 km^2 are identified for future development, and has a population densities ranging from 0.3 person per 1000 m^2 in partially developed area to 37.7 person per 1000 m^2 in fully developed and saturated areas. Area and population statistics for Aqaba together with the indications of the income level for each area are presented in Table 5 (Montgomery-Watson, 1999). Industry and commerce within the city occupy approximately 10 % of the area with the port occupying approximately 0.6 km^2. Heavy industry is located approximately 20 km outside the city, along the South Coast.

Table 4. Population Projection for Aqaba (Montgomery-Watson, 2000, 2001)

Area	Type	Population									Density (persons/1000 m^2)							
		1998	2002	2005	2010	2015	2020	2025	saturation	Area (1000m^2)	1998	2000	2005	2010	2015	2020	2025	
Residential Area No. 1	R	8514	8800	8800	8800	8800	8800	8800	8800	480.06	17.7	18.3	18.3	18.3	18.3	18.3	18.3	18.3
Residential Area No. 2	R	8584	9196	9500	9500	9500	9500	9500	9500	469.97	18.3	19.6	20.2	20.2	20.2	20.2	20.2	20.2
Residential Area No. 3	R	4526	5495	8915	12406	14174	15803	17000	17000	606.94	7.5	9.1	14.7	20.4	23.4	26	28	28
Residential Area No. 4	R	3037	3253	3864	4523	5167	5750	5750	5750	213.78	14.2	15.2	18.1	21.2	24.2	26.9	26.9	26.9
Residential Area No. 5	R	3286	3989	6472	9007	11681	14204	14204	14204	817.49	4	4.9	7.9	11	14.3	17.4	17.4	17.4
Residential Area No. 6	R		898	1456	2026	2628	3837	4488	4488	350.42	0	2.6	4.2	5.8	7.5	11	13	12.8
Residential Area No. 7	R		605	981	1366	1771	2586	3025	3025	275.36	0	2.2	3.6	5	6.4	9.4	11	11
Residential Area No. 8	R		1553	2520	3507	4548	6640	7766	7766	743.13	0	2.1	3.4	4.7	6	8.9	11	10.5
Residential Area No. 9	R		3943	6397	8903	11546	16859	20921	37556	1554.1	0	2.5	4.1	5.7	7	11	14	24.2
Residential Area No. 10	R		2547	4132	5751	7458	10890	13514	20378	1044.9	0	2.4	4	5.5	7	10	13	19.5
Hay Ar-Rimal	R	4869	5216	6195	7252	8285	9237	10049	12475	235.15	20.7	22.2	26.3	31	35	39	43	53.1
Low Income Housing Area	R	14618	15659	18598	21770	24872	27731	30169	37400	695.61	21	22.5	26.7	31	36	40	43	53.8
Hay Al -Fayha	R	1840	2234	3624	4242	4726	4726	4726	4726	395.19	4.7	5.7	9.2	11	12	12	12	12
Hay Al -Hamra	R	192	234	379	527	684	998	1239	2211	253.66	0.8	0.9	1.5	2.1	2.7	3.9	4.9	8.7
Hay An -Nasir	R	3740	3740	3740	3740	3740	3740	3740	3740	78.48	47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Hay Al -khazzan	R	1245	1334	1584	1661	1661	1661	1661	1661	196.35	6.3	6.8	8.1	8.5	8.5	8.5	8.5	8.5
Shallala-North	R	4201	4500	5345	5603	5603	5603	5603	5603	143.7	29.2	31.3	37.2	39	39	39	39	39
Shallala-South		3543	3795	4508	4725	4725	4725	4725	4725	153.78	23	24.7	29.3	30.7	30.7	30.7	30.7	30.7
Old Town	R	9313	9977	11849	12420	12420	12420	12420	12420	276.68	33.7	36.1	42.8	44.9	44.9	44.9	44.9	44.9
Salaheddin	R	1336	1431	1700	1782	1782	1782	1782	1782	127.28	10.5	11.2	13.4	14	14	14	14	14
Hay An Nakhil	R		346	561	781	1013	1479	1836	1730	114.95	0	3	4.9	6.8	8.8	12.9	16	15.1
Hay As-Safa	S	365	415	464	543	621	692	753	808	101	3.6	4.14	4.59	5.38	6.15	6.85	7.46	8
La Coat Verte	H			487	677	878	1283	1500	1500	148.51	0	0	3.28	4.56	5.9	8.64	10.10	10.1
Al-Breij, Government. Port Housing, Compound -Shmeisani	R	1147	1298	1298	1298	1298	1298	1298	1298	290	3.95	4.47						
Total		74356	90458	113369	132808	149581	172244	186469										534

Table 5. The Population Density in Aqaba City for Different Residential Area for the Year 1996.

Residential Area	**Area (1000 m^2)**	**No. of Flat**	**Population**	**Pop. Density Person / (1000 m^2)**	**Income Group**
Existing Housing Compound Neighborhoods					
Redwan Neighborhood(Residential one)	490	1,529	6,079	12.4	M
Dawha Neighborhood(Residential Two)	490	1,542	6,130	12.5	M
Zahraa Neighborhood(Residential Three)	630	750	2,982	4.7	M
Al-Manara Neighborhood(Residential Four)					
Part1	140	250	994	7.1	L
Part2	100	280	1,229	12.3	L
Fertilizer Housing Compound		129	513		M
Rabwa Neighborhood (Residential Five)	600	328	10,267	17.1	H
Rawda Neighborhood (low Income Housing)	720	2,625	10,438	14.5	M
Remal Neighborhood	240	875	3,477	14.5	M
Al-Naser Neighborhood(Popular Units)	318	680	2,703	8.5	L
Housing Compound Ports Establishment	70	57	224	3.2	M
Al-Barrej Neighborhood (Al-Shmeisani/Port Housing Compound)	290	206	819	2.8	M
Al-Ummaliya City in Rabeia	300	384	2,169	7.2	L
Palaces Zone & Area Beside		9			H
Al-Talla Al-Hamraa Neighborhood (Rectangular One	360			0.3	H
Housing Compound For Society's Members		31	123		M
Agricultural Engineers Society		156			M
Cooperative of Development & Care of Orphans Fund		196			M
Faiha Neighborhood (Rectangular two)	360			10.6	
Housing Compound Association for Aqaba Employees		192	763		M
Housing Compound Association for Doctors		34	134		H
Housing Compound Association For ARA Employees		20	80		H

Housing Compound Project for Red Sra Company	59.5	468	2,241	37.7	M
Housing Compound Project for Japan Company		50	199		M
Safa Neighborhood (Hotel Zone)		70	278		H
Housing Compound for Civil Aviation Authority		28+22	127		H
Improved Old Housing Compound					
South Old Town	113.5		3,483	30.7	L
North Old Town	115.4		3,168	27.4	L
North Al-Shallalah	161.8		3,000	18.5	L
Salah Al-Deen Neighborhood	72.4		730	10.1	L
Al-Khazan	230		2,393	10.4	L
Unimproved Housing Compound					
South Al-Shallalah	159		2,530	15.9	L
Manarah Neighborhood (Residential Four)	99	300	1,229	12.4	L
Total Existing (1996)	**6,119**		**68,502**		

Source (Montgomery-Watson, 1999)

4.2.3 Tourism

Tourism is a key force in Aqaba's growing economy. Aqaba is second to Amman in hotel accommodation with 15 % of Jordan's Hotel beds (MOTA, 2003). Accesses to the Red Sea coastline are the key factor in attracting tourist visitors to Aqaba. Crystal clear water, a spectacular mountain backdrop, sandy beaches and tropical climate all help to promote Aqaba as a recreation tourist destination.

The number of hotel beds has multiplied tenfold in less than a decade. According to study done by Montgomery-Watson, (1999); there were 3 hotels in 1975 with 276 beds. At the end of 1997, there were 29 hotels with 3684 beds; in 2000 there were 30 Hotels and lodging suites and apartment with 1739 rooms and 3548 beds, and employed 950 employees (640 Jordanian, 310 non Jordanian). While in 2003, there were 29 hotels, with total number of 1801 rooms and 3696 beds and 3 Suites and Apartment with 97 units, 121 rooms and 240 beds (MOTA, 2004). Table 6 shows the number of rooms and beds in Aqaba according to hotel classification in 2000 and 2003.

Table 6. Number of Rooms and Beds According to Hotel Classification in Aqaba for 2000 and 2003.

Year	2000			2003			
Class	No.	Rooms	Beds	No.	Suits	Rooms	Beds
*****	0	0	0	1		212	424
****	2	427	826	3		531	1036
***	7	626	1325	5		394	881
**	6	358	718	7		420	842
*	15	268	559	13		244	513
Apartment	2	60	120	3	97	121	240
Total	**32**	**1739**	**3548**	**32**	**97**	**1922**	**3936**

This table shows an increase of 60 % in beds number from 2000 to 2003 in the total number of beds, and this accentuated the finding of Twite, (2004) who reported that there is a rapid development in the Gulf of Aqaba and he expected that the number of rooms will increase from 700 to 5000 and this will lead to overuse of water resources.

On the other hand, the percentage of bed occupancy fluctuated from year to year which could be attributed to the political instability and regional conflicts. Occupancy in 1974 was estimated by Tourism, Tippests-Abbett-McCarthy-Stratto and Dar Al Handasah (TAMS-DAH) to be 40 % (Montgomery-Watson, 1999). This is comparable to the average occupancy recorded during the period 1989 to 2002 of 37 % for Aqaba and 40 % for Amman. The percentage of bed occupancy in Aqaba was 56.3 % in 1989 and 31.8 % in 2002 as shown in Table 7 and illustrated in Figure 7 (MOTA, 2004).

Table 7. Percentage of Occupied Rooms and Beds in Aqaba during 1989-2002

year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Room	60.1	45.6	27.8	35.8	41.46	45.72	45.98	40.51	40.17	34.22	39.48	36.86	34.8	38
Beds	56.3	43	24.6	31.2	34.79	40.21	38.25	33.77	35.59	28.65	34.12	31.25	32.8	31.8

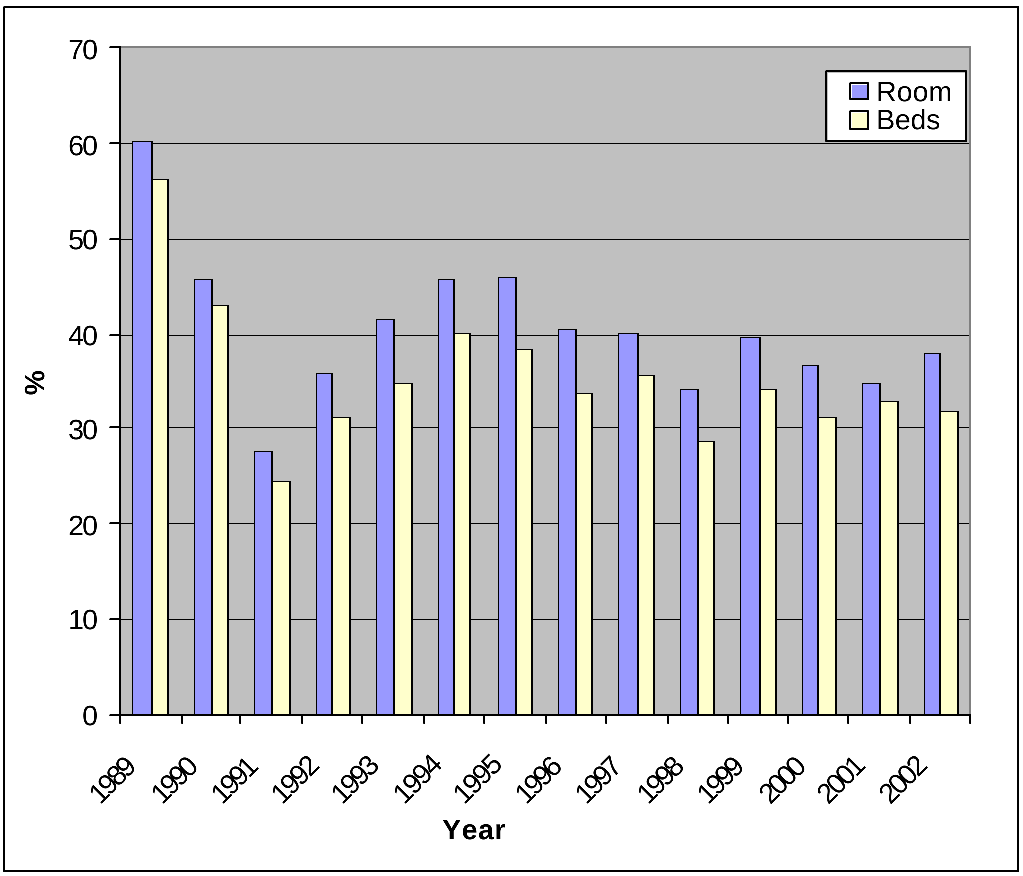


Figure 7: Occupied Rooms and Beds in Aqaba during the Year from 1989-2002

The seasonal variation in occupied beds in 2003 is presented in Table 8 and illustrated in Figure 8

Table 8. Percentage Rooms and Beds Occupancy Rates in Aqaba for the Year 2003.

Class	*****		****		***		**		*		Total	
Month	Room	Beds	Room	Beds	Room	Beds	Room	Beds	Room	Beds	Room	Beds
Jan	34.6	27.8	38.9	38.9	30.2	28.2	29.3	25.7	34.1	39.2	33.6	32.1
Feb	30.7	26.8	36.9	30.8	37.9	36.9	33.6	28.7	44.2	43.8	36.6	33.1
March	9.4	6.5	34.5	25.9	23.2	18.7	22.2	19.3	32.2	34.4	25.9	21.6
Apr.	37.2	31.6	53.6	43.6	31.8	22.5	34.2	57.6	34.9	35.6	39.8	39.3
May	51.6	43.9	52.6	159.2	41.2	28.7	40.2	50.4	47.4	46.2	46.4	74.4
June	59.7	43.3	78.3	149.9	43.5	38.2	46.3	92.1	42.5	48.5	56.2	83.8
July	60.9	51.8	95.5	106.8	78.9	69.8	55.4	109.9	38.3	51	70.7	84.6
Aug	94.5	80.3	78	189.6	92.9	84.5	78.5	100.4	46.2	41.5	79	111.1
Sep	64.7	55	115.4	139.2	89.9	79.5	94	82	47.9	44.2	89.7	89.1
Oct	86.1	69.1	60.4	45.8	81.6	70.5	73.2	65.4	49.2	44.2	69.5	58.6
Nov	55.9	50.8	40.9	42.6	74	60.6	42.8	36.8	48.9	41.4	51.4	46.3
Dec	57.1	46.2	29.9	54.7	58.1	45.9	42.3	35.6	38.1	40.7	43.3	45.3
Total	53.7	44.6	59.6	85.9	57.1	48.7	49.4	58.8	42	42.6	53.6	60.1

Source: Ministry of Tourism and Antiquates

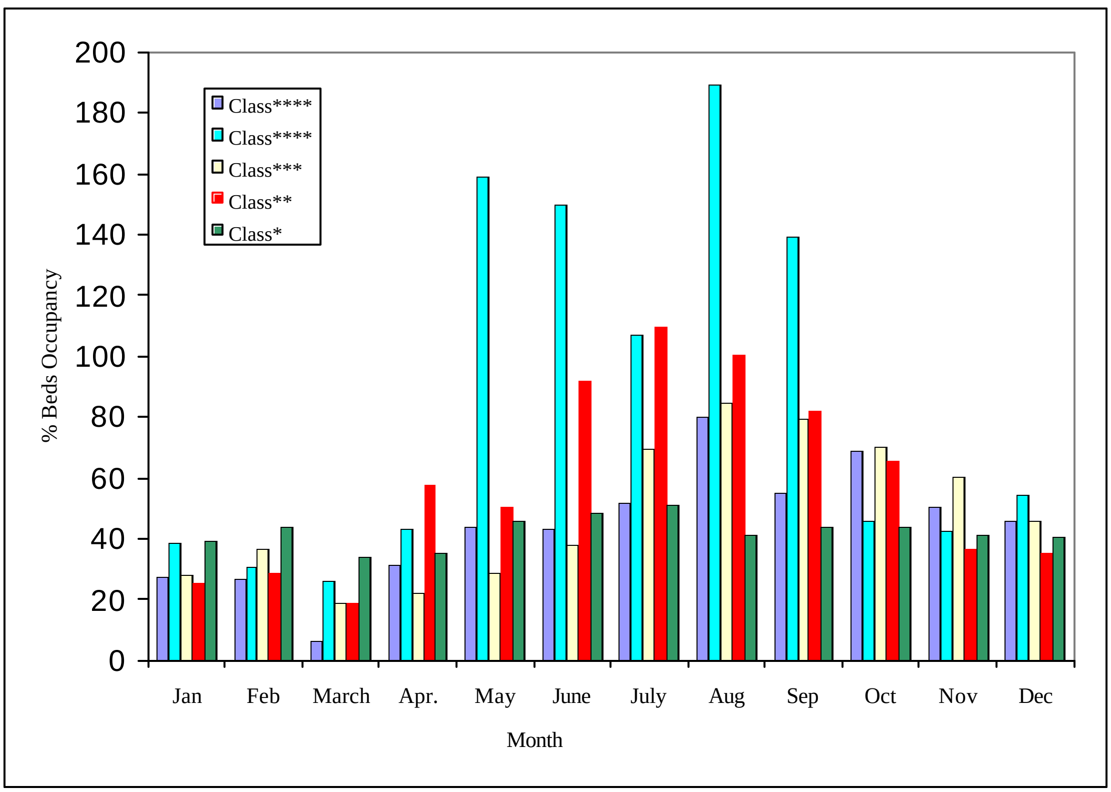


Figure 8: Percentage of Seasonal Variation in Occupied Rooms and Beds, in Aqaba 2003

Based on an average of 2361 occupied beds per night in 2003 for all hotels in Aqaba, the tourist population in 2003 represents only 2.1 % of the total population (Table 8 and Figure 8). Occupied beds in classified hotels peak in the month of August and are equivalent to 3.97 % of the permanent population of Aqaba with an average of 4373 occupied beds per night. As resort complexes are currently under construction, hotel capacity is expected nearly to double in the coming decade. New resort hotels with an estimated 40000 beds are projected to be completed by the year 2005; these new facilities are expected to generate employment for some 22,000 workers to be housed in nearby planned residential communities. As cited by MWI and GTZ (2004) in their report "Jordan projects for tourism development, 2003", the Aqaba complex alone is envisaged to have 6,000 bed units by the year 2020 requiring more than 1 MCM/year excluding landscaping, which planned to use recycled water. According to current ASEZA plans, tourist villages are planned for the South Coast at Qabous coast, and Ras al Yamaniyya. The tourist villages will include a golf course, amusement park and up to 10 new 4-star to 5-star resort hotels. Some 2000 hotel beds and 1000 vacation villas are slated for development along a five km stretch of shoreline.

4.2.4 Industry

Rapid economic development and population growth have occurred in the Gulf of Aqaba coastal zone over the past two decade. Industry and commerce within the city occupy approximately 10 % of the area, with the port occupying approximately 60 ha. Heavy industry is located approximately 20 km outside the city, along the South Coast. The main industries in the southern industrial zone are Jordan-Japanese Fertilizers Company. Jordan Indo Chemical Company, Holland Selvocem Company, Jordan Fertilizer Industry, Arab Potash Company, Jordan Timber Products Industry, Jordan-Norwegian Chemicals Company, Thermal Power Plant and Jordan Petroleum. These industries are currently receiving their water from the public network. The amount of water consumption for industry in Aqaba remained at about 400 MCM/year during the period from 1998 to 2003. The two major industries in terms of water consumption on the south coast are the oil-fed thermal power plant and the chemical and fertilizer industries which occupy about 410 ha. The chemical and fertilizer industries utilize potash and phosphate as row materials which are of high water consumption classes of industries.

At the present, Aqaba receive its water from Disi aquifer and the wells of Wadi al-Yutum. The potential allocated supply from these wells is excluding the demand. The development of an industrial free zone on the south coast at Aqaba, coupled with a potentially unlimited supply of water, is more likely to be conducive to industrial growth here than elsewhere in Jordan. The 1995 Revised Master Plan (1995-2020) identifies a number of new areas for industrial development. Existing and proposed industrial activities are located in four areas as fallows:

1. The light industry areas

   This area is located in a dedicated area in the north of the City. This area occupies 11 ha out of 30 ha allocated for industry.

2. Brick and Tile industrial Zone

   This area occupies about 16 ha out of 30 ha designated at the bottom of the mountain slopes east of the airport close to the raw material.

3. Free zone area-Airport road

   At present, this area is used for the storage and repair of trucks and construction equipment with no industrial activities. The fenced area is 24 ha out of 164 ha owned by the Free Zone Corporation.

4. South coast industrial area

A total of 1350 ha of land in the south coast of Aqaba in the Wadi I and Wadi II area near the border with Saudi Arabia is allocated for the development of heavy industry.

Land Use Changes in Aqaba Area

5.1 Introduction

Population growth is seriously increasing demands on the natural resources of land, water and raw materials. At the same time, human societies are developing rapidly with multivarious activities that tend to change social and economic aspects. Therefore, for better management and planning of the natural resources, planners need precise and site-specific information about recent and current distribution of land use. Land use is a major driving force for water demand subsequently. Land use changes affect the water budget through human activities that has been emerged as the phenomenon most evidently linked to water demand conflicts. The process of land use change is mainly accelerated by well-known driving forces of population increase, urbanization, and industrialization. On the other hand, such change is highly dependent on changeable socio-economic and natural conditions and behavioral characteristics of the people. The spatial and temporal land use changes therefore are needed to know the available resources of land and the utilized areas and to evaluate possible future trends of land conversion. Such information can support local planners and decision makers to formulate sustainable land use and water policy.

The use of traditional methods of ground survey and questionnaires to study and evaluate land use and its change is time and cost consuming. Alternatively, contemporary technology of remote sensing and GIS tools can be used for this purpose.

5.2 Aqaba Master Plan.

The responsibility for land use planning and development for the Aqaba City and the surrounding areas lies in the jurisdiction of ASEZA. In 2002, ASEZA adopted a new Master Plan, which would help to promote and stimulate investment in the region. The new Master Plan (Figure 9) encourages the investment in industrial and port activities, urban tourism, residential development, commercial and retail ventures, academic and institutional development, coastal communities and recreational and open space facilities. To date, detailed planning has been developed in five particular areas; Aqaba Town, the Port Areas, the Coral Coastal Zone, the Southern Industrial Zone, and the Airport Industrial Zone.

Aqaba Town

The new Master Plan for Aqaba Town was developed to complement the existing configuration of the city. Development in the town will be focused around the corniche. Areas of future opportunity include the conversion of the Main Port to a mixed-use community containing retail, commercial, residential, educational, and recreational uses.

Port Areas

The Aqaba Port Areas include three locations as following:

1. The main Port: Currently, Port activities are being undertaken in three different areas. The Master Plan calls for consolidating industrial activities into a common area. The area by the Port is expected to become more functional and efficient and will be transformed into a new urban, mixed-use waterfront district. Future plans for this new waterfront district will include a retail and entertainment complex.

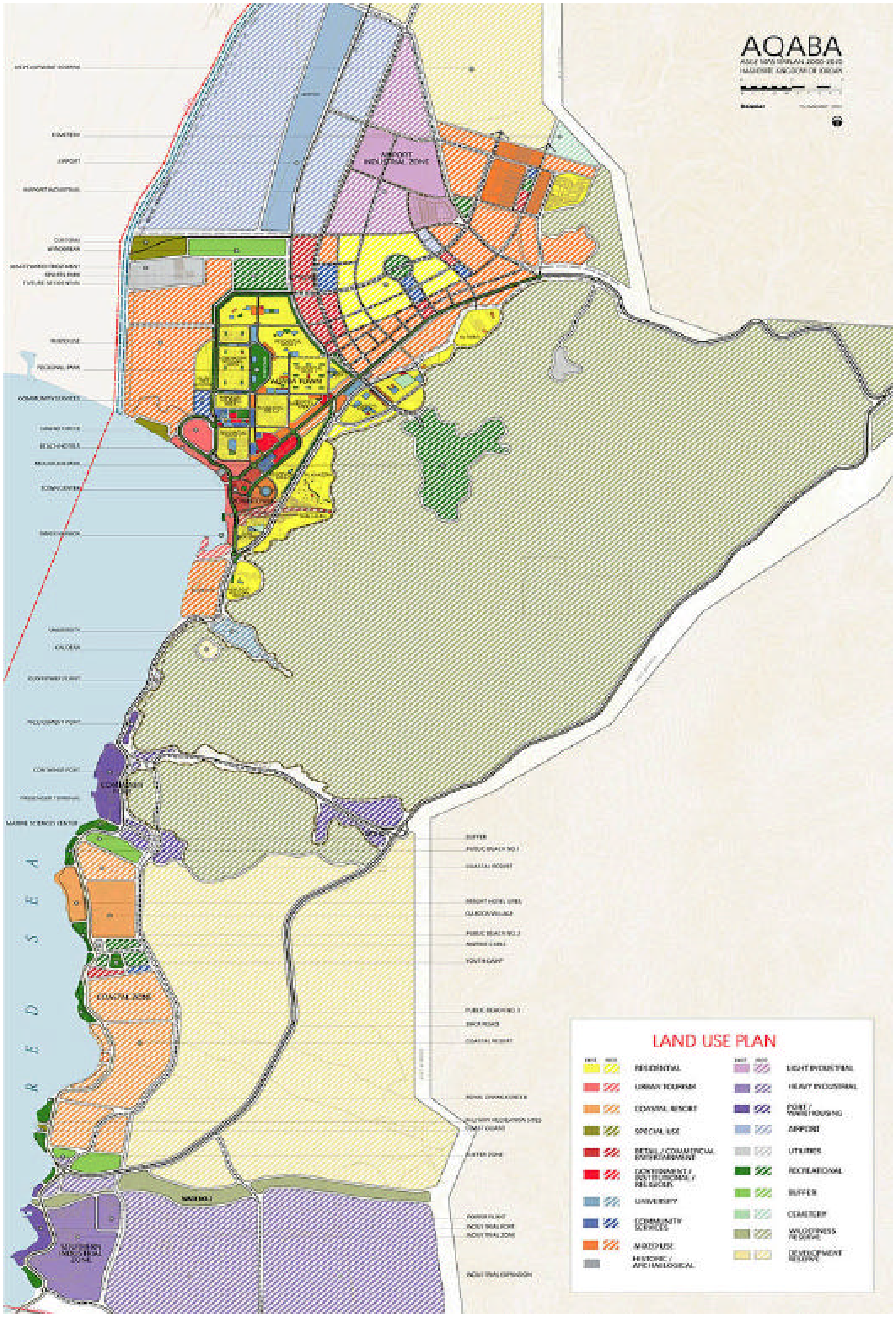


Figure 9: Land Use Master Plan as Adopted by ASEZA in 2002
Source: (www.aqabazone. com).

2. The container Port: At present, the Container Port is being expanded and upgraded to handle the increased demand for containerized cargoes.

3. The southern Industrial Zone Port : This Port will be expanded to include a new multi-purpose jetty terminal. Additional areas have been designated for the relocation of the phosphate port facilities that extends from the main to the industrial Ports.

Coral Coastal Zone

Private sector is currently transforming Aqaba's Coral Coastal Zone into a new resort community with a new marina, residential development, hotels and entertainment facilities.

Southern Industrial Zone

This zone adjacent to the border with Saudi Arabia has heavy industrial activities where Thermal Power Plant is located adjacent to the industrial Port facilities. Reorganizing of existing industrial parcels in the lower industrial areas will improve vehicular circulation and will redevelop this site and increase its capacity. New access roads and extended utilities systems, therefore are planned to serve the industrial expansion area.

Airport Industrial Zone

Land use in this Zone includes warehousing, logistics, distribution, light manufacturing, hi-tech industries, showrooms, and smart-office complexes. Opportunities exist for airport-related business activities, including air cargo services and aircraft maintenance services that require direct runway access.

Existing land use pattern of 1995 in the central parts of Aqaba City is presented in Figure 10, adopted by Aqaba Region Authority (ARA) through the 1995 Revised Master Plan (1995-2020). At that time, the responsibility for land use planning and development for the Aqaba City and the surrounding areas was of ARA. The area covered 8300 km^2 and included 27 km of coastline. Land use map comprised five categories of residential, hotels, commercial, services and industry.

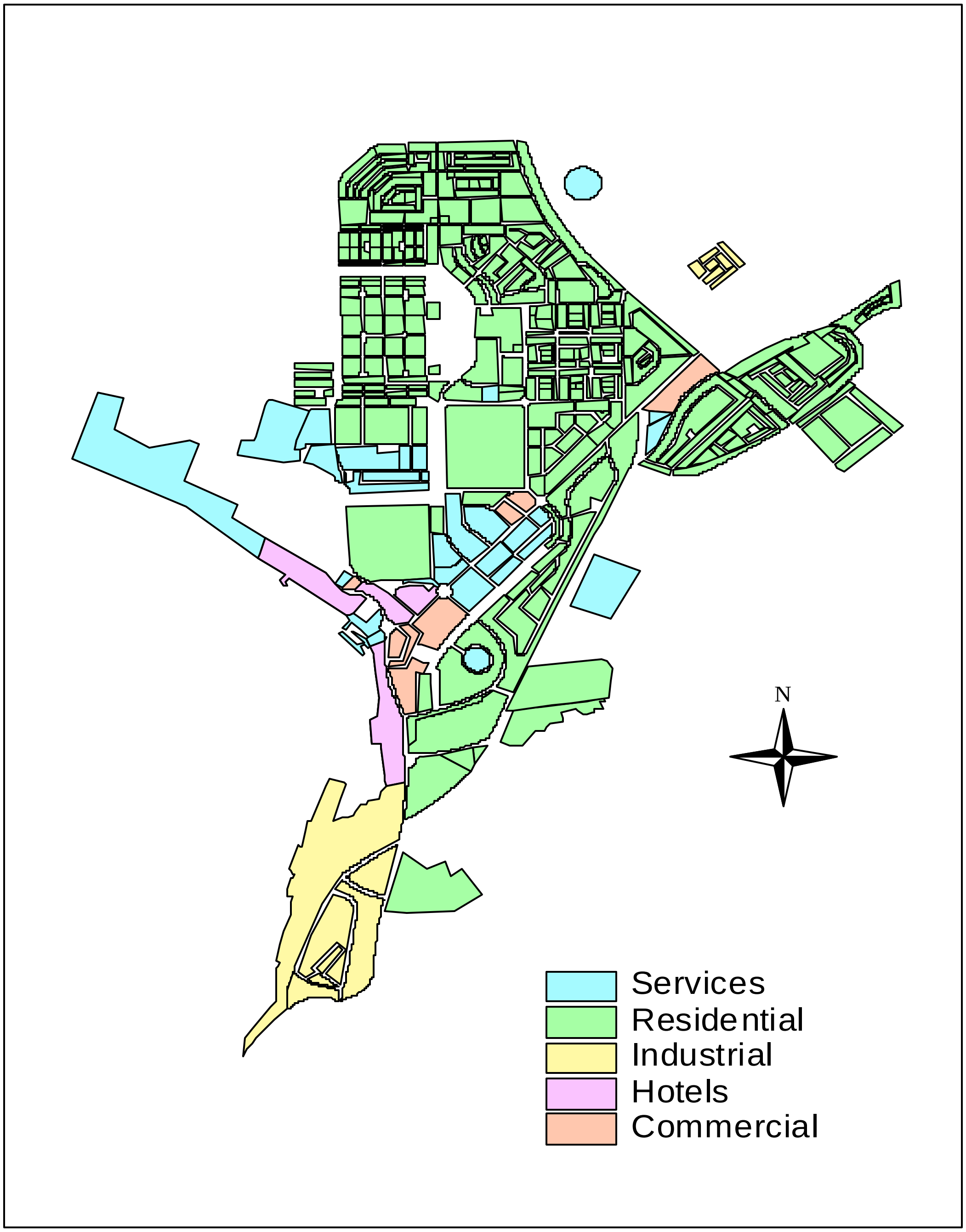


Figure 10: A Map Showing Existing Land Use Pattern in ASEZA Region. Source: (Montogomery-Watson, 2001)

5.3 Land Use Changes

To develop effective policy recommendations, land use change should be assessed to put future changes in context. Two primary areas were expected to be the focus of early development of the ASEZA. These are the Airport/Industrial Estates area and the Coral Coast area. According to the Master Plan, the area at the Airport will be developed for both residential and industrial purposes. The Coral Coast will be primarily for residential, touristic development and service companies. Land use was mapped and analyzed by implementing remote sensing and GIS tools and verified by field visits. For that reason, two satellite SPOT images with 10 m resolution having 3 bands were acquired for Aqaba Area and the surroundings.

5.3.1 Mapping of Land Use

This component of the study was focused on mapping land use and its change in Aqaba. The work included two aspects, firstly was the mapping of existing land use, and secondly was the analysis of land use changes in the study area. The method of land use mapping was based on the interpretation of multispectral satellite imagery of SPOT HRV taken on 1990 (Figure 11) and 2003 (Figure 12) with spatial resolution of 10 m. Results of interpretation were verified by a ground survey. The methodology included the following stages:

1. Preprocessing of satellite imagery: This stage included linear enhancement of the HRV bands and export of the enhanced images to carry out visual interpretation of land use.
2. Interpretation of Land use: On-screen digitizing was carried out to delineate land use parcels from the HRV images, following the classification scheme of CORINE (Annex A).

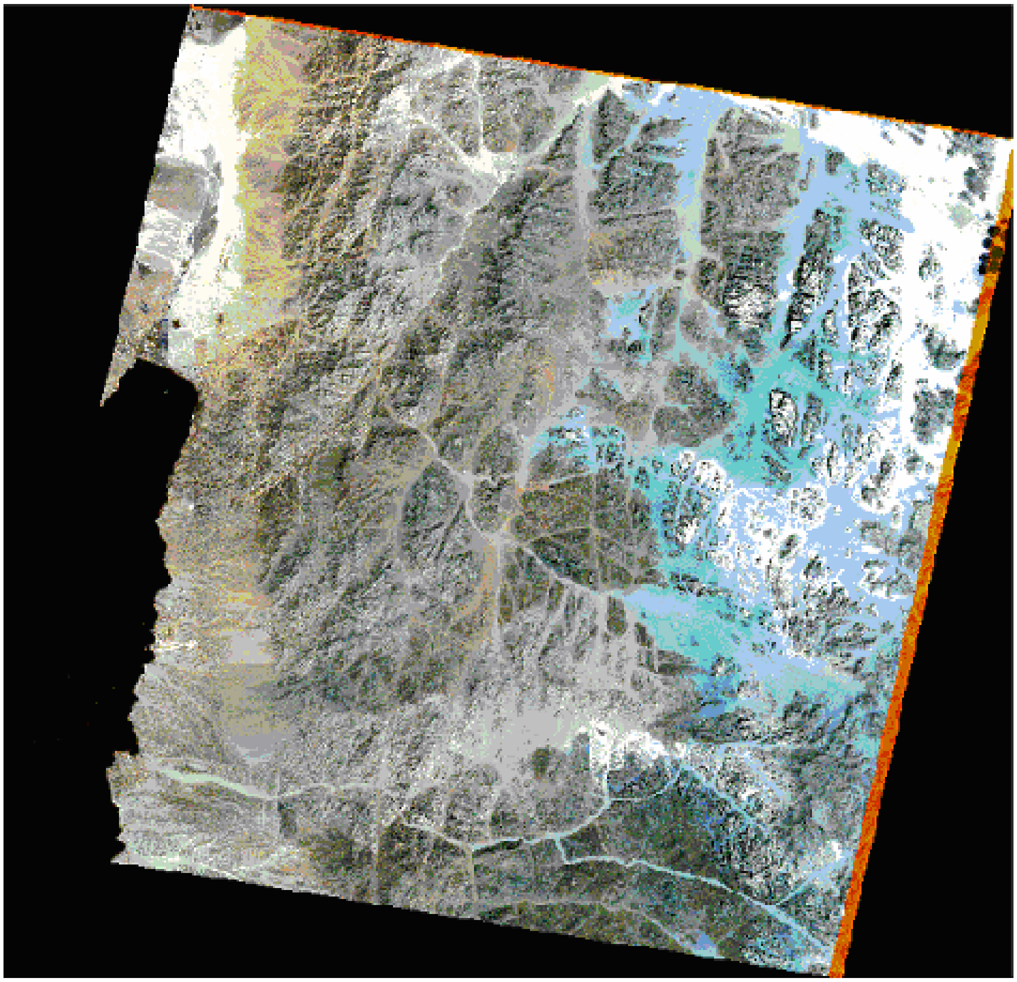


Figure 11: SPOT Satellite Imagery of Aqaba for the Year 1990.

3. Ground survey: Results of the land use interpretation were verified by two-day field visits implemented in September 2004. This ground survey was focused on the interpretation of the 2003 imagery and updating of the digitized map to represent land use in 2004. New and/or changed parcels between 2003 and 2004 were considered and added to the land use map. All stages of ground survey were carried out with the aid of a GPS unit with positional error of less than 5 m.

4. Analysis of maps: maps from the previous stage, in a digital format known as shape files, were rasterized using GIS GRID model to carry out area analysis of land use.
5. Analysis of land use changes: both grids were crossed-tabulated to carry out proportion of land use change for each class between 1990 and existing land use of 2004.

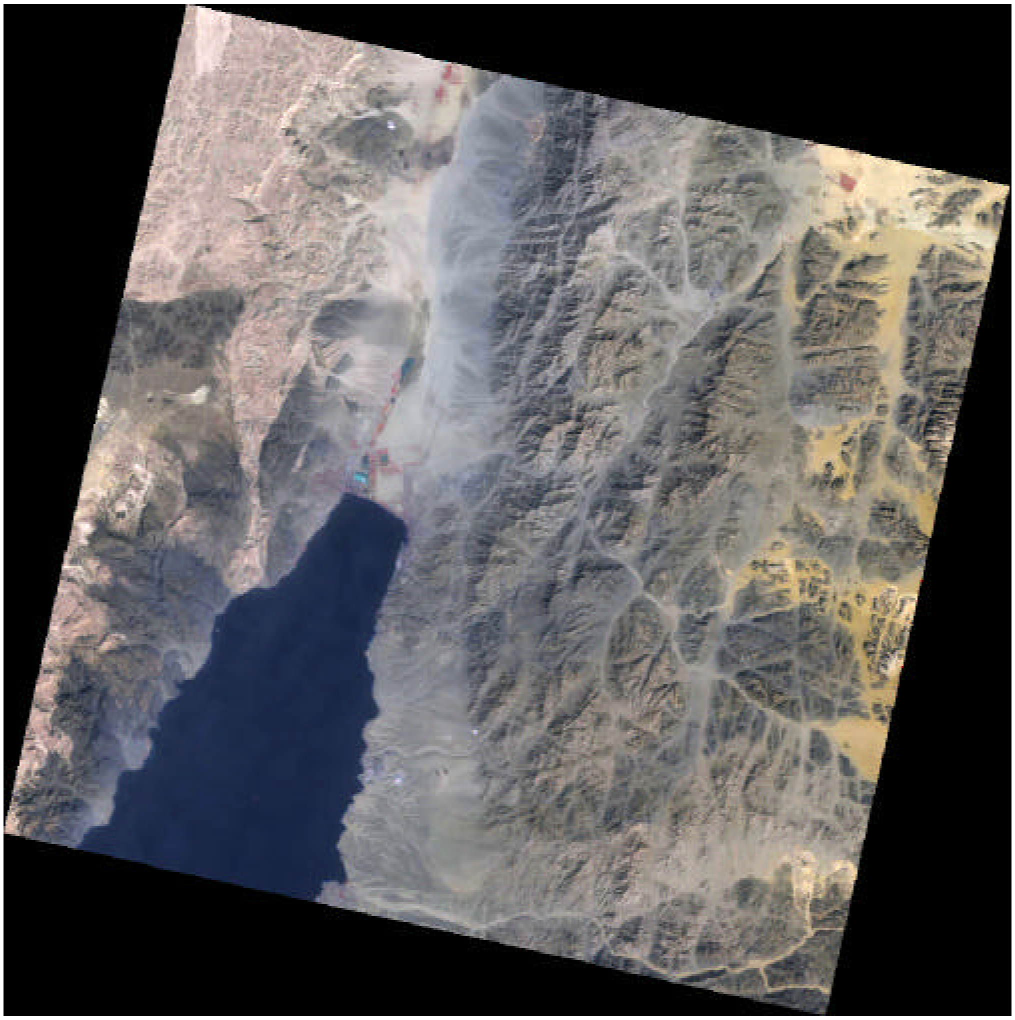


Figure 12: SPOT Satellite Imagery of Aqaba for the Year 2003.

5.3.2 Results and Discussion

Existing land use map of 2004 (Figure 13) showed that most of Aqaba governorate (72.30 %) was open spaces with little or no vegetation consisting of sandy soils in the lowland and occupied by large proportion of bare rock in the east and east north. Although other land use activities constituted small proportion of the area, however, they indicated an intensive activity on the shoreline of the Gulf of Aqaba. Compared with the total area of Aqaba, urbanized (3.20 %) and industrial areas (2.60 %) formed a considerable proportion of the area and reflected the rapid growth and development of the area.

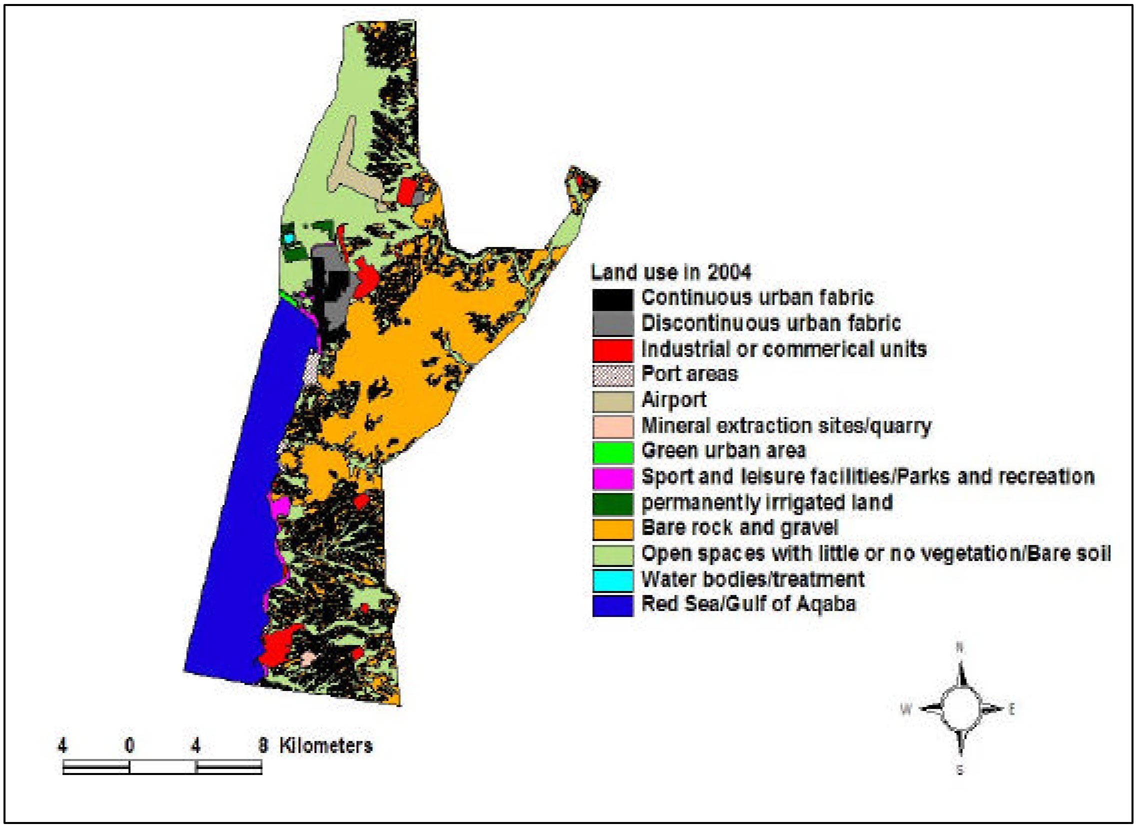


Figure 13: Land Use Map of 2004.

Analysis of land use maps of 1990 (Figure 14) and 2004 showed obvious changes between the two dates (Table 9). The urbanized areas increased from 1.94 % in 1990 to 3.24 % in 2003, industrial areas increased from 1.35 % to 2.60 % in 2003, Port area increased from 0.39 % in 1990 to 0.61 % in 2003 and the Airport area increased from 0.70 % in 1990 to 1.52 % in 2004. Although the proportion of each land use change was small, however, the area affected by this change was relatively high, taking into consideration that the total area of Aqaba Governorate was 6904.7 km^2. In terms of km^2, the urbanized area increased from 7.30 km^2 in 1990 to 12.15 km^2 in 2003, industrial areas increased from 5.10 km^2 to 9.75 km^2 in 2003, Port area increased from 1.46 km^2 in 1990 to 2.29 km^2 in 2003 and the Airport area increased from 2.63 km^2 in 1990 to 5.70 km^2 In 2004.

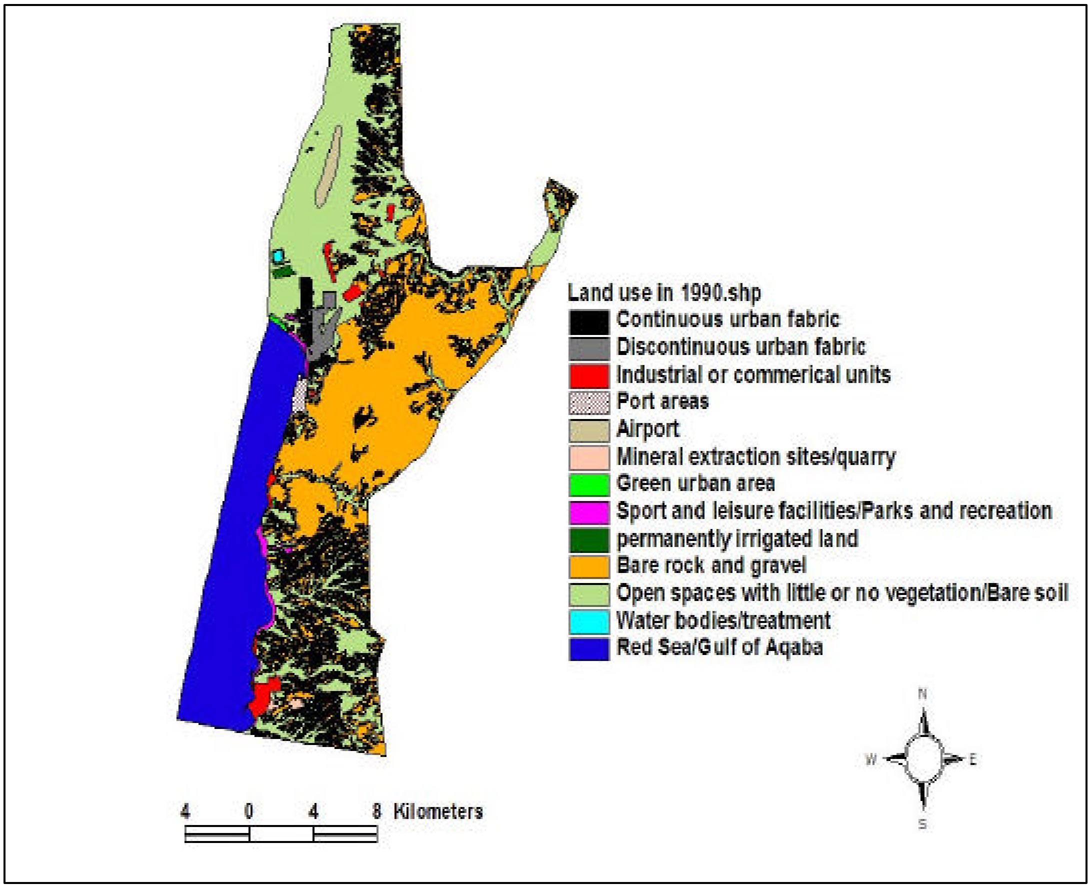


Figure 14: Land Use Map of 1990.

Table 9. Percentage Land Use of Aqaba in 1990 and 2004.

Code	Land Use	Year 1990	Year 2003
111	Continuous urban fabric	0.81	1.49
112	Discontinuous urban fabric	1.13	1.75
121	Industrial or commercial	1.35	2.60
123	Port areas	0.39	0.61
124	Airport	0.70	1.52
131	Mineral extraction sites/Quarries	0.25	0.25
141	Green urban areas	0.11	0.13
142	Sport and leisure facilities/Parks and recreations	0.85	1.10
212	Permanently irrigated land	0.19	0.54
332	Bare rock	39.13	37.78
333	Open spaces with little or no vegetation / Bare soil	37.42	34.54
512	Water bodies/treatments	0.07	0.09
523	Red Sea/Gulf of Aqaba	17.58	17.60

Land use maps were also analyzed in terms of change-type (results are shown in Table 10). The column total of the cross tabulation represents the class proportion in 2004 and the row total represents the class proportion in 1990. The intersection of the row and column for a particular class represents the unchanged proportion of that class in the land use maps for the two dates. For example, the continuous urban fabric (class 111) in 2004 contained 53.36 % of the same class in 1990. The continuous urban fabric of 2004 contained 34.84 %, 0.19 %, and 11.61 % of discontinuous fabric, parks and recreation facilities and open spaces of 1990, respectively.

The major trends of change observed between 1990 and 2004 were:

1. expansion of the urbanized area including ports and commercial areas,
2. a shift from open spaces and non-cultivated areas into the different classes, and
3. an incremental loss of a small part of the Gulf for developing shorelines and ports.

These changes although small in proportion and hardly noticed on the output maps (Figure 13 and 14), reflect the rapid development of the area after nominating the area as a free zone of trade.

Table 10. Percentage Land Use Change Between 1990 (row map) and 2004 (column map).

	Land use in 2004													
Land use in 1990	**Class ***	**111**	**112**	**121**	**123**	**124**	**131**	**141**	**142**	**212**	**333**	**332**	**512**	**523**
	111	53.36	--	--	--	--	--	--	1.04	--	0.02	--	--	--
	112	34.84	33.20	--	--	--	--	4.98	1.75	--	0.01	--	--	--
	121	--	1.70	41.36	22.28	--	--	2.14	8.83	--	0.04	--	--	--
	123	--	--	0.11	62.81	--	--	--	0.64	--	--	--	--	0.02
	124	--	--	--	--	46.49	--	--	--	--	--	--	--	--
	131	--	--	4.11	--	--	51.02	--	--	--	0.06	--	--	--
	141	--	0.19	--	2.96	--	--	64.86	--	--	--	--	--	0.03
	142	0.19	--	2.17	6.49	--	--	6.41	55.68	--	0.32	0.01	--	0.10
	212	--	--	--	--	--	--	--	--	33.42	0.02	--	4.62	--
	333	11.61	61.73	47.28	--	42.97	36.06	21.62	29.61	66.10	95.44	1.17	30.33	--
	332	--	3.18	4.93	2.16	10.55	12.92	--	2.14	--	4.09	98.82	--	--
	512	--	--	--	--	--	--	--	--	0.49	0.01	--	65.05	--
	523	--	--	0.06	3.31	--	--	--	0.30	--	--	--	--	99.86

*: Class abbreviation is shown in table 9, following CORINE classification scheme.

Table 11 shows the changes in land use versus water consumption between 1990 and 2003.

Table 11. Changes in Land Use between 1990 and 2003

	1990			2004		
Sector	**Area %**	**Area km^2**	**Water Consumption MCM**	**Area %**	**Area km2**	**Water Consumption MCM**
Municipal	2.05	7.70	1.95	3.37	12.60	3,82
Services	1.09	4.09	1.19	2.13	7.98	2,33
Hotels	0.85	3.20	0.25	1.10	4.13	0.48
Industry	1.35	5.10	3.75	2.60	9.75	4.07

Further analysis of land use change was made to calculate the rate of change. It could be concluded that the rate of change during the 13-year period was 0.377 km^2/ year for municipal, 0.299 km^2/ year for services, and 0.072 km^2/ year for touristic and 0.358 km^2/year for industry. The population density was 123 person / km^2 in 1990 and 228 person / km^2 in 2004. The urban areas increased from 7.70 km^2 in 1990 to 12.60 km^2 in 2004. Accordingly, the municipal water consumption increased from 1.95 MCM in 1990 to 3.82 MCM/ year in 2004. Service areas increased from 4.09 km^2 in 1990 to 7.98 km^2 in 2004 and the service water consumption increased from 1.19 MCM in 1990 to 2.33 MCM/ year in 2004. The Hotel areas increased from 3.20 km^2 in 1990 to 4.13 km^2 in 2004. The touristic water consumption increased from 0.25 MCM in 1990 to 0.48 MCM/ year in 2004 and the industrial areas increased from 5.10 km^2 in 1990 to 9.75 km^2 in 2004. Based on these findings, water consumption was consistent with land use changes. The trend of increased urbanization, industrial, and touristic facilities resulted in increased water consumption in Aqaba. Therefore, such a relationship can be developed to project future water consumption in the area. This, however, might require more data of multi temporal land use maps and water consumption.

As a result of the changes in lifestyle and investment in the area, a waste water treatment plant and a small irrigated area were detected on the SPOT imagery and the ground. This indicates the urgent need for planning the water resources of the area and possibly the projection of future land use changes, particularly at the shorelines.

Water Resources Management and Modeling

6.1 Introduction

The scarcity of water in Jordan is not only confined by the limited and exhausted resources but by increasing demand for municipal and agricultural purpose as well as the rapidly growing needs of industry and tourism. The population increase and the growing demand for food production as well as the improvement of the standard of living have put great pressure on the already exploited water resources. The measured per capita share of available renewable water resources has reached 165 cubic meters (m^3) and an average share of 1.0 donum per capita of rainfed agricultural land. This has put the country in a condition that can hardly earn a balance in trade of food commodities and can afford to allocate a modest amount of about 50 m^3 of water per capita per year for municipal purposes. Realizing that, the Government of Jordan, in 1997, has adopted a "National Water Strategy" given first priority in water allocation to meet basic human needs, followed by tourism and industrial purposes and remaining amount will be left for the agricultural sector (MWI, 1997). Out of about 940 MCM of water consumed in 2004, about 64 % were used in the agricultural sector, 30 % diverted to municipal uses and only 5 % for the industrial purposes while the rest of about 1 % were used in remote area for livestock watering (Shatanawi, 2004). So far, water consumed by the commercial and tourism purposes like hotels; restaurants ….etc were included within the municipal uses. Recently, the expected increase in tourism and associated activities, due to their role in the economical growth, tourism has been considered by the Government of high priority in term of water allocation.

The situation in Aqaba area is, somehow, different from the rest of the country, where most of its water is demanded for industrial and tourism sectors and therefore, the priorities are different. For example, in 2003, industrial, commercial, services and tourism enterprises consumed about 69 % (7.37 MCM) from a total water supply of 10.71 MCM while the municipal sector used only 31 % (3.3 MCM). The prospective of Aqaba to take its place as leading free economical zone in attracting tourist, investors and industry is very high. These conditions will create a business atmosphere in trade, industry and other activities, which would encourage people to immigrate to Aqaba from other urban and rural area of Jordan seeking jobs and business opportunities. In addition, local tourism as well as global tourism might boom in very short time, if the political and economical situations in the region become stable.

All of the above conditions will put high pressure on the natural resources, mainly water, and will create a tremendous impact on the terrestrial and marine environment unless precaution and mitigation measures are planned ahead of time. At the present time, the City of Aqaba and its premises are enjoying the fresh groundwater of Disi and Wadi al-Yutum because the Ministry of Water and Irrigation has allocated a maximum of 20.00 MCM from Disi (17.50 MCM) and Wadi al-Yutum (2.50 MCM). The abundance of water will not last for long; sooner and as the economical development grows as planned or expected, the area will suffer shortages of water like the rest of the country. The Ministry of Water and Irrigation (MWI) and Aqaba Special Economic Zone Authority (ASEZA) through their newly established water company would have to seek other supply options while working in reducing the unaccounted for losses to a reasonable percentage. Supply options might include desalination of sea water and brackish water and water recycling for industrial purposes as well as using reclaimed wastewater for irrigation and landscape.

6.2 Objectives

Considering the above conditions, this study was initiated in the framework of SMART research project (an EC funded project entitled “Sustainable Management of Scarce Resources in the Coastal Zone”; contract No. ICA3-CT-2002-10006).

The study aims at:

1. Analyzing past and present water uses in terms of sectoral uses.
2. Evaluating water efficiency and suggesting way to reduce the unaccounted for water.
3. Evaluating future scenario for water consumption by sectors using modeling tools.
4. Identifying objectives, criteria and constraints for water resources management, and
5. Setting up policy guidelines for sustainable use of water resources.

The above objectives will be met through a systematic manner by integrating of physical, economic and policy elements in one comprehensive approach that directly derives the policy guidelines from the data and model results. These will necessary lead into a multi-objectives, multi-criteria decision problems. The study will demonstrate how to reconcile conflicting interest and development objectives through the proper choices and trade-off in terms of feasible and non dominated scenarios. These scenarios include water use efficiency, allocation, economic efficiency, social compatibility, environmental compatibility and reliability given the policy instrument of zoning, pricing, economic incentives and direct regulation. All come within a general objective of regional development and sustainable management of water resources taking into accounts land use changes, economical and social development and environmental constraints.

6.3 Aqaba Water Supply and Distribution System

6.3.1 Water Supply

Aqaba city and the south coast draw their potable water for all purposes from two well fields penetrating the southern desert aquifer (Disi aquifer). There are four wells that are operating in Abu Edba'a area and nines wells in Disi area (Figure 15), their discharge and depth of water are presented in Table 12.

Table 12. Average Daily Pumping Rate in m^3/hr and Depth of Water of Disi and Abu Edba'a Wells.

Wells Name	Discharge m^3/hr	Depth of water (m)
Al-Disi well W 3	360	200
Al-Disi well W 5	720	150
Al-Disi well W 6	650	103
Al-Disi well W 8	540	250
Al-Disi well W 9	720	200
Al-Disi well W 11	360	100
Al-Disi well W 13	540	175
Al-Disi well W 14	360	150
Al-Disi well W 15	360	100
Abu Edba'a AD 3	216	200
Abu Edba'a AD 4	540	250
Abu Edba'a AD 5	540	250
Abu Edba'a AD 6	270	360

Source: WAJ

The total discharge of the thirteen wells averaged about 1800 m^3/hr totaling an annual amount of about 15.00 MCM. However additional wells be drilled when needed provided that the total annual flow will not exceed 17.50 MCM; a maximum amounts that has been allocated for Aqaba area from Disi and Abu Edba'a aquifers. These wells are operated and managed by the Water Authority. The wells were equipped with submersible pumps delivering water into a reinforced concrete collection reservoir of 2250 m^3 in capacity located at an elevation of 843 m above mean sea level (amsl).

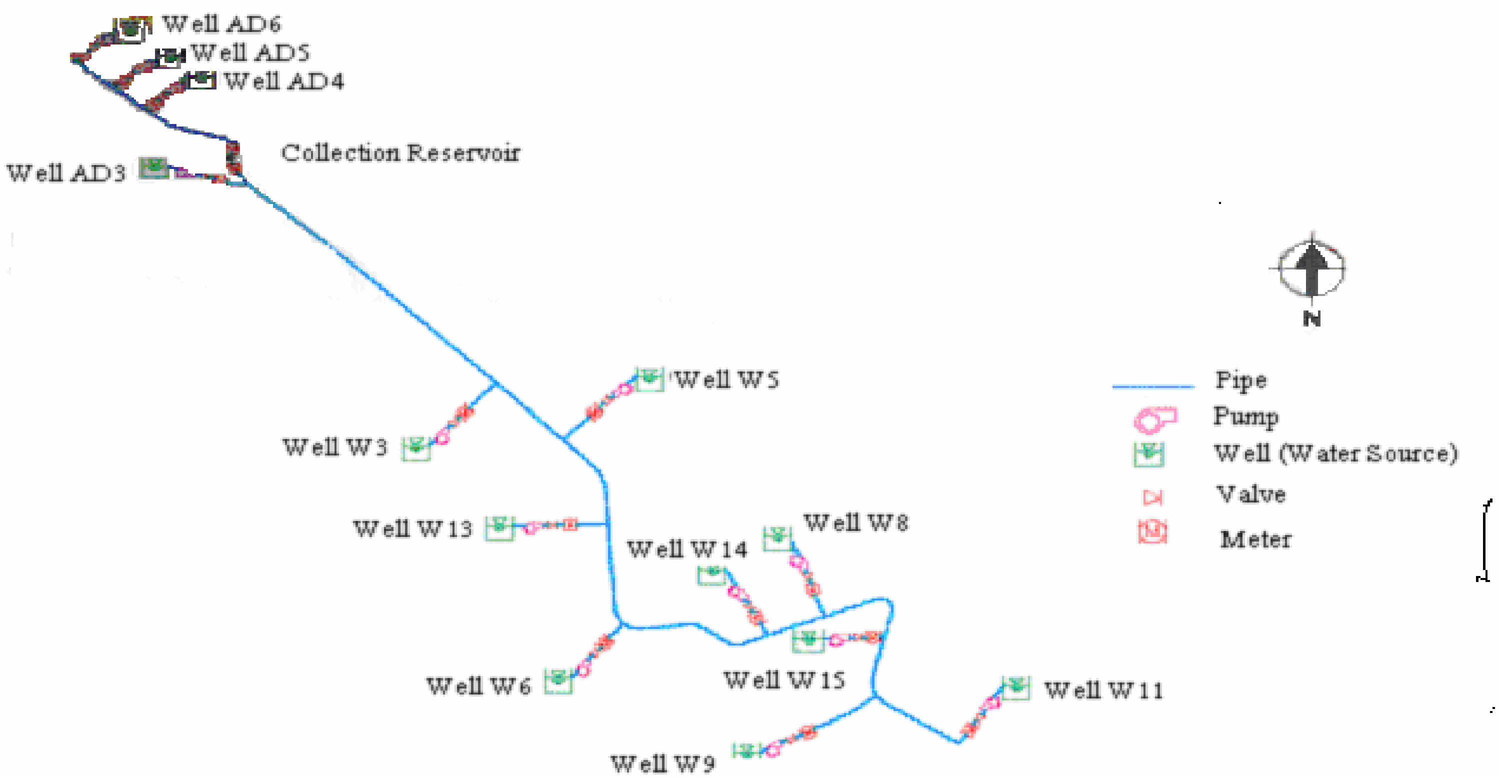


Figure 15: Schematic Diagram Showing the Collection Systems of Disi and Abu Edba'a Wells
Source: (Montogomery-Watson, 2000)

There are other governmental wells that produce about 2.00 MCM and are used for irrigation near the village of Disi. On the other hand, about 50.00 MCM of groundwater are used for irrigation by the agricultural companies. They draw their water from about 50 wells. These companies have released the land and the right to pump water from Disi-Mudawwarah aquifers in 1995 for 25 years. The releases will end by the year 2010.

Water for the village of Wadi Araba (Wadi Araba Country) is drawn from the wells penetrating the alluvial fans. These wells have relatively low discharge rate (30-40 m^3/hr) and medium quality (700-1000 ppm). The population centers in Quwayrah and Disi draw their municipal water supply from the Disi aquifer.

Table 13 shows the volume of water supply from Disi wells for Aqaba Area during the years 1998-2003.

6.3.2 Transmission System

The Aqaba water transmission system is comprised of the following components

1. The Well fields and Collection Reservoir
2. The Transmission line from the Collection Reservoir to the Terminal Reservoir.
3. Chlorination facilities at the outlet from the Terminal Reservoir.
4. The Trunk Main from the Terminal Reservoir to Wadi 2 Joint Fertilizer Industry (JFI) Reservoir

A schematic diagram of the water distribution system network for Aqaba City is presented in Figure 16.

Table 13. Monthly Pumping Rate in Cubic Meters of Disi Wells for Aqaba Area for the Years: 1998-2003

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1998	1,217,631	1,149,864	1,279,430	1,298,201	1,519,589	1,571,064	1,644,321	1,631,347	1,598,015	1,507,576	1,359,115	1,386,392	**17,162,545**
1999	1,306,359	1,137,188	1,451,265	1,482,218	1,513,330	1,345,632	1,527,667	1,417,306	1,587,562	1,553,934	1,353,975	1,347,257	**17,023,693**
2000	1,112,482	925,202	1,240,935	1,221,585	1,384,649	1,479,839	1,578,549	1,729,349	1,408,341	1,458,565	1,382,386	1,340,718	**16,262,600**
2001	1,157,869	1,006,452	1,300,256	1,221,585	1,392,649	1482,327	1,578,549	1,729,322	1,437,375	1,511,566	1,348,389	1,322,418	**16,488,757**
2002	1,169,145	1,276,065	1,248,865	1,429,429	1,570,436	1,530,373	1,467,506	1,769,038	1,585,913	1,616,055	1,400,990	1,451,089	**17,514,904**
2003	1,364,452	1,200,175	1,297,657	1,430,048	1,641,430	1,615,424	1,753,502	1,610,485	1,619,696	1,658,372	1,493,260	1,386,557	**18,071,058**

Source: MWI

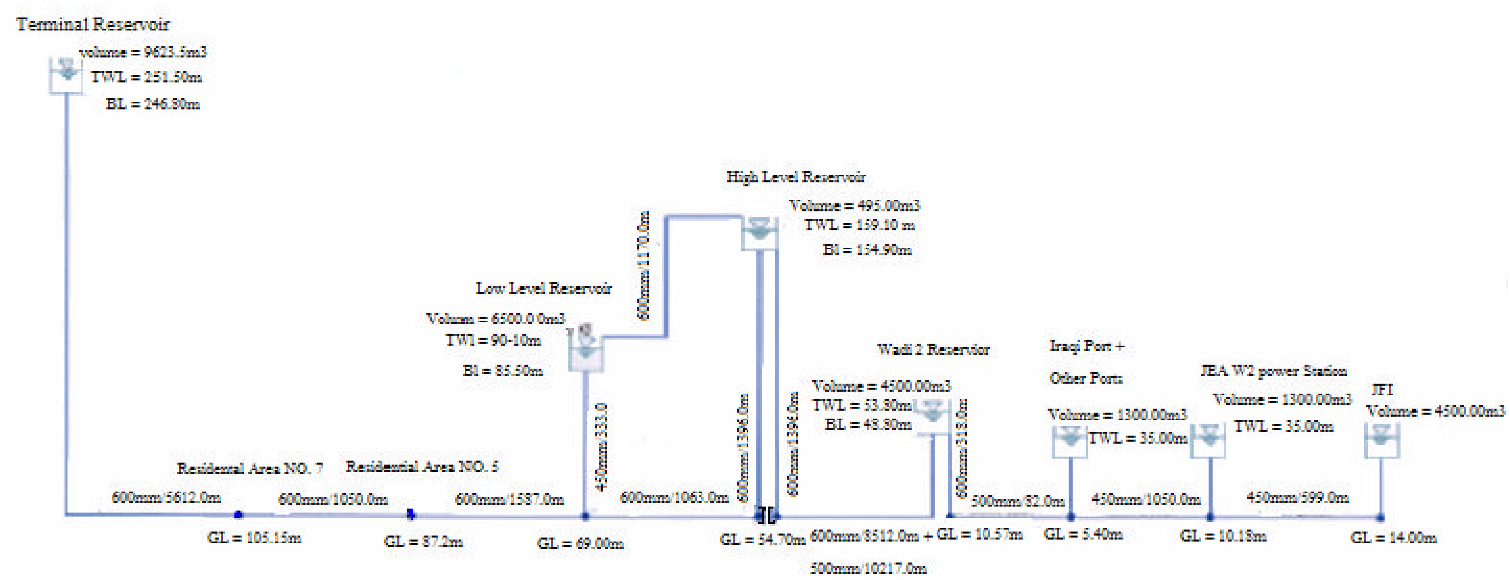


Figure 16: Schematic Diagram of Aqaba Water Distribution Network (Source: Montgomery-Watson, 2000)

a. Collection Reservoir

Water from 13 wells penetrating Disi and Abu Edba'a aquifers are piped into a collection reservoir. The reservoir is a cylindrical shape with a capacity of 2250 m^3 and is located at an elevation of 843 m (amsl). The reservoir acts as a balance reservoir to ensure continuous flow of water to Aqaba. Water from the collection reservoir is pumped primarily into a main carrier pipe of 63.80 km which allows water to reach, by gravity, the terminal reservoir.

b. Transmission Line

A Ductile Iron (DI) trunk main, 63.80 km long and ranging in size from 800 to 500 mm in diameter, carries the water from the well field water collection tank to the terminal reservoir outside Aqaba. The design capacity of the transmission line is 663 l/s, which is equivalent to maximum annual production 17.50 MCM/yr. Terminal reservoir has a capacity of 9000 m^3 and TWL of 251.50 m (amsl).

c. Main Trunk

In specifying the WaterWare nodes, reaches and cross section, Aqaba water transmission system starts at the Terminal Reservoir. Therefore Terminal Reservoir was considered as start node. The daily time series of the pumping rate of Disi wells was selected as flow input. This section of the pipeline comprises 25 km of 500 mm and 600 mm DI. A wadi 2 JFI reservoir has a capacity of 4500 m^3, a TWL of 51.5 mAMSL and is located on the south coast next to southern Industrial Zone. The Terminal Reservoir supplies the High Level Reservoir as well as Low Level Reservoir. A ductile iron (DI) pipeline of 500 mm in diameter was constructed from the Trunk Main to the High Level Reservoir and ductile iron outlet main, 600 mm in diameter, was constructed from the reservoir to the Main Trunk.

6.3.3 Distribution System

The distribution system is divided into three distribution zones as shown in Figure 17 (Montgomery-Watson, 2002). One is supplied directly by connections to the transmission line which contributed to 12 % and 24 % of the total domestic water supply of Aqaba.

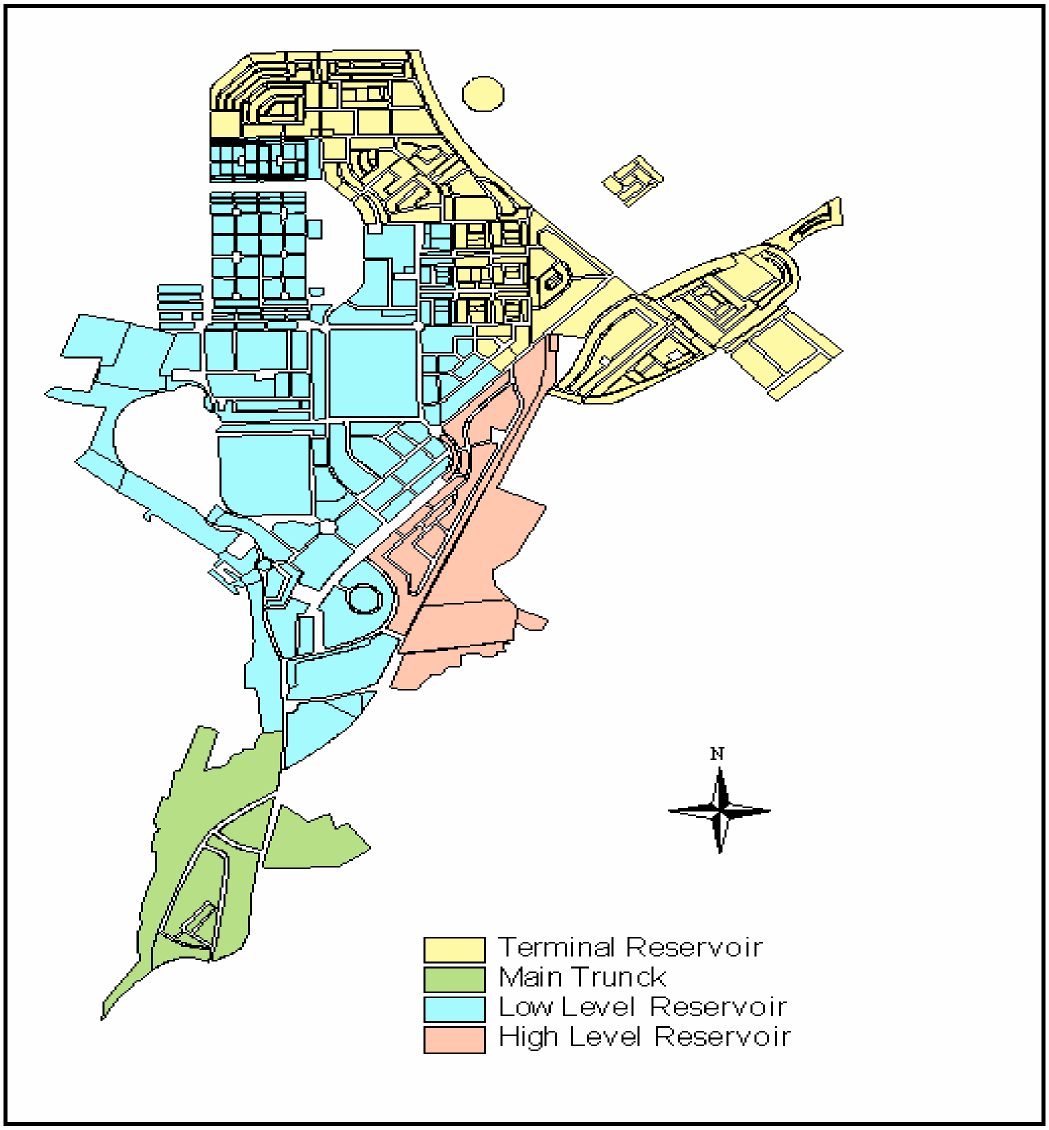


Figure 17: Water Distribution Zones from Water Sources.
Source: (Montogomery-Watson, 2001)

The other two zones supply water to the high and low level reservoir which contributed to 8 % and 56 % respectively of the total Aqaba Domestic water supply.

The direct connections at the transmission line serve the developed 7th, 8th 9th and 10th residential area and the light industrial area. The Low Level Reservoir is fed from the transmission line by a 600 mm DI pipeline. This reservoir has a capacity of 6550 MCM and TWL of 90.10 m (amsl). It supplies the low level zone at Aqaba which cover most of the city and serves approximately 60,000 people. The Trunk Main then by passing the city and feeding the High Level Reservoir of 500 m³ in capacity and TWL 159.10 m (amsl). This reservoir supplies an approximately 10,000 people in the near by high area including Shallaleh, al-Khazan and part of the fifth residential area. The Trunk Main continues towards the south coast supplying the Port housing, Shemesani area and then runs along the coastel highways until it reaches Wadi 2 JFI reservoirs near the industrial port close to the largest industrial consumers in the system. Here it supplies the fertilizer factory's reservoir of about 4500 m³ capacities and the thermal power station's of 1300 m³ capacities (Montogomery-Watson, 1999).

6.3.4 Conveyance Losses

In terms of quantity, actual demands equal actual production plus losses. Under ideal conditions, actual municipal and touristic water consumption should be equal to water billed, however, in reality the former exceeds billed amounts due to administrative losses; i.e., water not accounted for, due to illegal abstractions, non-operational meters and/or un-metered connection. Actual demand can be broken down into leakage and consumption. Figure 18 shows the analysis of the water management system in Aqaba which explains how actual demand is broken down into different components of losses and consumption. These components are:

a. **Leakage**

Physical losses from the water network are termed leakage and includes;

? Background leaks from pipes, reservoirs, valves and pumps that are typically

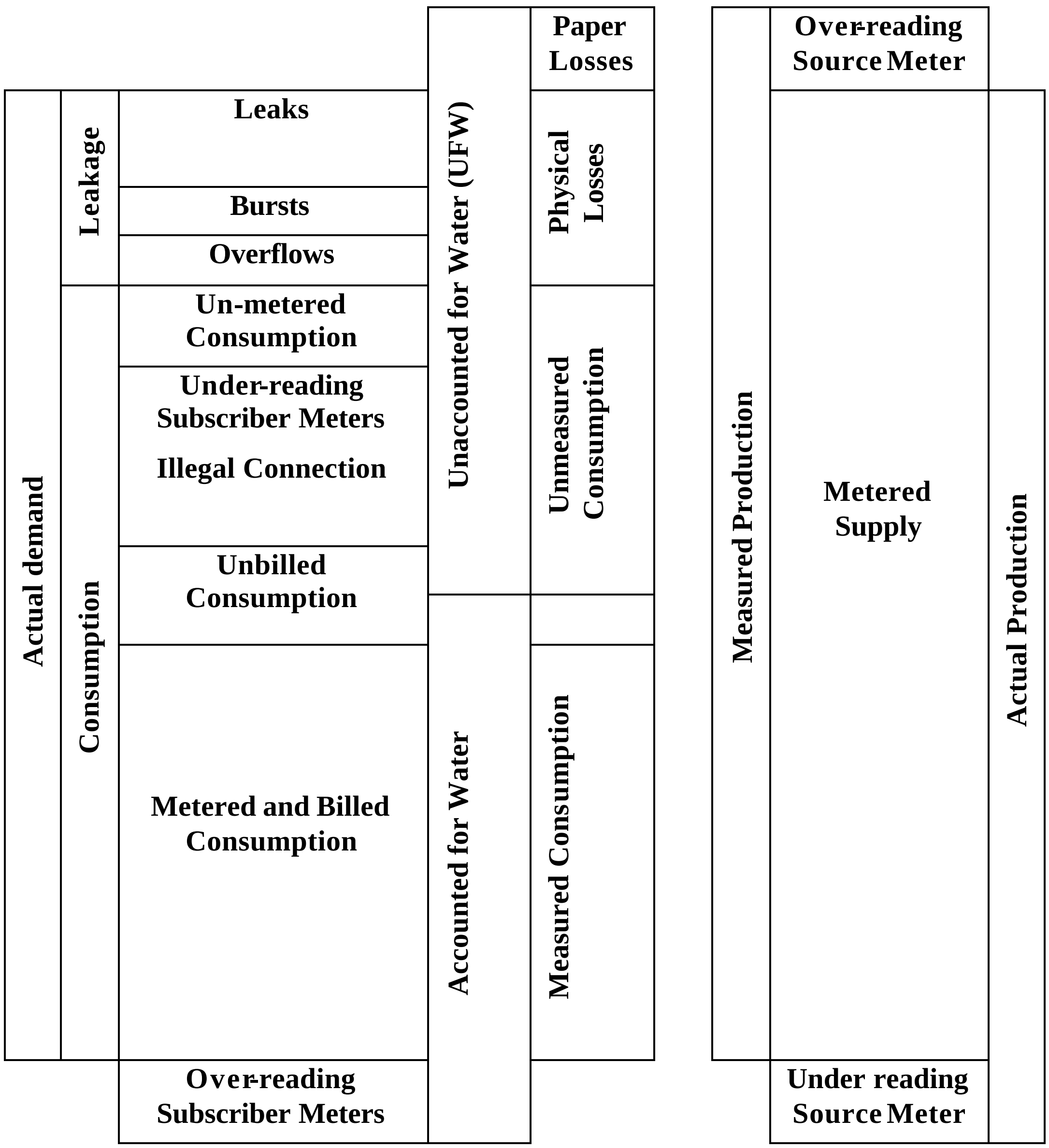


Figure 18: Schematic Chart Analyzing Water Management System in Aqaba.

characterized by having a low rate but high volume because they tend to go unnoticed and occur at many locations throughout the network.

? Bursts are isolated events, which are typically characterized by water visible at the surface and /or loss of supply to subscribers. Bursts are high flow rate but can be considered low volume if their occurrence is infrequent.

? Overflows from reservoirs caused by inoperable inlet control valves.

b. Consumption

Consumption includes all instances where water is taken from the system and used for a definite purpose. It can be spilt into measured and unmeasured consumption depending on whether the water use is paid for or not.

Un measured consumption either unbilled and/or un-metered. Includes;

? Illegal connections, water taken without the permission of the Water Authority.

? Un-metered consumption: water used without permission of the Water Authority but not paid for. Water used for fire fighting and WAJ operational use would be included.

? Unbilled consumption includes un-metered consumption but could also include some metered consumption where free issue water is provided for Water Authority and public buildings.

? Under-reading subscriber meters occur if the meter is in-operable, in need of maintenance or the flows are too low to register on the meter. Low flows can be a problem if roof tanks are trickle fed.

c. **Unaccounted for Water**

The Unaccounted for Water (UFW) is the net value of the measured production less the than diverted amounts. UFW comprises both administrative losses and physical network losses. It includes 'losses' resulting from leakage, illegal abstraction unbilled water such as that provided to tankers and fire hydrant points, unmeasured consumption and a paper loss associated with over-estimating source meters. Meter accuracy is important in determining production and accounted for water as an under-reading source meter and over-reading subscriber meters will artificially reduce the UFW. Conversely an over-reading source meter will artificially inflate the UFW.

UFW = Water Supplied – Water Billed

where

UFW % = Administrative losses % + Physical losses %

UFW % = 1- (water billed/ water supplied) *100 %

Water consumed = Billed water + Administrative losses

6.4 Water Demand by Sector

Table 14 shows water consumptions for each sector on quarterly basis (every three months) for the years 1998-2003. Figure 19 shows also the variation in water consumption on quarterly basis for the same period. The immediate results which could be obtained from this table are that the average per capita water consumption has averaged 203 lpcd.

Water consumption increases from 4.40 MCM/year in 1998 to 6.60 MCM/year in 2003 which equivalent to 158 l/c/d and 213 l/c/d respectively.

Table 14. Water Consumed for Each Category from the Year 1998-2003 (CM).

	Commercial	Domestic	Tourism	Service	Total	Industry	Grant Total
Q_1/1998	51,386	494,928	69,765	340,090			
Q_2/1998	71,970	575,468	77,225	420,932			
Q_3/1998	133,185	612,060	77,269	420,110			
Q_4/1998	74,980	504,620	76,760	307,947			
Total	**331,521**	**2,187,076**	**301,019**	**1,489,079**	**4,308,695**	**4,882,461**	**9,191,156**
Q_1/1999	94,905	686,264	112,160	542,109			
Q_2/1999	81,963	656,426	94,905	458,707			
Q_3/1999	133,730	805,614	116,474	562,959			
Q_4/1999	120,788	835,451	107,847	521,258			
Total	**431,386**	**2,983,755**	**431,386**	**2,085,033**	**5,931,560**	**4,403,051**	**10,334,611**
Q_1/2000	88,726	644,370	84,289	428,841			
Q_2/2000	110,907	705,739	88,726	536,051			
Q_3/2000	115,343	828,476	133,088	557,493			
Q_4/2000	128,652	889,844	137,525	621,819			
Total	**443,628**	**3,068,429**	**443,628**	**2,144,204**	**6,099,889**	**3,975,239**	**10,075,128**
Q_1/2001	95,807	694,216	104,931	463,064			
Q_2/2001	95,806	662,661	95,806	463,064			
Q_3/2001	127,742	851,992	123,180	617,419			
Q_4/2001	136,866	946,658	132,304	661,520			
Total	**456,221**	**3,155,527**	**456,221**	**2,205,067**	**6,273,036**	**3,962,359**	**10,235,395,**
Q_1/2002	75,066	746,361	112,600	362,820			
Q_2/2002	107,908	649,010	103,216	521,554			
Q_3/2002	154,824	876,163	112,599	748,316			
Q_4/2002	131,366	973,515	140,749	634,935			
Total	**469,164**	**3,245,049**	**469,164**	**2,267,625**	**6,451,002**	**4,242,151**	**10,693,153**
Q_1/2003	139,976	868,012	101,362	676,551			
Q_2/2003	111,016	767,857	86,882	536,575			
Q_3/2003	115,842	901,397	120,669	559,904			
Q_4/2003	115,842	801,243	173,763	559,904			
Total	**482,676**	**3,338,509**	**482,676**	**2,332,934**	**6,636,795**	**4,076,039**	**10,712,834**

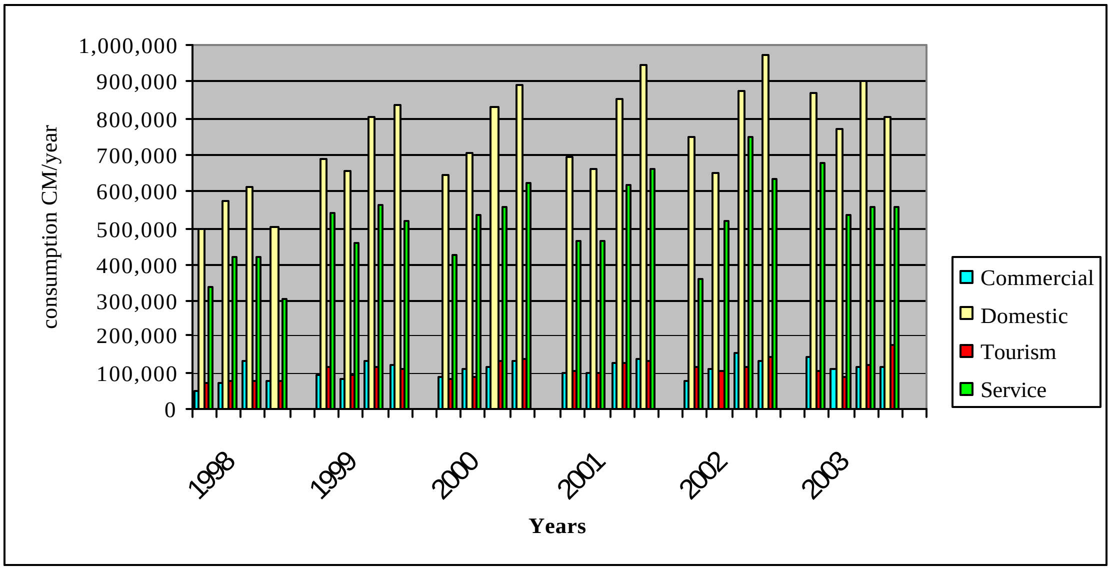


Figure 19: Water Consumed for Each Category from the Year 1998-2003

6.4.1 Residential Demand

Residential consumption in the Aqaba has been increasing from a total of 2.00 MCM/year in 1998 to around 3.30 MCM/year in the year 2003. Residential water use in the year 2003 represents 31 % of the total water use in Aqaba, consumption ranges from 0.77 MCM/quarter to 0.90 MCM/quarter to have its peak in the third quarter (0.90 MCM/quarter). The peak consumption in July through September may be partially attributed to high seasonal temperatures encountered during the summer months.

6.4.2 Commercial and Service Demand

Commercial demand are consumed by the commercial stores, restaurants and small factories, while service demand is the water diverted to public agencies including the port corporation, ASEZA facilities and other government agencies. Commercial consumption is approximately 0.48 MCM/year in 2003 which represents 4.5 % of the total water used in Aqaba and ranges from 0.10 MCM/quarter. Services consumption use is approximately 2.30 MCM/year in the year 2003 which represents 22 % of the total water used in Aqaba and it has been increased from 1.50 MCM/year in 1998 to 2.30 MCM/year in 2003.

6.4.3 Tourism Demand

Due to the progressive tourist expansion in Aqaba city, the tourist consumption in the Governorate of Aqaba has increased from a total of 0.30 MCM/yr in 1998, to about 0.50 MCM/yr in the year 2003. Tourism consumption ranges from 0.08 MCM/quarter to 0.20 MCM/quarter in the year 2003. The water consumption in the second quarter (April- June) is less than the other three quarters. Its peak is in the third and fourth Quarter (0.17 MCM/quarter). The peaking in July through September may be due to hot weather conditions, and the tendency to peak from October through December is due to touristic season in Aqaba. The water demand of the tourist population in 2003 represents 8.90 % from the total non-industrial demand.

As an example, Table 15 shows the water consumed by the Movenpick Hotel (Five stars) from January 2002 to March 2005 (from Movenpick Hotel, 2005). Five-star hotels provide in general more water consuming accommodations than hotels of lower standard (MWI& GTZ, 2004).

The behavior in water consumption was 782 liters per occupied night of the total water billed in 2002, and 800 liters per occupied bed night in the August (Peak month). In 2004, the average water consumption was 617 liters per occupied night of the total billed consumption, and 728 liters per occupied bed night in the August. The reduction in water consumption can be attributed to the use of water saving devices.

In addition to the regular growth of tourist water demand, increased demand may be due to sudden introduction of additional number of beds upon completion of touristic development projects.

Despite the steady increase of the number of bed units during the past years from 3682 in 1997 to 8896 in 2003, records showed almost steady values for the historical amounts of water consumed. In absolute terms, one would expect that the investment in big hotels during the recent years would result in increased touristic water consumption.

Table 15. Movenpick Resort Aqaba Monthly Water Consumption

Month	Rooms	Number of occupancy	Water Consumption (M3)
Jan.2002	1598	2445	2000.0
Fep.2002	2455	4465	3338.8
Mar.2002	2690	4674	3034.6
Apr.2002	3283	5419	3722.6
May.2002	3559	5966	3872.9
Jun.2002	2540	4080	3170.4
Jul.2002	2823	5074	5347.0
Aug.2002	4244	7900	6307.3
Sep.2002	2965	4480	4427.0
Oct.2002	3090	4540	4386.0
Nov.2002	2088	3077	2409.0
Dec.2002	3122	5131	2754.0
Total	**34457**	**57251**	**44769.6**
Jan.2003	2593	3862	2895.0
Fep.2003	1886	3003	2383.5
Mar.2003	1351	1677	1793.3
Apr.2003	2463	4045	2750.5
May.2003	4380	6579	3966.7
Jun.2003	3795	5502	4201.7
Jul.2003	3932	6920	5272.0
Aug.2003	5867	10453	6680.0
Sep.2003	4084	6990	5331.0
Oct.2003	5661	9440	5066.7
Nov.2003	3555	6466	4036.5
Dec.2003	3752	6097	3717.0
Total	**43319**	**71034**	**48094.0**
Jan.2004	2928	5028	3445.0
Fep.2004	3318	5589	4037
Mar.2004	3673	6094	3959
Apr.2004	5591	10228	5300
May.2004	4582	8009	5296
Jun.2004	4743	8111	5357
Jul.2004	4714	8800	5243
Aug.2004	5918	12284	6473
Sep.2004	5527	9840	5758
Oct.2004	5931	10564	5867
Nov.2004	5158	9435	6873
Dec.2004	4137	7032	4723
Total	**56220**	**101014**	**62331**
Jan.2005	4397	7911	5173
Fep.2005	3652	6125	3194
Mar.2005	5384	9830	4901
Total	**13433**	**23866**	**13268**

6.4.4 Industrial Demand

Industrial consumption was around 4.07 MCM in 2003 which represents about 38 % of the total water consumption by all sectors in Aqaba. Table 16 shows water consumption by different majors industries in Aqaba while Figure 20 illustrates their trend.

Table 16. Water Supply for the Industrial Sector in Aqaba from Disi Line during the Period 1998-2003 (CM).

Industry	1998	1999	2000	2001	2002	2003
Fertilizer Plant	3,303,447	3,463,729	3,319,603	3,294,188	3,619,783	3,358,670
Thermal Power Plant	756,966	918,207	645,355	656,804	484,328	358,012
Electric Company (Central Station)	16,508	4,981	1,297	1,686	1,976	2,335
Rice Factory	1,559	1,277	1,578	1,589	2,834	3,915
Holland Selvocem Co.	4,264	5,995	6,355	7,036	8,279	11,123
Arab Potash Company					54,795	9,269
Camira Potash Company					68,301	322,687
Jordan Petroleum					1,310	NA
Hassad Factory	2,635	3,857				
Cement Factory	2,179	5,005	1,051	1,056	NA	1,028
National Ammonia Co.					109	NA
Total	**4,087,558**	**4,403,051**	**3,975,239**	**3,962,359**	**4,242,151**	**4,067,039**

Source: AWD

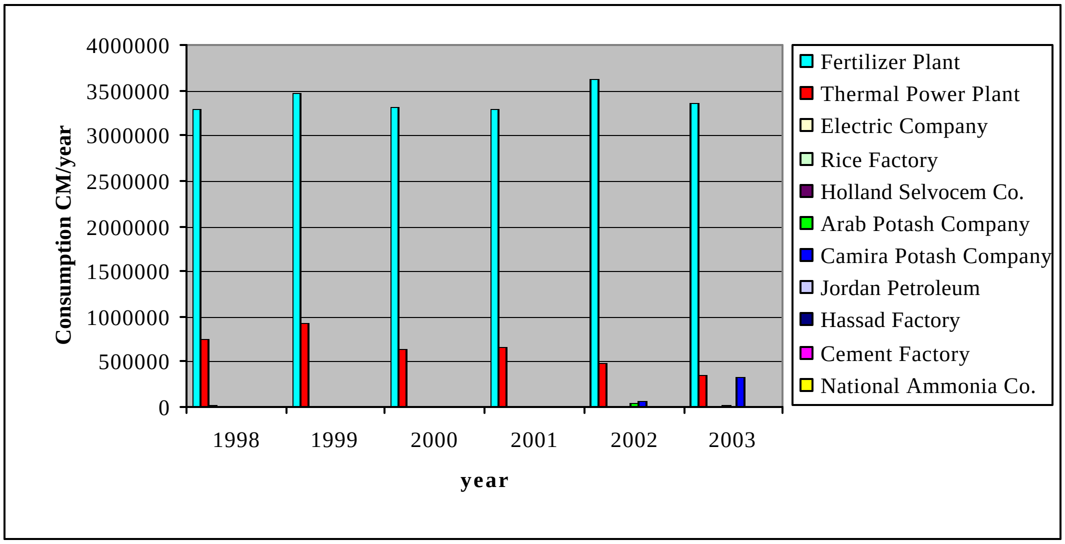


Figure 20: Water Supply for Industrial Sector in Aqaba during the Period 1998-2003

The monthly amount of water used by industries for the years (1999, 2000, 2001, 2002 and 2003 are presented in Annex B. The decrease in water use starting from 2000 was due to the shut down of Hassad factory and the National Ammonia Company. Increasing in water use in 2002 is due to developments of new industries (Potash Company). The fluctuation from year to year could be attributed to the administrative losses (meter inaccuracies, and un-billed industrial consumption). Monthly fluctuations in water are closely linked to the average temperature.

In the future, the industrial sector in Jordan will be gaining even more importance as the government is working towards creating a favorable investment environment to increase the contribution of this sector to the national economy. Currently, new laws such as the Investment Promotion Law have been issued. Other laws were revised and modified to attract foreign investment to the country and provide the proper climate for its success and profitability. In addition, existing industries are expanding and big projects are under planning. The increased income and change in way of life have also contributed to increase of water consumption. This gives a general idea about current priorities.

6.4.5 Irrigation Sector

Irrigation in Aqaba Governorate occurs mainly in the Disi and Madawwara areas. Table 17 shows the monthly water supply for irrigation purposes during the 1996-2003 from wells namely; (Agricultural Disi well, el-Ghal, al-Mneisheer, Attwayisi, Shakriyyeh, wadi Yutum, um-Mathlla, Qatar, Attaweel and Finan). This table demonstrates significant increase in water use during this period. The water use increased form 5 % in 1998 to 20 % in year 2003. The irrigation share has averaged 17 % of the total water use in Aqaba.

Table17. Water Supply in Cubic Meters for Agriculture Purposes from Wells during the Period 1996-2003.

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1996	35,470	33,620	440,80	48,419	57,886	52,350	57,634	54,389	50,834	84,272	45,259	48,821	**613,034**
1997	51,712	50,829	51,659	75,567	60,447	90,367	86,477	85,368	82,496	79,472	78,522	85,684	**878,600**
1998	75,418	57,279	50,170	77,310	65,089	67,995	81,392	59,566	62,500	77,941	69,163	85,261	**829,084**
1999	52,971	61,874	75,778	70,992	72,074	78,989	82,052	88,427	70,673	70,492	62,005	50,647	**836,974**
2000	211,792	117,590	114,603	83,604	162,614	139905	152,045	189,901	171,108	248,588	264,089	244,763	**2,100,602**
2001	211,792	174,781	156,441	143,600	162,614	140,605	15,2045	189,901	178,655	196,546	282,071	282,071	**2,271,122**
2002	154,632	191,458	211,517	217,533	221,238	239,522	260,590	30,5019	268,388	296,146	258,207	275,705	**2,899,955**
2003	269,312	247,981	290,369	274,227	247,286	268,487	275,387	269,232	253,001	217,369	234,764	243,965	**3,091,380**

Source: AWD

Treated wastewater effluent presently produced in Aqaba Governorate is about 2 MCM/year, it is expected to reach up to 7 MCM/year by the year 2020 (JICA, 2001). The treated effluent from the existing WWTP is reused for irrigation few palm orchards, the green belt and Aqaba landscaping areas. Table 18 shows the amounts of recycled wastewater that are being used in the year 2003 by the different stakeholder and their average usage for yearly demand.

Table 18. Irrigation Usage of Recycled Wastewater in Aqaba

Farm name	Purpose	Winter 2003 usage m^3/day	Summer 2003 usage m^3/ day	Average usage m^3/year
as-Salam	Nursery for Palm trees	400	400	150,000
al-Haq	Planted with date palm	1000	1500	456,000
an-Nakeel	Produces date palms for the city of Aqaba greening program	1250	1250	500,000
ASEZA's Landscaping	North Aqaba and Landscaping	800	1200	400,000
Wind breaks	Wind breaks around the treatment plant	600	900	300,000
Green belt	Green belt and airport forestation	400	600	**200,000**
Totals		**4450**	**5850**	**2,006,000**

Irrigation represents approximately 50 % of the total treated effluent after evaporation losses are considered (Wilbur Smith *et al*, 2001).

It has been reported by Waller, (2004), that there are approximately 50,000 trees and shrubs in Aqaba that are being irrigated by the reclaimed water. While the future plan is to increase the number of trees and shrubs in a greening program. The Aqaba Special Economic Zone Authority is planting approximately 100 ha of new landscaping in order to make Aqaba look greener and more attractive to tourists. The plan is to irrigate much of the newly planted areas with reclaimed water.

In the future, water supply for irrigation will be reduced due to water shortage, restrictions on well drilling and equipping private wells with water meters and reduction in irrigated area due to water shortage. The fossil water from Disi aquifer will be pumped to Amman to augment the shortage of drinking water supplies. Therefore, treated wastewater must be considered as new sources of water that can be used for agriculture to increase food production and to protect the environment. The impacts of this sewage influx are nutrient enrichment; possibly leading to eutrophication increased suspended matter resulting in reduced light penetration to the marine water.

Also it is important to take into consideration the reduced seepage from irrigated areas resulting from excess irrigation near the coast of Aqaba. Return flow and excess irrigation water are rich in nutrient. These nutrients will have a negative impact on the sustainability of coral reef in Aqaba. Nutrient such as N and P will enhance the growth of algae, which reduce sun light penetration to beach bottom, which is essential for the growth of the coral. Also possible leakage of treated wastewater from sewer into the Gulf's water may be occurring so the discharge into the sea must be regulated However untreated sewage and wastewater may inter the Gulf from other sources and from other cities around the Gulf.

6.5 Water Resources Modeling (WaterWare System)

In this section, Water Resources Management Model (WRM) will be used to evaluate the current and future situation of day-to-day water supply demand management for each demand point (node) for different sectors. WRM is one of the main components of the WaterWare Modeling system.

WaterWare (http://www.ess.co.at/WaterWare) is an integrated, model-based information and decision support system for water resource management. WaterWare is the outcome of EUREKA EUROENVIRON project EU 487, a collaborative research program involved universities, a research institute and two commercial companies; namely, University of Bologna, Italy, University College Cork, Republic of Ireland; University of Newcastle Upon Tyne, UK; International Institute for Applied Systems Analysis, Austria ; Thames Water International, UK; Ansaldo Industria Spa, Italy. The role assigned to the three academic partners involved adapting existing models and formulating new ones for inclusion within the DSS, whereas the role of the International Institute for Applied Analysis was to develop the architectural framework and create a software environment for model integration. The two commercial companies were to assume the responsibility for providing the domain knowledge and applying the prototype system (Jamieson and Fedra, 1996). The model describes a dynamic water budget for a given catchments in terms of water demand and supply, allocation policies, efficiency and use, water quality and the economics of demand and supply. The aim was to develop a comprehensive, easy-to-use decision-support system (DSS) for integrated river basin planning which would be capable of addressing a wide range of issues such as:

? Determining the limits of sustainable development.

? Evaluating the impact of new environmental legislation.

? Deciding what, where and when new resources should be developed.

? Assessing the environmental impact water-related developments.

? Formulating strategies for river and groundwater pollution– control schemes.

The complexity of these issues made it difficult to envisage an all-embracing software program, capable of coping with every eventuality. Therefore, the approach adopted has been to create a flexible, modular package which allows the selection of appropriate elements for a particular application, thereby avoiding the need to implement the wholepackage. This 'pick-and-mix' approach is particularly suitable for river-basin planning, and pipe network management.

The WaterWare system provides an integrated framework for easy access to advanced tools of data analysis, simulation modelling, rule-based assessment and multi-criteria decision support for a broad range of water resources management problems. WaterWare model combines:

1. Integrated data base management for hydrological, hydrometeorological, water quality and water use data, linked to on-line monitoring systems;
2. Object data base for River Basin Objects or objects of pipe networks with
3. Embedded expert systems functionality;
4. A geographic information system, and
5. A suite of simulation and optimization models for strategic analysis, optimization, and operational forecasting, of water flow and quality together with
6. Assessment and reporting functions, and
7. A rule-based expert system for Environmental Impact Assessment.

The software system comprises a set of standards to ensure compatibility, conventions which provide consistency, shared tools for displaying results, and a common language for problem-representation thereby providing the greatest flexibility for future updates and continuing development. The basic architecture comprises:

? A main program that co-ordinates the individual tasks and provides access through a menu of options by means of either a single screen with triggers to individual applications or components, or, in more complex situations, an expert system for coordinating individual components in a problem-specific manner.

- A GIS that stores, displays all geo-coded information
- A generic database management system (DBMS) that provides access to non-spatial but nevertheless geo-referenced data.
- At least one or more simulation, optimization, expert systems models with accesses to data both the GIS and DBMS, which provide s the analytical capability.
- A set of pre-and post- processors which supports mainly editing of input data and the visualization or analysis of model output, in addition to the handling of multiple scenarios for each of the models.
- A user-interface with accesses to different functional components of the system and the various help and explain files.
- A set of utility functions which assist in the data preparation and management tasks.

WaterWare currently includes:

- A dynamic (daily) rainfall-runoff model.
- An irrigation water demand estimation model based in FAO's CROPWAT.
- A 2D, vertically integrated finite-difference groundwater flow and transport model
- A dynamic water Resources model.
- Both a stochastic and a dynamic river water quality model that use a waste load allocation optimization model as a post-processor and a rule based environmental Impact assessment expert system.

These tools are embedded into a user interface that translates the specific functionality of a given model into a decision support tools: the component models and tools are restructured in terms of decision variables and performance variables, relating to the objectives, criteria, and constraints of various tasks and decision problems (Fedra, 2000). From a users point of view WaterWare consists of a central information systems component with GIS and data bases as well as the multi-media hypertext system that provides background information and describes a specific river basin. Linked to this data layer are a set of models that can perform scenario analysis, i.e., answer What-If and How-To questions for various water quantity and quality issues (Fedra and Jamieson, 1996).

WaterWare describes a river basin by set of interacting objects, which are spatially referenced. River Basin objects represent real world entities. Network objects represent different layers of abstraction, including the nodes and reaches of a network representation of the water system. Scenario objects represent model oriented collection of instantiations of Network Objects that are partially derived from, and linked to, the River Basin Objects (Fedra and Jamieson, 1996)

All objects are spatially referenced, that is they are known by location, both through their coordinates as well as through being members of large geographical object classes. The GIS provides the base layer of data, as well as a set of display functions.

Objects have two main functions:

1. They can obtain or update their current state in a given context, referring to sources of information. Object can show an autonomous behavior, using simulation models as methods.

2. They can report their current state or parts of their state to clients, so that the individual autonomous behavior can be synchronized and coordinated into coherent representation.
3. The River Basin Objects in WaterWare are grouped by classes; each of these classes has a set of specific attributes, organized in a set of data structures and associated methods that include

- **A header** with name and location, and meta-data information; the header also includes the linkages to geographical objects.
- **Descriptors**, using the embedded rule-based expert systems functionality for editing and inferences; they also provide linkages to the hypertext help and explain system.
- **Lists**, which contain (tabular) attribute data, or references to related objects.
- **Time series**, as a specific form of a list that may be private or a reference to another object's private time series.

Individual objects inherit their basic properties from their class. Many object properties are static and can be stored in their respective data bases and files; since methods are arbitrary functions, these references can be simple read statements from local files, an embedded SQL call to a local or network-accessible data base, or a URL for a call to an http server over local or wide-range networks, or any remote procedure call (rpc) that can utilize a remote information resources (Fedra, 2000).

6.6 Water Resources Management Model (WRM)

The Water Resources Management Model (WRM) is one of the core components of the WaterWare Modeling System. The application of the WRM is used to describe water flow and availability, to represent the dynamic of water demand and supply for each node and to summarize the annual water budget. This is done through node to node analysis for a branched water supply and demand network. The network can take the form of a loop or tree setting. The model is based on the continuality equation or mass balance approach at any nodal point. For flow in natural streams (river), channel routing is considered in the model in the form of Muskingom method while for pipe network the routing element is ignored.

In order to simulate the behavior of a river basin or a pipe network over time it is described as a system of nodes and reaches. These nodes represent the different components of a river system. The nodes are connected by reaches which represent natural or man-made channels which carry flow through the river system (on line manual, http://www. ess.co.at/Smart/WaterWware/Manaual Reference). The elements of the WRM Model are:

1. **Start** node which provides the input flow at the beginning of a water course. This could represent: a spring; an upstream catchments; an inter-basin transfer; or a major input of groundwater to the water system
2. **Confluence** nodes which provide for the joining of several reaches. Is characterized by more than one inflow
3. **Diversion** nodes which represent branching of flow to several channels; it is characterized by more than one outflow and rules to distribute the flow.
4. **Demand** nodes that describe the consumptive use of water. They include:
   ? **Municipal** node which represents municipal water demand (domestic, commercial, services and tourism).
   ? **Industrial** node which represents water demands for industry.
   ? **Irrigation** node which represents water demands for irrigation.

5. **Geometry** nodes do not affect the flow directly, but are used to start a new reach or serve as a place holder to provide a network structure consistent with other models.

6. **Terminal** nodes which represent outlets from the basin considered in the model, including outflow to the sea

6.6.1 Model Dynamics

The model operates on a daily time step to represent the dynamics of water demand and supply, and the routing process if the channel system is employed. This daily time step can be aggregated, for output and reporting purposes, to a weekly, monthly, and annual scale.

Start node: This node provides the input flow to the simulation model, which represent the natural flows. The flow is represented in the following form

$$Q_j = ß?_j + Q?_j$$

where

Q_j = outflow in m^3/day from the start node in day j

$?_j$ = inflow in m^3/day to a start node in day j

$Q?_j$ = input flow in m^3/day to a start node in day j

$ß = 0$ = in case where the start node represents a head water source.

Confluence Node: This node provides the joining of natural tributaries or man-made conveyance channels. The equation governing the flow at a confluences node is

$$Q_j = \overset{n}{\underset{i=1}{?}} ?_j^i$$

where

Q_j = outflow in m^3/day from a confluence node in day j

$?_j^i$ = i-th channel or pipe inflow in m^3/day to a confluence in day j

Diversion Node: This node represents diversions flow to other nodes in the system. The diversion rule is such that a minimum downstream release is given priority. The operation rule is described as follows

$Q_j = ?_j$	$AD_j = 0$	when $?_j < DWT_j$
$Q_j = DWT_j$	$AD_j = ?j - DWT_j$	when $DWT_j = ?j = DWT_j + TD_j$
$Q_j = ?_j - TD_j$	$AD_j = TDj$	when $?_j > DWT_j + TD_j$

where

Q_j = actual downstream flow in m^3/day from a diversion node in day j

$?_j$ = inflow in m^3/day to a diversion node in day j

AD_j = actual diversion flow in m^3/day in day j

DWT_j = downstream target flow in m^3/day in day j

TDj = diversion target flow in m^3/day in day j

6.7 Projection of Future Water Demand

The driving forces for water demand in Aqaba are population growth, soc io-economic development, technological changes and increased industrial and tourism activities. Demographic changes through natural growth and migration can affect the water balance by demanding more water than already available. Industrial and tourism activities will demand more water and will generate more waste while technological changes might introduce good demand management resulting in water saving At the present, the water supply for Aqaba depend on the non-renewable ground water of Disi Aquifers. The precise water demand for the city of Aqaba can not be easily predicted for a number of reasons, mainly the difficulty in projecting future population. As such, it is difficult to determine, with confidence, the future growth rate because it is very much related to political stability of the region. Although historical data on demographic changes are available, but previous studies have failed in predicting exact percentage in the rise of population and the growth in tourism. For example, Montogomery-Watson (2000) has estimated the population of Aqaba till the year 2025 as shown in Table 19.

Table 19. Projected Population for Aqaba (Source: Montgomery-Watson 2000).

Year	Aqaba without Freeport (Low Projection)	Additional Population from Freeport	Total Aqaba population (high Projection)
2005	**88,982**	**26,626**	**115,608**
2006	92,274	31,554	123,828
2007	95,688	36,360	132,048
2008	99,229	41,039	140,268
2009	102,900	49,996	152,896
2010	**106,707**	**58,817**	**165,524**
2011	110,655	68,900	179,555
2012	114,750	78,836	193,586
2013	118,995	88,622	207,617
2014	123,398	98,250	221,648
2015	**127,964**	**107,715**	**235,679**
2016	132,699	117,011	249,710
2017	137,609	126,132	263,741
2018	142,700	135,072	277,772
2019	147,980	14,224	290,204
2020	**153,455**	**147,946**	**301,401**
2021	159,133	152,523	311,656
2022	165,021	156,185	321,206
2023	171,127	159,114	330,241
2024	177,458	161,458	338,916
2025	**184,024**	**163,333**	**347,357**

With the establishment of the free economical zone area, they have predicted the population of Aqaba to reach 115,608 people in the year 2005 which is an over estimated figure compared to the actual population of 91,200 according to the recent census of 2004. They have also projected the total water demand for Aqaba up to year 2025 (Table 20). For the year 2020, the projection ranged from 32 MCM as low projection to 69 MCM at the maximum. Their projection for 2005 was not fulfilled as the water consumption remained at the level of 2003.

Table 20. Total Water Demand Projections for Aqaba Governorate for Target Years.

Target Year	Demand (MCM/year)							
	Low Projection				High Projection			
	Non-Ind.	Ind.	UFW	Total	Non-Ind.	Ind.	UFW	Total
1998	4.4	5.0	4.5	14	4.4	5.0	4.5	14
2000	4.8	5.7	4.4	15	5.6	9.7	6.5	22
2005	5.9	7.7	3.9	18	8.9	19.5	8.2	37
2010	7.2	10.5	3.1	21	14.0	24.8	6.8	46
2015	8.5	13.8	3.9	26	21.5	28.1	8.8	58
2020	9.8	17.8	4.9	32	27.7	30.7	10.3	69
2025	11.1	22.4	5.9	39	32.3	32.5	11.4	76

For the purpose of this research, a different approach has been taken by considering the censuses of 1979, 1994 and 2004 as milestones. In 1979, the population of Aqaba was 27,000; it was 79,839 in 1994, while the 2004 census recorded Aqaba population as 88,278 people. Taking that into consideration, the population growth percentage for the last 30 years was analyzed and new figures were established and constructed as shown in Table 21. The analysis was linked to the economical development associated with the political situation prevailed during that period. An annual population increase of 7.3 % was estimated for the period of 1974-1984. This period witnessed the economical jump associated with the increase in oil prices and the political stability following the 1973 Arab-Israli war. During this period Aqaba port served as an important export-import hup not only for Jordan but for the neighboring Arab countries. The economical activities during the period 1984-1994 slowed down due to the first and second gulf wars but the importance of Aqaba as an outlet to Jordan and Iraq remained of great significant. The average population growth during this period was estimated at 5.3% reflecting the prevailed conditions in the second decade. An average increase in population of 3.3% was calculated for the last 10 years based on the census of 1994 and 2004.

Table 21. The Constructed Population Growth for Aqaba City for the Last Three Decades Based on Analysis of 1979, 1994 and 2004 Census.

Year	Aqaba Population	Year	Aqaba Population
1974	18,980	1990	51,500
1975	20,370	1991	54,075
1976	21,855	1992	56,779
1977	23,450	1993	60,100
1978	25,160	1994	63,804
1979	27,000	1995	65,900
1980	28,970	1996	68,050
1981	31,085	1997	70,320
1982	33,355	1998	72,640
1983	35,790	1999	75,040
1984	38,068	2000	77,515
1985	40,350	2001	80, 070
1986	42,370	2002	82,735
1987	44,488	2003	85,460
1988	46,712	2004	88,286
1989	49,050	2005	91,200

These values will be used to project Aqaba population under three growth models. The first model assumes that the current trend continues i.e. a percentage increase of 3.3%. The second model assume a 5.3 % annual population increase which is similar to the period of 1984-1994, while the third model is based on 7.3 % annual increase in population that duplicates the trend during the period of 1974-1984. To project water demand, it is necessary to estimate the per capita demand for various uses. The municipal per capita demand was assumed at 165 lpcd following the analysis of Montgomery–Watson (2000). They have expected that the residential per capita to be 83 lpcd, an equivalent of 12 lpcd for the commercial sector, the equivalent tourist consumption is 12 lpcd and the services town consumption is equivalent to 41 lpcd while the services for the south area consumption is 17 lpcd .

The actual historical industries consumption varied from 4.882 MCM in 1998 to 4.075 MCM in 2003. Future industrial consumption will be calculated different than the calculation of Montgomery-Watson (2000). Their estimate for 2005 ranged from 7.7 to 8.9 MCM, where in reality; this figure could not be achieved by the end of 2005 because the level of industrial activities remained as it was in 2003. Therefore, the estimates of Montgomery-Watson for non-industrial purposes will be used for calculating future water demand while industrial demand will be less than their estimation. Furthermore, it is assumed that the growth of industrial demand will follow the same growth trend in population as for the three growth models.

On the other hand, many studies (e.g. Wilburt Smith, 2001) estimated the unaccounted for water (UFW) at 36 % for 2000. They expected thatthis value could be reduced to 28 % by the year 2003 through the systematic network rehabilitation and improving management. They have also estimated that UFW can be further reduced to 20 % for the year 2005 and 15 % for the years 2010, 2015 and 2020. However these estimates are not achieved and would not be achievable in the near future. Therefore, reasonable figures are estimated for the purpose of this study so that the UFW could be reduced from 36 % in 2003 to 30 % in 2010 and 25 % in 2020.

6.8 Scenario Development

For the purpose of this study, different scenario will evaluated under different growth models; namely, low growth model (3.3 % population increase), medium growth model (5.3 % population increase) and high growth model (7.3 % population increase). The projected population for the above three growth models as used to predict the future water demands and are presented in Tables 22, 23, and 24

Table 22. Population Growth and Future Water Demand (MCM) under Status Quo Model or Low Growth Model (3.3%).

Year	2005		2010		2015		2020	
Population	91,200		107,275		126,183		148,422	
Sector	lpcd	Demand	lpcd	Demand	lpcd	Demand	lpcd	Demand
Municipal	95	3.132	95	3.720	95	4.375	95	5.147
Services	58	1.931	58	2.271	58	2.671	58	3.142
Tourism	12	0.399	12	0.470	12	0.553	12	0.650
Non Ind.	165	5.492	165	6.461	165	7.599	165	8.939
Industrial		4.071		4.789		5.633		6.625
Actual demand		9.563		11.250		13.232		15.564
UFW	0.36	5.379	0.36	6.328	0.36	7.443	0.36	8.755
Total		14.942		17.578		20.675		24.312

Table 23. Population Growth and Future Water Demand under Medium Growth Model (5.3%).

Year	2005		2010		2015		2020	
Population	91,200		118,069		152,854		197,888	
Sector	lpcd	Demand	lpcd	Demand	lpcd	Demand	lpcd	Demand
Municipal	95	3.162	95	4.094	95	5.300	95	6.862
Services	58	1.930	58	2.500	58	3.236	58	4.189
Tourism	12	0.400	12	0.512	12	0.670	12	0.867
Non Ind.	165	5.492	165	7.111	165	9.206	165	11.918
Industrial		4.071		5.270		6.823		8.833
Actual demand		9.563		12.381		16.029		20.751
UFW	0.36	5.379	0.36	6.964	0.36	9.016	0.36	11.672
Total		14.942		19.345		25.045		32.423

Table 24. Population Growth and Future Water Demand under High Growth Model (7.3 %).

Year	2005		2010		2015		2020	
Population	91,200		129,716		184,498		262,416	
Sector	lpcd	Demand	lpcd	Demand	lpcd	Demand	lpcd	Demand
Municipal	95	3.162	95	4.498	95	6.397	95	9.099
Services	58	1.930	58	2.746	58	3.906	58	5.555
Tourism	12	0.400	12	0.568	12	0.808	12	1.149
Non Ind.	165	5.492	165	7.812	165	11.111	165	15.804
Industrial		4.071		5.790		8.236		11.714
Actual demand		9.563		13.602		19.347		27.518
UFW	0.36	5.379	0.36	7.651	0.36	10.883	0.36	15.480
Total		14.942		21.253		30.230		43.00

The scenario will be also evaluated under supply and demand management options. For supply management, water supply will be augmented by introducing desalination plant and reusing treated effluent for industrial and irrigation purposes or recycling industrial waste water on site. It is assumed that UFW could be reduced to 25 % by the year 2020 as a demand management intervention.

A total of 13 scenarios will be tested using WRM; these scenarios are:

Scenario 1: base line scenario for 2003 with current responses

Scenario 2: status quo (BAU) scenario with current responses

Scenario 3: medium growth (OPT) scenario with current responses

Scenario 4: high growth (PESS) scenario with current responses

Scenario 5: Status quo (BAU) scenario with water demand management responses

Scenario 6: medium growth (OPT) scenario with water demand management responses

Scenario 7: high growth (PESS) scenario with water demand management responses

Scenario 8: Status quo (BAU) scenario with water supply management responses

Scenario 9: medium growth (OPT) scenario with water supply management responses

Scenario 10: high growth (PESS) scenario with water supply management responses

Scenario 11: Status quo (BAU) scenario with water supply and demand management

Scenario 12: medium growth (OPT) scenario with water supply and demand management

Scenario 13: high growth (PESS) scenario with water supply and demand management

6.9 Application of WRM to Aqaba

This section describes the application of the Water Resources Management Model (WRM) to Aqaba by projecting water demand for the next 15 years and analyzing water balance at each node and determining the system efficiency and reliability. The model operates on a daily time series to represent the dynamic of water supply and demand at each node by routing the flow through the pipe network system. For this purposes, daily values of the pumping rate (in m^3/s as a model requirement) was acquired from the record of the Ministry of Water and Irrigation. The daily pumping rate of year 1998 (Table 25) was considered to represent supply pattern for other years. A multiplier was used to scale the data for any other year if pumping rate has been changed from one year to another.

Demand data for each land use zone was acquired, smoothed and corrected into daily bases by using a scaling factor (multiplier) for the whole city and for each zone.

After data preparation and processing for WRM operation, the following steps were performed

1. Preparation a schematic GIS diagram showing water distribution in Aqaba with nodal points of supply, demand, diversion, confluence, treatments, and end nodes.
2. Storing the daily pumping rate for 1998 in m^3/s to be retrieved and scaled for further uses.
3. Storing the time series of different demand at the 5 demand nodes; these nodes are: the terminal reservoir, the high level reservoir, the low level reservoir, the WAJ reservoir and the main trunk.

Table 25. Disi Wells Daily Pumping Rate m^3/day in 1998

Day	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1	31330	30270	23356	20149	34605	30639	33540	37030	39350	38314	33873	28954
2	28731	28050	35795	19987	36976	36000	37110	31450	39488	39356	35865	35030
3	22759	29469	30453	18035	37824	36291	36925	33515	38782	39248	33465	29640
4	30110	39063	31307	29815	37255	36539	36432	32258	38655	35590	26923	33458
5	28251	20578	30230	21925	37536	34031	36517	32997	38835	36182	38947	32829
6	17849	25105	29728	27131	34888	35640	37821	29790	39455	29470	32760	34435
7	26164	29845	34852	19253	37206	36149	35605	32473	38475	33204	34205	35988
8	28910	35880	31098	18361	31540	36255	34375	32287	38270	34826	24740	35986
9	27766	26810	27787	28187	32953	36805	35945	32576	38562	36720	34585	34924
10	27643	27328	23830	31538	39035	35930	36835	34421	38592	37060	34250	28356
11	26504	20562	29635	30605	23547	36110	36739	38703	38646	37220	32565	31854
12	23903	31525	34435	31190	30200	36280	37586	37365	39279	36035	36792	27520
13	27348	31399	30485	25540	32235	36144	36270	37082	40466	29355	37213	28375
14	24087	24215	35360	29844	29452	35471	36094	37823	37920	37822	31162	26792
15	23065	23680	30143	35446	34733	36401	28505	37445	37901	37281	35048	27363
16	27154	22488	31437	35905	35605	35984	35551	38093	38918¯	36177	32682	28390
17	28304	25770	26251	30965	35360	38437	36423	37232	38919¯	34100	32708	23480
18	27542	35401	30476	33806	32572	33223	37752	36870	38918¯	37176	29390	22121
19	28825	29224	32163	33845	32268	36310	36425	38690	38919¯	36945	34560	29414
20	15798	28627	27865	19645	33925	35000	36834	36445	39503	30679	34556	33415
21	27687	33028	26636	22442	28735	36280	37296	37752	37747	35141	33324	27524
22	30167	35003	25894	35642	33981	36550	35790	36948	39131	26285	36560	29651
23	29038	27689	41271	32130	35704	33345	36640	38666	39129	32984	23568	29260
24	27685	22844	32878	33662	27980	35770	38195	31809	39575	36300	31963	24390
25	28793	22603	17326	38438	33889	36175	36265	36789	37562	32752	32944	28735
26	32115	29703	27300	24715	33756	35832	37631	37531	39208	33243	34470	31662
27	33292	24537	31058	30482	35525	33348	28329	37909	39075	27427	28845	29448
28	29426	26872	30231	35828	33324¯	36030	37660	37606	39242	34208	31674	31010
29	32986		22341	32210	31811	36592	37267	37551	39598	32675	28806	22877
30	20859		20090	29542¯	30809	34278	36492	36134	39440	37210	32346	30694
31	27349		21299		27806		37511	38030		34842		28384
Total	841440	787568	903010	826721	999711	1067839	1118360	1111270	1011886	1075827	980789	921959
Average	27143	28127	29129	27557	32249	35595	36076	35847	33730	34704	32693	29741

Source: Montgomery-Watson (¯: Missing data)

Prior to that, the daily values of the pumping rate were calculated for the years 1998-2003 (Annex C). Annex D shows an example of the calculation for the year 2003. These data were tabulated in a note pad and entered into the mainframe through an interactive screen "Scenario editor" (Figure 21). This was used later to provide tools for the selection, design and maintenance of model scenario, the definition of nodes and reaches, and the configuration of elements. The data were imported to the time series model. The screen was hyperlinked with the times series model which covers 365 or 366 days of daily values completed with no missing value. Any missing data was estimated by taking the average of proceeding and succeeding values and then recording it at the missing cell. As a model requirement, the flow must be in m^3/s. The time series were selected at the level of the "node editor" (Figure 22) to be associated with respect to node input data. Some demand nodes needed modification because their input was a fraction of the time series; therefore, with each time series, a scaling factor or multiplier was stored. The multiplier can be used to convert unit measurement or to scale historical time series to a new set of assumptions. The multiplier can be applied also if the same pattern of time series is reused for different nodes by modifying their absolute values. Time series were stored and managed in data base. For example, the daily variation in water produced from well fields for Aqaba city for the year 1998 are shown in Table 25.

The model can show the flow direction as shown in the screen dump of Figure 23 for the base line scenario of 2003 and Figure 24 for supply and demand management scenario. The screen dump of Figure 24 indicates the presence of the desalination unit and the treatment plant. Both are considered as input to the system.

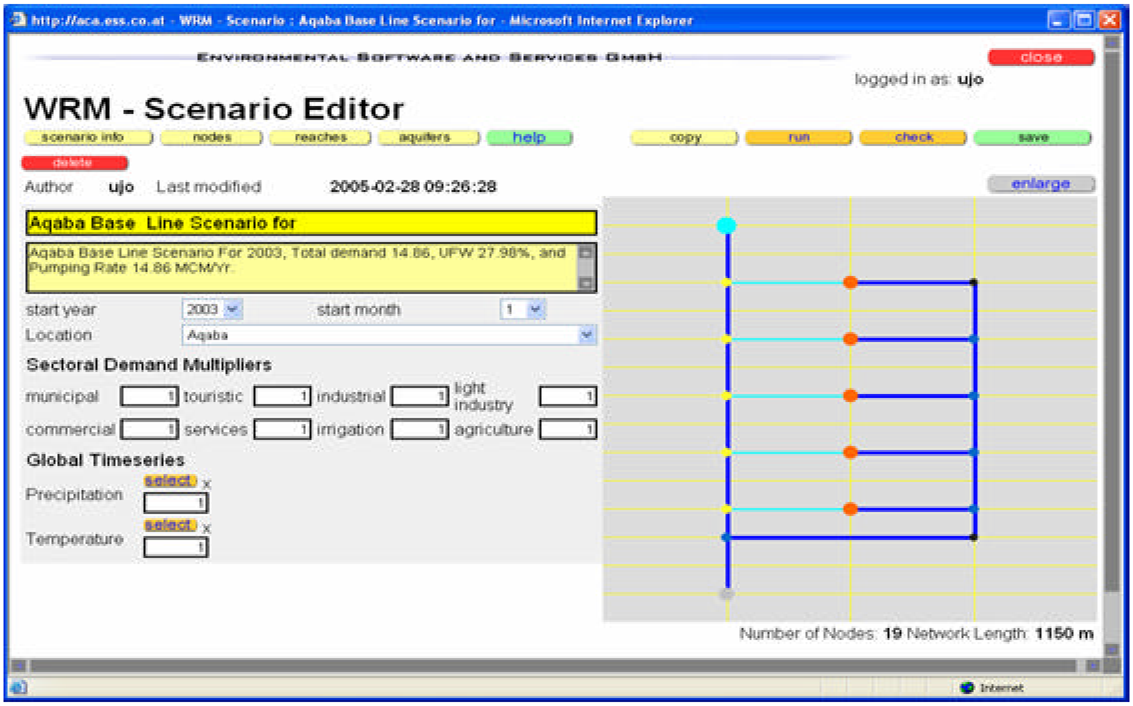


Figure 21: Scenario Editor

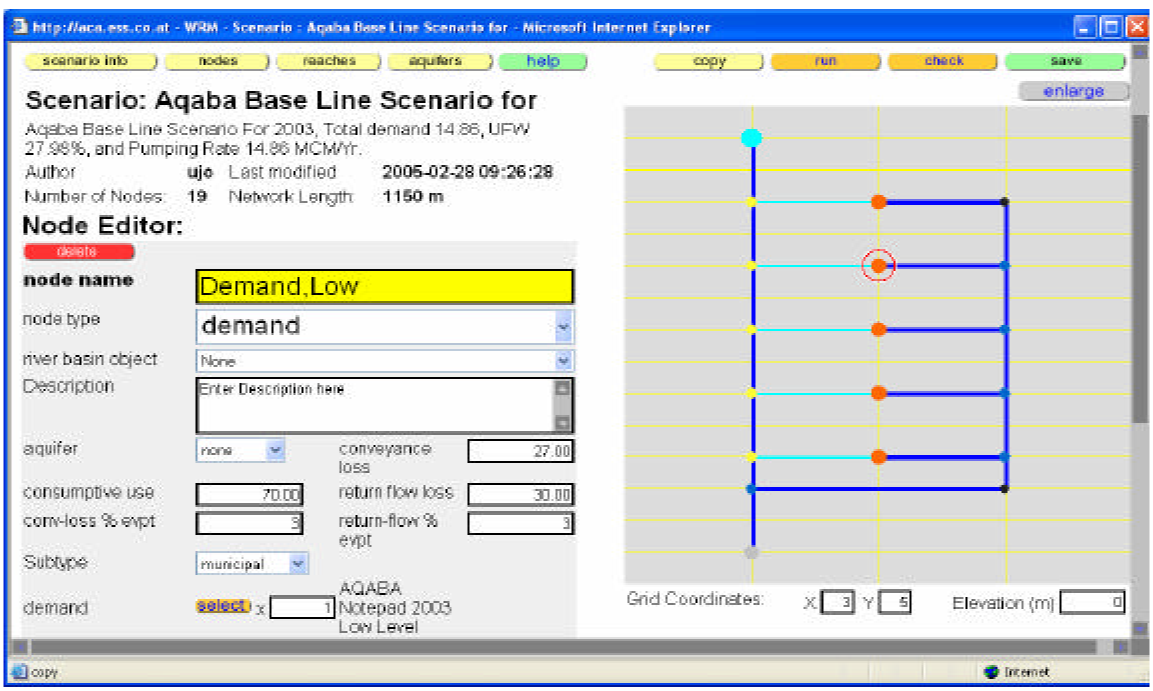


Figure 22: Node Editor

Geometry	4	12	treatment
Confluence	4	7	conf 2
Confluence	4	5	conf 1
Confluence	4	9	conf 3
Confluence	4	11	conf 4
Confluence	2	12	conf 5
Demand	3	9	Demand,Trunk
Demand	3	5	Demand,Low
Demand	3	11	Demand,WAJ
Demand	3	3	Demand,Terminal
Demand	3	7	Demand,high
diversion,single	2	9	div 4
diversion,single	2	11	div 5
diversion,single	2	3	div 1
diversion,single	2	7	div 3
diversion,single	2	5	div 2
End	2	14	End
Geometry	4	3	gemotry Node Terminal
Start	2	1	START NODE

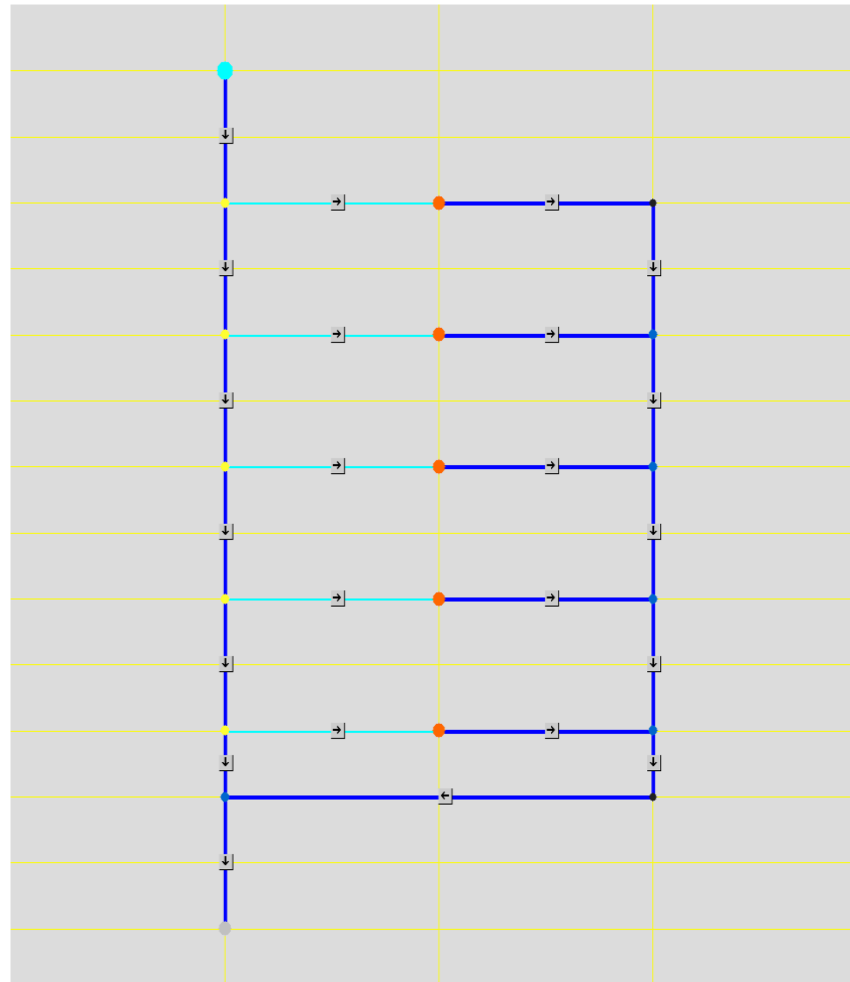


Figure 23: Water Flow Direction in Aqaba Network System

Type	X	Y	Node Name	
Confluence	4	9	conf 3	
Confluence	4	7	conf 2	
Confluence	2	10	confluence Treatment M	
Confluence	4	5	conf 1	
Confluence	2	12	conf 5	
Confluence	2	1	Confluence Desalination	
Demand	3	3	Demand,Terminal	
Demand	3	7	Demand,high	
Demand	3	9	Demand,Trunk	
Demand	3	11	Demand,WAJ	
Demand	3	5	Demand,Low	
diversion,single	2	5	div 2	
diversion,single	2	7	div 3	
diversion,single	2	9	div 4	
diversion,single	2	3	div 1	
diversion,single	2	11	div 5	
End	2	14	end	
Geometry	4	3	gemotry Node Terminal	
Geometry	4	10	Treatment, M	
Geometry	4	11	Geometry	
Geometry	4	12	treatment	
Start	1	1	START NODE	
Start	3	1	Desalination Node	

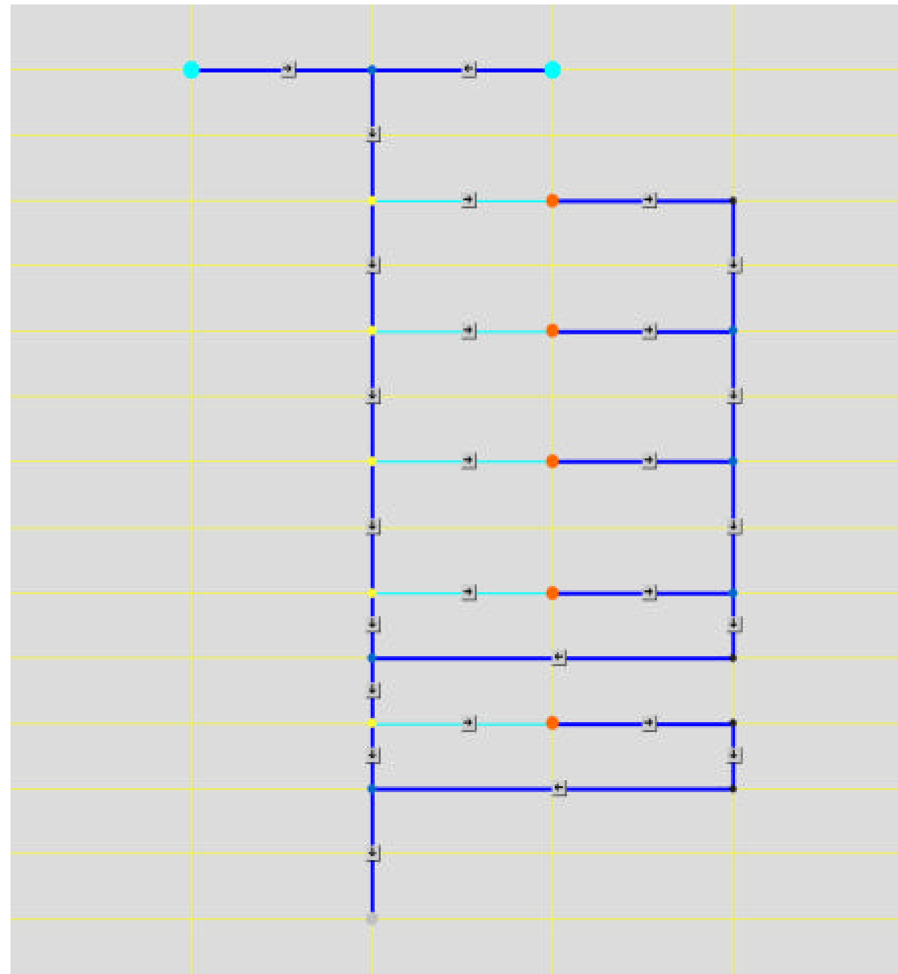


Figure 24: Water Flow Direction in Aqaba Network System with Desalination Plant

6.10 Analysis of Scenario Results.

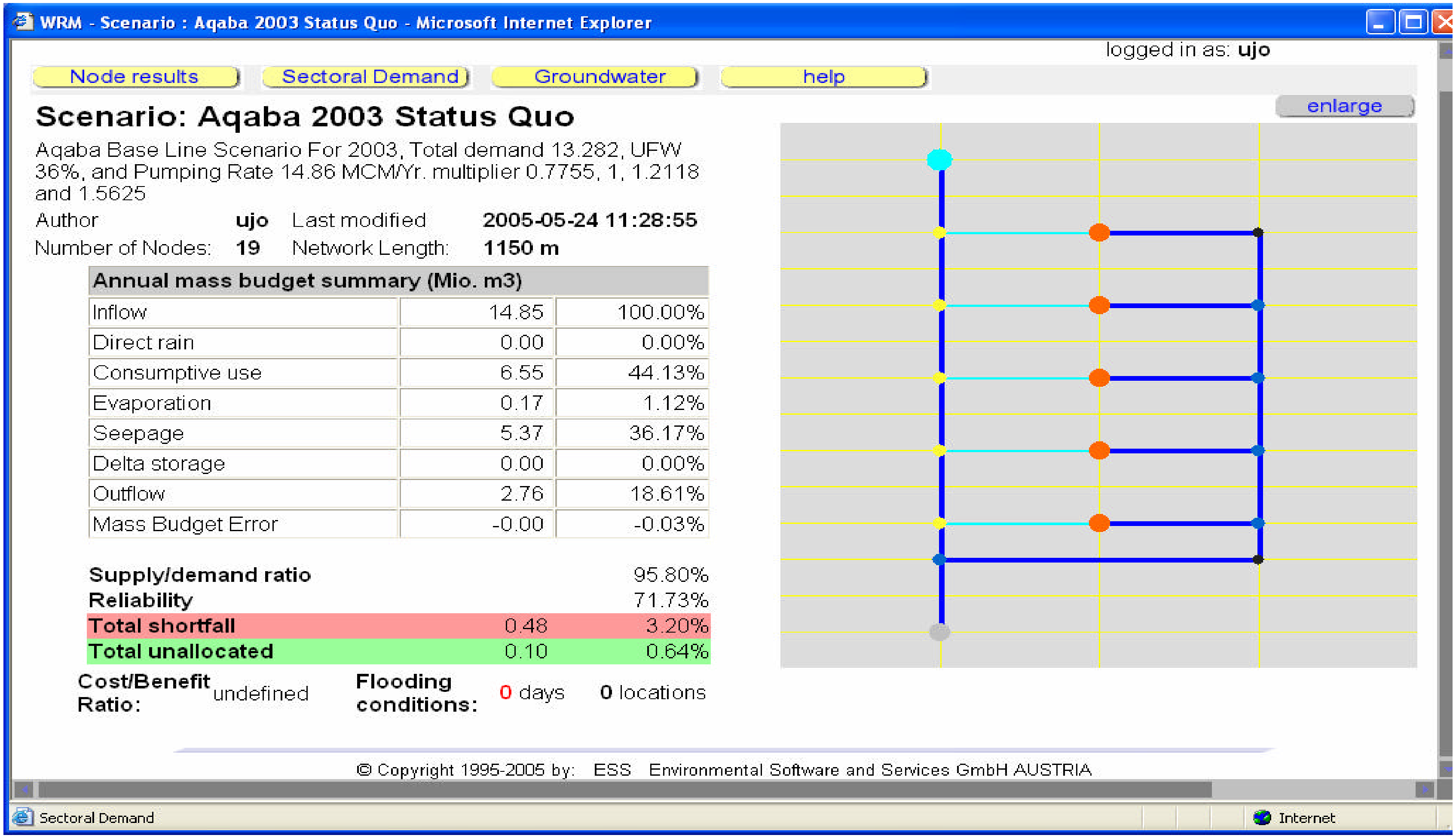
For the purpose of determine the response to the pressure caused by the driving forces (population growth and industrial expansion), different scenarios were evaluated under different growth models:

6.10.1 The Current State Scenario

Year 2003 was considered as a baseline year for further comparison. In this year, the monthly inflow was evaluated as it varies from month to month as well for the monthly demand. The maximum monthly flow of 1.50 MCM has been observed in July which is considered the peak month. The tables displayed on the screen dump of Figure 25 and 26 summarize the annual mass budget and the annual sectorial demand for the year 2003. It can be noticed that the total demand has reached 9.22 MCM, while the consumption represents only 6.55 MCM indicating that the losses are in the order of 36 % or 5.37 MCM. The supply demand ratio was high (98.75 %) for the domestic and services sectors while it was relatively less for the industrial sector (89.88 %). This because the model gives the first priority in water allocation to domestic uses. The model gave relatively high reliability of 71.73 % with only a 3.2 % shortfall indicating high model performance which would indicate a reasonable validity. Model calibration with actual observation indicates that the model performance well for management of water at the small scale level of Aqaba.

6.10.2 Future Scenario under Current Response

Under the assumption that the UFW will remain at 36%, three runs were performed for the three growth model (3.3%, 5.3% and 7.5 % annual increase in population). For the first growth model, the annual mass budget for the year 2020 is presented in the table displayed in Figure 27 while the annual sectoral projection is displayed in Figure 28.



WRM - Scenario : Aqaba 2003 Status Quo - Microsoft Internet Explorer

logged in as: **ujo**

Node results | Sectoral Demand | Groundwater | help

enlarge

Scenario: Aqaba 2003 Status Quo

Aqaba Base Line Scenario For 2003, Total demand 13.282, UFW 36%, and Pumping Rate 14.86 MCM/Yr. multiplier 0.7755, 1, 1.2118 and 1.5625

Author	**ujo**	Last modified	**2005-05-24 11:28:55**
Number of Nodes:	**19**	Network Length:	**1150 m**

Annual mass budget summary (Mio. m3)		
Inflow	14.85	100.00%
Direct rain	0.00	0.00%
Consumptive use	6.55	44.13%
Evaporation	0.17	1.12%
Seepage	5.37	36.17%
Delta storage	0.00	0.00%
Outflow	2.76	18.61%
Mass Budget Error	-0.00	-0.03%

Supply/demand ratio		95.80%
Reliability		71.73%
Total shortfall	0.48	3.20%
Total unallocated	0.10	0.64%

Cost/Benefit Ratio: undefined **Flooding conditions:** 0 days 0 locations

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Sectoral Demand Internet

Figure 25: Annual Mass Budget Summary for the Base Line Scenario for 2003.

http://aca.ess.co.at/WRM/MODEL/results.php?rnet_id=431 - Microsoft Internet Explorer

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Scenario: Aqaba 2003 Status Quo

Aqaba Base Line Scenario For 2003, Total demand 13.282, UFW 36%, and Pumping Rate 14.86 MCM/Yr. multiplier 0.7755, 1, 1.2118 and 1.5625

Author	**ujo**	Last modified	**2005-05-24 11:28:55**
Number of Nodes:	**19**	Network Length:	**1150 m**

Annual Sectoral Demand

	Demand (Mm3)	NetSupply (Mm3)	Cons.use (Mm3)	Losses (Mm3)	Shortfall (Mm3)	Unallocated (Mm3)	Supply/demand (%)	Reliability (%)
Domestic	3.91	3.91	2.90	2.45	0.05	0.05	98.75	51.96
Agricultural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	4.07	3.69	2.74	2.31	0.41	0.03	89.88	38.63
Services	1.24	1.24	0.91	0.77	0.02	0.02	98.75	52.33
Generic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.22	8.83	6.55	5.54	0.48	0.10	94.83	49.37

Done Internet

Figure 26. Annual Sectoral Demand for the Base Line Scenario for 2003 .

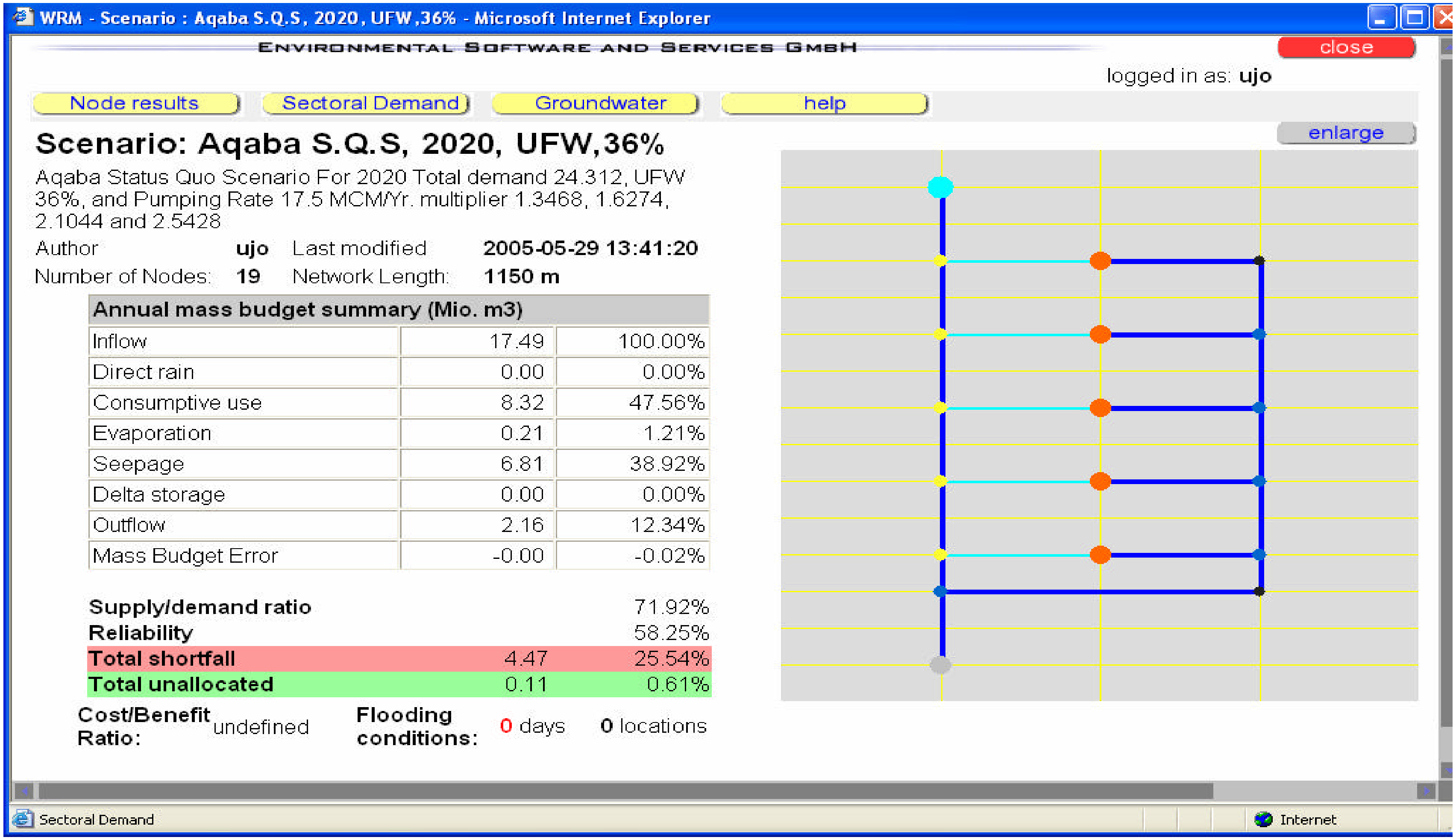

Figure 27 : Annual Mass Budget Summary for the Status Quo Scenario for the Year 2020 When the UFW 36 %

http://aca.ess.co.at/WRM/MODEL/results.php?rnet_id=438 - Microsoft Internet Explorer

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Scenario: Aqaba S.Q.S, 2020, UFW,36%

Aqaba Status Quo Scenario For 2020 Total demand 24.312, UFW 36%, and Pumping Rate 17.5 MCM/Yr. multiplier 1.3468, 1.6274, 2.1044 and 2.5428

Author	**ujo**	Last modified	**2005-05-29 13:41:20**
Number of Nodes:	**19**	Network Length:	**1150 m**

Annual Sectoral Demand

	Demand (Mm3)	NetSupply (Mm3)	Cons.use (Mm3)	Losses (Mm3)	Shortfall (Mm3)	Unallocated (Mm3)	Supply/demand (%)	Reliability (%)
Domestic	6.79	6.79	5.03	4.26	0.09	0.09	98.74	51.87
Agricultural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	6.62	2.41	1.81	1.51	4.21	0.00	36.40	0.00
Services	2.14	1.99	1.48	1.25	0.17	0.02	92.01	43.84
Generic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	15.56	11.20	8.32	7.02	4.47	0.11	71.29	39.89

Done Internet

Figure 28 : Annual Sectoral Demand for the Status Quo Scenario for the Year 2020 When the UFW 36 %.

It can be seen that the projected net water demand for 2020 is 8.32 MCM and the losses are in the order of 6.81 MCM representing about 39% of the total inflow (17.5 MCM). Under this scenario the supply to demand ratio is about 72 % with 58.25 % reliability and a total shortfall of 4.47 MCM (25.54 %).

In evaluating the water sectoral demand, it can be observed from Figure 28. That S/D ratio is above 90 % for the domestic and services sectors while it is very low for the industrial sector. This indicates that the model gives high or first priority in water allocation to the domestic and services sectors with second priority to the industrial sector. The shortfall of 4.47 MCM has occurred on the expenses of water allocated to industries. This is a major problem in the model that should be modified to consider all sector of the same importance or at least give the users the option of determining allocation priority.

For the second growth model with 36 % UFW, supply to demand ratio has dropped to about 54 % with a total shortfall of 9.67 MCM and a system reliability of 48.44 %. (Figure 29) However, this would be a major water deficit that will occur by the year 2020 unless certain supply and demand management measures are taken. Again, low priority was given to the industrial sector by looking to the sectoral water demand (Figure 30) where the supply to demand ratio has been calculated as 4%.

The situation for the high growth model with keeping the UFW as 36 % is more severe. The supply demand ratio has dropped to 40.69 % with a total shortfall of 16.41 MCM. The system reliability has also dropped to 32.3 % (Figure 31). For sectoral water demand (Figure 32), S/D ratio was calculated as 89.83 while it was zero for the industrial sector and 8. 33 % for the services. The same explanation can be given and the same intervention can be suggested for model development in improving the model performance and reducing the UFW. The annual return flow (treated wastewater) that can be generated could reach about 2.5 MCM which could be used for restricted irrigation and landscaping. In additions, industrial wastewater can be recycled or reused for cooling and washing raw material.

6.10.3 Scenarios using Demand Management Option.

Considering the results of the previous set of scenarios where the current responses has been kept as it is; i.e continuous assumption of 36 % UFW, the latter could be reduced to reasonable and achievable figure of 25 %. This can be considered as demand management option and thus three runs were performed under the three growth models. The results (Figure 33, 35 and 37) indicates that the supply to demand ratio has reached 84.10 %, 63.19 % and 47.69 %, respectively under the three growth models indicating that shortage is increasing. If the medium growth model is adopted, which is more likely, the water management analysis will be different. In this case, out of 17.5 MCM as a total supply, only 5.06 MCM or 28.94 % were lost as UFW and other physical losses. The system reliability was 56.4 % and the total shortfall reached 44.41 MCM. The mass budget summary Table in Figure 36 reveals that S/D for domestic sector is 98.59 and for services, it is 81.23 % while for the industrial sector, the S/D has reached 19.53 %. The system reliability for the domestic sector is 40.23 % while there is no reliability in the system for the industrial sectors. The total amount of generated wastewater can reach 2.54 MCM that can be used again for irrigation and landscaping.

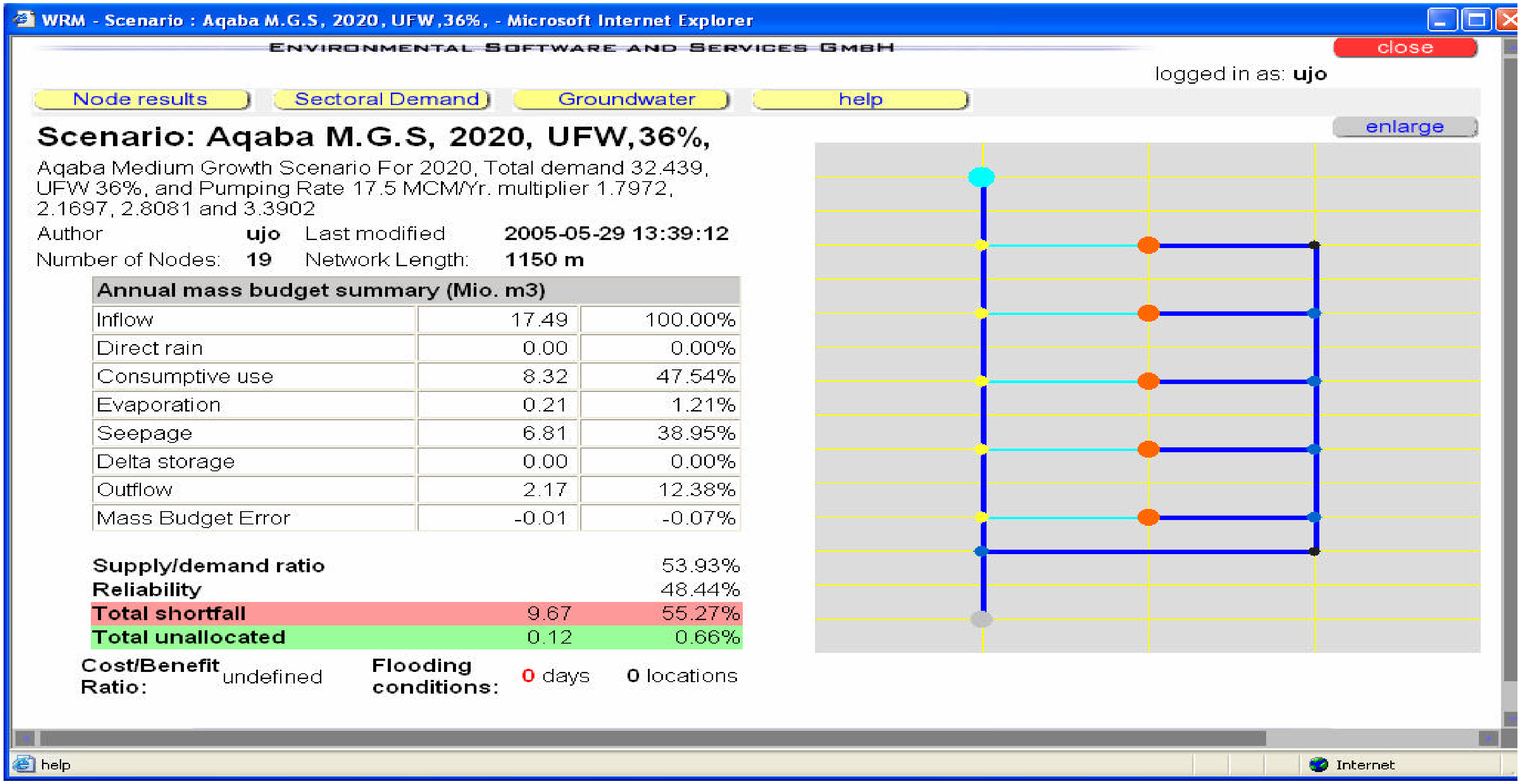

Figure 29 : Annual Mass Budget for the Medium Growth Scenario for the Year 2020 When the UFW 36 %.

http://aca.ess.co.at/WRM/MODEL/results.php?rnet_id=439 - Microsoft Internet Explorer

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Scenario: Aqaba M.G.S, 2020, UFW,36%,

Aqaba Medium Growth Scenario For 2020, Total demand 32.439, UFW 36%, and Pumping Rate 17.5 MCM/Yr. multiplier 1.7972, 2.1697, 2.8081 and 3.3902

Author	**ujo**	Last modified	**2005-05-29 13:39:12**
Number of Nodes:	**19**	Network Length:	**1150 m**

Annual Sectoral Demand

	Demand (Mm3)	NetSupply (Mm3)	Cons.use (Mm3)	Losses (Mm3)	Shortfall (Mm3)	Unallocated (Mm3)	Supply/demand (%)	Reliability (%)
Domestic	9.07	8.89	6.59	5.58	0.28	0.10	96.95	47.49
Agricultural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	8.83	0.35	0.26	0.22	8.48	0.00	3.98	0.00
Services	2.86	1.96	1.46	1.23	0.91	0.01	68.03	23.29
Generic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	20.76	11.20	8.32	7.02	9.67	0.12	53.42	33.15

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Figure 30: Annual Sectoral Demand for the Medium Growth Scenario for the Year 2020 When the UFW 36 %.

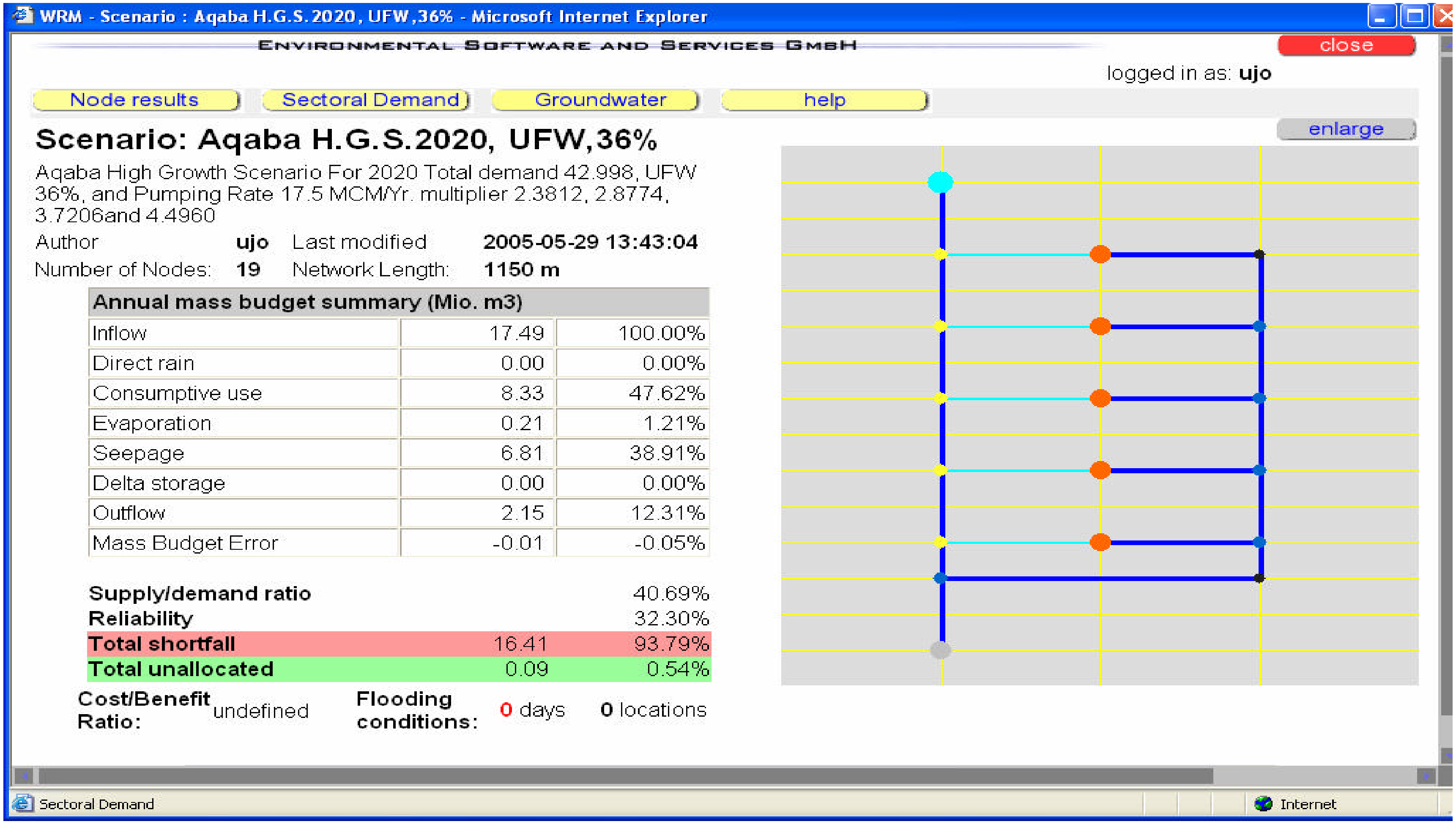

Figure 31: Annual Mass Budget Summary for the High Growth Scenario for the Year 2020 When the UFW 36 %.

http://aca.ess.co.at/WRM/MODEL/results.php?rnet_id=440 - Microsoft Internet Explorer

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Scenario: Aqaba H.G.S.2020, UFW,36%

Aqaba High Growth Scenario For 2020 Total demand 42.998, UFW 36%, and Pumping Rate 17.5 MCM/Yr. multiplier 2.3812, 2.8774, 3.7206and 4.4960

Author	**ujo**	Last modified	**2005-05-29 13:43:04**
Number of Nodes:	**19**	Network Length:	**1150 m**

Annual Sectoral Demand

	Demand (Mm3)	NetSupply (Mm3)	Cons.use (Mm3)	Losses (Mm3)	Shortfall (Mm3)	Unallocated (Mm3)	Supply/demand (%)	Reliability (%)
Domestic	12.01	10.88	8.09	6.82	1.22	0.09	89.83	36.90
Agricultural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	11.71	0.00	0.00	0.00	11.71	0.00	0.00	0.00
Services	3.79	0.32	0.24	0.20	3.48	0.00	8.33	0.00
Generic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	27.51	11.20	8.33	7.02	16.41	0.09	40.37	22.14

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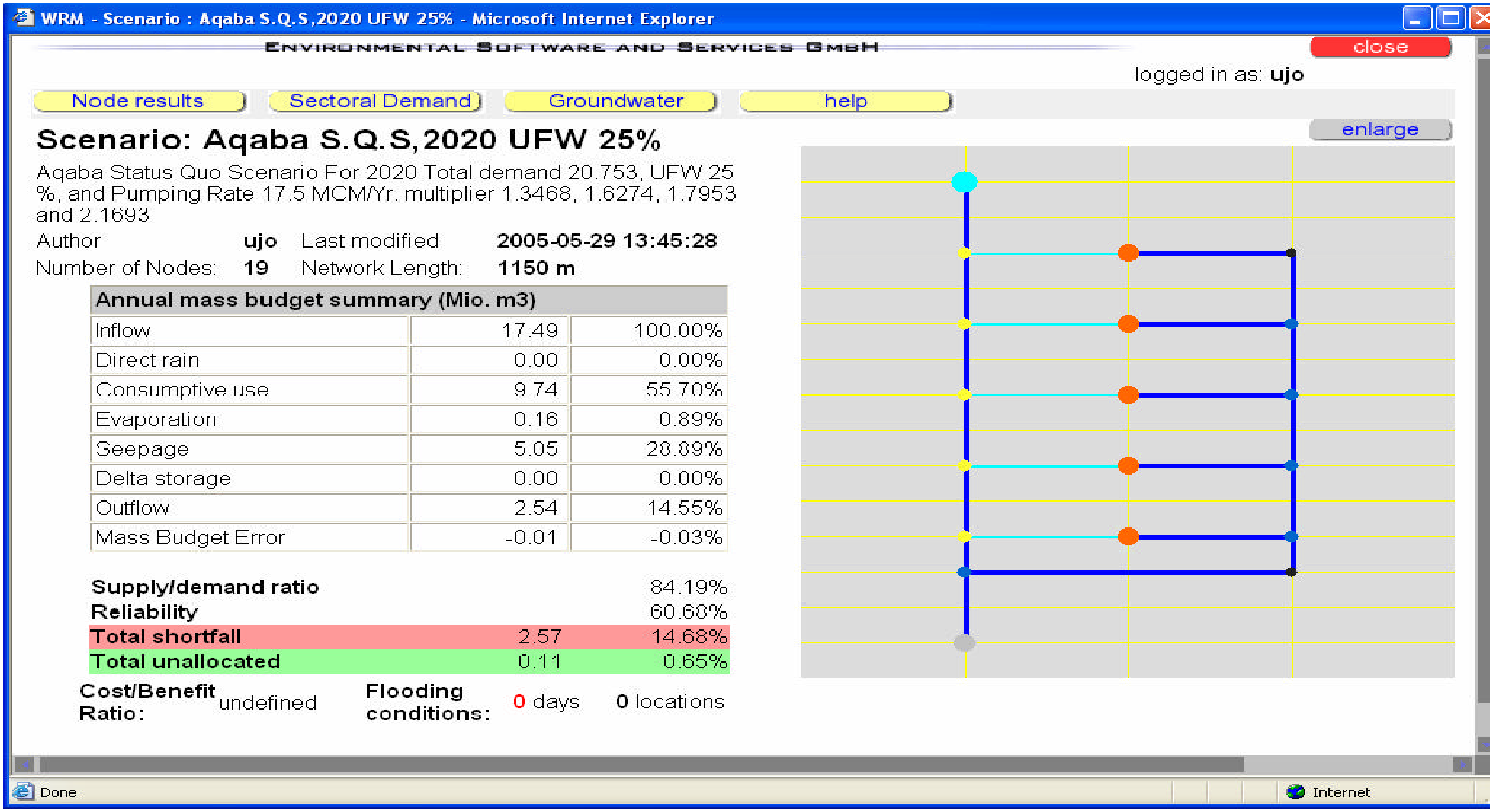
Figure 32: Annual Sectoral Demand for the High Growth Scenario for the Year 2020 When the UFW 36 %.



Annual mass budget summary (Mio. m3)		
Inflow	17.49	100.00%
Direct rain	0.00	0.00%
Consumptive use	9.74	55.70%
Evaporation	0.16	0.89%
Seepage	5.05	28.89%
Delta storage	0.00	0.00%
Outflow	2.54	14.55%
Mass Budget Error	-0.01	-0.03%
Supply/demand ratio		84.19%
Reliability		60.68%
Total shortfall	2.57	14.68%
Total unallocated	0.11	0.65%

Figure 33: Annual Mass Budget Summary for the Status Quo Scenario for the Year 2020 When the UFW 25%.

http://aca.ess.co.at/WRM/MODEL/results.php?rnet_id=441 - Microsoft Internet Explorer

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Scenario: Aqaba S.Q.S,2020 UFW 25%

Aqaba Status Quo Scenario For 2020 Total demand 20.753, UFW 25 %, and Pumping Rate 17.5 MCM/Yr. multiplier 1.3468, 1.6274, 1.7953 and 2.1693

Author	**ujo**	Last modified	**2005-05-29 13:45:28**
Number of Nodes:	**19**	Network Length:	**1150 m**

Annual Sectoral Demand

	Demand (Mm3)	NetSupply (Mm3)	Cons.use (Mm3)	Losses (Mm3)	Shortfall (Mm3)	Unallocated (Mm3)	Supply/demand (%)	Reliability (%)
Domestic	6.79	6.79	5.03	2.70	0.09	0.09	98.73	51.05
Agricultural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	6.62	4.18	3.13	1.65	2.45	0.00	63.07	2.19
Services	2.14	2.13	1.58	0.85	0.04	0.03	98.28	50.96
Generic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	15.56	13.11	9.74	5.21	2.57	0.11	83.50	41.26

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Figure 34: Annual Sectoral Demand for the Status Quo Scenario for the Year 2020 When the UFW 25%.

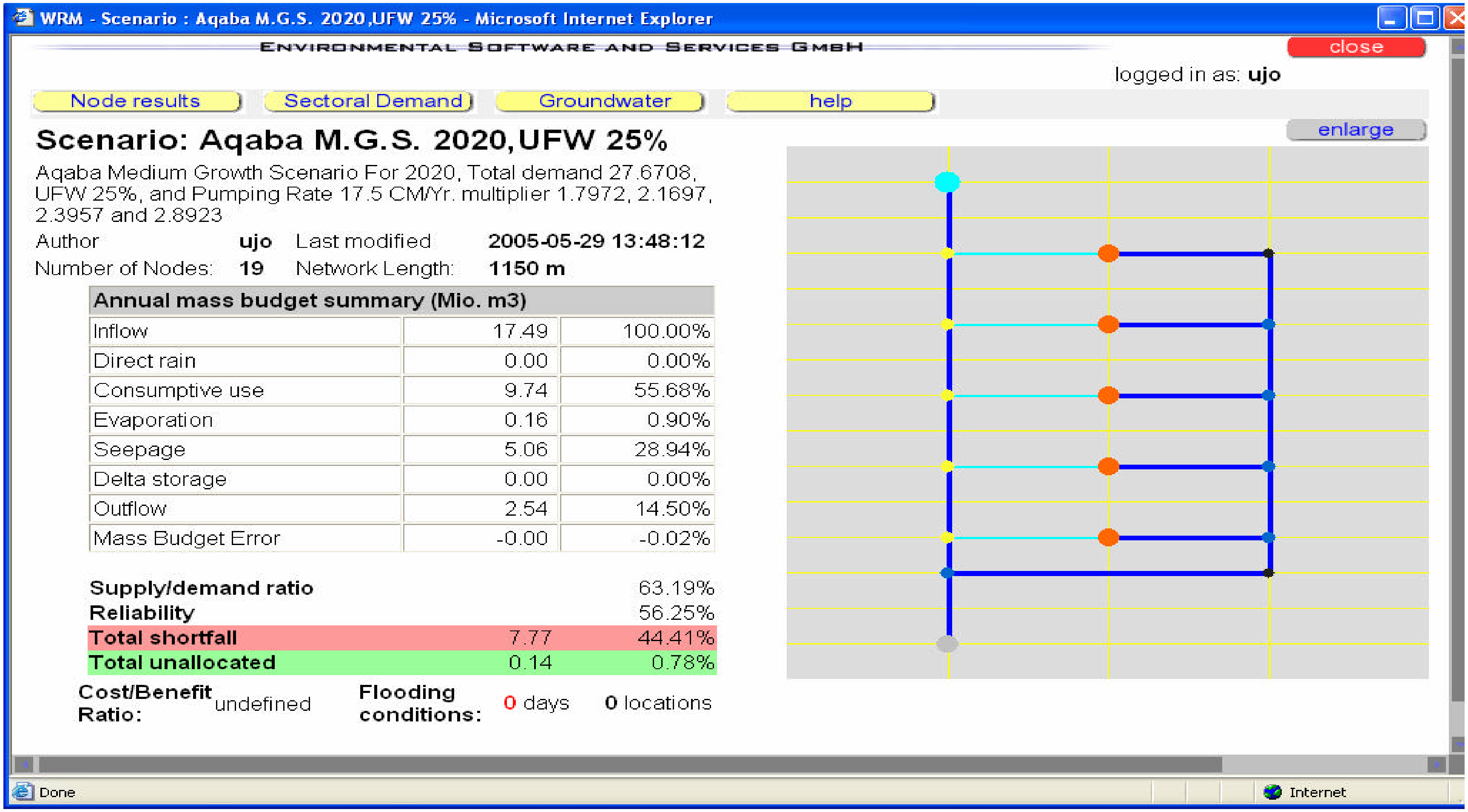

Figure 35: Annual Mass Budget for the Medium Growth Scenario for the Year 2020 When the UFW 25%.

http://aca.ess.co.at/WRM/MODEL/results.php?rnet_id=442 - Microsoft Internet Explorer

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Scenario: Aqaba M.G.S. 2020,UFW 25%

Aqaba Medium Growth Scenario For 2020, Total demand 27.6708, UFW 25%, and Pumping Rate 17.5 CM/Yr. multiplier 1.7972, 2.1697, 2.3957 and 2.8923

Author	**ujo**	Last modified	**2005-05-29 13:48:12**
Number of Nodes:	**19**	Network Length:	**1150 m**

Annual Sectoral Demand

	Demand (Mm3)	NetSupply (Mm3)	Cons.use (Mm3)	Losses (Mm3)	Shortfall (Mm3)	Unallocated (Mm3)	Supply/demand (%)	Reliability (%)
Domestic	9.07	9.05	6.70	3.60	0.13	0.11	98.59	50.23
Agricultural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	8.83	1.72	1.29	0.68	7.10	0.00	19.53	0.00
Services	2.86	2.35	1.74	0.93	0.54	0.02	81.23	39.45
Generic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	20.76	13.12	9.74	5.22	7.77	0.14	62.57	38.03

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Figure 36: Annual Sectoral Demand for the Medium Growth Scenario for the Year 2020 When the UFW 25%.

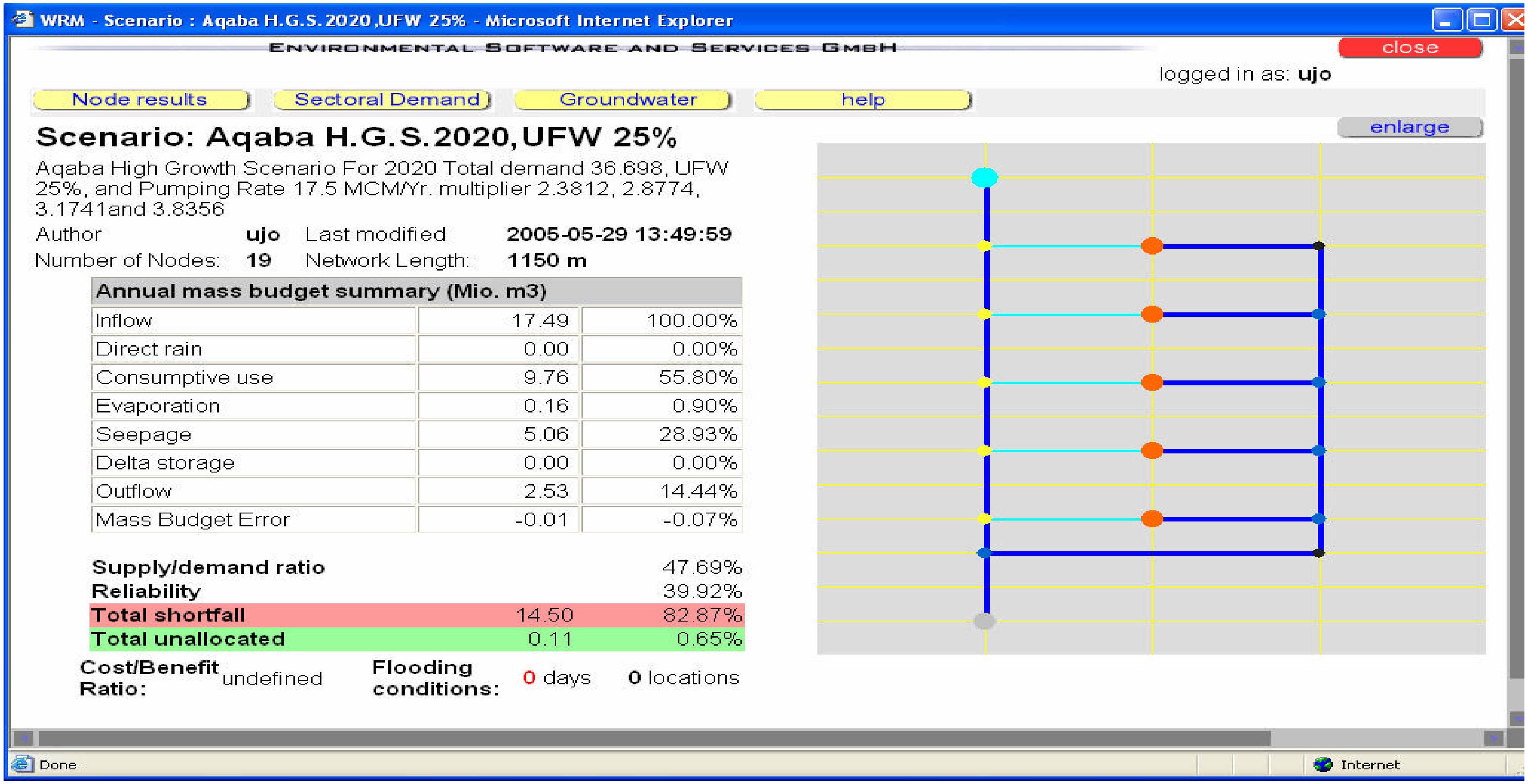

Figure 37: Annual Mass Budget for the High Growth Scenario for the Year 2020 When the UFW 25%.

http://aca.ess.co.at/WRM/MODEL/results.php?rnet_id=443 - Microsoft Internet Explorer

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logged in as: **ujo**

Scenario: Aqaba H.G.S.2020,UFW 25%

Aqaba High Growth Scenario For 2020 Total demand 36.698, UFW 25%, and Pumping Rate 17.5 MCM/Yr. multiplier 2.3812, 2.8774, 3.1741and 3.8356

Author	**ujo**	Last modified	**2005-05-29 13:49:59**
Number of Nodes:	**19**	Network Length:	**1150 m**

Annual Sectoral Demand

	Demand (Mm3)	NetSupply (Mm3)	Cons.use (Mm3)	Losses (Mm3)	Shortfall (Mm3)	Unallocated (Mm3)	Supply/demand (%)	Reliability (%)
Domestic	12.01	11.46	8.51	4.56	0.66	0.11	94.49	44.20
Agricultural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	11.71	0.03	0.02	0.01	11.68	0.00	0.25	0.00
Services	3.79	1.64	1.23	0.65	2.16	0.00	43.15	4.38
Generic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	27.51	13.13	9.76	5.22	14.50	0.11	47.31	27.40

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Figure 38: Annual Sectoral Demand for the High Growth Scenario for the Year 2020 When the UFW 25 %.

6.10.4 Scenario using Supply Management Option

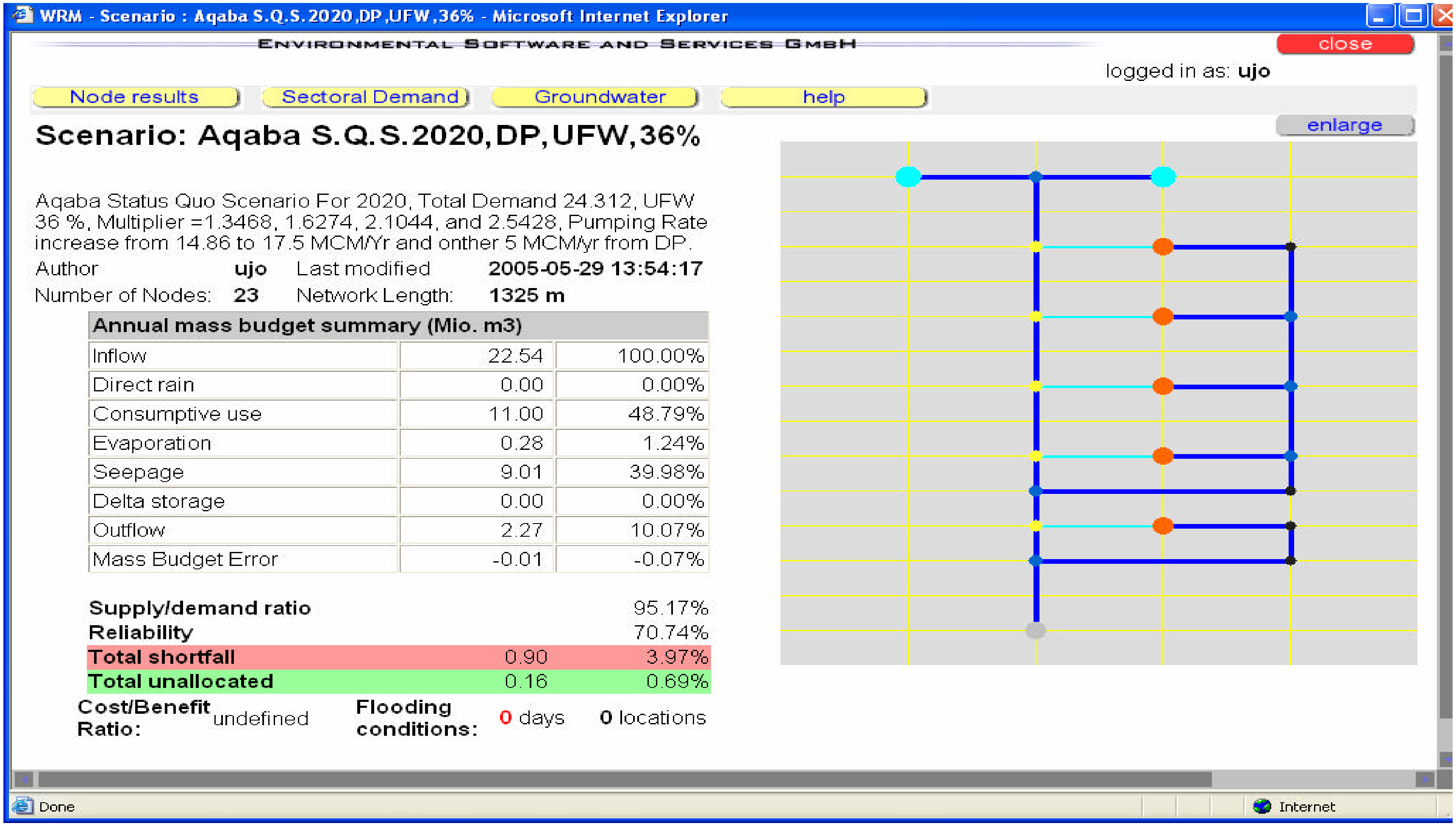
In this case, the UFW was kept at 36 % level but the supplies was augmented through desalination water considering the shortages that were obtained from the three runs under the current responses which were 4.47 MCM, 9.67 MCM and 16.41 MCM; respectively for the three growth models.

Under the low growth model (3.3 %), an additional amount of 5 MCM of desalinized water is needed to overcome the water shortage. Under this option, the model results (Figure 39) indicate that the global S/D ratio and the system reliability are 95.17 and 70.74 % respectively while the shortfall is 0.9 MCM. The annual sectoral demand results (Figure 40) show that the S/D ratio for all sectors were relatively high; they were 98.74 %, 88.20 % and 98.62 % for the domestic, industrial and services sectors respectively. An amount of 2.27 MCM could be generated as wastewater that can also be used for restricted agriculture use and landscape irrigation.

For the medium growth model (5.3 %), the actual demand reached 20.76 MCM and the losses were 11.82 MCM while the global S/D ratio was 90.86 and a reliability value of 63.59 was obtained (Figure 41). In this case, an additional 10 MCM of desalinated water was needed to augment the deficit of 9.67 MCM. The results of annual sectoral demand analysis Figure 42 show that the supply to demand ratio of 98.74 %, 78.62 % and 98.10 % are obtained for the different sectors, namely domestic, industrial and services, respectively. An amount of 2.06 MCM can be generated as wastewater.

The total water demand for the high growth model can reach 43.0 MCM by the 2020. This will require a supply intervention by introducing a desalination plant with a capacity of 20 MCM while keeping the UFW at the 36 % level.

In doing that the S/D ratio can reach 92.73 % and the reliability would be moderate in the order of 66.22 % (Figure 43). The total shortfall is relatively small of about 6% and the total unallocated water is also small of about 0.24 MCM. In viewing the results of annual sectoral demand as show n in (Figure 44) , it can be concluded that S/D ratio for the different sectors are high; they are 98.74 %, 82.82 % and 98.36 % for the domestic, industrial and services sectors, respectively. The amount of generated wastewater can reach 2.62 MCM.



Annual mass budget summary (Mio. m3)		
Inflow	22.54	100.00%
Direct rain	0.00	0.00%
Consumptive use	11.00	48.79%
Evaporation	0.28	1.24%
Seepage	9.01	39.98%
Delta storage	0.00	0.00%
Outflow	2.27	10.07%
Mass Budget Error	-0.01	-0.07%

Supply/demand ratio		95.17%
Reliability		70.74%
Total shortfall	0.90	3.97%
Total unallocated	0.16	0.69%

Figure 39: Annual Mass Budget Summary for the Status Quo Scenario for the Year 2020 with the Desalination Plant and UFW 36% .

http://aca.ess.co.at/WRM/MODEL/results.php?rnet_id=449 - Microsoft Internet Explorer

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Scenario: Aqaba S.Q.S.2020,DP,UFW,36%

Aqaba Status Quo Scenario For 2020, Total Demand 24.312, UFW 36 %, Multiplier =1.3468, 1.6274, 2.1044, and 2.5428, Pumping Rate increase from 14.86 to 17.5 MCM/Yr and onther 5 MCM/yr from DP.

Author	**ujo**	Last modified	**2005-05-29 13:54:17**
Number of Nodes:	**23**	Network Length:	**1325 m**

Annual Sectoral Demand

	Demand (Mm3)	NetSupply (Mm3)	Cons.use (Mm3)	Losses (Mm3)	Shortfall (Mm3)	Unallocated (Mm3)	Supply/demand (%)	Reliability (%)
Domestic	6.79	6.79	5.03	4.26	0.09	0.09	98.74	51.87
Agricultural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	6.62	5.88	4.38	3.68	0.78	0.04	88.20	35.89
Services	2.14	2.14	1.59	1.34	0.03	0.03	98.62	52.05
Generic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	15.56	14.82	11.00	9.29	0.90	0.15	94.24	48.71

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Figure 40: Annual Sectoral Demand for the Stuts Quo Scenario for the Year 2020 with Desalination Plant and UFW 36 %

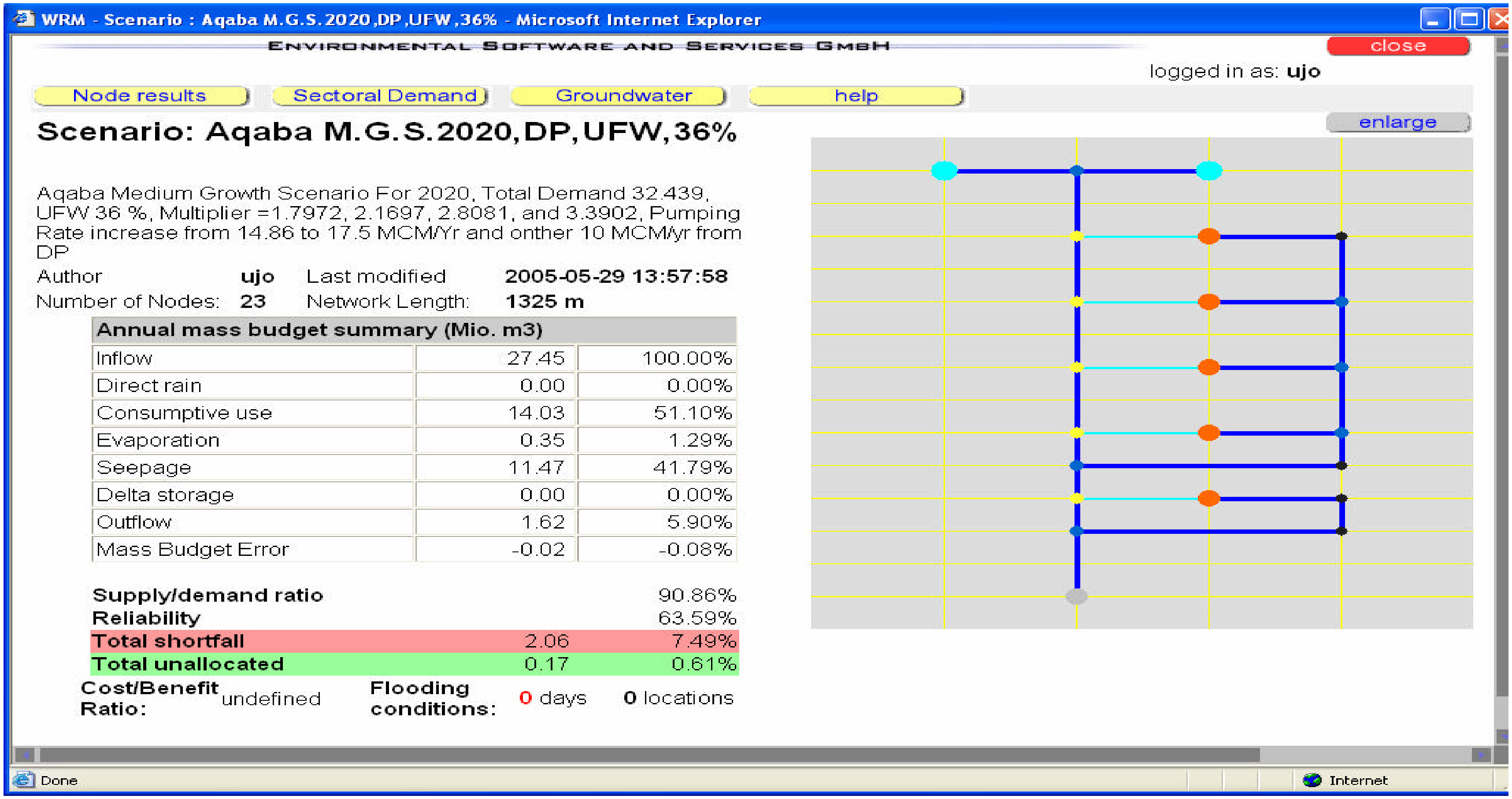

Figure 41: **Annual Mass Budget Summary for the Medium Growth Scenario for the Year 2020 with the Desalination Plant and UFW 36%.**

http://aca.ess.co.at/WRM/MODEL/results.php?rnet_id=447 - Microsoft Internet Explorer

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Scenario: Aqaba M.G.S.2020,DP,UFW,36%

Aqaba Medium Growth Scenario For 2020, Total Demand 32.439, UFW 36 %, Multiplier =1.7972, 2.1697, 2.8081, and 3.3902, Pumping Rate increase from 14.86 to 17.5 MCM/Yr and onther 10 MCM/yr from DP

Author	**ujo**	Last modified	**2005-05-29 13:57:58**
Number of Nodes:	**23**	Network Length:	**1325 m**

Annual Sectoral Demand

	Demand (Mm3)	NetSupply (Mm3)	Cons.use (Mm3)	Losses (Mm3)	Shortfall (Mm3)	Unallocated (Mm3)	Supply/demand (%)	Reliability (%)
Domestic	9.07	9.07	6.71	5.69	0.11	0.12	98.74	51.42
Agricultural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	8.83	6.96	5.21	4.35	1.89	0.02	78.62	13.42
Services	2.86	2.84	2.11	1.78	0.05	0.04	98.10	50.14
Generic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	20.76	18.87	14.03	11.82	2.06	0.17	90.09	43.56

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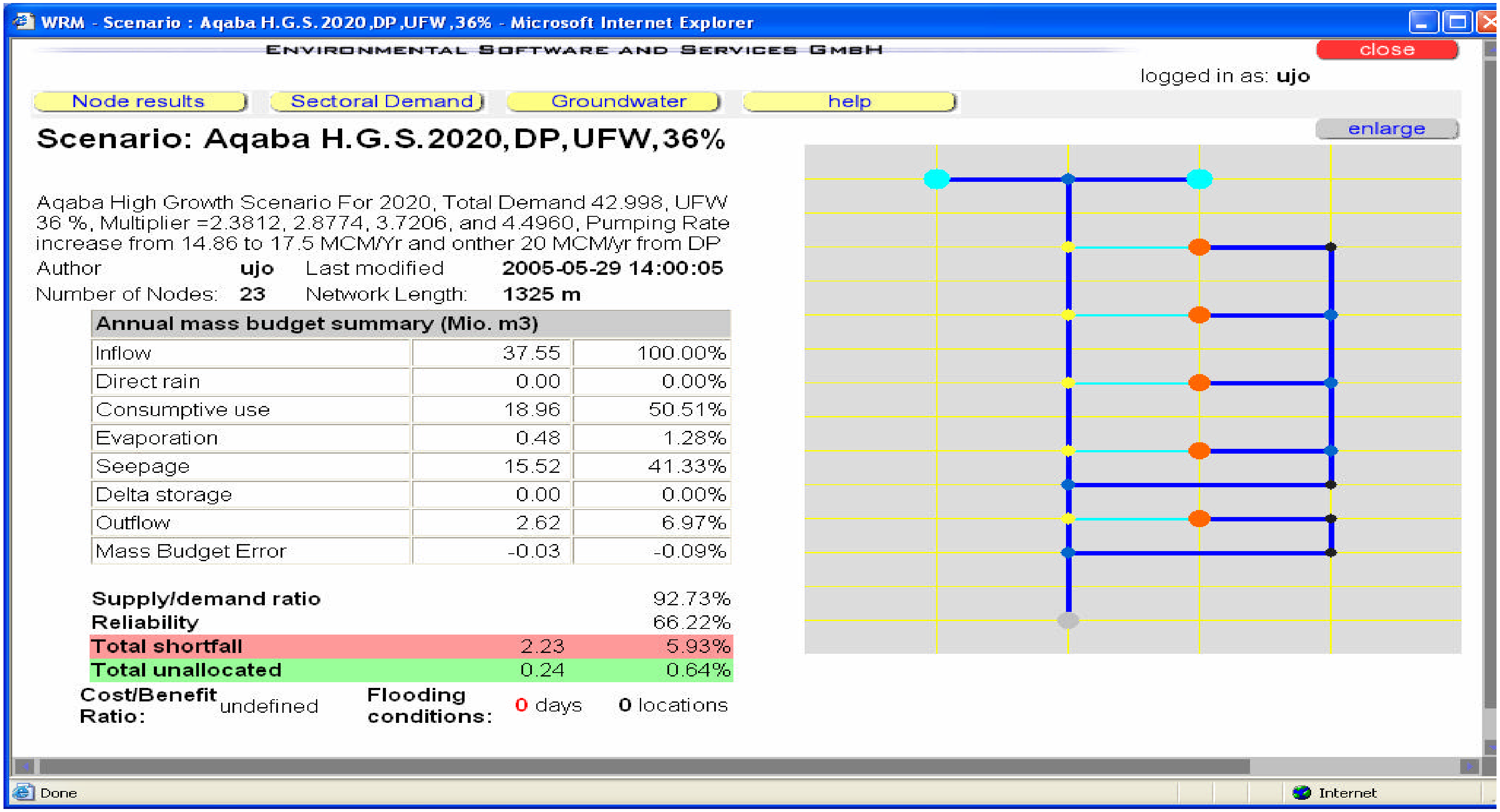
Figure 42: Annual Sectoral Demand for the Medium Growth Scenario for the Year 2020 with Desalination Plant and UFW 36 %


WRM - Scenario : Aqaba H.G.S.2020,DP,UFW,36% - Microsoft Internet Explorer

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Scenario: Aqaba H.G.S.2020,DP,UFW,36%

Aqaba High Growth Scenario For 2020, Total Demand 42.998, UFW 36 %, Multiplier =2.3812, 2.8774, 3.7206, and 4.4960, Pumping Rate increase from 14.86 to 17.5 MCM/Yr and onther 20 MCM/yr from DP

Author	**ujo**	Last modified	**2005-05-29 14:00:05**
Number of Nodes:	**23**	Network Length:	**1325 m**

Annual mass budget summary (Mio. m3)		
Inflow	37.55	100.00%
Direct rain	0.00	0.00%
Consumptive use	18.96	50.51%
Evaporation	0.48	1.28%
Seepage	15.52	41.33%
Delta storage	0.00	0.00%
Outflow	2.62	6.97%
Mass Budget Error	-0.03	-0.09%

Supply/demand ratio		92.73%
Reliability		66.22%
Total shortfall	2.23	5.93%
Total unallocated	0.24	0.64%

Cost/Benefit Ratio: undefined **Flooding conditions:** 0 days 0 locations

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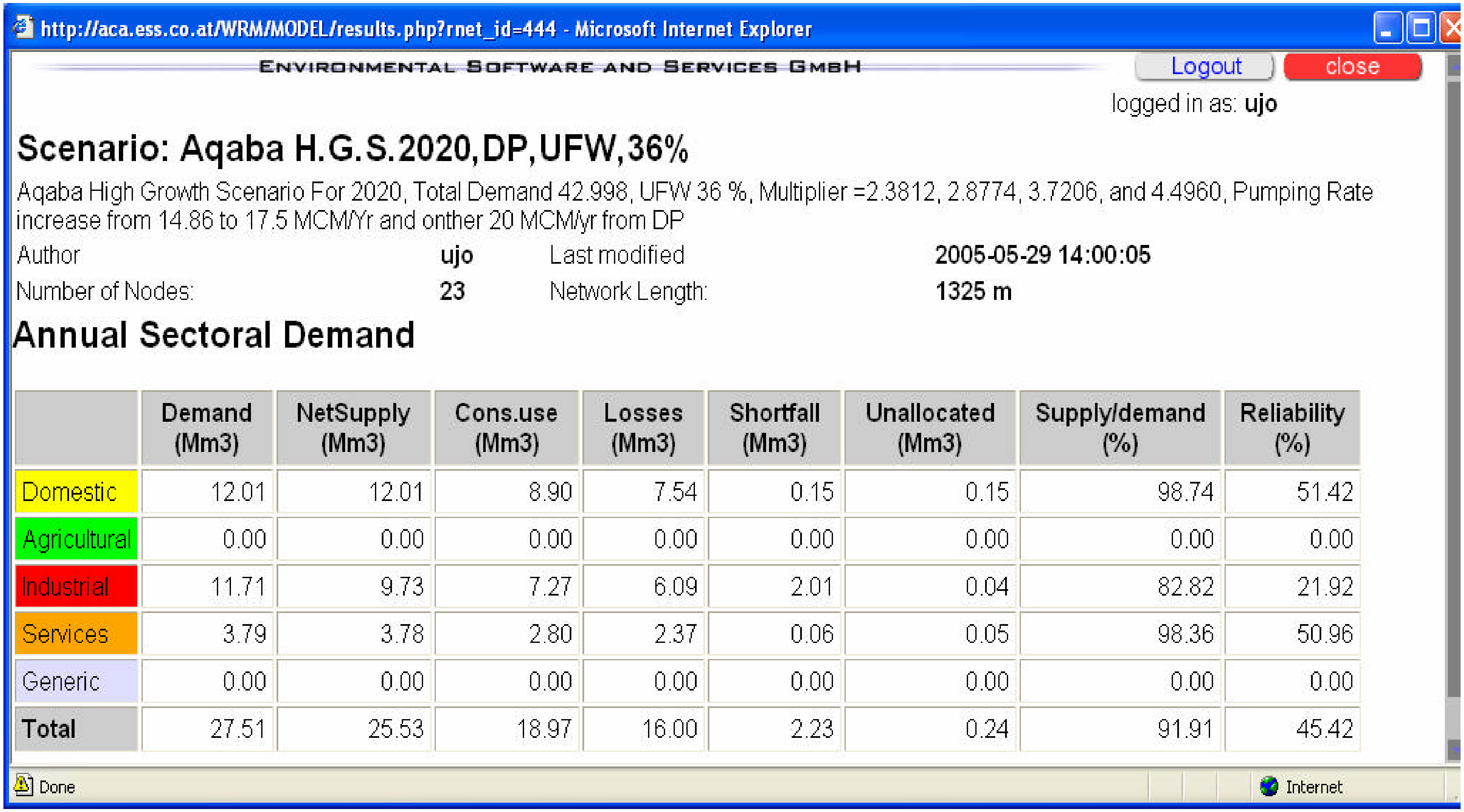
Figure 43: Annual Mass Budget Summary for the High Growth Scenario for the Year 2020 with the Desalination Plant and UFW 36% .



http://aca.ess.co.at/WRM/MODEL/results.php?rnet_id=444 - Microsoft Internet Explorer

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Scenario: Aqaba H.G.S.2020,DP,UFW,36%

Aqaba High Growth Scenario For 2020, Total Demand 42.998, UFW 36 %, Multiplier =2.3812, 2.8774, 3.7206, and 4.4960, Pumping Rate increase from 14.86 to 17.5 MCM/Yr and onther 20 MCM/yr from DP

Author	**ujo**	Last modified	**2005-05-29 14:00:05**
Number of Nodes:	**23**	Network Length:	**1325 m**

Annual Sectoral Demand

	Demand (Mm3)	NetSupply (Mm3)	Cons.use (Mm3)	Losses (Mm3)	Shortfall (Mm3)	Unallocated (Mm3)	Supply/demand (%)	Reliability (%)
Domestic	12.01	12.01	8.90	7.54	0.15	0.15	98.74	51.42
Agricultural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	11.71	9.73	7.27	6.09	2.01	0.04	82.82	21.92
Services	3.79	3.78	2.80	2.37	0.06	0.05	98.36	50.96
Generic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	27.51	25.53	18.97	16.00	2.23	0.24	91.91	45.42

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Figure 44: Annual Sectoral Demand for the High Growth Scenario for the Year 2020 with Desalination Plant and UFW 36 %

6.10.5 Scenario using Demand and Supply Management Options.

In this case, the UFW was reduced from 36 % to 25 % as a demand management option and supply as increased by adding desalination plants of different capacity according to deficit. Three runs were made under the three growth model.

For the low growth model, an additional water supply of 5 MCM were needed which can come from a desalination plant Table in Figure 45 shows that the global S/D ratio is 97.94 and the reliability is 77.23 whereas the total shortfall of 0.48 is recorded and amount of 1.78 MCM has not been allocated. The amount of treated effluent that can be used for irrigation has been calculated by the model as 4.24 MCM.

Figure 46 shows the results of the annual sectoraldemand; from which the S/D ratio for the domestic, industrial and services are 98.73 %, 94.01 % and 100 % respectively. Adopting this option may fulfill the system requirement and any possible shortage.

Table in Figure 47 shows the annual mass budget summary under the medium growth model which indicates that the supply to demand ratio is 97.17 % and the reliability is 71.86 %. The total supply has reached 27.5 MCM with UFW of 7.8 MCM. The annual sectoral demand results in Figure 48 shows the S/D for different sectors as 98.73 %, 92.67 % and 98.70 % for the three sectors respectively. The generated wastewater amount of 4.46 MCM can be reused for irrigation and/ or recycled in the industries.

The results of scenario under the high growth are shown in Figure 49 and 50 indicating a S/D ratio of 97.79 %. This is achieved by augmenting additional 20 MCM of desalination water to have a total supply of 37.5 MCM. The amount of shortfall and the unallocated water are minimum with less than 1 MCM. Sectoral S/D ratios show that their values are above 90 % indicating good system adequacy and high satisfaction with losses of 10.4 MCM. Significant amount of treated waste water have been generated, which should be used for irrigation or other purposes.

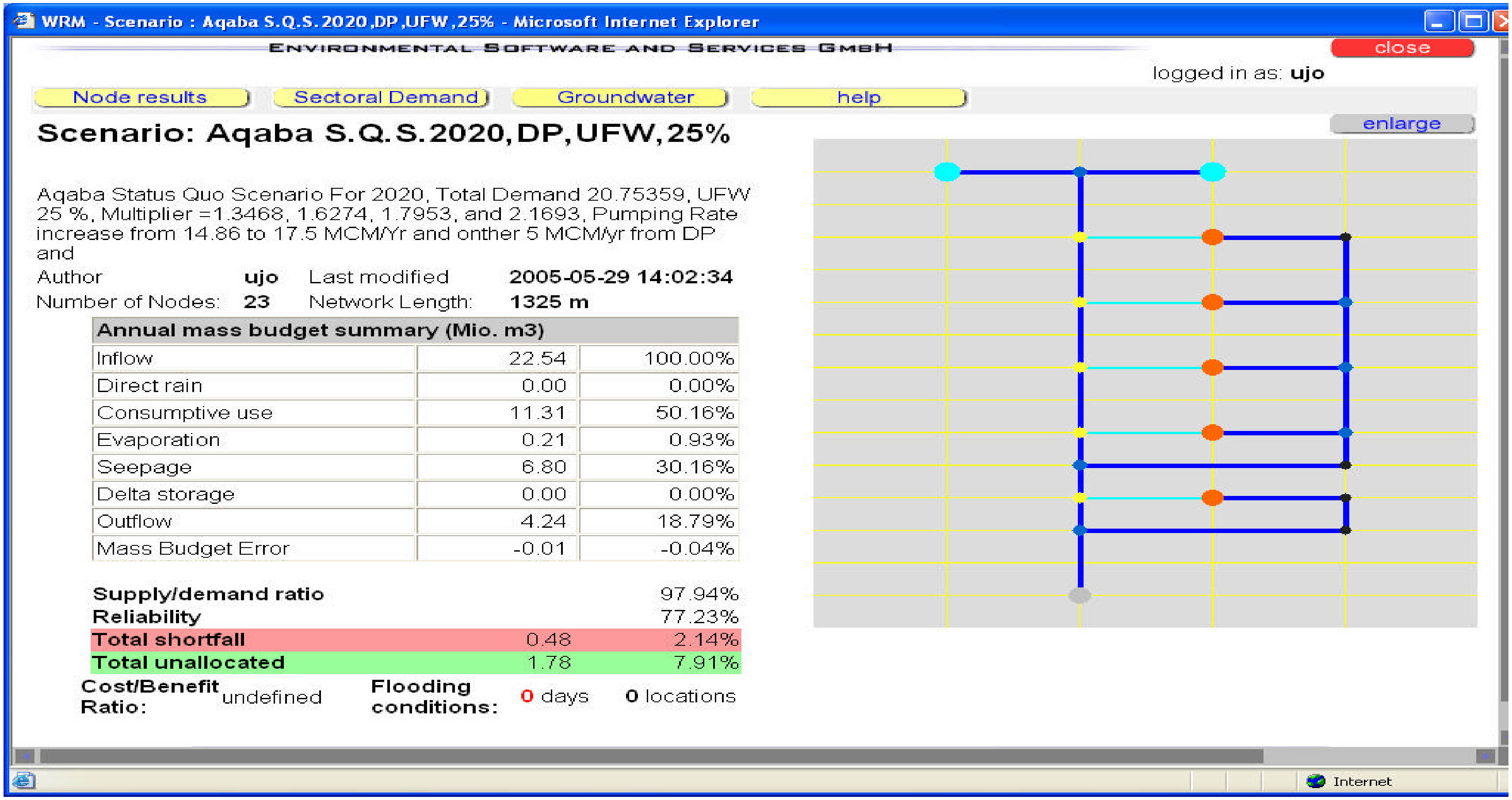
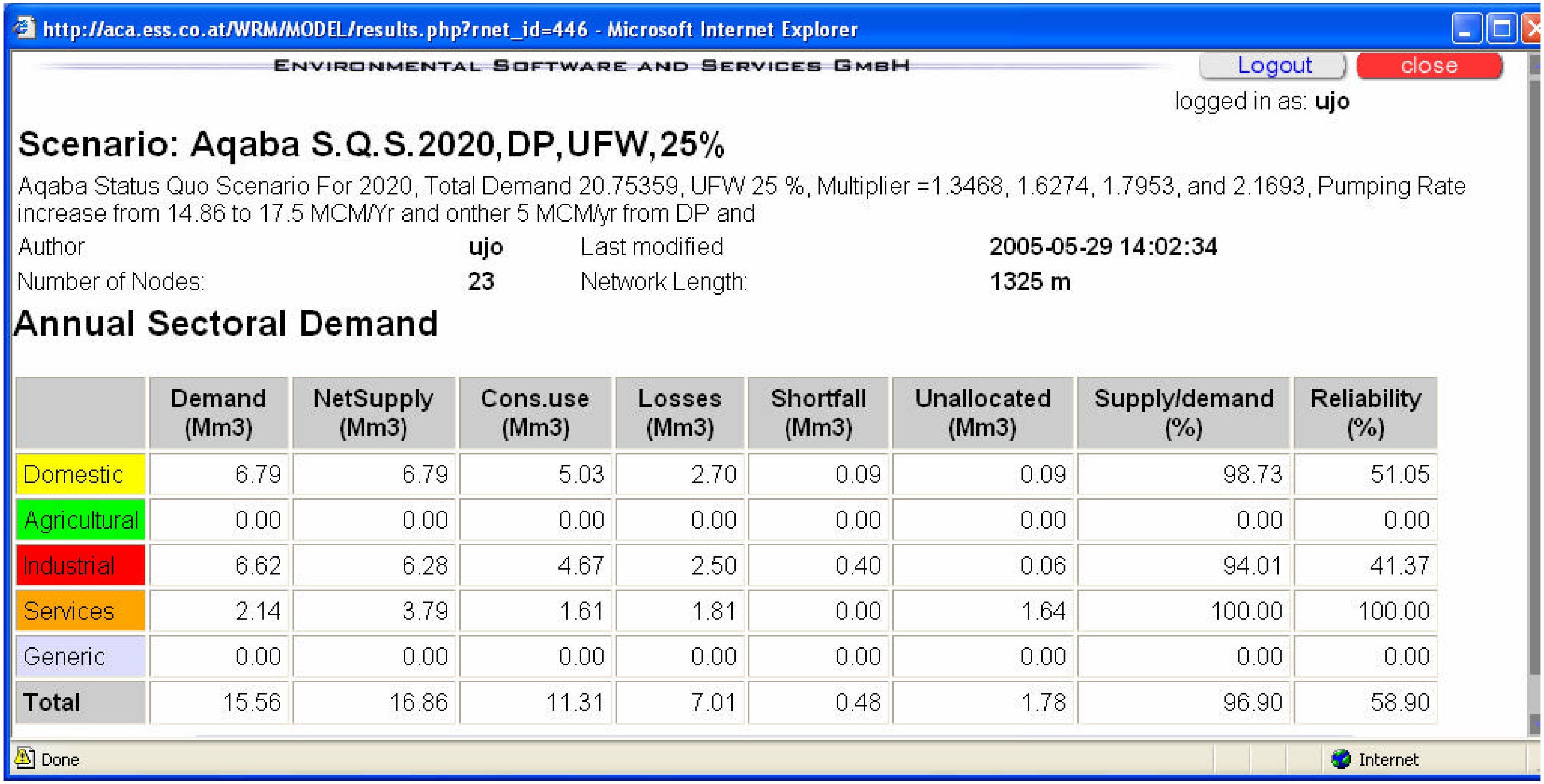


Figure 45: Annual Mass Budget Summary for the Status Quo Scenario for the Year 2020 with the Desalination Plant and UFW 25% .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Scenario: Aqaba S.Q.S.2020,DP,UFW,25%

Aqaba Status Quo Scenario For 2020, Total Demand 20.75359, UFW 25 %, Multiplier =1.3468, 1.6274, 1.7953, and 2.1693, Pumping Rate increase from 14.86 to 17.5 MCM/Yr and onther 5 MCM/yr from DP and

Author	**ujo**	Last modified	**2005-05-29 14:02:34**
Number of Nodes:	**23**	Network Length:	**1325 m**

Annual Sectoral Demand

	Demand (Mm3)	NetSupply (Mm3)	Cons.use (Mm3)	Losses (Mm3)	Shortfall (Mm3)	Unallocated (Mm3)	Supply/demand (%)	Reliability (%)
Domestic	6.79	6.79	5.03	2.70	0.09	0.09	98.73	51.05
Agricultural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	6.62	6.28	4.67	2.50	0.40	0.06	94.01	41.37
Services	2.14	3.79	1.61	1.81	0.00	1.64	100.00	100.00
Generic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	15.56	16.86	11.31	7.01	0.48	1.78	96.90	58.90

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Figure 46: Annual Sectoral Demand for the Stuts Quo Scenario for the Year 2020 with Desalination Plant and UFW 25 %

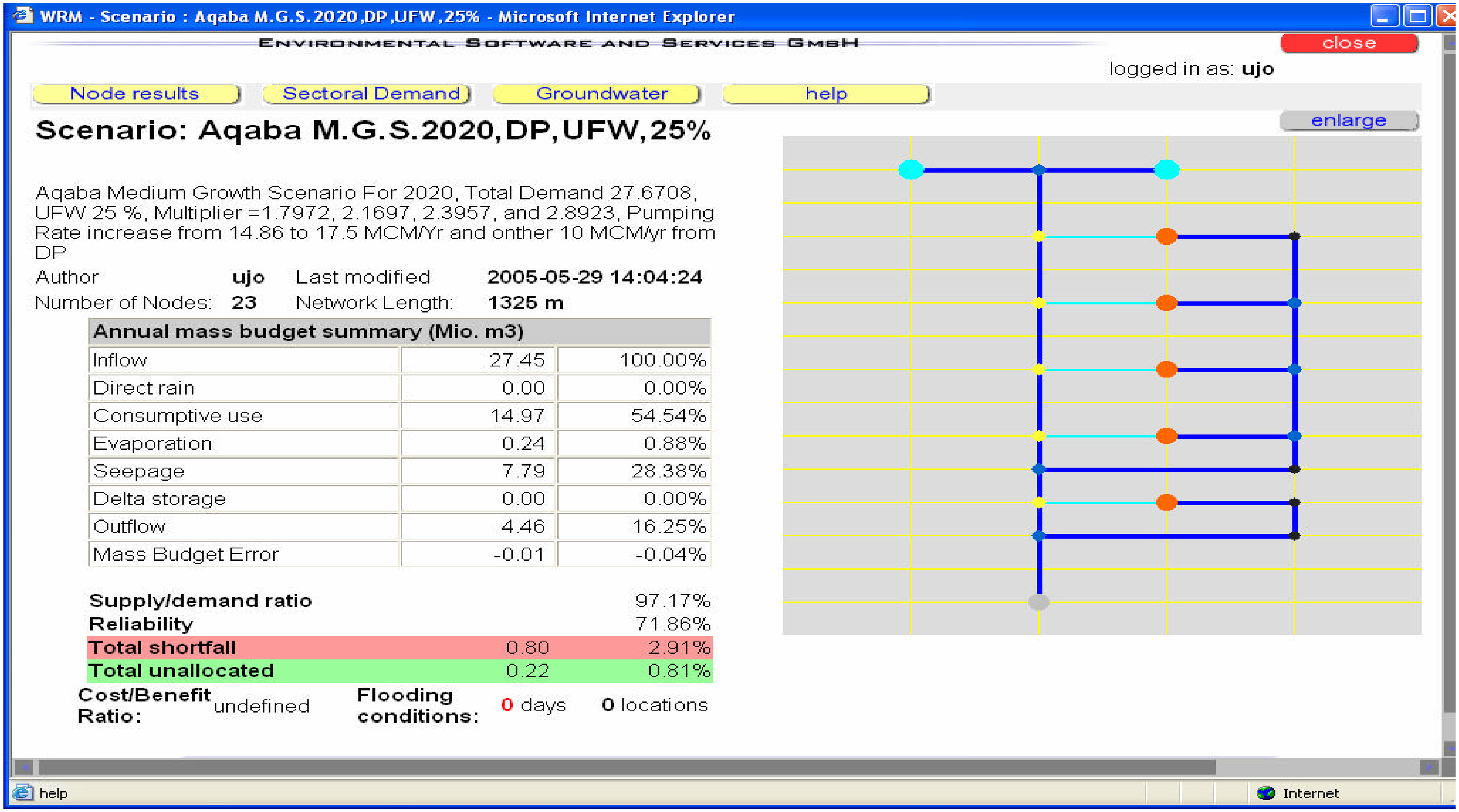

Figure 47: Annual Mass Budget Summary for the Medium Growth Scenario for the Year 2020 with the Desalination Plant and UFW 25% .

http://aca.ess.co.at/WRM/MODEL/results.php?rnet_id=448 - Microsoft Internet Explorer

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Scenario: Aqaba M.G.S.2020,DP,UFW,25%

Aqaba Medium Growth Scenario For 2020, Total Demand 27.6708, UFW 25 %, Multiplier =1.7972, 2.1697, 2.3957, and 2.8923, Pumping Rate increase from 14.86 to 17.5 MCM/Yr and onther 10 MCM/yr from DP

Author	**ujo**	Last modified	**2005-05-29 14:04:24**
Number of Nodes:	**23**	Network Length:	**1325 m**

Annual Sectoral Demand

	Demand (Mm3)	NetSupply (Mm3)	Cons.use (Mm3)	Losses (Mm3)	Shortfall (Mm3)	Unallocated (Mm3)	Supply/demand (%)	Reliability (%)
Domestic	9.07	9.06	6.71	3.61	0.12	0.11	98.73	51.05
Agricultural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	8.83	8.25	6.14	3.28	0.65	0.07	92.67	38.90
Services	2.86	2.86	2.12	1.14	0.04	0.04	98.70	51.51
Generic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	20.76	20.18	14.97	8.03	0.80	0.22	96.15	48.71

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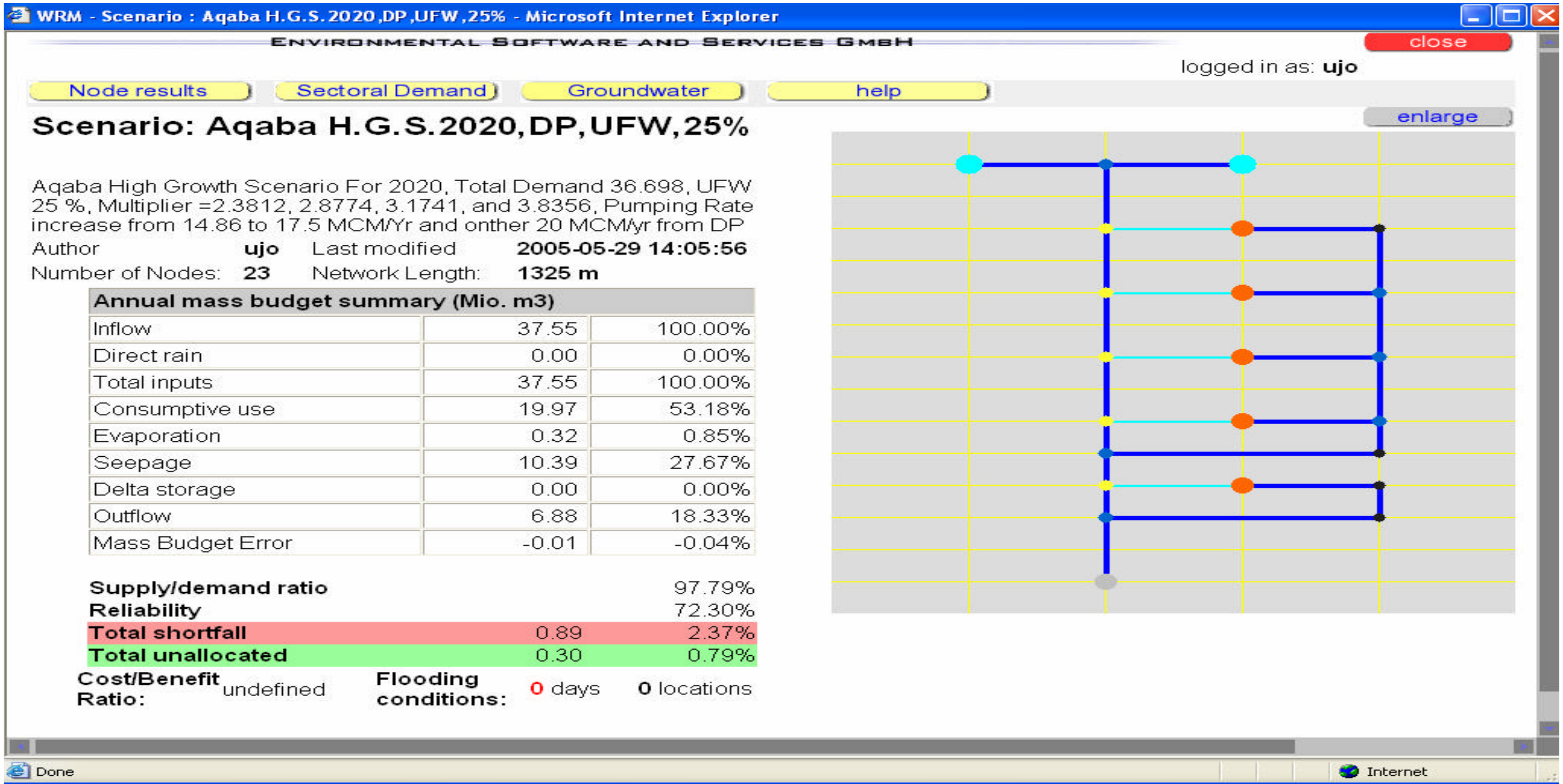
Figure 48: Annual Sectoral Demand for the Medium Growth Scenario for the Year 2020 with Desalination Plant and UFW 25 %


WRM - Scenario : Aqaba H.G.S.2020,DP,UFW,25% - Microsoft Internet Explorer

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Node results | Sectoral Demand | Groundwater | help

enlarge

Scenario: Aqaba H.G.S.2020,DP,UFW,25%

Aqaba High Growth Scenario For 2020, Total Demand 36.698, UFW 25 %, Multiplier =2.3812, 2.8774, 3.1741, and 3.8356, Pumping Rate increase from 14.86 to 17.5 MCM/Yr and onther 20 MCM/yr from DP

Author **ujo** Last modified **2005-05-29 14:05:56**

Number of Nodes: **23** Network Length: **1325 m**

Annual mass budget summary (Mio. m3)		
Inflow	37.55	100.00%
Direct rain	0.00	0.00%
Total inputs	37.55	100.00%
Consumptive use	19.97	53.18%
Evaporation	0.32	0.85%
Seepage	10.39	27.67%
Delta storage	0.00	0.00%
Outflow	6.88	18.33%
Mass Budget Error	-0.01	-0.04%

Supply/demand ratio		97.79%
Reliability		72.30%
Total shortfall	0.89	2.37%
Total unallocated	0.30	0.79%

Cost/Benefit Ratio: undefined **Flooding conditions:** 0 days 0 locations

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Figure 49: Annual Mass Budget Summary for the High Growth Scenario for the Year 2020 with the Desalination Plant and UFW 25%

http://aca.ess.co.at/WRM/MODEL/results.php?rnet_id=445 - Microsoft Internet Explorer

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logged in as: **ujo**

Scenario: Aqaba H.G.S.2020,DP,UFW,25%

Aqaba High Growth Scenario For 2020, Total Demand 36.698, UFW 25 %, Multiplier =2.3812, 2.8774, 3.1741, and 3.8356, Pumping Rate increase from 14.86 to 17.5 MCM/Yr and onther 20 MCM/yr from DP

Author	**ujo**	Last modified	**2005-05-29 14:05:56**
Number of Nodes:	**23**	Network Length:	**1325 m**

Annual Sectoral Demand

	Demand (Mm3)	NetSupply (Mm3)	Cons.use (Mm3)	Losses (Mm3)	Shortfall (Mm3)	Unallocated (Mm3)	Supply/demand (%)	Reliability (%)
Domestic	12.01	12.01	8.89	4.78	0.15	0.15	98.73	51.05
Agricultural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	11.71	11.12	8.26	4.42	0.69	0.10	94.11	40.55
Services	3.79	3.79	2.81	1.51	0.05	0.05	98.73	51.78
Generic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	27.51	26.92	19.97	10.71	0.89	0.30	96.76	49.10

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Figure 50: Annual Sectoral Demand for the High Growth Scenario for the Year 2020 with Desalination Plant and UFW 25 %

6.10.6 Summary of the Analysis

Table 26 summarizes the results of the 13 model runs in terms of responses under different WRM indicators for the base line of 2003 and the four management options. The current water supply from Disi aquifers is 14.85 MCM and it can be increased to a maximum amount of 17.5 MCM (Aqaba allocation by the MWI). It is clear that Aqaba city will be under deficit by the 2020 unless certain measures are taken. The model has examined these options in which the UFW can practically be reduced from 36% (at the present) to 25% in the future (achievable). The reduction will be gradual so that UFW can be reduced to 30% in 2010 and further be reduced to 25% by the year 2020.

It is anticipated that future responses will include supply and management measures and the medium growth model most likely will prevail, and this would be the optimistic response. As such and in addition to reduction of the UFW to 25%, the supply should be augment through 10 MCM of desalinated water. Under such conditions, the global demand to supply ratio would reach 79.17 and the sectoral S/D ratios will be 98.7%, 92.7% and 98.7% for the domestic, industrial and services sectors, respectively. Table 26 shows that the generated effluent varies from 1.62 MCM to 6.88 MCM. The latter figure agrees with JICA projection (2001) in estimating that the treated effluent can reach 7 MCM by the year 2020.

It is clear from the analysis of sectoral supply to demand ratio that the model gives high priority in water allocation to the domestic and services sectors with less priority to the industrial sector. This would be considered as a major set back to the model and as such, the model should be modified to allow the users to enter their preferences and priority in water allocation to different sectors. As the model is under development, further verification by other users will allow for more flexibility and options to be added.

Table 26. Summary of the Results of the 13 Runs under Different Management Option for the Three Growth Models.

Indicators	Scenarios												
	Baseline	Current response			Water demand management response			Water supply management response			Water supply and demand management response		
	2003	BAU	OPT	PESS	BAU	OPT	PESS	BAU	OPT	PESS	BAU	OPT	PESS
Supply (MCM)	14.85	17.50	17.50	17.50	17.50	17.50	17.50	22.50	27.50	37.50	22.50	27.50	37.50
Population growth (%)	3.30	3.30	5.30	7.30	3.30	5.30	7.30	3.30	5.30	7.30	3.30	5.30	7.30
Multiplier	1.00	1.35	1.80	2.38	1.35	1.80	2.38	1.35	1.80	2.38	1.35	1.80	2.38
Supply/Demand ratio (%)	95.80	71.92	53.93	40.69	84.19	63.19	47.69	95.17	90.86	92.73	97.94	79.17	97.79
Global Efficiency (%)	63.00	60.00	61.57	59.86	70.21	70.15	70.15	58.78	56.93	57.39	68.90	70.75	71.48
Reliability (%)	71.73	58.25	53.93	32.30	60.68	56.25	39.92	70.74	63.59	66.22	77.23	71.86	72.30
Total Shortfall (%)	3.20	25.54	52.27	93.75	14.68	44.41	82.87	3.97	7.49	5.93	2.14	2.91	2.37
Total Unallocated (%)	0.64	0.61	0.66	0.54	0.65	0.78	0.65	0.69	0.61	0.64	7.91	0.81	0.79
Flooding Conditions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sectoral Water Budget (%)													
Domestic (S/D)	98.75	98.74	96.95	89.83	98.73	90.59	94.49	98.74	98.74	98.74	98.73	98.73	98.73
Industrial (S/D)	89.88	36.40	3.98	0.00	63.07	19.53	0.25	88.20	78.62	82.82	94.01	92.67	94.11
Services (S/D)	98.75	92.01	68.03	8.33	98.28	81.23	43.15	98.65	98.10	98.36	100.00	98.70	98.73
Domestic (Reliability)	51.96	51.87	47.49	36.90	51.05	50.23	44.20	51.87	51.42	51.42	51.05	51.05	51.05
Industrial (Reliability)	38.63	0.00	0.00	0.00	2.19	0.00	0.00	35.89	13.12	21.92	41.37	38.90	40.55
Services (Reliability)	52.33	43.84	23.29	0.00	50.96	39.45	4.38	52.05	50.14	50.69	100.00	51.51	51.78
Return flow amount (MCM)	2.76	2.16	2.17	2.15	2.54	2.54	2.53	2.27	1.62	2.62	4.24	4.46	6.88
Return Flow %	18.61	12.34	12.38	12.31	14.55	14.50	14.44	10.17	5.90	6.97	18.79	16.25	18.33

Policy Guidelines for Water Resources Management

7.1 Introduction

Policies are general principles or guidelines articulated by the governing body which set the direction that are intended to be taken by the authority to carry out its function (Shatanawi, 1998). According to the Water Words Dictionary, water policy is defined as the actions governing the management, administration, and procedures used to implement and direct a formal water planning process by which water rights, water use and water diversions are evaluated, ranked and allocated on the basis by legislative mandates, regulations or norms. Policies are intended to serve as guidance for officials as they conduct their work and as information to stakeholder and the general public. Policy statements need to be clearly stated and unambiguous. If they are too general, they may not give adequate direction to the people implementing them, resulting in inefficiencies. If they are too specific, they may be restrictive and may soon become outdated or irrelevant. Policy statements should be supported by strategies which provide more details about how the policy to be implemented and they should also be supported by action plans which establish a time framework and identify resources for carrying them out.

The aim of this chapter is to obtain a set of policy guidelines that can be used by decision makers to formulate policy statements. Scenarios presented in previous chapters will be evaluated using comparative analysis through decision support system. The relevant information needed for obtaining policy guidelines are derived from the key issues (demographics changes, technological changes…) in the form of indicators. An indicator is an observed value representative of a phenomenon to study which quantity information by aggregating different and multiple data. In short, indicators simplify information that can help to reveal complex phenomena.

7.2 DPSIR Conceptual Framework

In dealing with environment indicators and building scenarios for water resources management, the DPSIR conceptual framework seems to respond to sustainability of water use and therefore has been adopted. This framework, developed by the European Environmental Agency (EEA, 2000) for environmental reporting purposes, structures the description of the environmental problems and constructs the cause-effect relationships between sectors and human activities. The DPSIR-chain of casual links is a methodology to describe the relationship between the origin (causes) and the impacts on a system. Variations of the DPSIR-chain include PSR, DSR and DPS. **DPSIR** stands for the elements **D**riving force, **P**ressure, **S**tate, **I**mpact and **R**esponse. These are elements of a chain and the chain links the elements in a casual way. This methodology is based upon the consideration that one or more driving forces cause one or more pressure on a system. The pressure determines the status of the system. By rating the change of the state of a system the resulting impact can be evaluated. The DPSIR-methodology is a very useful instrument to describe a system, its determining parameters and its actual state. More and more it is used for environmental planning issues and for developing management strategies.

The DPSIR framework aims at analyzing the cause-effect relationship between interacting components of complex social, economic and environment systems and at organizing the information flow between its parts. The framework was originally developed for social case studies and then broadly applied to environmental and sustainable development, describing and organizing its operational information.

1. Driving force of environmental change; they are the underlying causes and origins of pressure on the environment (they are factors influencing a variety of relevant variables)
2. Pressure describe the variables which directly cause (or may cause) environmental problems
3. State shows the conditions of the environment.
4. Impact on population, economy and ecosystems describe the ultimate effects of changes of state, in terms of damage caused.
5. Response demonstrates the efforts of society (e.g. politicians, decision-makers) to solve the problems.

From the point of view of the decisional context, the Impact describes the existing problems. The negative Impact arises as the change of the environment's State reduces the value (either in quantitative or qualitative terms) of the natural resources. The Response refers to the decision act: the chosen options aimed at reducing the negative pressure on the state of the environment. The Driving forces, Pressure and State are the possible levels of intervention: decision makers can choose one of them (or a combination of them) as a concrete object for his response. However, levels differ in their response "elasticity". For example, the local water resources manager will not be able to intervene on the socio-economic system (Driving forces); he will probably have to operate directly on the pressure in order to mitigate the impact. He could also intervene on the State but, as soon as his action ceases, the situation may return to its former condition. Therefore, a Response needs to be considered in terms of effectiveness to obtain positive result for the whole socio-economic and environmental system.

The DPSIR framework is to be filled according to a particular decision situation with the problem relevant description (indicators). In order to explore all possible problem solution, those Driving force-Pressure-State chains should be identified, which contribute to the understanding of the environmental problem (Impact) consequently, in a given decision situation, may be affected by the decision maker. As in Figure 51, the activities oriented to the problem solution may be divided into: (i) modeling procedure aiming to reconstruct the problem underlying cause-effect relationship described by the D-P-S chains; (ii) procedures oriented to the impending choice from the available problems solving options, comprising the prediction of decision outcomes, exploration and aggregation of the preferences of decision makers.

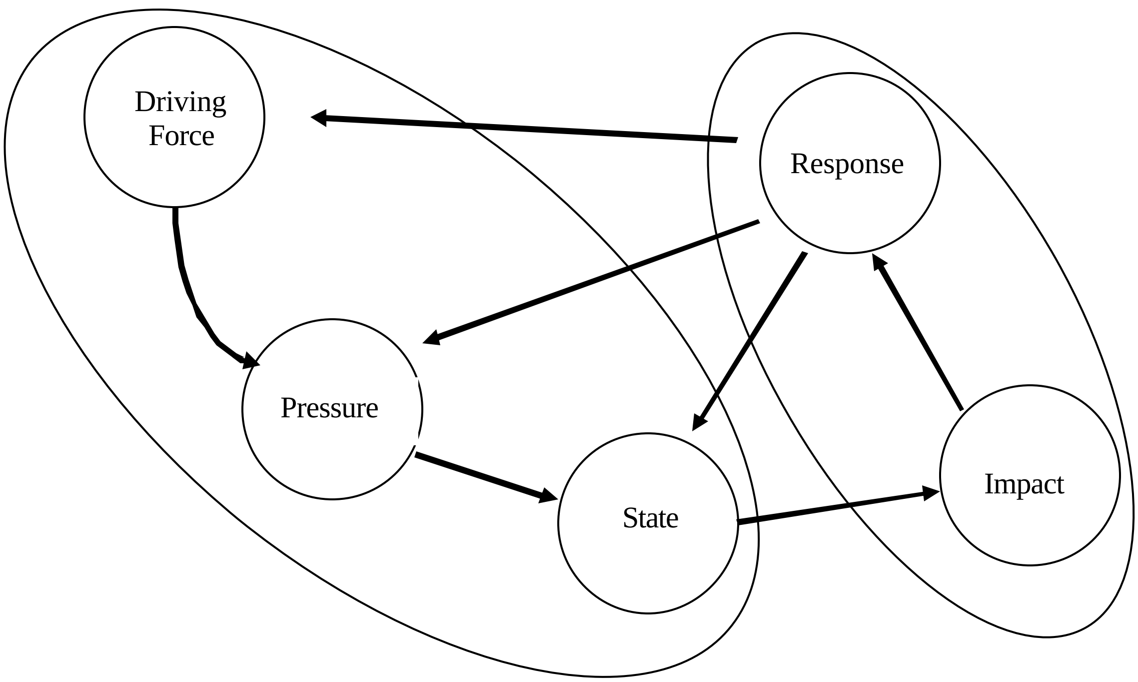

Figure 51: DPSIR as an Underlying Framework

The driving forces basically are any activities which have effects on quality and quantity of the system. It is possible and reasonable to place these activities in group of their origin. For instance, reasonable group are such like “Agriculture”, “industry” or “traffic”.

As the driving forces describe “what” is having effects on the system, the pressures describe “how” the driving forces affect the system. For instance pressure may be “nutrient surplus” or “noise”. The element “pressure” does not contain the impact that a driving force has on system but just quantifies the driving force.

The element “state” contains the conditions (or the state) of a system. Since the state of a system is a function of (measurable) parameters or processes being the result of the pressures, indicators are necessary to describe the state of the system. Here indicators can be the measured parameters themselves or, on a more integrated level, indicators can be the result of the interaction of parameters. Indicators showing the results of interactions between pressures may be used if parameters are not measurable or in order to simplify very complex systems. According to the causal character of the DPSIR-chain, changing the pressure causes changes in the state of a system. The element “impact” contains the description and the consequences of changing the state. The last element in the DPSIR-chain is the element “Response”. Regarding the elements “State” and the “Impact” of a system it can be decided if and which measures have to be taken to reach or to conserve a clearly defined state of the regarded systems.

Table 27: Water Related Issues for Aqaba Classified According to DPSIR Conceptual Frame Work.

Driving force	**Pressures**	**State**	**Impacts**	**Responses**
Demographic changes	Water supply	Water availability	Less water	New supply
Socio-economic	Water use	Quality and quantity	Less water quality	Rationing, reducing per capita share,
Land use changes	Water demand	Water availability	High demand	Water allocation
Technological changes	Cost of development	Water quality	Water saving	Desalination
Climatic changes	Water Supply	Water availability	Higher demand , low S/D ratio	Desalination, water allocation
Urban development	Water demand	Water availability	More wastes and wastewater	Rationing, awareness
Tourism expansion	Water demand Marine system	Water availability	Slow development, high cost	New supply, pricing awareness
Industrial activities	Water demand	Quality and availability	Low economic growth	Recycling, desalination pricing
Agriculture	Water demand Nutrient surplus	Quality and quantity	Less water, less production	Reuse, water allocation awareness

7.3 Scenario Definition

The magnitude of problems and the effectiveness of responses can vary, according to different scenarios. In a DPSIR framework, Aqaba scenario: status quo, medium growth and high growth can be defined by D indicators, which measure the forces that drive the pressure on the water system. In DPSIR indicators list, D indicators have been classifies in 3 broad categories, i.e. Demography, Economic Development (Agricultural, Industry, Tourism) and Technological changes.

Scenarios should be conceptually distinguished from policy responses. In particular, scenarios should include those "external" (or independent) variables that are not linked to the implementation of policies explicitly targeting water issues. For example, precipitation patterns, population growth and general economic trends (i. e. tourism demand, industrial growth, etc.) can be variables defining scenarios, while the change in cropping patterns, the increase in investments for water conveyance, regulations addressing water pollution problems have be intended as policy options, not be confused with scenarios.

7.4 Decision Support System

Recent advances in computer technology and water resource modeling, availability of real time data, and the improvements in the ability to develop user-friendly model interface have led to significant growth in the development and application of decision support systems (DSS) for water resources systems. Decision support systems are systems that utilize decision theory, operation research and information science to support decision-making activities. These systems have become very popular, owing to the introduction of the personal computer and electronic spreadsheet programs. They enable analysts to model quantitative aspects of a problem and then engage in sensitivity analysis to measure the effect of decision variables on the desired outcome (Al-Jayyousi and Shatanawi, 1995).

Many quantitative approaches may be incorporated in decision support systems such as benefice analysis, linear programming, multiobjective or multicriteria decision analysis. Multiobjective methods have been developed over the years because of the recognition that the solution to complex problems must explicitly embrace a range of competing concerns (porter et el., 1991). Many approaches have utilized a multiobjective technique to deal with the complexity of real-world problems (e.g. Ridgley and Rijsberman, 1992; Westphal et al. 2003).

First, the divide-and conquer strategy common to most multi-criteria evaluation methods wherein one first disaggregates a problem into components more easily analyzed, and then re-aggregates them to synthesize the insights from the analyses, reduces the complexity that evaluators need to confront. Aggregation of consequences through theoretically rigorous commensuration can help maintain complexity within the cognitive limitations of decision makers (Miller, 1956). Logical deduction can also be facilitated, for example, in cases where multi-criteria evaluation helps one to order an entire set of alternatives from knowledge of only pair wise preferences.

Second, multi-criteria evaluation may provide effective ways to handle and represent uncertainty. For example, techniques are available that require only qualitative information concerning people's preferences and the perceived importance of different criteria and impacts (Saaty, 1980). Software packages implementing some methods allow quite extensive sensitivity analysis (e.g. Expert Choice 11, 2004). The Analytic Hierarchy Process, developed by Saaty (Saaty, 1980; Saaty et al., 1982) will be adopted in this work to model a multiobjecives-multicriteria water policy for Aqaba using the Expert Choice Model, Version 11.

7.5 Analytical Hierarchy Process

Decision theory using the analytic hierarchy process will be used to assess different future water policies to meet demand for the year 2015. The analytical hierarchy process is a generalization of Saaty's eigen vector procedure has 'the respondent compare his or her intensity of preference for one criterion 'i' relative to that of another criterion j' or for one alternative over another, and represent this comparison as a positive ratio a_i/a_j. This procedure is designed to capture the perceptions of those closely involved with certain set of preferences among sets of alternative. It could, therefore, be considered as a multiobjectives-multicriteria model.

To apply this model, a complex unstructured score card problem needs first to be broken down into its component parts. The "scorecard" problem is addressed by the construction of a value tree. Value trees are well known decision tools in many planning and resource management issues, including water resources (Fatti, 1990), and land use (Edwards, 1977). Also known as objectives hierarchies (Keeney and Raiffa, 1976) and analytic hierarchies (Saaty, 1980), value trees are hierarchical structure that represent one or more person's general values regarding a decision situation and relate them to specific attributes which can characterize decision alternatives.

Once identified, these attributes can be used to evaluate existing alternatives or to focus thinking in the creation of new ones (Keeney, 1992). After arranging these attributes into a hierarchical order, numerical values representing subjective judgments on the relative importance of each part are assigned. To come up with the final outcomes, those judgments are then synthesized (via the use of eigen vectors) to determine which variables have the highest priority. A number of procedures are available for determining weights, and these can be applied to the entire set of value scores or to subsets formed through hierarchical structuring (Saaty, 1980). The assumptions adopted by the analytical hierarchy process are simple. There must be a finite number of possible positive action, that is, a_1, a_2,…a_n , where n finite number. Analysts are supposed to assign a finite number of values to rank (scale) the importance of attributes. The scale might either be numeric or subjective. The Saaty scaling methods that has been used ranges from 1 to denote the equal importance of two attributes to 9 to represent an absolute importance of one attribute over the other (Table 28). This procedure is based on two basic ideas: pair wise comparison and consistency of thought. After the problem is decomposed to a tree or 'hierarchy' of components of various levels, a pair wise comparison is carried out from the top level to lower levels. Then, after each comparison, a 'consistency' check is made to enable the analyst to revise his/her weight so as to obtain a consistency value below 0.1.

Table 28: The Ranking System of the Analytic Hierarchy Processes Adopted by Saaty (1980)

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favor one item over another
5	Essential or strong	Experience and judgment strongly favor one item over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another
9	Absolute importance	The evidence favors one item over all.
2,4,6,8	Intermediate values between adjacent scale values importance	Compromise is needed
Reciprocals of the above, non zero	If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	A reasonable assumption
Rationales	Ratios arising from scale	If consistency is to be obtained using such values

7.6 Scenario Development

From a planning prospective, various scenarios for satisfying water demand for Aqaba were examined. These scenarios were classified according to different projection of urban population, industrial activities, services, commercial and tourism activities. The scenarios are to be constrained by limited water supplies from Disi and Wadi al-Yutum well fields as well as many demand management options. For the purposes of reducing the number of sectors, commercial consumption will be combined with the municipal sector. The irrigation requirement for agricultural activities, landscaping and recreation parks and golf course will be overlooked in the analysis because it is anticipated that they will rely completely on the reclaimed domestic water. The situation in the year 2015 will be analyzed using MCA where a significant deficit is expected resulting in low supply to demand ratio. The later (S/D) will be used as an indicator to pressure produced by different driving forces. Scenario analysis will be presented to shed some lights on the responses and policy option.

7.6.1 Status quo Scenario.

This scenario considers the present realities on the different consumption sectors by assuming a population growth of 3.3 % for the coming 10 years, constant growth of industry, steady grow th in tourism, and also a steady growth in services associated with the above activities. This assumption is based on the results of the last census of November, 2004 which has shown that the population growth of Aqaba is 3.3 % since the previous census of 1994. In spite of the fact that this scenario is characterized by almost a minimum growth model, it is expected that the UFW will be reduced from 28% to 22% in the coming 10-year period. It should be mentioned that under this scenario, measures to increase efficiency in administration and in distribution are assumed to go in parallel with other measures of controlling and management of water demand and augmentation of water supply.

As can be seen from Table 29, there will be no water deficit till 2010 since maximum supply of 17.5 MCM will produce little surplus. Under the status quo assumption, Aqaba will continue to relay on the groundwater of Disi and Wadi al-Yutum. The only concern that might arise is the faith of the wastewater generated from municipal and industrial consumption; municipal includes water consumed by domestic, commercial, services and tourism sectors. It is expected that about 4-5 MCM of treated water can be generated which can be utilize for restricted agriculture and la ndscaping provided that certain measure should be taken to prevent return flow from polluting the coastal water

Table 29. Population Projection and Future Water Demand under Status qua Scenario (3.3 % Population Growth)

Year	**2005**		**2010**		**2020**	
Population	91,200		107,275		148.422	
Sector	lpcd	Demand	lpcd	Demand	lpcd	Demand
Municipal	95	3.162	95	3.720	95	5.147
Services	58	1.930	58	2.271	58	3.142
Tourism	12	0.400	12	0.470	12	0.650
Non-industrial		**5.492**		**6.461**		**8.939**
Industrial		**4.071**		**4.790**		**6.625**
Actual Demand		**9.563**		**11.251**		**15.564**
UFW (%)		36 %		30 %		25%
UFW		5.379		4.822		5.188
Total Demand		**14.942**		**16.073**		**20.752**

7.6.2 Medium Growth Scenario.

In this scenario, a population growth of 5.3% is expected which has been based on the trend in growth for the period 1974-1984 associated with the ambitious plan of ARA. The minimum per capita requirement is assumed to be 95 lpcd for the municipal (domestic and commercial). However, the demand in industry will be increase from 4.1 MCM to 8 MCM while the tourism sector will also double in 2010 and triple in 2020. Table 30 shows the projection for water demand for the years 2010 and 2020. It should be also assumed here that the physical system loses and the administrative loses are reduced from 36 % to 30 % in 2010 and to 25 % in 2020.

The total demand by the year 2020 will reach about 27.668 MCM; about 11.9 MCM are or non industrial purposes. The deficit will about 7 MCM which can be covered by small scale desalination plant. At this point, the question that might be raised about the coast of desalination and who is going to pay the difference. It is, therefore, recommended for Aqaba to price the water according to the opportunity cost of desalination. This will serve two purposes; first implicitly enforce people to save water to achieve the target goal of reducing the losses to 15 %. Second; is to cover the real cost of providing the services.

Table 30. Population Projection and Future Water Demand under Medium Growth Scenario (5.3 % Population Growth)

Year	**2005**		**2010**		**2020**	
Population	91,200		118,069		197,888	
Sector	lpcd	Demand	lpcd	Demand	lpcd	Demand
Municipal	95	3.162	95	4.094	95	6.862
Services	58	1.930	58	2.500	58	4.189
Tourism	12	0.400	24	0.517	36	0.867
Non-industrial						**11.918**
Industrial		**4.071**		**5.270**		**8.833**
Actual Demand		**9.563**		**13.629**		**20.751**
UFW (%)		36 %		30 %		25 %
UFW		5.379		5.841		6.917
Total Demand		**14.942**		**19.470**		**27.686**

7.6.3 High Growth Scenario

This scenario is realistic if the region is going to witness political and economical stability and it is with line of many projections that were performed by the consulting companies (Montgomery-Watson, 1999) in their analysis for Aqaba Master Plan The high growth scenario copies the growth model of 1974-1984 by assuming 7.3 % increase in population. Population growth percentages will be an indicator of other economical activities including tourism, industry, port handling and other commercial and service activities. In this model, tourism will increase by two folds and industry will expand by two folds also and thus population due to natural growth and immigration will increase from 91,200 people in 2005 to 262,416 people by the year 2020. Table 31 shows the projected population and its water demand for the next 10 years.

With the assumption that water losses or UFW will drop from 36 % in 2005 to 30 % in 2010 to a minimum of optimal level of 25 % by 2020, the total water demand will reach 36.691 MCM. Out of that, about 15.80 MCM will be demanded for non-industrial use. Under this scenario, a deficit of 18.50 MCM will occur against a supply of 17.5 MCM. However, about 7 MCM of reclaimed water could be produced which should be used again for restricted agriculture and landscaping as well as for some industries to be used for cooling purposes.

Table 31. Population Projection and Future Water Demand under High Growth Scenario (7.3 % Population Growth)

Year	2005		2010		2020	
Population	91,200		129,716		262,416	
Sector	lpcd	Demand	lpcd	Demand	lpcd	Demand
Municipal	95	3.162	95		95	9.099
Services	58	1.930	58		58	5.555
Tourism	12	0.400	30	0.568		1.149
Non-industrial				**7.819**		**15.804**
Industrial		**4.071**		**5.79**		**11.714**
Actual Demand		**9.563**		**13.609**		**27.518**
UFW (%)		36 %		30 %		25
UFW		5.379		5.829		9.172
Total Demand		**14.942**		**19.438**		**36.691**

7.7 Multi Criteria Analysis

For evaluating the previous three scenarios of projected water demand and their associated deficits in 2015, the problem was analyzed in term of measures and constraints (Table 32). The deficit to each scenario was estimated, decomposition or "back planning" is performed to illustrate the components and the rational of each scenario as shown in Table 32.

Table 32. Measures and Associated Constraints to Overcome Deficit by each Scenario by Year 2020.

Scenario	Deficit (MCM)	Measures	Constraints
Status quo	3-4 MCM	- Improve system efficiency - Price water to cover O&M cost	- Users acceptability. - Resources availability
Medium growth	10 MCM	- Improve system efficiency - augment by desalination. - Price water to cover operating cost	- Resource availability. - Environmental concern - Users acceptability. - High cost
High growth	18-20 MCM	- Desalination - Recycling water - Price water to cover operating cost	- High cost - Water quality - Users acceptability - Environmental concern.

The analysis using MCA is intended to reveal the implicit assumptions, constraints, and priorities, a water decision maker may encounter when addressing future water strategies. This exercise will also come up with policy guidelines to be used in formulating future strategies of water resources planning for Aqaba (Figure 52). The key issue here is the demography.

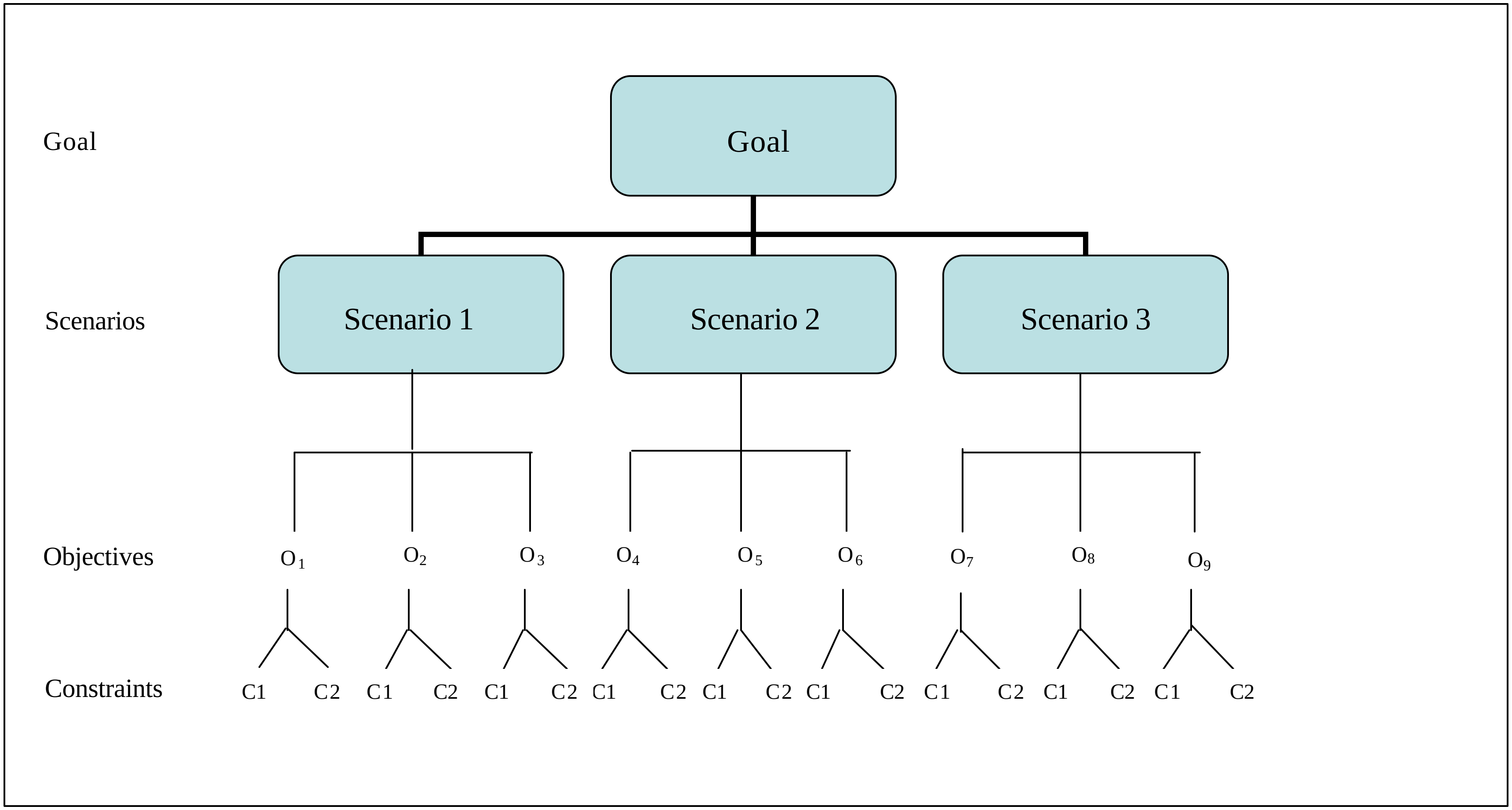

Figure 52: The Decomposition of the Problem into Goals, Scenarios, Objective and Constraints.

Changes in terms of life style and population. Also, technological changes are of the same importance.

The goal in this modeling effort is to active an optimal intersectoral water allocation and policy of water according to social classes and consumption rate. All scenarios assumed constant and steady per capita allocation of 83 lpcd plus 12 lpcd for commercial. The equivalent lpcd for tourism is increased to 3 folds in scenario 1, two folds for scenario 2 and four folds in scenario 3. Industry is doubled for scenario 2 and tripled for scenario 3. The objectives desired under each scenario are summarized in Table 33.

Table 33. Desired Objectives for the Three Scenarios.

Objectives for scenario 1	Objectives for scenario 2	Objectives for scenario 3
1- Meet the growing demand.	4- Ensure enough water to meet basic need	7- Ensure safeguarding for environment
2- Treat all sectors equally	5- Encourage industrial growth.	8- Prioritize water for non-domestic
3- Optimize water use	6- reduce losses	9- Meet future domestic, tourism and industrial demand.

Each objective is subject to levels of constraints which are cost and quality. Table 34 provides weights for all level of the hierarchy process namely scenarios objectives and constraints. Scenario 3 has the highest weight (0.48) followed by S1 and S2 with weights of 0.32 and 0.20 respectively. The objectives are prioritized according to their weight in the next section and similarly for the constraints.

Table 34 Weights of Objectives and Constraints underDeferent Scenario

Scenario 1 Weight= 0.2						Scenario 2 Weight= 0.32						Scenario 3 Weight= 0.48					
O_1		O_2		O_3		O_4		O_5		O_6		O_7		O_8		O_9	
0.677		0.223		0.100		0.743		0.070		0.187		0.425		0.275		0.300	
C1	C2	C1	C2	C1	C2	C1	C2	C1	C2	C1	C2	C1	C2	C1	C2	C1	C2
0.5	0.5	0.6	0.4	0.67	0.33	0.5	0.5	0.3	0.7	0.35	0.65	0.4	0.6	0.35	0.65	0.25	0.75

7.8 Policy Guideline

As the main goal of this chapter is to sustain the fresh water resources for the present and future generations, optimize their uses and reduce the risk of pollution, policy guidelines have been concluded through the analysis of different scenarios. The analysis involved identifying indicators, defining objectives subject to constraints. These scenarios reflect three possible conditions that might occur in the future which are all realistic as they might repeat past experiences in the last three decades. This period has witnessed different population growth rate indicating the economical growth and the political stability. The period 1974-1984 has the greatest population growth of 7.3%, the growth has dropped to 5.3 % during 1984-1994 while in the last 10 year period (1994-2001) there was additional drop that has reached 3.3 %.

In developing these scenario, an optimistic approached was followed in assuming that immediate measure should be taken by reducing the water losses (UFW) from 28 % to 15 % by the year 2015 for the last two scenarios. The results of the analytical hierarchy process of the DSS approach have prioritized the objectives in the following order:

? Ensure enough water to meet basic needs.

? Meet the growing demand.

? Ensure safeguarding for environment.

? Meet future domestic, tourism and industrial demand.

? Prioritize water for non-domestic use.

? Treat all sectors equally.

? Reduce losses.

? Optimize water use.

? Encourage industrial growth.

The above objectives which are listed in a descending order were subjected to two constraints, namely cost and environmental concerns. From the above analysis the following guidelines can be recommended for decision makers to formulate their policy.

1. Promoting greater efficiency and adopting conservation measures such as reducing the unaccounted for water through encouraging the technical and managerial initiatives. Therefore the following actions should be taken:

   ? Reducing physical losses from the water supply networks. Losses are currently estimated at 27.9 % of water supplied by these networks; these losses could conceivably be reduced to 15 % by performing much-needed maintenance work in problem areas and upgrading the monitoring and managerial skills.

   ? Reducing industrial water demand. This could be accomplished through a comprehensive study on the current methods of industrial water use and the adoption of appropriate water saving technologies.

   ? Reducing residential water demand. Possibility of saving water by adopting simple household conservation measures such as smaller flush cabinets and shower heads, reduced water pressure, improved plumbing and household leakage-control. Potentially, significant amount of water could be saved by changing personal consumption practices.

   ? Changing patterns of personal consumption. Domestic water can be saved by changing patterns of water use, through awareness of the waste involved in using bathtubs, washing cars using hoses, leaving taps open while shaving, dishwashing.

   ? Preventing over-extraction. Over-extraction reduces the quantity of water and increases its salinity, making it unsuitable for use.

2. Employing pricing policies aiming at recovering the operation and maintenance cost and reflecting the opportunity value of water. The pricing policy could be used as a water saving measure.
3. Involvement of the private sector and non-governmental organization in the decision making process and policy formulation. In addition, stakeholders should participate in all activities leading to pricing and conservation measures.
4. Establishing a set of indicators to examine the performance of the system such as supply/demand ratio, quality indicators, and efficiency indicators.
5. Putting great concern to the protection of the marine environment and coastal water by adopting strict regulation on pollution control and establishing a monitoring job.
6. Augmenting additional water supply through desalination by encouraging private enterprises to have their own units. This plant should be put under the surveillance of Ministry of Environment in cooperation with the Department of Environment in ASEZA.
7. Realizing that water is a finite resources and that water to Aqaba is drown from a non-renewable groundwater aquifer. When this water is transported to the Middle of the country (Amman Area), Aqaba will be under the risk of non-sustainable groundwater supply.

Conclusions and Recommendations

It is clear that Aqaba will suffer water shortage by the year 2010 even if all conventional resources have been completely developed. This is based on the population growth associated with the ambitious plan for promoting Aqaba area as a venue for various economical activities. Industry will expand, tourism will boom and other commercial activities and services will increase. In addition to that, the importance of Aqaba Port as a regional hub and a local access will be more significant. All of the above economical activities will sharply increase the demand for water. The non-renewable groundwater of Disi will not sustain for ever and will not meet Aqaba future demand. Therefore, new non-conventional resources should be explored such as desalination, recycling water for industry and use of reclaimed municipal water for irrigation and landscaping. If the inherent water supply-demand imbalances are not alleviated, ASEZ can never realize its full potential for social and economic development. Based on the above conclusion, the following recommendation can be suggested:

1. Immediate measures should be taken to reduce the unaccounted for water in Aqaba. Such an amount of lost water (4-5 MCM) can be made available for the planned industrial and Tourism development.
2. Reclaimed wastewater effluent should be used in industry such as the fertilizer company, agriculture and landscapes, golf courses, palm trees parks and greenbelt areas.
3. All new industries should have their on-site treatment or at least a preliminary treatment prior to discharge their own effluent to the sewer system. Industries should be encouraged to minimize their waste generation and reuse the treated effluent on site.

4. It is highly recommended that all new hotels and other tourist facilities have their own package wastewater treatment plants and the treated effluent be used for irrigation or landscaping purposes.

5. Large industries and tourism projects must provide their own water using desalination or other appropriate technologies.

6. Studies should be carried to determine options of new water supply resources for Aqaba rather than relaying on Disi Aquifer. One of which is conducting research on the desalination of seawater

7. Scientific and technological research and development to make more efficient use of available resources without contaminating or degrading the coastal water and the environment should be encouraged. It is highly recommended that adaptive and comparative research be carried out on pricing, conservation subsidies and the like be performed on a country-wide basis.

8. Detailed studies are needed to delineate the surface catchments of the Red Sea basins to identify their extent, hydrological characteristics. Floods from these basins should be evaluated in order to reduce their hazards to urban areas. In addition, studies and measures should be carried out to use flood water for beneficial use such as the enhancement of natural recharge of Wadi Araba and Wadi al-Yutum aquifers.

9. ASEZA should revisit its policy and future plan by considering the results of this research. After five years in investment, the economical development has not been to the expectation. Population growth has been at the minimum growth rate (3.3%) and industrial expansion and other economical development have not fulfill their objectives.

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LIST OF APPENDICES

Annex A

CORINE Land Cover Classification Scheme.

Current classification:
CORINE Land Cover Classification

Code	Label	Class Description
1.	**Artificial areas**	
1.1.	Urban fabric	Areas mainly occupied by dwellings and buildings used by administrative/public utilities or collectivities, including their connected areas (associated lands, approach road network, parking-lots
1.1.1	Continuous Urban Fabrics	Most of the land is covered by structures and the transport network Building, roads and artificially surfaced areas cover more than 80 % of the total surface. Non-linear areas of vegetation and bare soil are exceptional.
1.1.2	Discontinuous Urban Fabrics	Most of the land is covered by structures. Building, roads and artificially surfaced areas associated with vegetated areas and bare soil, which occupy discontinuous but significant surfaces.
1.2.	Industrial, commercial and transport units	Areas mainly occupied by industrial activities of transformation and manufacturing, trade, financial activities and services, transport infrastructures for road traffic and rail networks, airport installations, river and sea port installations, including their associated lands and access infrastructures. Includes industrial livestock rearing facilities.
1.2.1	Industrial or Commercial	Artificially surfaced areas (with concrete, asphalt, tarmacadam, or stabilized, e.g. beaten earth) without vegetation occupy most of the area, which also contains buildings and/or vegetation.
1.2.2	Road and rail Networks and associated land	Motorways and railways, including associated installations (stations, platforms, embankments). Minimum width for inclusion: 100 m.
1.2.3	Port Areas	Infrastructure of port areas, including quays, dockyards and marinas
1.2.4	Airports	Airports installations: runways, buildings and associated land
1.3.	Mine, dump and construction sites	Artificial areas mainly occupied by extractive activities, construction sites, man-made waste dump sites and their associated lands.
1.3.1	Mineral extraction sites	Areas with open-pit extraction of construction material (sandpits, quarries) or other minerals (open-cast mines). Includes flooded gravel pits, except for river-bed extraction.
1.3.2	Dump Sites	Public, industrial or mine dump sites.

1.3.3	Construction Sites	Spaces under construction development, soil or bedrock excavations, earthworks.
1.4.	Artificial non-agricultural vegetated areas	Areas voluntarily created for recreational use. Includes green or recreational and leisure urban parks, sport and leisure facilities.
1.4.1	Green Urban areas	Areas with vegetation within urban fabric, includes parks and cemeteries with vegetation, and mansions and their grounds.
1.4.2	Sport and leisure facilities	Camping grounds, sports grounds, leisure parks, golf courses, racecourses, etc. Includes formal parks not surrounded by urban areas.
2.	**Agricultural areas**	
2.1.	Arable land	Lands under a rotation system used for annually harvested plants and fallow lands, which are permanently or not irrigated. Includes flooded crops such as rice fields and other inundated croplands.
2.1.1.	Non-irrigated arable land	Cereals, legumes, fodder crops, root crops and fallow land. Includes flowers and fruit trees (nurseries cultivation) and vegetables, whether open field, under plastic or glass (includes market gardening). Includes aromatic, medicinal and culinary plants. Does not include permanent pastures.
2.1.2.	Permanently irrigated land	Crops irrigated permanently or periodically, using a permanent infrastructure (irrigation channels, drainage network). Most of these crops cannot be cultivated without an artificial water supply. Does not include sporadically irrigated land.
2.1.3.	Rice fields	Land prepared for rice cultivation. Flat surfaces with irrigation channels. Surfaces periodically flooded.
2.2.	Permanent crops	All surfaces occupied by permanent crops, not under a rotation system. Includes ligneous crops of standards cultures for fruit production such as extensive fruit orchards, olive groves, chestnut groves, walnut groves shrub orchards such as vineyards and some specific low-system orchard plantation, espaliers and climbers.
2.2.1	Vineyards	Areas planted with vines.
2.2.2	Fruit trees and berry plantations	Parcels planted with fruit trees or shrubs: single or mixed fruit species, fruit trees associated with permanently grassed surfaces. Includes chestnut and walnut groves.
2.2.3	Olive Groves	Areas planted with olive trees, including mixed occurrence of olive trees and vines on the same parcel

2.3.	Pastures	Lands, which are permanently used (at least 5 years) for fodder production. Includes natural or sown herbaceous species, unimproved or lightly improved meadows and grazed or mechanically harvested meadows.
2.3.1	Pastures	Dense grass cover, of floral composition, dominated by graminacea, not under a rotation system. Mainly for grazing, but the fodder may be harvested mechanically. Includes areas with hedges (bocage).
2.4.	Heterogeneous agricultural areas	Areas of annual crops associated with permanent crops on the same parcel, annual crops cultivated under forest trees, areas of annual crops, meadows and/or permanent crops which are juxtaposed, landscapes in which crops and pastures are intimately mixed with natural vegetation or natural areas.
2.4.1.	Annual crops associated with permanent crops	Non-permanent crops (arable land or pasture) associated with permanent crops on the same parcel.
2.4.2.	Complex cultivation patterns	Juxtaposition of small parcels of diverse annual crops, pasture and/or permanent crops
2.4.3.	Land principally occupied by agriculture, with significant areas of natural vegetation	Areas principally occupied by agriculture, interspersed with significant natural areas.
2.4.4.	Agro-forestry areas	Annual crops or grazing land under the wooded cover of forestry species.
3.	**Forests and semi-natural areas**	
3.1.	Forests	Areas occupied by forests and woodlands with a vegetation pattern composed of native or exotic coniferous and/or deciduous trees and which can be used for the production of timber or other forest products. The forest trees are under normal climatic conditions higher than 5 m with a canopy closure of 30 % at least. In case of young plantation, the minimum cut-off-point is 500 subjects by ha.
3.1.1.	Broad-leaved forest	Vegetation formation composed principally of trees, including shrub and bush understoreys, where broad-leaved species predominate
3.1.2.	Coniferous forest	Vegetation formation composed principaly of trees, including shrub and bush understoreys, where coniferous species predominate

3.1.3	Mixed forest	Vegetation formation composed principally of trees, including shrub and bush understoreys, where neither broad-leaved nor coniferous species predominate.
3.2.	Shrubs and/or herbaceous vegetation associations	Temperate shrubby areas with Atlantic and alpine heaths, sub Alpine bush and tall herb communities, deciduous forest re-colonization, hedgerows, dwarf conifers. Mediterranean and sub-Mediterranean evergreen sclerophyllous bush and scrub (maquis, garrigue, mattoral, phrygana sensu lato), re-colonisation and degradation stages of broad-leaved evergreen forests. Dry thermophilous grasslands of the lowlands, hills and mountain zone. Poor Atlantic a sub-Atlantic mat-grasslands of acid soils; grasslands of decalcified sands; Alpine and sub Alpine grasslands. Humid grasslands and tall herb communities; lowland and mountain mesophile pastures and hay meadows.
3.2.1	Natural grassland	Low productivity grassland. Often situated in areas of rough, uneven ground. Frequently includes rocky areas, briars and heathland.
3.2.2.	Moors and heathland	Vegetation with low and closed cover, dominated by bushes, shrubs and herbaceous plants (heather, briars, broom, gorse, laburnum, etc.) .
3.2.3.	Sclerophyllous vegetation	Bushy sclerophyllous vegetation includes maquis and garrigue. In case of shrub vegetation areas composed of sclerophyllous species such as Juniperus oxycedrus and heathland species such as Buxus spp. or Ostrya carpinifolia with no visible dominance (each species occupy about 50% of the area), priority will be given to sclerophyllous vegetation and the whole area will be assigned class 323.
3.2.4.	Transitional woodland/shrub	Bushy or herbaceous vegetation with scattered trees. Can represent either woodland degradation or forest regeneration/recolonisation.
3.3.	Open spaces with little or no vegetation	Natural areas covered with little or no vegetation, including open thermophile formations of sandy or rocky grounds distributed on calcareous or siliceous soils frequently disturbed by erosion, steppic grasslands, perennial steppe-like grasslands, meso- and thermo-Mediterranean xerophile, mostly open, short-grass perennial grasslands, alpha steppes, vegetated or sparsely vegetated areas of stones on steep slopes, screes, cliffs, rock fares, limestone pavements with plant communities colonising their tracks, perpetual snow and ice, in land sand-dune, coastal sand-dunes and burnt areas.
3.3.1.	Beaches, dunes, and sand plains	Beaches, dunes and expanses of sand or pebbles in coastal or continental locations, including beds of stream channels with torrential regime.
3.3.2.	Bare rock	Scree, cliffs, rock outcrops, incuding active erosion, rocks and reef flats situated above the high-water mark.
3.3.3.	Sparsely vegetated areas	Includes steppes, tundra and badlands. Scattered high-altitude vegetation

3.3.4.	Burnt areas	Areas affected by recent fires, still mainly black.
3.3.5.	Glaciers and perpetual snow	Land covered by glaciers or permanent snowfields.
4.	**Wetlands**	
4.1.	Inland wetlands	Areas flooded or liable to flooding during the great part of the year by fresh, brackish or standing water with specific vegetation coverage made of low shrub, semi-ligneous or herbaceous species. Includes water-fringe vegetation of lakes, rivers, and brooks and of fens and eutrophic marshes, vegetation of transition mires and quaking bogs and springs, highly oligotrophic and strongly acidic communities composed mainly of sphagnum growing on peat and deriving moistures of raised bogs and blanket bogs.
4.1.1	Inland marshes	Low-lying land usually flooded in winter, and more or less saturated by water all year round.
4.1.2.	Peatbogs	Peatland consisting mainly of decomposed moss and vegetable matter. May or may not be exploited.
4.2.	Coastal wetlands	Areas which are submerged by high tides at some stage of the annual tidal cycle. Includes salt meadows, facies of saltmarsh grass meadows, transitional or not to other communities, vegetation occupying zones of varying salinity and humidity, sands and muds submerged for part of every tide devoid of vascular plants, active or recently abandoned salt-extraction evaporation basins.
4.2.1.	Salt marches	Vegetated low-lying areas, above the high-tide line, susceptible to flooding by seawater. Often in the process of filling in, gradually being colonized by halophilic plants.
4.2.2.	Salines	Salt-pans, active or in process of abandonment. Sections of salt marsh exploited for the production of salt by evaporation. They are clearly distinguishable from the rest of the marsh by their parcellation and 423 Intertidal flats Generally unvegetated expanses of mud, sand or rock lying between high and low water marks. 0 m contour on maps.
4.2.3.	Intertidal Flats	Generally unvegetated expanses of mud, sand or rock lying between high and low water marks
5.	**Water bodies**	
5.1.	Inland waters	Lakes, ponds and pools of natural origin containing fresh (i.e non-saline) water and running waters made of all rivers and streams. Man-made fresh water bodies including reservoirs and canals.
5.1.1.	Water Courses	Natural or artificial water-courses serving as water drainage channels. Includes canals. Minimum width for inclusion: 100 m.

5.1.2.	Water Bodies	Natural or artificial stretches of water.
5.2.	Marine waters	Oceanic and continental shelf waters, bays and narrow channels including sea lochs or loughs, fiords or fjords, rya straits and estuaries. Saline or brackish coastal waters often formed from sea inlets by sitting and cut-off from the sea by sand or mud banks.
5.2.1.	Coastal Lagoons	Stretches of salt or brackish water in coastal areas which are separated from the sea by a tongue of land or other similar topography. These water bodies can be connected to the sea at limited points, either permanently or for parts of the year only.
5.2.2.	Estuaries	The mouth of a river within which the tide ebbs and flows.
5.2.3	Sea and Ocean	Zone seaward of the lowest tide limit.

Annex B

The Monthly Water Supply for Industries for the Period 1999-2003.

Table B.1. Monthly Water Supply for Industrial in the Year 1999

Industry	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec.	total
Fertilizer Plant	285,211	200,000	250,000	314,109	317,667	176,785	293,580	331,726	324,931	335,570	307,728	326,422	3,463,729
Thermal Power plant	114,781	75,473	87,715	93,473	74,497	67,991	89,678	80,771	0	73,380	64,290	96,158	918,207
Electric Company (central station)	733	711	640	311	386	622	126	200	389	258	233	372	4,981
Rice Factory	20	60	95	135	132	111	115	121	110	188	133	57	1,277
Hassad Factory	45	20	62	304	128	13	3,065	33	8	88	48	43	3,857
Holland Selvocem Co.	239	332	453	88	758	577	521	1,015	584	519	544	365	5,995
Cement Factory	122	53	117	481	467	642	461	553	308	448	695	658	5,005
Total	**401,151**	**276,649**	**339,082**	**408,901**	**394,035**	**246,741**	**387,546**	**414,419**	**326,330**	**410,451**	**373,671**	**424,075**	**4,403,051**

Source: AWD

Table B.2. Monthly Water Supply for Industrial in the Year 2000

Industry	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec.	total
Fertilizer Plant	299,715	212,073	152,250	196,632	250,944	319,760	331,062	334,566	363,848	329,350	279,403	250,000	3,319,603
Thermal Power plant	50,807	34,401	40,865	50,037	62,020	38,373	67,569	74,684	60,295	54,905	47,344	6,4055	645,355
Electric Company (central station)	71	89	104	154	46	0	220	230	170	68	77	68	1297
Rice Factory	143	132	91	102	183	167	175	133	138	129	104	81	1578
Hassad Factory	0	0	0	0	0	0	0	0	0	0	0	0	0
Holland Selvocem Co.	270	372	301	359	594	846	736	605	509	513	518	732	6,355
Cement Factory	48	76	92	31	95	79	168	92	127	153	66	24	1051
Total	**351,054**	**247,143**	**193,703**	**247,315**	**313,882**	**359,225**	**399,930**	**410,310**	**425,087**	**385,118**	**327,512**	**314,960**	**3,975,239**

Source: AWD

Table B.3. Monthly Water Supply for Industrial in the Year 2001

Industry	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec.	total
Fertilizer Plant	299,715	212,073	152,250	196,632	250,944	319,760	331,062	334,566	363,848	275,259	268,984	289,095	**3,294,188**
Thermal Power plant	50,807	34,401	40,865	50,037	62,020	38,373	67,569	74,684	60,241	58,435	42,083	77,289	**656,804**
Electric Company (central station)	71	89	104	154	46	0	220	230	170	306	120	176	**1,686**
Rice Factory	143	132	91	102	183	167	175	133	138	108	104	113	**1,589**
Hassad Factory	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Holland Selvocem Co.	270	372	301	359	594	846	736	605	509	982	879	583	**7,036**
Cement Factory	48	76	92	31	95	79	168	92	127	113	84	51	**1,056**
Total	**351,054**	**247,143**	**193,703**	**247,315**	**313,882**	**359,225**	**399,930**	**410,310**	**425,033**	**335,203**	**312,254**	**367,307**	**3,962,359**

Source: AWD

Table B.4. Monthly Water Supply for Industrial in the Year 2002

Industry	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec.	total
Fertilizer Plant	,	,	,	,	,	,	,	,	,	,	,	,	, ,
Thermal Power Plant	,	,	,	,	,	,	,	,	,	,	,	,	,
Electric Company (central station)	88	74	121	194	167	244	305	138	185	205	145	110	1,976
Rice Factory	149	134	143	295									,
National Ammonia Company				**No water in the location**									
Holland Selvocem Co.						,	,	,					,
Arab Potash Company			,			,	,	,	,	,	,	,	,
Camira Potash Company			,	††	,	,		,		,	,	,	,
Jordan Petroleum												0	
Cement Factory						††	No water						†
Total	,	,	,	,	,	,	,	,	,	,	,	,	, ,

† (malfunctioning in the system) †† (meter closed) Source: AWD

Table B.5. Monthly Water Supply for Industrial in the Year 2003

Industry	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Fertilizer Plant	,	,	,	,	,	,	,	,	,	,	,	,	, ,
Thermal Power Plant	,	,	,	,	,	,	,	,	,	,	,	,	,
Electric Company (central station)													,
Rice Factory											,		,
National Ammonia company													
Holland Selvocem Co.				,					,				,
Arab Potash Company							,		,				,
Camira Potash Company	,	,	,	,		,	,	,	,	,	,	,	,
Jordan Petroleum													
Cement Factory													,
Total	,	,	,	,	,	,	,	,	,	,	,	,	, ,

Source: AWD

Annex C

The Daily Pumping Rate from Disi Aquifer to Aqaba for the Period 1998-2003

Table C.1. Daily Pumping Rate from Wells That Supply Aqaba for the Year1998

Day	January	February	March	April	May	June	July	August	September	October	Nov ember	December
1	42528.92	41518.23	31794.33	28729.18	47998.5	43126.849	46872.8	52375.3	52207.5	50914.4	44550.4	40861.846
2	39000.91	39333.06	48727.44	28498.19	52362	50672.886	51861.9	44482.9	52207.5	52299.0	47170.3	49436.709
3	30894.21	40425.65	41455.42	25714.96	53816.5	51082.492	51603.4	47403.6	50672.0	52155.5	44013.8	41829.976
4	40872.83	54629.25	42617.96	42511.31	52362	51431.572	50914.4	45625.7	50672.0	47294.5	35409.6	47218.196
5	38349.33	28407.21	41151.85	31261.46	52362	47901.361	51033.2	46671.0	50672.0	48081.2	51223.8	46330.509
6	24229.13	34962.72	40468.48	38684.37	49453	50166.157	52855.6	42135.0	52207.5	39161.8	43086.6	48597.005
7	35516.33	41518.23	47443.74	27451.63	52362	50882.616	49758.7	45929.8	50672.0	44123.8	44987.1	50788.704
8	39243.89	50258.91	42333.45	26179.78	45089.5	51031.819	48039.7	45666.8	50672.0	46279.3	32538.5	50785.881
9	37690.97	37147.89	37826.21	40190.05	46544	51805.988	50233.8	46075.5	50672.0	48796.1	45486.8	49287.115
10	37524.00	38240.48	32439.58	44968.03	53816.5	50574.355	51477.6	48685.1	50672.0	49247.9	45046.2	40017.908
11	35977.86	28407.21	40341.88	43637.72	33453.5	50827.72	51343.4	54741.5	50672.0	49460.6	42830.1	44954.523
12	32447.14	43703.40	46876.08	44471.84	42180.5	51067.009	52527.1	52849.1	52207.5	47885.9	48389.5	38838.088
13	37123.55	43703.40	41498.98	36415.86	45089.5	50875.578	50688.0	52448.8	53743.0	39009.0	48943.2	40044.722
14	32696.91	33870.14	48135.27	42552.66	42180.5	49928.276	50442.0	53496.9	49136.5	50260.5	40984.8	37810.685
15	31309.59	32777.55	41033.42	50540.20	49453	51237.326	39836.3	52962.2	49136.5	49541.6	46095.8	38616.519
16	36860.21	31684.97	42794.93	51194.66	49453	50650.365	49683.2	53878.8	50672.0	48074.6	42984.0	40065.891
17	38421.27	36055.31	35735.27	44151.03	49453	54103.159	50901.8	52661.0	50672.0	45314.5	43018.2	33136.567
18	37386.90	49166.33	41486.73	48201.83	46544	46764.036	52759.1	52149.0	50672.0	49402.1	38654.3	31218.654
19	39128.51	40425.65	43783.22	48257.43	45089.5	51109.236	50904.6	54723.2	50672.0	49095.1	45454.0	41511.029
20	21445.00	39333.06	37932.39	28010.56	47998.5	49265.306	51476.2	51547.8	52207.5	40768.4	45448.7	47157.512
21	37583.73	45888.57	36259.37	31998.62	40726	51067.009	52121.9	53396.5	49136.5	46697.8	43828.3	38843.733
22	40950.20	48073.74	35249.29	50819.66	47998.5	51447.055	50017.2	52259.3	52207.5	34929.4	48084.4	41845.5
23	39417.64	38240.48	56181.87	45812.13	49453	46935.761	51205.1	54689.2	52207.5	43831.5	30997.1	41293.694
24	37581.01	31684.97	44756.55	47996.51	39271.5	50349.143	53378.2	44990.7	52207.5	48238.0	42038.3	34420.82
25	39085.07	31684.97	23585.74	54806.30	47998.5	50919.213	50681.0	52034.4	49136.5	43523.2	43328.6	40552.779
26	43594.52	40425.65	37163.26	35239.55	47998.5	50436.413	52590.0	53083.9	52207.5	44175.6	45335.6	44683.559
27	45192.24	33870.14	42279.00	43462.35	49453	46939.983	39590.3	53618.5	50672.0	36446.9	37937.5	41559.013
28	39944.33	37147.89	41153.21	51084.87	46544	50715.113	52630.6	53190.0	52207.5	45458.0	41658.2	43763.413
29	44776.86	0.00	30412.62	45926.19	45089.5	51506.174	52081.3	53112.2	52207.5	43420.9	37886.2	32285.572
30	28315.06	0.00	27348.35	42122.06	43635	48249.033	50998.3	51108.0	52207.5	49447.3	42542.1	43317.452
31	37124.91	0.00	28994.15	0.00	39271.5	0	52422.3	53789.7	0.0	46300.5	0.0	40057.424
Total	**1142213**	**1092585**	**1229260**	**1220891**	**1454500**	**1503069**	**1562929**	**1571781**	**1535515**	**1429635**	**1289952**	**1301131**

Table C.2. Daily Pumping Rate from Wells That Supply Aqaba for the Year1999

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	46668.39	40861.93	35576.43	33208.01	47561.448	36343189	43354.5	44281.2	51574.2	52830.6	44620.1	40719.865
2	42796.98	38711.30	54523.82	32941.02	51885.216	42702.269	47969.1	37608.5	51574.2	54267.4	47244.1	49264.933
3	33901.24	39786.62	46386.76	29723.88	53326.472	43047.445	47730.0	40077.9	50057.3	54118.5	44082.6	41684.631
4	44851.10	53765.70	47687.59	49138.76	51885.216	43341.617	47092.7	38574.8	50057.3	49074.5	35465.0	47054.129
5	42081.98	27958.16	46047.08	36135.08	51885.216	40366.692	47202.6	39458.5	50057.3	49890.8	51304.0	46169.526
6	26587.42	34410.05	45282.42	44715.20	49002.704	42275.246	48888.2	35623.5	51574.2	40635.7	43154.0	48428.146
7	38973.24	40861.93	53087.42	31731.30	51885.216	42879.009	46023.8	38831.9	50057.3	45784.5	45057.4	50612.23
8	43063.61	49464.44	47369.24	30261.17	44678.936	43004.743	44433.8	38609.4	50057.3	48021.1	32589.4	50609.417
9	41359.54	36560.68	42325.84	46455.62	46120.192	43657.139	46463.2	38955.0	50057.3	50632.7	45558.0	49115.858
10	41176.32	37635.99	36298.44	51978.48	53326.472	42619.237	47613.7	41161.3	50057.3	51101.5	45116.7	39878.859
11	39479.70	27958.16	45140.76	50440.78	33148.888	42832.748	47489.6	46281.8	50057.3	51322.1	42897.1	44798.321
12	35605.31	43012.56	52452.24	51404.93	41796.424	43034.398	48584.4	44681.8	51574.2	49688.1	48465.2	38703.139
13	40736.90	43012.56	46435.50	42093.04	44678.936	42873.078	46883.3	44343.4	53091.1	40477.2	49019.8	39905.58
14	35879.39	33334.73	53861.22	49186.56	41796.424	42074.783	46655.8	45229.5	48540.4	52152.2	41049.0	37679.306
15	34357.05	32259.42	45914.56	58419.34	49002.704	43177.925	36846.1	44777.5	48540.4	51406.2	46167.9	38482.34
16	40447.92	31184.11	47885.61	59175.83	49002.704	42683.29	45953.9	45552.4	50057.3	49883.9	43051.2	39926.676
17	42160.93	35485.36	39986.17	51034.10	49002.704	45592.975	47081.1	44522.8	50057.3	47020.0	43085.5	33021.428
18	41025.88	48389.13	46421.79	55716.42	46120.192	39408.263	48799.0	44089.9	50057.3	51261.4	38714.7	31110.179
19	42937.00	39786.62	48991.47	55780.69	44678.936	43069.983	47083.7	46266.3	50057.3	50942.9	45525.1	41366.792
20	23532.31	38711.30	42444.65	32377.36	47561.448	41516.095	47612.4	43581.7	51574.2	42302.8	45519.8	46993.655
21	41241.86	45163.19	40572.61	36987.16	40355.168	43034.398	48209.6	45144.6	48540.4	48455.4	43896.9	38708.764
22	44936.01	47313.82	39442.38	58742.37	47561.448	43354.665	46262.9	44183.2	51574.2	36244.0	48159.6	41700.101
23	43254.28	37635.99	62865.00	52954.16	49002.704	39552.976	47361.6	46237.6	51574.2	45481.2	31045.6	41150.212
24	41238.88	31184.11	50080.58	55479.09	38913.912	42429.449	49371.6	38037.8	51574.2	50053.5	42104.1	34301.219
25	42889.33	31184.11	26391.39	63350.52	47561.448	42909.849	46876.9	43993.0	48540.4	45161.3	43396.3	40411.871
26	47837.70	39786.62	41584.03	40733.34	47561.448	42502.992	48642.6	44880.3	51574.2	45838.3	45406.5	44528.299
27	49590.93	33334.73	47308.31	50238.06	49002.704	39556.535	36618.6	45332.3	50057.3	37818.7	37996.8	41414.609
28	43832.23	36560.68	46048.60	59048.92	46120.192	42737.854	48680.1	44970.0	51574.2	47168.9	41723.4	43611.349
29	49135.12	0.00	34030.36	53086.01	44678.936	43404.484	48172.1	44904.2	51574.2	45055.1	37945.5	32173.391
30	31071.05	0.00	30601.58	48688.82	43237.68	40659.677	47170.3	43209.8	51574.2	51308.3	42608.6	43166.938
31	40738.39	0.00	32443.16	0.00	38913.912	0	48487.5	45477.0	0.0	48043.1	0.0	39918.237
Total	**1253388**	**1075314**	**1375487**	**1411226**	**1441256**	**1266643**	**1445615**	**1328879**	**1516889**	**1483442**	**1291970**	**1296610**

Table C.3. Daily Pumping Rate from Wells That Supply Aqaba for the Year 2000

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	33536	29882	29132	26778	40327	38446	42781	51298	42066	43092	38622	34418
2	30754	27459	44647	26563	43993	45173	47335	43568	42066	44263	40893	41641
3	24362	29074	37984	23969	45215	45538	47099	46429	40829	44142	38157	35234
4	32230	38765	39049	39624	43993	45849	46470	44687	40829	40028	30698	39772
5	30240	20190	37706	29139	43993	42702	46579	45711	40829	40694	44407	39025
6	19106	25036	37080	36057	41549	44721	48242	41268	42066	33145	37353	40934
7	28006	29882	43471	25587	43993	45360	45415	44985	40829	37344	39001	42780
8	30946	35535	38789	24402	37883	45493	43846	44727	40829	39169	28209	42777
9	29721	26651	34659	37461	39105	46183	45849	45128	40829	41299	39434	41515
10	29589	27459	29723	41914	45215	45085	46984	47684	40829	41681	39052	33707
11	28370	20190	36964	40674	28107	45311	46862	53615	40829	41861	37131	37866
12	25586	31497	42951	41452	35439	45524	47942	51762	42066	40528	41950	32714
13	29274	30689	38024	33943	37883	45354	46264	51370	43303	33015	42430	33730
14	25783	24228	44105	39663	35439	44509	46039	52396	39591	42538	35531	31848
15	24689	23421	37598	47108	41549	45676	36359	51873	39591	41930	39962	32527
16	29066	22613	39212	47718	41549	45153	45346	52770	40829	40688	37264	33748
17	30297	25844	32743	41153	41549	48231	46459	51578	40829	38352	37294	27911
18	29481	34727	38013	44928	39105	41689	48154	51076	40829	41812	33511	26296
19	30855	29074	40117	44980	37883	45562	46461	53597	40829	41552	39405	34965
20	16910	28266	34756	26108	40327	43918	46983	50487	42066	34505	39401	39721
21	29637	32304	33223	29826	34217	45524	47572	52298	39591	39523	37996	32718
22	32291	34727	32298	47369	40327	45863	45651	51184	42066	29563	41686	35247
23	31083	27459	51478	42701	41549	41842	46735	53564	42066	37097	26872	34782
24	29634	22613	41009	44737	32995	44885	48719	44065	42066	40826	36444	28993
25	30820	22613	21611	51084	40327	45393	46257	50964	39591	36836	37563	34158
26	34376	29074	34052	32846	40327	44962	48000	51992	42066	37388	39303	37637
27	35636	24228	38739	40511	41549	41845	36135	52516	40829	30847	32889	35006
28	31498	26651	37707	47616	39105	45211	48037	52096	42066	38474	36115	36862
29	35309	27459	27866	42807	37883	45916	47535	52020	42066	36749	32845	27194
30	22328	0	25058	39262	36661	43012	46547	50057	42066	41850	36881	36487
31	29275	0	26566	0	32995	0	47846	52683	0	39187	0	33741
Total	**900690**	**807612**	**1126332**	**1137981**	**1222035**	**1339934**	**1426504**	**1539448**	**1237233**	**1209977**	**1118297**	**1095955**

Table C.4. Daily Pumping Rate from Wells That Supply Aqaba for the Year 2001

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	35226	31603	29584	25366	40591	38497	42781	51297	42796	46833	36827	32672
2	32304	29940	45340	25162	44281	45233	47335	43567	42796	48106	38993	39528
3	25589	30772	38574	22705	45511	45599	47099	46428	41538	47974	36383	33446
4	33854	41584	39656	37535	44281	45911	46470	44686	41538	43503	29271	37754
5	31764	21623	38291	27602	44281	42759	46579	45710	41538	44226	42343	37045
6	20069	26613	37656	34156	41821	44781	48242	41268	42796	36022	35617	38857
7	29418	31603	44146	24238	44281	45421	45415	44984	41538	40586	37188	40609
8	32505	38257	39391	23115	38131	45554	43846	44727	41538	42569	26897	40607
9	31219	28277	35197	35486	39361	46245	45849	45127	41538	44884	37601	39409
10	31081	29108	30185	39704	45511	45145	46984	47683	41538	45300	37237	31997
11	29800	21623	37538	38530	28291	45372	46862	53615	41538	45495	35405	35944
12	26875	33267	43618	39266	35671	45585	47942	51761	42796	44047	40000	31054
13	30749	33267	38614	32153	38131	45414	46264	51369	44055	35882	40458	32019
14	27082	25782	44789	37572	35671	44569	46039	52395	40279	46231	33879	30232
15	25933	24950	38181	44624	41821	45737	36359	51872	40279	45570	38104	30877
16	30531	24118	39820	45202	41821	45213	45346	52770	41538	44220	35532	32036
17	31824	27445	33251	38983	41821	48295	46459	51577	41538	41682	35560	26495
18	30967	37425	38603	42560	39361	41744	48154	51075	41538	45441	31953	24962
19	32410	30772	40740	42609	38131	45623	46461	53597	41538	45159	37574	33191
20	17763	29940	35296	24732	40591	43977	46983	50487	42796	37500	37569	37706
21	31130	34930	33739	28253	34441	45585	47572	52297	40279	42954	36230	31058
22	33918	36594	32799	44871	40591	45924	45651	51183	42796	32129	39748	33458
23	32649	29108	52277	40450	41821	41897	46735	53563	42796	40317	25623	33017
24	31128	24118	41646	42378	33211	44944	48719	44064	42796	44371	34750	27522
25	32374	24118	21946	48391	40591	45453	46257	50963	40279	40034	35817	32425
26	36109	30772	34580	31115	40591	45022	48000	51991	42796	40634	37476	35728
27	37432	25782	39340	38375	41821	41901	36135	52515	41538	33525	31360	33229
28	33085	28277	38293	45105	39361	45271	48037	52095	42796	41814	34436	34992
29	37088	0	28299	40551	38131	45977	47535	52019	42796	39940	31318	25815
30	23453	0	25447	37192	36901	43070	46547	50056	42796	45483	35167	34635
31	30750	0	26979	0	33211	0	47846	52682	0	42589	0	32029
Total	**946077**	**831671**	**1143815**	**1077985**	**1230035**	**1341722**	**1426504**	**1539421**	**1258720**	**1315020**	**1066318**	**1040347**

Table C.5. Daily Pumping Rate from Wells That Supply Aqaba for the Year 2002

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	37763	41215	26798	28518	44392	37026	36196	48751	44762	46664	39171	36662
2	34630	39046	41070	28288	48427	43505	40049	41405	44762	47933	41475	44356
3	27432	40130	34941	25526	49772	43857	39849	44123	43445	47801	38699	37531
4	36292	54230	35921	42198	48427	44156	39317	42469	43445	43346	31134	42366
5	34052	28200	34685	31031	48427	41125	39409	43442	43445	44067	45039	41569
6	21514	34707	34109	38399	45737	43070	40816	39219	44762	35892	37884	43603
7	31536	41215	39988	27249	48427	43685	38424	42752	43445	40440	39555	45569
8	34846	49892	35681	25987	41701	43813	37097	42507	43445	42416	28610	45567
9	33467	36877	31882	39894	43046	44478	38791	42887	43445	44722	39995	44222
10	33319	37961	27342	44637	49772	43420	39752	45316	43445	45137	39607	35905
11	31946	28200	34003	43316	30940	43638	39648	50954	43445	45331	37659	40335
12	28811	43384	39510	44144	39011	43843	40562	49192	44762	43888	42547	34847
13	32963	43384	34978	36148	41701	43679	39142	48820	46078	35752	43034	35929
14	29033	33623	40571	42239	39011	42866	38952	49795	42129	46065	36036	33925
15	27801	32538	34585	50168	45737	43990	30762	49297	42129	45406	40530	34648
16	32730	31454	36070	50817	45737	43486	38366	50151	43445	44061	37794	35948
17	34116	35792	30120	43826	45737	46450	39307	49017	43445	41532	37824	29731
18	33197	48807	34967	47847	43046	40149	40741	48540	43445	45278	33987	28010
19	34744	40130	36903	47902	41701	43880	39309	50937	43445	44997	39966	37245
20	19042	39046	31972	27804	44392	42296	39751	47981	44762	37365	39961	42311
21	33372	45553	30562	31763	37666	43843	40249	49702	42129	42799	38536	34852
22	36361	47723	29710	50445	44392	44170	38624	48643	44762	32013	42278	37545
23	35000	37961	47353	45475	45737	40296	39541	50905	44762	40172	27254	37050
24	33370	31454	37724	47643	36320	43227	41219	41877	44762	44211	36962	30883
25	34705	31454	19879	54403	44392	43716	39137	48434	42129	39890	38097	36385
26	38709	40130	31323	34980	44392	43302	40611	49411	44762	40488	39862	40091
27	40128	33623	35635	43142	45737	40300	30572	49908	43445	33404	33357	37288
28	35468	36877	34686	50708	43046	43541	40642	49509	44762	41663	36628	39266
29	39759	0	25634	45588	41701	44220	40218	49437	44762	39796	33312	28968
30	25142	0	23051	41812	40356	41424	39382	47571	44762	45319	37405	38866
31	32965	0	24438	0	36320	0	40481	50068	0	42435	0	35941
Total	**1014213**	**1084607**	**1036094**	**1211896**	**1345198**	**1290451**	**1206916**	**1463019**	**1316525**	**1310285**	**1134196**	**1167414**

Table C.6. Daily Pumping Rate from Wells That Supply Aqaba for the Year 2003

Day	January	February.	March	April	May	June	July	August	September	October	November	December
1	40526	35885	25828	27016	45725	38352	44023	44316	45665	50878	43108	35596
2	37164	33996	39584	26799	49882	45063	48709	37638	45665	52262	45643	43065
3	29439	34940	33676	24182	51268	45427	48466	40110	44322	52119	42589	36439
4	38948	47217	34621	39977	49882	45738	47819	38605	44322	47261	34263	41133
5	36543	24553	33430	29397	49882	42598	47930	39490	44322	48047	49566	40360
6	23088	30219	32874	36378	47111	44612	49642	35652	45665	39134	41692	42334
7	33843	35885	38541	25815	49882	45249	46733	38863	44322	44093	43531	44243
8	37395	43439	34389	24619	42954	45382	45119	38640	44322	46246	31485	44241
9	35916	32107	30728	37794	44340	46071	47180	38986	44322	48762	44014	42935
10	35756	33052	26352	42287	51268	44975	48348	41194	44322	49213	43588	34860
11	34283	24553	32772	41036	31869	45201	48222	46319	44322	49426	41444	39161
12	30919	37773	38080	41820	40183	45413	49334	44717	45665	47852	46823	33833
13	35375	37773	33712	34245	42954	45243	47606	44379	47008	38981	47359	34884
14	31157	29274	39102	40015	40183	44401	47375	45265	42979	50225	39658	32938
15	29835	28330	33333	47527	47111	45565	37414	44813	42979	49507	44604	33640
16	35124	27386	34764	48142	47111	45043	46663	45589	44322	48040	41593	34902
17	36611	31163	29029	41519	47111	48113	47807	44558	44322	45282	41626	28866
18	35626	42495	33702	45328	44340	41587	49551	44125	44322	49367	37403	27195
19	37285	34940	35567	45380	42954	45451	47810	46303	44322	49060	43983	36161
20	20435	33996	30814	26340	45725	43811	48347	43616	45665	40740	43977	41080
21	35813	39662	29455	30091	38797	45413	48953	45180	42979	46665	42410	33838
22	39021	41551	28635	47790	45725	45751	46976	44218	45665	34905	46528	36453
23	37561	33052	45639	43081	47111	41740	48092	46274	45665	43800	29994	35972
24	35811	27386	36358	45135	37412	44775	50133	38068	45665	48204	40677	29985
25	37244	27386	19160	51538	45725	45282	47600	44028	42979	43492	41926	35326
26	41541	34940	30189	33138	45725	44853	49393	44916	45665	44144	43868	38925
27	43063	29274	34345	40871	47111	41743	37183	45368	44322	36421	36709	36203
28	38063	32107	33431	48039	44340	45101	49431	45006	45665	45426	40310	38123
29	42668	0	24706	43188	42954	45804	48915	44940	45665	43390	36660	28125
30	26981	0	22216	39611	41569	42907	47898	43244	45665	49412	41165	37735
31	35376	0	23553	0	37412	0	49235	45513	0	46268	0	34895
Total	**1088410**	**944334**	**998584**	**1148095**	**1385619**	**1336666**	**1467905**	**1329933**	**1343093**	**1428622**	**1248194**	**1133444**

Annex D

The Daily Water Consumption at Each Node Point in Aqaba for the Year 2003

Table D.1. Daily Water Consumption for all Sectors from Each Node for the Month of Jan, 2003

Day	Industry WAJ	Non-industry	Terminal Res.	Low Level Res.	High Level Res.	Main Trunk
1	13423.79	22097.90	2651.75	12374.82	1767.83	5303.50
2	12310.21	20264.75	2431.77	11348.26	1621.18	4863.54
3	9751.42	16052.54	1926.30	8989.42	1284.20	3852.61
4	12901.06	21237.40	2548.49	11892.94	1698.99	5096.98
5	12104.54	19926.20	2391.14	11158.67	1594.10	4782.29
6	7647.66	12589.38	1510.73	7050.06	1007.15	3021.45
7	11210.34	18454.18	2214.50	10334.34	1476.33	4429.00
8	12386.90	20391.01	2446.92	11418.96	1631.28	4893.84
9	11896.74	19584.11	2350.09	10967.10	1566.73	4700.19
10	11844.04	19497.36	2339.68	10918.52	1559.79	4679.37
11	11356.02	18693.99	2243.28	10468.63	1495.52	4486.56
12	10241.58	16859.43	2023.13	9441.28	1348.75	4046.26
13	11717.64	19289.29	2314.71	10802.00	1543.14	4629.43
14	10320.42	16989.21	2038.71	9513.96	1359.14	4077.41
15	9882.53	16268.37	1952.20	9110.29	1301.47	3904.41
16	11634.52	19152.45	2298.29	10725.37	1532.20	4596.59
17	12127.25	19963.58	2395.63	11179.60	1597.09	4791.26
18	11800.76	19426.12	2331.13	10878.63	1554.09	4662.27
19	12350.48	20331.05	2439.73	11385.39	1626.48	4879.45
20	6768.88	11142.76	1337.13	6239.94	891.42	2674.26
21	11862.89	19528.39	2343.41	10935.90	1562.27	4686.81
22	12925.48	21277.60	2553.31	11915.46	1702.21	5106.62
23	12441.75	20481.29	2457.75	11469.52	1638.50	4915.51
24	11862.03	19526.98	2343.24	10935.11	1562.16	4686.48
25	12336.77	20308.48	2437.02	11372.75	1624.68	4874.04
26	13760.13	22651.58	2718.19	12684.89	1812.13	5436.38
27	14264.43	23481.75	2817.81	13149.78	1878.54	5635.62
28	12607.99	20754.96	2490.59	11622.78	1660.40	4981.19
29	14133.32	23265.92	2791.91	13028.92	1861.27	5583.82
30	8937.34	14712.42	1765.49	8238.95	1176.99	3530.98
31	11718.07	19289.99	2314.80	10802.40	1543.20	4629.60
Total	**360527.00**	**593490.46**	**71218.86**	**332354.66**	**47479.24**	**142437.71**

Table D.2. Daily Water Consumption for all Sectors from Each Node for the Month of Feb, 2003

Day	Industry (WAJ)	Non-industry	Terminal Res.	Low Level Res.	High Level Res.	Main Trunk
1	11608.58	21350.25	2562.03	11956.14	1708.02	5124.06
2	10997.60	19784.43	2374.13	11079.28	1582.75	4748.26
3	11303.09	20785.29	2494.23	11639.76	1662.82	4988.47
4	15274.45	27552.19	3306.26	15429.23	2204.18	6612.53
5	7942.71	14514.22	1741.71	8127.96	1161.14	3483.41
6	9775.65	17707.24	2124.87	9916.05	1416.58	4249.74
7	11608.58	21050.49	2526.06	11788.27	1684.04	5052.12
8	14052.49	25307.14	3036.86	14172.00	2024.57	6073.71
9	10386.63	18909.82	2269.18	10589.50	1512.79	4538.36
10	10692.12	19275.18	2313.02	10794.10	1542.01	4626.04
11	7942.71	14502.94	1740.35	8121.64	1160.23	3480.70
12	12219.56	22235.44	2668.25	12451.85	1778.84	5336.51
13	12219.56	22146.57	2657.59	12402.08	1771.73	5315.18
14	9470.16	17079.50	2049.54	9564.52	1366.36	4099.08
15	9164.67	16702.15	2004.26	9353.20	1336.17	4008.52
16	8859.18	15861.40	1903.37	8882.38	1268.91	3806.74
17	10081.14	18176.28	2181.15	10178.72	1454.10	4362.31
18	13747.01	24969.29	2996.31	13982.80	1997.54	5992.63
19	11303.09	20612.48	2473.50	11542.99	1649.00	4947.00
20	10997.60	20191.40	2422.97	11307.18	1615.31	4845.94
21	12830.54	23295.54	2795.47	13045.50	1863.64	5590.93
22	13441.52	24688.57	2962.63	13825.60	1975.09	5925.26
23	10692.12	19529.80	2343.58	10936.69	1562.38	4687.15
24	8859.18	16112.49	1933.50	9023.00	1289.00	3867.00
25	8859.18	15942.51	1913.10	8927.81	1275.40	3826.20
26	11303.09	20950.33	2514.04	11732.19	1676.03	5028.08
27	9470.16	17306.61	2076.79	9691.70	1384.53	4153.59
28	10386.63	18953.55	2274.43	10613.99	1516.28	4548.85
29	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	0.00
Total	**305489.00**	**555493.08**	**66659.17**	**311076.13**	**44439.45**	**133318.34**

Table D.3. Daily Water Consumption for all Sectors from Each Node for the Month of March, 2003

Day	Industry (WAJ)	Non-industry	Terminal Res.	Low Level Res.	High Level Res.	Main Trunk
1	6711.74	16473.62	1976.83	9225.23	1317.89	3953.67
2	10325.76	25247.18	3029.66	14138.42	2019.77	6059.32
3	8776.90	21479.33	2577.52	12028.42	1718.35	5155.04
4	9035.04	22081.68	2649.80	12365.74	1766.53	5299.60
5	8518.75	21322.04	2558.64	11940.34	1705.76	5117.29
6	8518.75	20967.97	2516.16	11742.06	1677.44	5032.31
7	10067.62	24582.06	2949.85	13765.95	1966.56	5899.69
8	8776.90	21934.26	2632.11	12283.19	1754.74	5264.22
9	8002.46	19598.93	2351.87	10975.40	1567.91	4703.74
10	6711.74	16807.95	2016.95	9412.45	1344.64	4033.91
11	8518.75	20902.37	2508.28	11705.33	1672.19	5016.57
12	9809.47	24287.94	2914.55	13601.25	1943.04	5829.11
13	8776.90	21501.90	2580.23	12041.06	1720.15	5160.46
14	10067.62	24940.37	2992.84	13966.61	1995.23	5985.69
15	8518.75	21260.68	2551.28	11905.98	1700.85	5102.56
16	9035.04	22173.37	2660.80	12417.09	1773.87	5321.61
17	7486.18	18515.54	2221.87	10368.70	1481.24	4443.73
18	8776.90	21495.55	2579.47	12037.51	1719.64	5158.93
19	9293.18	22685.44	2722.25	12703.84	1814.83	5444.50
20	8002.46	19653.94	2358.47	11006.21	1572.32	4716.95
21	7486.18	18787.09	2254.45	10520.77	1502.97	4508.90
22	7486.18	18263.74	2191.65	10227.69	1461.10	4383.30
23	11874.62	29109.56	3493.15	16301.35	2328.76	6986.29
24	9293.18	23189.75	2782.77	12986.26	1855.18	5565.54
25	4904.74	12220.50	1466.46	6843.48	977.64	2932.92
26	7744.32	19255.43	2310.65	10783.04	1540.43	4621.30
27	8776.90	21906.05	2628.73	12267.39	1752.48	5257.45
28	8518.75	21322.74	2558.73	11940.74	1705.82	5117.46
29	6453.60	15757.71	1890.93	8824.32	1260.62	3781.85
30	5679.17	14170.02	1700.40	7935.21	1133.60	3400.81
31	6195.46	15022.76	1802.73	8412.75	1201.82	3605.46
Total	**258144.00**	**636917.46**	**76430.09**	**356673.78**	**50953.40**	**152860.19**

Table D.4. Daily Water Consumption for all Sectors from Each Node for the Month of April, 2003

Day	Industry (WAJ)	Non-industry	Terminal Res.	Low Level Res.	High Level Res.	Main Trunk
1	7320.92	10236.40	1228.37	5732.39	818.91	2456.74
2	7262.06	10154.10	1218.49	5686.30	812.33	2436.98
3	6552.82	9162.42	1099.49	5130.95	732.99	2198.98
4	10832.96	15147.07	1817.65	8482.36	1211.77	3635.30
5	7966.21	11138.67	1336.64	6237.66	891.09	2673.28
6	9857.76	13783.51	1654.02	7718.76	1102.68	3308.04
7	6995.37	9781.20	1173.74	5477.47	782.50	2347.49
8	6671.27	9328.04	1119.36	5223.70	746.24	2238.73
9	10241.44	14319.99	1718.40	8019.20	1145.60	3436.80
10	11458.99	16022.42	1922.69	8972.55	1281.79	3845.38
11	11120.00	15548.42	1865.81	8707.12	1243.87	3731.62
12	11332.55	15845.62	1901.47	8873.55	1267.65	3802.95
13	9279.69	12975.22	1557.03	7266.12	1038.02	3114.05
14	10843.50	15161.81	1819.42	8490.61	1212.94	3638.83
15	12878.92	18007.82	2160.94	10084.38	1440.63	4321.88
16	13045.70	18241.01	2188.92	10214.96	1459.28	4377.84
17	11250.80	15731.31	1887.76	8809.54	1258.51	3775.52
18	12283.05	17174.64	2060.96	9617.80	1373.97	4121.91
19	12297.22	17194.45	2063.33	9628.89	1375.56	4126.67
20	7137.80	9980.35	1197.64	5589.00	798.43	2395.28
21	8154.06	11401.33	1368.16	6384.74	912.11	2736.32
22	12950.14	18107.39	2172.89	10140.14	1448.59	4345.77
23	11674.09	16323.17	1958.78	9140.98	1305.85	3917.56
24	12230.73	17101.48	2052.18	9576.83	1368.12	4104.36
25	13966.04	19527.86	2343.34	10935.60	1562.23	4686.69
26	8979.93	12556.09	1506.73	7031.41	1004.49	3013.46
27	11075.31	15485.93	1858.31	8672.12	1238.87	3716.62
28	13017.72	18201.89	2184.23	10193.06	1456.15	4368.45
29	11703.16	16363.82	1963.66	9163.74	1309.11	3927.32
30	10733.77	15008.38	1801.01	8404.69	1200.67	3602.01
31	0.00	0.00	0.00	0.00	0.00	0.00
Total	**311114.00**	**435011.84**	**52201.42**	**243606.63**	**34800.95**	**104402.84**

Table D.5. Daily Water Consumption for all Sectors from Each Node for the Month of May, 2003

Day	Industry (WAJ)	Non-industry	Terminal Res.	Low Level Res.	High Level Res.	Main Trunk
1	12562.47	17580.56	2109.67	9845.11	1406.44	4219.33
2	13704.52	18785.11	2254.21	10519.66	1502.81	4508.43
3	14085.20	19215.93	2305.91	10760.92	1537.27	4611.82
4	13704.52	18926.86	2271.22	10599.04	1514.15	4542.45
5	13704.52	19069.61	2288.35	10678.98	1525.57	4576.71
6	12943.15	17724.34	2126.92	9925.63	1417.95	4253.84
7	13704.52	18901.96	2268.24	10585.10	1512.16	4536.47
8	11801.11	16023.43	1922.81	8973.12	1281.87	3845.62
9	12181.79	16741.29	2008.95	9375.12	1339.30	4017.91
10	14085.20	19831.16	2379.74	11105.45	1586.49	4759.48
11	8755.66	11962.71	1435.52	6699.12	957.02	2871.05
12	11039.75	15342.67	1841.12	8591.89	1227.41	3682.24
13	11801.11	16376.52	1965.18	9170.85	1310.12	3930.36
14	11039.75	14962.66	1795.52	8379.09	1197.01	3591.04
15	12943.15	17645.59	2117.47	9881.53	1411.65	4234.94
16	12943.15	18088.60	2170.63	10129.61	1447.09	4341.26
17	12943.15	17964.13	2155.70	10059.91	1437.13	4311.39
18	12181.79	16547.73	1985.73	9266.73	1323.82	3971.45
19	11801.11	16393.28	1967.19	9180.24	1311.46	3934.39
20	12562.47	17235.10	2068.21	9651.65	1378.81	4136.42
21	10659.07	14598.39	1751.81	8175.10	1167.87	3503.61
22	12562.47	17263.55	2071.63	9667.59	1381.08	4143.25
23	12943.15	18138.89	2176.67	10157.78	1451.11	4353.33
24	10278.39	14214.83	1705.78	7960.30	1137.19	3411.56
25	12562.47	17216.81	2066.02	9641.41	1377.34	4132.03
26	12562.47	17149.24	2057.91	9603.57	1371.94	4115.82
27	12943.15	18047.95	2165.75	10106.85	1443.84	4331.51
28	12181.79	16929.77	2031.57	9480.67	1354.38	4063.14
29	11801.11	16161.11	1939.33	9050.22	1292.89	3878.67
30	11420.43	15652.06	1878.25	8765.15	1252.16	3756.49
31	10278.39	14126.43	1695.17	7910.80	1130.11	3390.34
Total	**380681.00**	**524818.25**	**62978.19**	**293898.22**	**41985.46**	**125956.38**

Table D.6. Daily Water Consumption for all Sectors from Each Node for the Month of Jun, 2003

Day	Industry (WAJ)	Non-industry	Terminal Res.	Low Level Res.	High Level Res.	Main Trunk
1	10280.70	15565.69	1867.88	8716.79	1245.26	3735.77
2	12079.55	18289.27	2194.71	10241.99	1463.14	4389.43
3	12177.19	18437.11	2212.45	10324.78	1474.97	4424.91
4	12260.41	18563.10	2227.57	10395.34	1485.05	4455.14
5	11418.87	17288.95	2074.67	9681.81	1383.12	4149.35
6	11958.76	18106.38	2172.77	10139.57	1448.51	4345.53
7	12129.55	18364.97	2203.80	10284.38	1469.20	4407.59
8	12165.11	18418.82	2210.26	10314.54	1473.51	4420.52
9	12349.66	18698.24	2243.79	10471.01	1495.86	4487.58
10	12056.06	18253.71	2190.45	10222.08	1460.30	4380.89
11	12116.46	18345.15	2201.42	10273.29	1467.61	4402.84
12	12173.50	18431.52	2211.78	10321.65	1474.52	4423.57
13	12127.87	18362.43	2203.49	10282.96	1468.99	4406.98
14	11902.05	18020.52	2162.46	10091.49	1441.64	4324.92
15	12214.10	18492.99	2219.16	10356.08	1479.44	4438.32
16	12074.18	18281.14	2193.74	10237.44	1462.49	4387.47
17	12897.27	19527.35	2343.28	10935.32	1562.19	4686.56
18	11147.75	16878.46	2025.41	9451.94	1350.28	4050.83
19	12183.57	18446.76	2213.61	10330.19	1475.74	4427.22
20	11744.01	17781.24	2133.75	9957.49	1422.50	4267.50
21	12173.50	18431.52	2211.78	10321.65	1474.52	4423.57
22	12264.10	18568.69	2228.24	10398.47	1485.50	4456.49
23	11188.68	16940.44	2032.85	9486.64	1355.23	4065.70
24	12002.38	18172.42	2180.69	10176.56	1453.79	4361.38
25	12138.27	18378.18	2205.38	10291.78	1470.25	4410.76
26	12023.18	18203.92	2184.47	10194.20	1456.31	4368.94
27	11189.69	16941.96	2033.04	9487.50	1355.36	4066.07
28	12089.62	18304.51	2196.54	10250.53	1464.36	4393.08
29	12278.19	18590.03	2230.80	10410.42	1487.20	4461.61
30	11501.75	17414.43	2089.73	9752.08	1393.15	4179.46
31	0.00	0.00	0.00	0.00	0.00	0.00
Total	**358306.00**	**542499.91**	**65099.99**	**303799.95**	**43399.99**	**130199.98**

Table D.7. Daily Water Consumption for all Sectors from Each Node for the Month of July, 2003

Day	Industry (WAJ)	Non-industry	Terminal Res.	Low Level Res.	High Level Res.	Main Trunk
1	11258.55	16762.26	2011.47	9386.87	1340.98	4022.94
2	12456.92	18546.44	2225.57	10386.00	1483.71	4451.14
3	12394.82	18453.98	2214.48	10334.23	1476.32	4428.95
4	12229.33	18207.59	2184.91	10196.25	1456.61	4369.82
5	12257.86	18250.07	2190.01	10220.04	1460.01	4380.02
6	12695.58	18901.77	2268.21	10584.99	1512.14	4536.43
7	11951.72	17794.28	2135.31	9964.80	1423.54	4270.63
8	11538.84	17179.57	2061.55	9620.56	1374.37	4123.10
9	12065.85	17964.20	2155.70	10059.95	1437.14	4311.41
10	12364.61	18409.00	2209.08	10309.04	1472.72	4418.16
11	12332.38	18361.02	2203.32	10282.17	1468.88	4406.65
12	12616.70	18784.33	2254.12	10519.22	1502.75	4508.24
13	12174.95	18126.63	2175.20	10150.91	1450.13	4350.39
14	12115.87	18038.67	2164.64	10101.66	1443.09	4329.28
15	9568.43	14245.92	1709.51	7977.72	1139.67	3419.02
16	11933.60	17767.30	2132.08	9949.69	1421.38	4264.15
17	12226.31	18203.09	2184.37	10193.73	1456.25	4368.74
18	12672.42	18867.29	2264.07	10565.68	1509.38	4528.15
19	12226.98	18204.09	2184.49	10194.29	1456.33	4368.98
20	12364.27	18408.50	2209.02	10308.76	1472.68	4418.04
21	12519.35	18639.39	2236.73	10438.06	1491.15	4473.45
22	12013.82	17886.74	2146.41	10016.57	1430.94	4292.82
23	12299.15	18311.54	2197.39	10254.46	1464.92	4394.77
24	12821.12	19088.69	2290.64	10689.66	1527.09	4581.28
25	12173.27	18124.13	2174.90	10149.51	1449.93	4349.79
26	12631.80	18806.82	2256.82	10531.82	1504.55	4513.64
27	9509.35	14157.96	1698.96	7928.46	1132.64	3397.91
28	12641.54	18821.31	2258.56	10539.93	1505.70	4517.11
29	12509.62	18624.90	2234.99	10429.94	1489.99	4469.98
30	12249.47	18237.58	2188.51	10213.04	1459.01	4377.02
31	12591.52	18746.84	2249.62	10498.23	1499.75	4499.24
Total	**375406.00**	**558921.91**	**67070.63**	**312996.27**	**44713.75**	**134141.26**

Table D.8. Daily Water Consumption for all Sectors from Each Node for the Month of Aug, 2003

Day	Industry (WAJ)	Non-industry	Terminal Res.	Low Level Res.	High Level Res.	Main Trunk
1	10978.74	18506.45	2220.77	10363.61	1480.52	4441.55
2	9324.37	15717.74	1886.13	8801.94	1257.42	3772.26
3	9936.61	16749.77	2009.97	9379.87	1339.98	4019.94
4	9563.93	16121.56	1934.59	9028.07	1289.72	3869.17
5	9783.03	16490.88	1978.91	9234.90	1319.27	3957.81
6	8832.21	14888.13	1786.58	8337.35	1191.05	3573.15
7	9627.67	16229.01	1947.48	9088.24	1298.32	3894.96
8	9572.53	16136.05	1936.33	9036.19	1290.88	3872.65
9	9658.21	16280.48	1953.66	9117.07	1302.44	3907.32
10	10205.22	17202.56	2064.31	9633.43	1376.20	4128.61
11	11474.76	19342.57	2321.11	10831.84	1547.41	4642.22
12	11078.06	18673.88	2240.87	10457.37	1493.91	4481.73
13	10994.16	18532.44	2223.89	10378.17	1482.60	4447.79
14	11213.85	18902.77	2268.33	10585.55	1512.22	4536.67
15	11101.78	18713.86	2245.66	10479.76	1497.11	4491.33
16	11293.90	19037.71	2284.53	10661.12	1523.02	4569.05
17	11038.63	18607.41	2232.89	10420.15	1488.59	4465.78
18	10931.31	18426.49	2211.18	10318.84	1474.12	4422.36
19	11470.90	19336.07	2320.33	10828.20	1546.89	4640.66
20	10805.30	18214.09	2185.69	10199.89	1457.13	4371.38
21	11192.80	18867.29	2264.07	10565.68	1509.38	4528.15
22	10954.43	18465.47	2215.86	10340.66	1477.24	4431.71
23	11463.79	19324.08	2318.89	10821.48	1545.93	4637.78
24	9430.81	15897.16	1907.66	8902.41	1271.77	3815.32
25	10907.29	18386.01	2206.32	10296.17	1470.88	4412.64
26	11127.28	18756.84	2250.82	10503.83	1500.55	4501.64
27	11239.35	18945.75	2273.49	10609.62	1515.66	4546.98
28	11149.52	18794.32	2255.32	10524.82	1503.55	4510.64
29	11133.21	18766.83	2252.02	10509.43	1501.35	4504.04
30	10713.10	18058.66	2167.04	10112.85	1444.69	4334.08
31	11275.23	19006.22	2280.75	10643.49	1520.50	4561.49
Total	**329472.00**	**555378.54**	**66645.43**	**311011.98**	**44430.28**	**133290.85**

Table D.9. Daily Water Consumption for all Sectors from Each Node for the Month of Sep, 2003

Day	Industry (WAJ)	Non-Industry	Terminal Res.	Low Level Res.	High Level Res.	Main Trunk
1	12508.87	19665.92	2359.91	11012.91	1573.27	4719.82
2	12508.87	19734.89	2368.19	11051.54	1578.79	4736.37
3	12140.96	19382.05	2325.85	10853.95	1550.56	4651.69
4	12140.96	19318.58	2318.23	10818.40	1545.49	4636.46
5	12140.96	19408.54	2329.02	10868.78	1552.68	4658.05
6	12508.87	19718.39	2366.21	11042.30	1577.47	4732.41
7	12140.96	19228.62	2307.43	10768.03	1538.29	4614.87
8	12140.96	19126.17	2295.14	10710.65	1530.09	4590.28
9	12140.96	19272.10	2312.65	10792.38	1541.77	4625.30
10	12140.96	19287.09	2314.45	10800.77	1542.97	4628.90
11	12140.96	19314.08	2317.69	10815.89	1545.13	4635.38
12	12508.87	19630.44	2355.65	10993.04	1570.43	4711.30
13	12876.78	20223.66	2426.84	11325.25	1617.89	4853.68
14	11773.06	18951.25	2274.15	10612.70	1516.10	4548.30
15	11773.06	18941.75	2273.01	10607.38	1515.34	4546.02
16	12140.96	19450.52	2334.06	10892.29	1556.04	4668.12
17	12140.96	19450.52	2334.06	10892.29	1556.04	4668.12
18	12140.96	19450.52	2334.06	10892.29	1556.04	4668.12
19	12140.96	19450.52	2334.06	10892.29	1556.04	4668.12
20	12508.87	19742.38	2369.09	11055.73	1579.39	4738.17
21	11773.06	18864.79	2263.77	10564.28	1509.18	4527.55
22	12508.87	19556.47	2346.78	10951.62	1564.52	4693.55
23	12508.87	19555.47	2346.66	10951.06	1564.44	4693.31
24	12508.87	19778.37	2373.40	11075.89	1582.27	4746.81
25	11773.06	18772.33	2252.68	10512.51	1501.79	4505.36
26	12508.87	19594.95	2351.39	10973.17	1567.60	4702.79
27	12140.96	19528.48	2343.42	10935.95	1562.28	4686.84
28	12508.87	19611.94	2353.43	10982.69	1568.96	4706.87
29	12508.87	19789.86	2374.78	11082.32	1583.19	4749.57
30	12508.87	19710.90	2365.31	11038.10	1576.87	4730.62
31	0.00	0.00	0.00	0.00	0.00	0.00
Total	**367908.00**	**583511.55**	**70021.39**	**326766.47**	**46680.92**	**140042.77**

Table D.10. Daily Water Consumption for all Sectors from Each Node for the Month of Oct, 2003

Day	Industry (WAJ)	Non-Industry	Terminal Res.	Low Level Res.	High Level Res.	Main Trunk
1	13274.55	21233.95	2548.07	11891.01	1698.72	5096.15
2	13635.57	21811.44	2617.37	12214.40	1744.91	5234.74
3	13598.15	21751.58	2610.19	12180.89	1740.13	5220.38
4	12330.78	19724.29	2366.91	11045.60	1577.94	4733.83
5	12535.88	20052.38	2406.29	11229.33	1604.19	4812.57
6	10210.39	16332.53	1959.90	9146.22	1306.60	3919.81
7	11504.10	18401.94	2208.23	10305.09	1472.16	4416.47
8	12066.07	19300.87	2316.10	10808.49	1544.07	4632.21
9	12722.28	20350.54	2442.06	11396.30	1628.04	4884.13
10	12840.08	20538.97	2464.68	11501.82	1643.12	4929.35
11	12895.52	20627.65	2475.32	11551.48	1650.21	4950.63
12	12484.95	19970.91	2396.51	11183.71	1597.67	4793.02
13	10170.55	16268.79	1952.26	9110.52	1301.50	3904.51
14	13104.09	20961.28	2515.35	11738.32	1676.90	5030.71
15	12916.65	20661.45	2479.37	11570.41	1652.92	4958.75
16	12534.15	20049.61	2405.95	11227.78	1603.97	4811.91
17	11814.54	18898.51	2267.82	10583.17	1511.88	4535.64
18	12880.27	20603.26	2472.39	11537.83	1648.26	4944.78
19	12800.24	20475.24	2457.03	11466.13	1638.02	4914.06
20	10629.27	17002.57	2040.31	9521.44	1360.21	4080.62
21	12175.21	19475.45	2337.05	10906.25	1558.04	4674.11
22	9106.90	14567.37	1748.08	8157.73	1165.39	3496.17
23	11427.88	18280.02	2193.60	10236.81	1462.40	4387.20
24	12576.77	20117.77	2414.13	11265.95	1609.42	4828.27
25	11347.50	18151.44	2178.17	10164.81	1452.12	4356.35
26	11517.62	18423.56	2210.83	10317.19	1473.88	4421.65
27	9502.56	15200.28	1824.03	8512.16	1216.02	3648.07
28	11851.96	18958.37	2275.00	10616.69	1516.67	4550.01
29	11320.82	18108.77	2173.05	10140.91	1448.70	4346.10
30	12892.05	20622.10	2474.65	11548.38	1649.77	4949.30
31	12071.62	19309.74	2317.17	10813.45	1544.78	4634.34
Total	**372739.00**	**596232.62**	**71547.91**	**333890.27**	**47698.61**	**143095.83**

Table D.11. Daily Water Consumption for all Sectors from Each Node for the Month of Nov, 2003

Day	Industry (WAJ)	Non-industry	Terminal Res.	Low Level Res.	High Level Res.	Main Trunk
1	11756.15	18772.71	2252.73	10512.72	1501.82	4505.45
2	12447.50	19876.69	2385.20	11130.95	1590.14	4770.41
3	11614.55	18546.59	2225.59	10386.09	1483.73	4451.18
4	9344.04	14920.96	1790.52	8355.74	1193.68	3581.03
5	13517.16	21584.76	2590.17	12087.47	1726.78	5180.34
6	11369.86	18155.88	2178.71	10167.29	1452.47	4357.41
7	11871.37	18956.71	2274.80	10615.76	1516.54	4549.61
8	8586.40	13711.12	1645.33	7678.23	1096.89	3290.67
9	12003.26	19167.31	2300.08	10733.69	1533.38	4600.15
10	11886.99	18981.65	2277.80	10629.72	1518.53	4555.60
11	11302.19	18047.80	2165.74	10106.77	1443.82	4331.47
12	12769.23	20390.44	2446.85	11418.65	1631.24	4893.71
13	12915.35	20623.77	2474.85	11549.31	1649.90	4949.70
14	10815.25	17270.25	2072.43	9671.34	1381.62	4144.86
15	12163.95	19423.90	2330.87	10877.39	1553.91	4661.74
16	11342.79	18112.65	2173.52	10143.08	1449.01	4347.04
17	11351.82	18127.06	2175.25	10151.15	1450.16	4350.49
18	10200.25	16288.19	1954.58	9121.39	1303.06	3909.17
19	11994.58	19153.45	2298.41	10725.93	1532.28	4596.83
20	11993.19	19151.23	2298.15	10724.69	1532.10	4596.30
21	11565.61	18468.45	2216.21	10342.33	1477.48	4432.43
22	12688.71	20261.87	2431.42	11346.65	1620.95	4862.85
23	8179.64	13061.59	1567.39	7314.49	1044.93	3134.78
24	11093.25	17714.17	2125.70	9919.94	1417.13	4251.40
25	11433.73	18257.85	2190.94	10224.40	1460.63	4381.88
26	11963.35	19103.57	2292.43	10698.00	1528.29	4584.86
27	10011.10	15986.15	1918.34	8952.24	1278.89	3836.68
28	10992.95	17554.00	2106.48	9830.24	1404.32	4212.96
29	9997.57	15964.53	1915.74	8940.14	1277.16	3831.49
30	11226.18	17926.43	2151.17	10038.80	1434.11	4302.34
31	0.00	0.00	0.00	0.00	0.00	0.00
Total	**340398.00**	**543561.74**	**65227.41**	**304394.57**	**43484.94**	**130454.82**

Table D.12. Daily Water Consumption for all Sectors from Each Node for the Month of Dec, 2003

Day	Industry (WAJ)	Non-industry	Terminal Res.	Low Level Res.	High Level Res.	Main Trunk
1	9636.74	16046.56	1925.59	8986.07	1283.72	3851.17
2	11659.01	19413.93	2329.67	10871.80	1553.11	4659.34
3	9865.06	16426.74	1971.21	9198.98	1314.14	3942.42
4	11135.80	18542.71	2225.13	10383.92	1483.42	4450.25
5	10926.45	18194.12	2183.29	10188.70	1455.53	4366.59
6	11460.98	19084.17	2290.10	10687.14	1526.73	4580.20
7	11977.86	19944.86	2393.38	11169.12	1595.59	4786.77
8	11977.20	19943.75	2393.25	11168.50	1595.50	4786.50
9	11623.73	19355.18	2322.62	10838.90	1548.41	4645.24
10	9437.71	15715.14	1885.82	8800.48	1257.21	3771.63
11	10601.95	17653.76	2118.45	9886.11	1412.30	4236.90
12	9159.46	15251.82	1830.22	8541.02	1220.15	3660.44
13	9444.03	15725.67	1887.08	8806.38	1258.05	3774.16
14	8917.16	14848.36	1781.80	8315.08	1187.87	3563.61
15	9107.21	15164.81	1819.78	8492.29	1213.18	3639.55
16	9449.02	15733.98	1888.08	8811.03	1258.72	3776.16
17	7814.83	13012.82	1561.54	7287.18	1041.03	3123.08
18	7362.52	12259.65	1471.16	6865.40	980.77	2942.32
19	9789.84	16301.49	1956.18	9128.84	1304.12	3912.36
20	11121.49	18518.88	2222.27	10370.57	1481.51	4444.53
21	9160.79	15254.04	1830.48	8542.26	1220.32	3660.97
22	9868.72	16432.84	1971.94	9202.39	1314.63	3943.88
23	9738.59	16216.14	1945.94	9081.04	1297.29	3891.87
24	8117.71	13517.15	1622.06	7569.60	1081.37	3244.12
25	9563.85	15925.19	1911.02	8918.10	1274.01	3822.04
26	10538.04	17547.35	2105.68	9826.52	1403.79	4211.36
27	9801.16	16320.34	1958.44	9139.39	1305.63	3916.88
28	10321.04	17186.01	2062.32	9624.17	1374.88	4124.64
29	7614.14	12678.63	1521.44	7100.03	1014.29	3042.87
30	10215.86	17010.88	2041.31	9526.09	1360.87	4082.61
31	9447.03	15730.66	1887.68	8809.17	1258.45	3775.36
Total	**306855.00**	**510957.64**	**61314.92**	**286136.28**	**40876.61**	**122629.83**

Annex E

Detailed Analysis for Supply Demand Nodes for the Base Line Scenario for 2003.

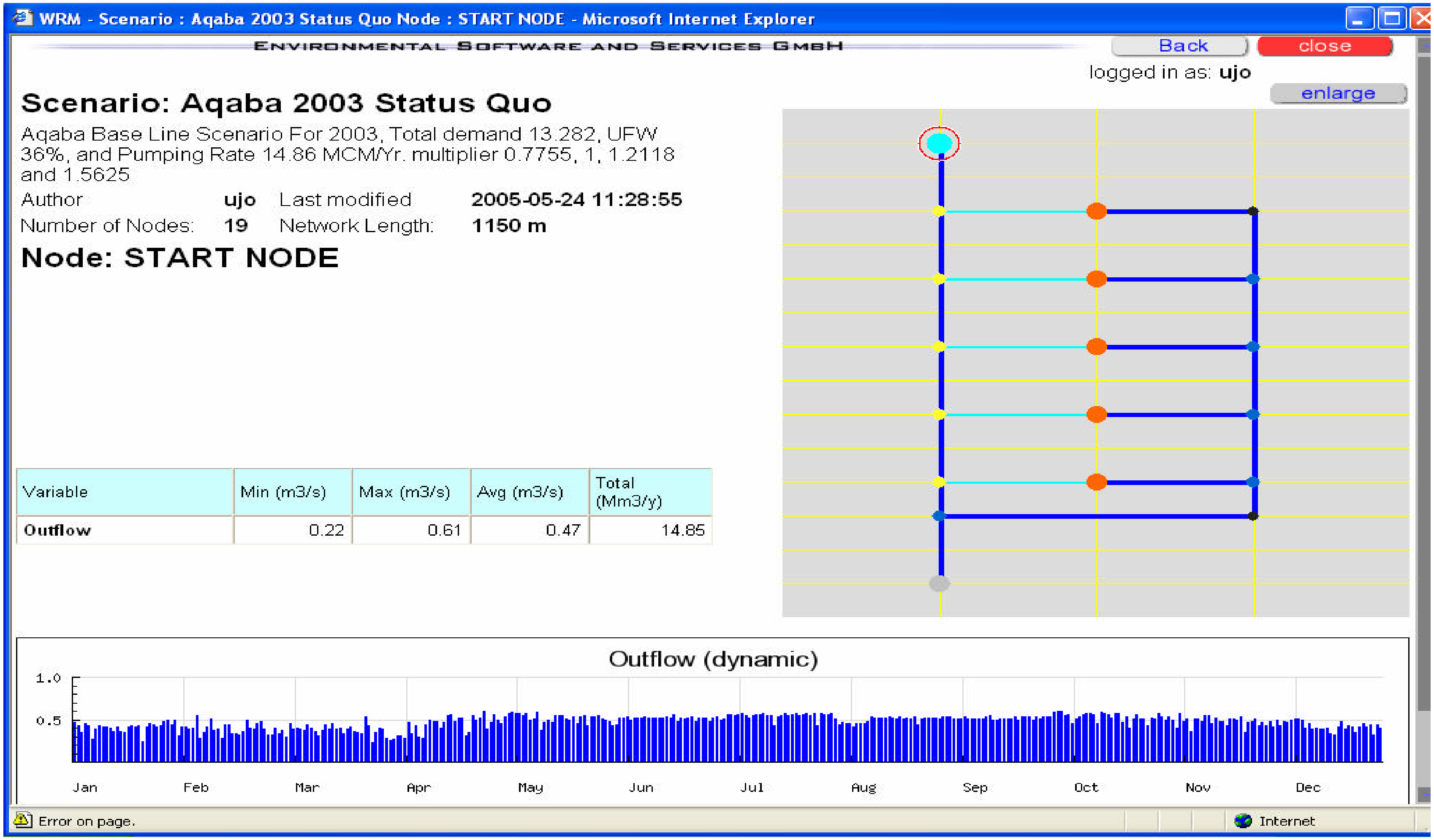
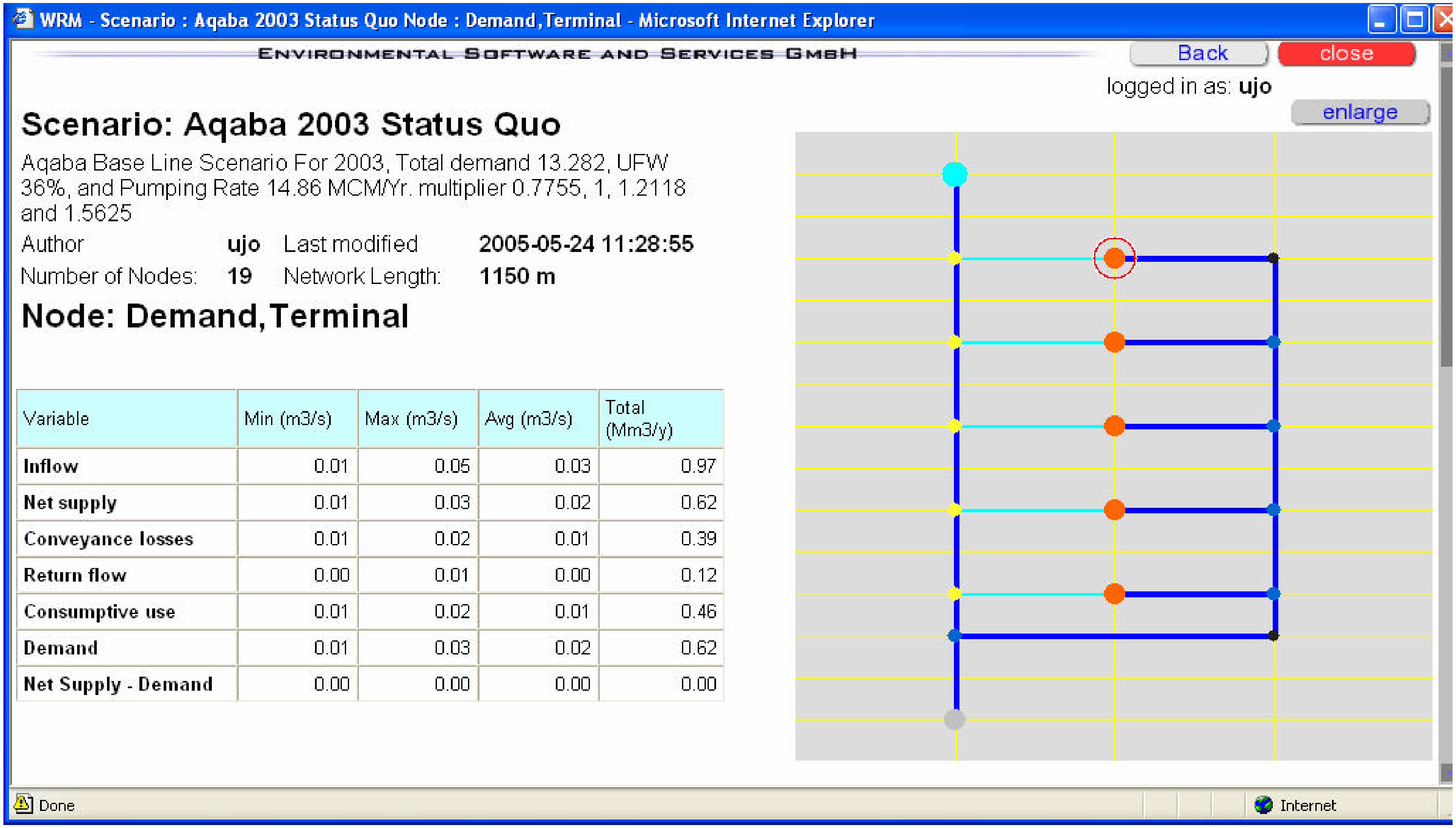


Figure E.1: Daily Pumping Rate for the Base Line Scenario for 2003.



Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow	0.01	0.05	0.03	0.97
Net supply	0.01	0.03	0.02	0.62
Conveyance losses	0.01	0.02	0.01	0.39
Return flow	0.00	0.01	0.00	0.12
Consumptive use	0.01	0.02	0.01	0.46
Demand	0.01	0.03	0.02	0.62
Net Supply - Demand	0.00	0.00	0.00	0.00

Figure E.2: Daily Detailed Analysis of Water Demand and Supply for the Terminal Demand Node for theBase Line Scenario for 2003.

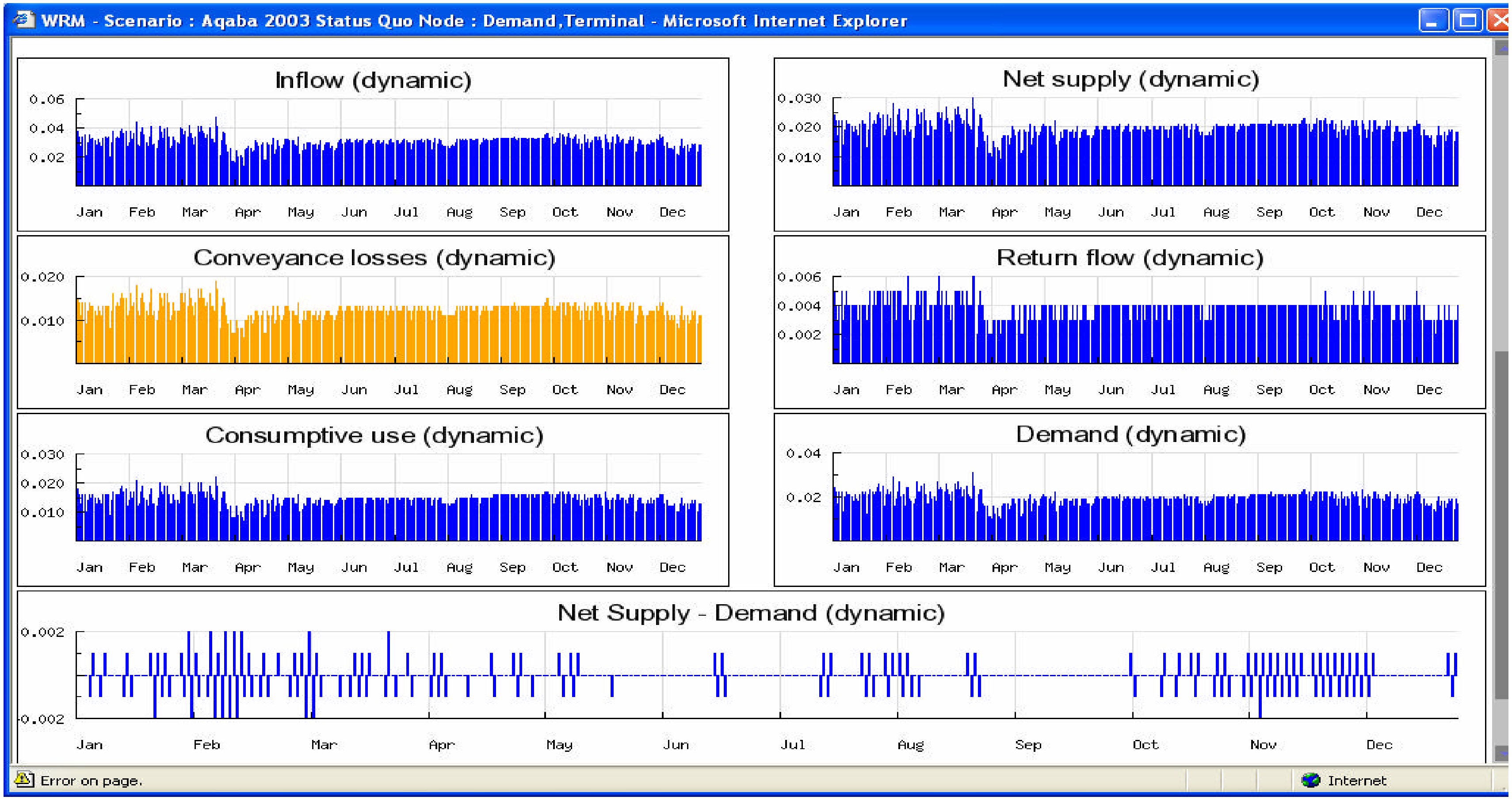
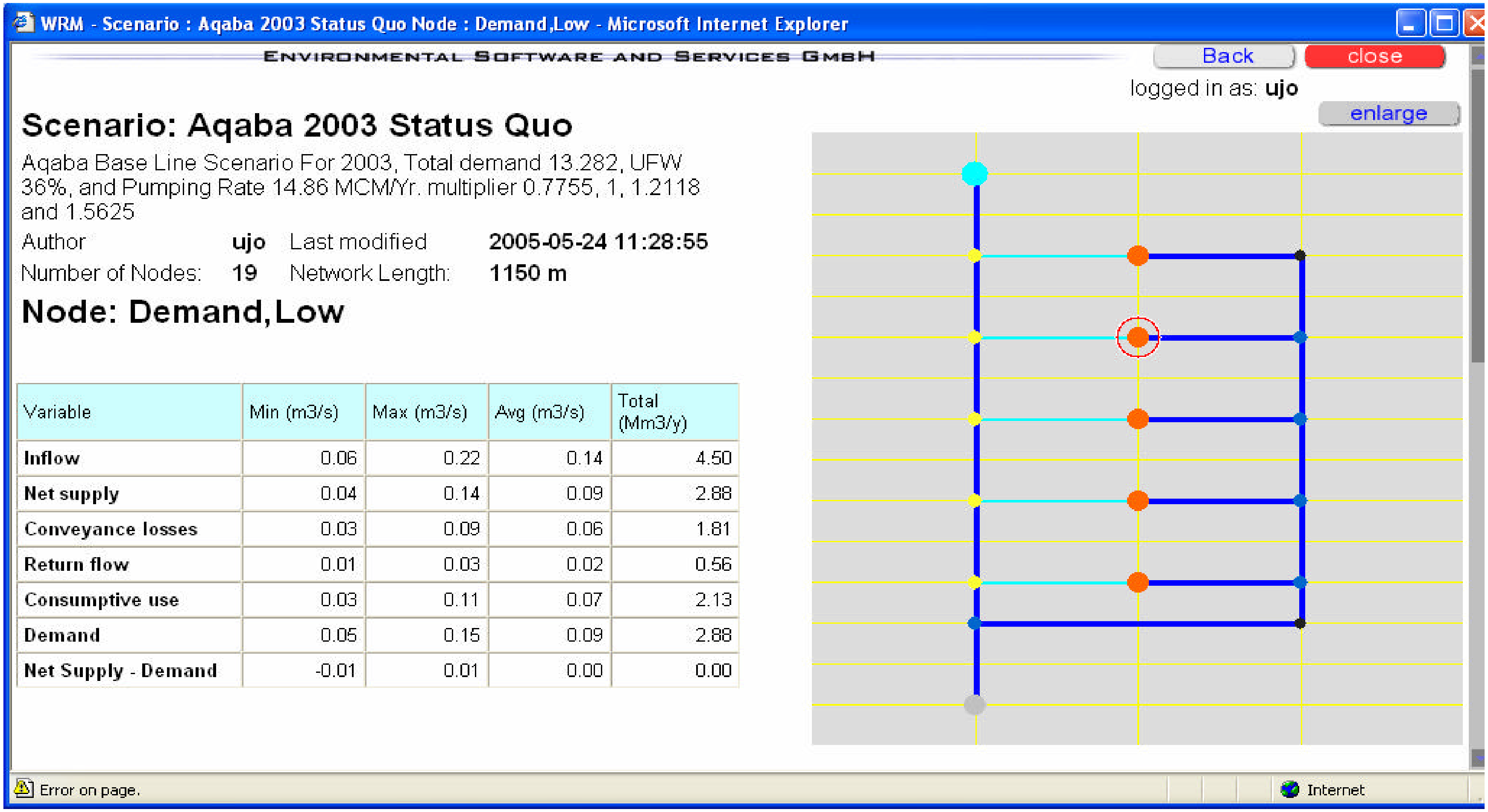


Figure E.3: Daily Analysis of Water Demand and Supply for the Terminal Demand Node for the Base Line Scenario for 2003.



WRM - Scenario : Aqaba 2003 Status Quo Node : Demand,Low - Microsoft Internet Explorer

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Scenario: Aqaba 2003 Status Quo

Aqaba Base Line Scenario For 2003, Total demand 13.282, UFW 36%, and Pumping Rate 14.86 MCM/Yr. multiplier 0.7755, 1, 1.2118 and 1.5625

Author **ujo** Last modified **2005-05-24 11:28:55**

Number of Nodes: **19** Network Length: **1150 m**

Node: Demand,Low

Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow	0.06	0.22	0.14	4.50
Net supply	0.04	0.14	0.09	2.88
Conveyance losses	0.03	0.09	0.06	1.81
Return flow	0.01	0.03	0.02	0.56
Consumptive use	0.03	0.11	0.07	2.13
Demand	0.05	0.15	0.09	2.88
Net Supply - Demand	-0.01	0.01	0.00	0.00

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Figure E.4: Daily Detailed Analysis of Water Demand and Supply for the Low Level Node for the Base Line Scenario for 2003.

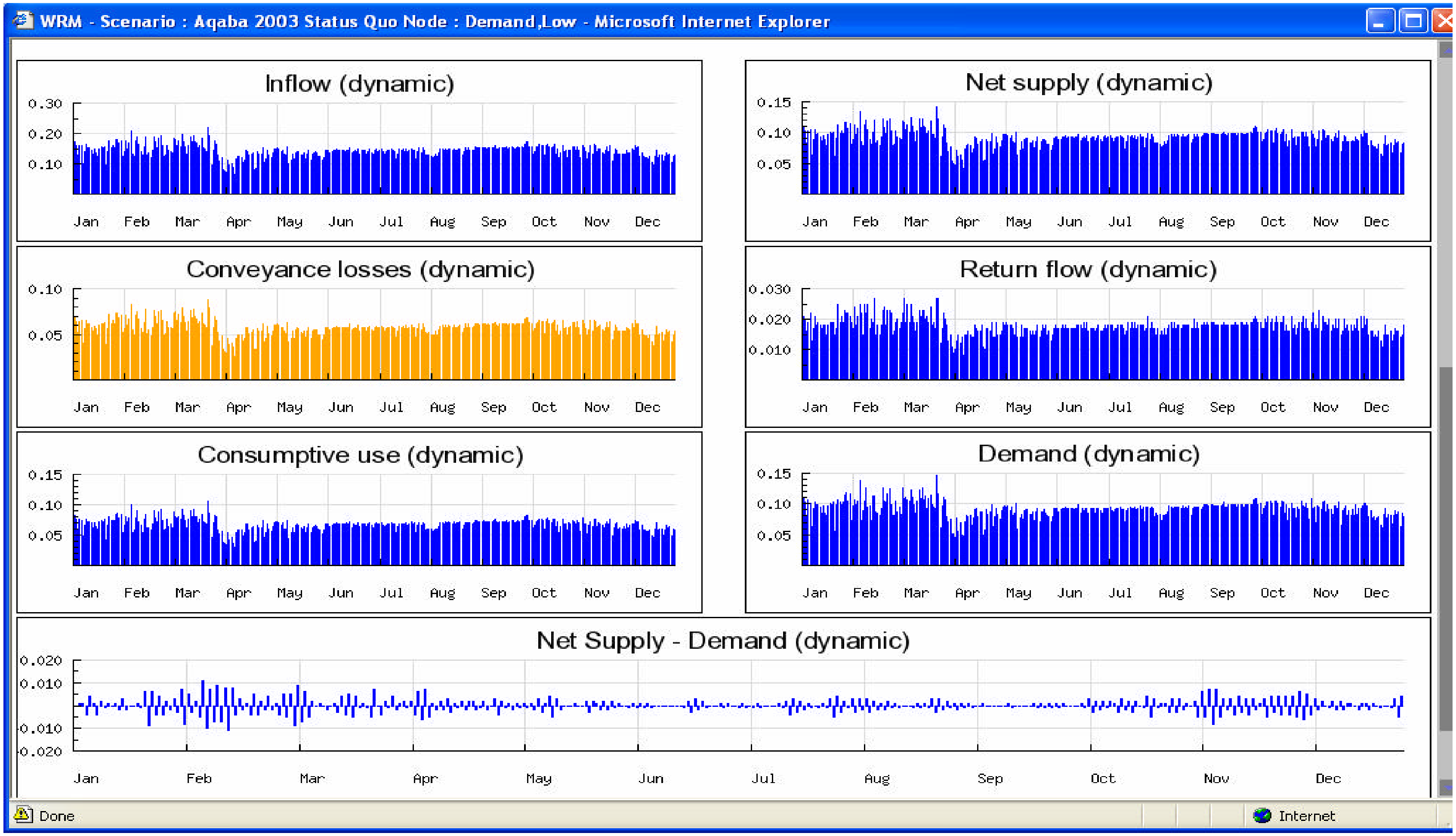
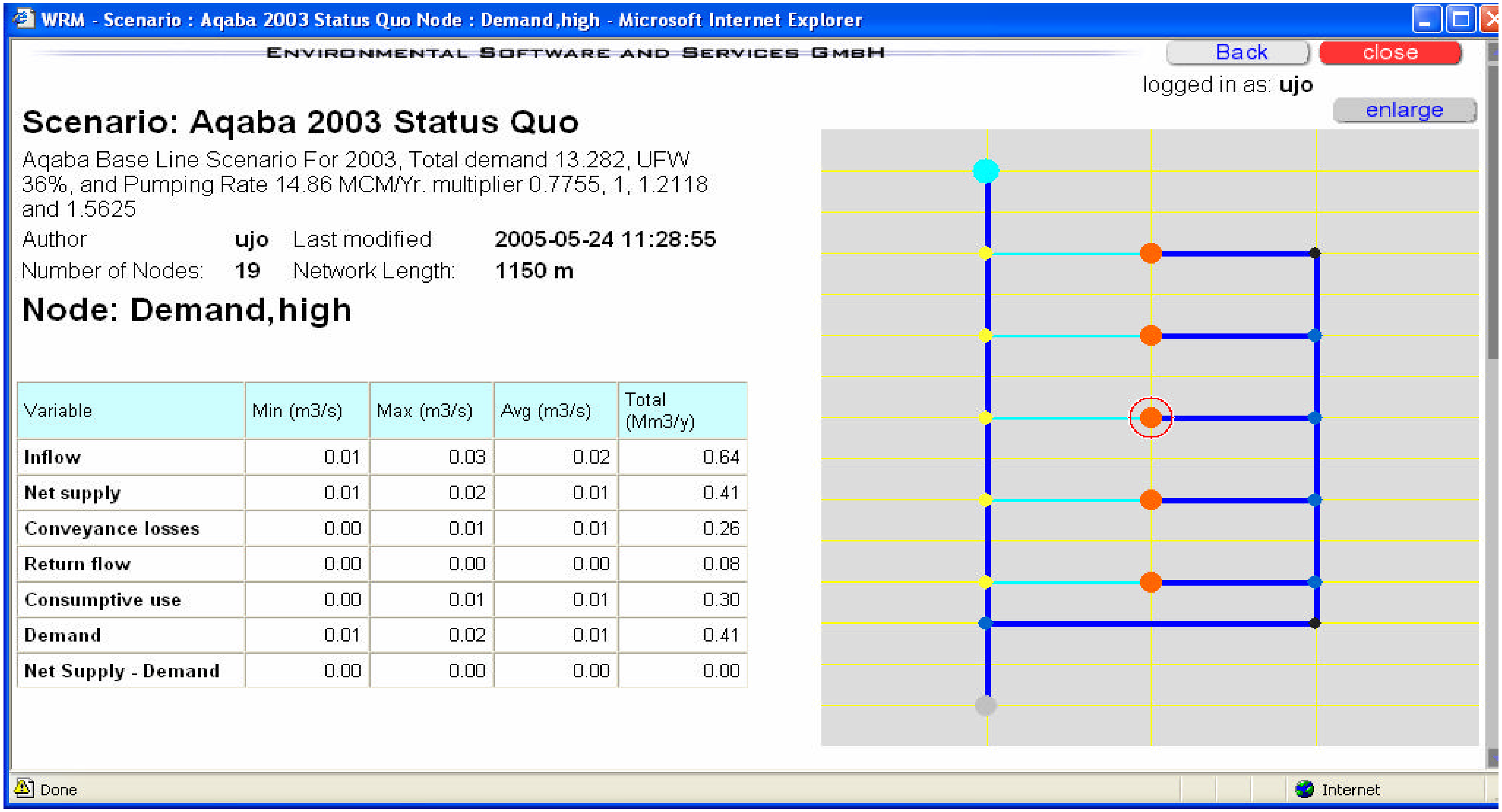


Figure E.5: Daily Analysis of Water Demand and Supply for the Low Level Node for the Base Line Scenario for 2003


WRM - Scenario : Aqaba 2003 Status Quo Node : Demand,high - Microsoft Internet Explorer

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Aqaba Base Line Scenario For 2003, Total demand 13.282, UFW 36%, and Pumping Rate 14.86 MCM/Yr. multiplier 0.7755, 1, 1.2118 and 1.5625

Author	**ujo**	Last modified	**2005-05-24 11:28:55**
Number of Nodes:	**19**	Network Length:	**1150 m**

Node: Demand,high

Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow	0.01	0.03	0.02	0.64
Net supply	0.01	0.02	0.01	0.41
Conveyance losses	0.00	0.01	0.01	0.26
Return flow	0.00	0.00	0.00	0.08
Consumptive use	0.00	0.01	0.01	0.30
Demand	0.01	0.02	0.01	0.41
Net Supply - Demand	0.00	0.00	0.00	0.00

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Figure E 6: Daily Detailed Analysis of Water Demand and Supply for theHigh Level Node for the Base Line Scenario for 2003.

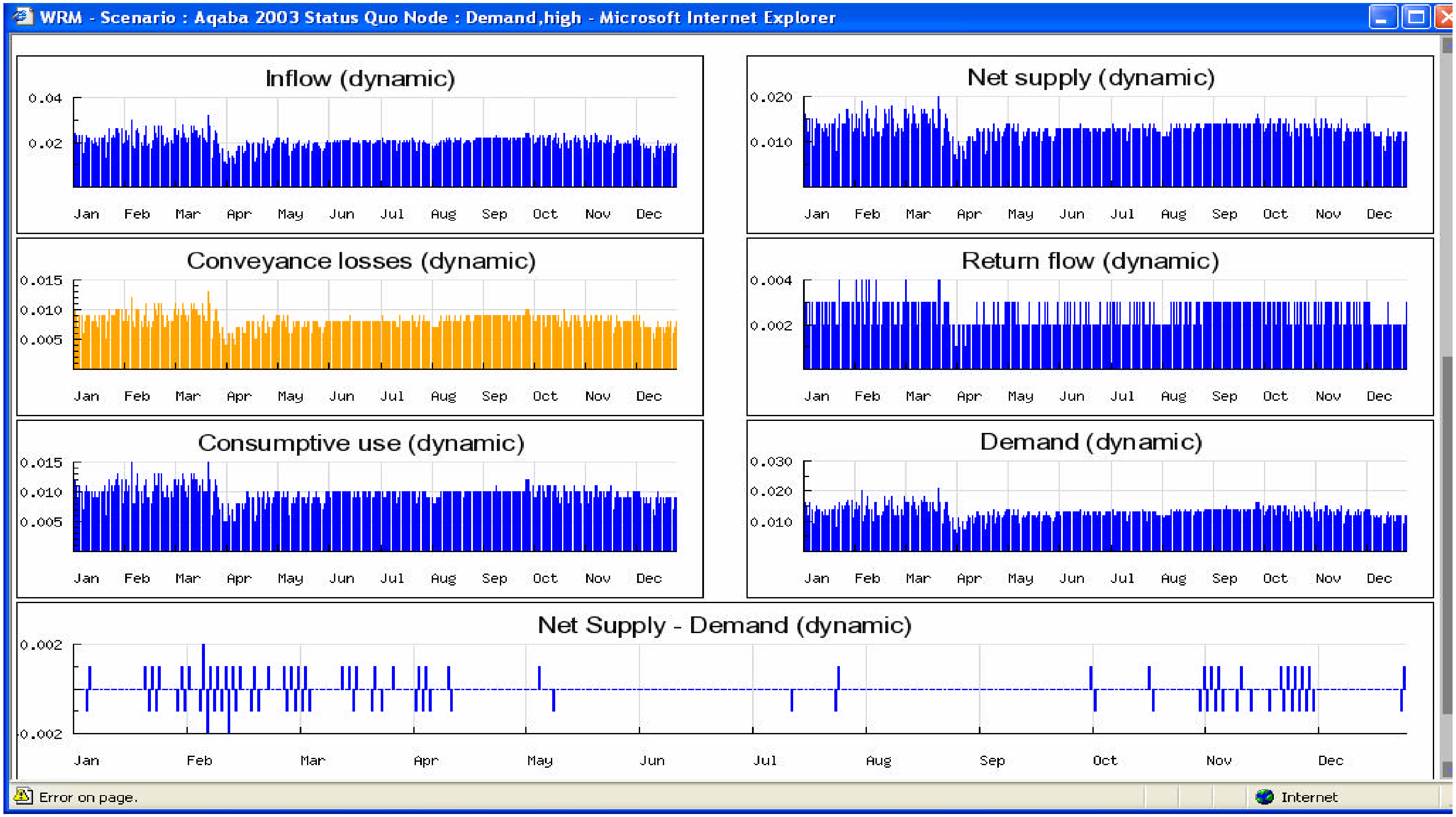
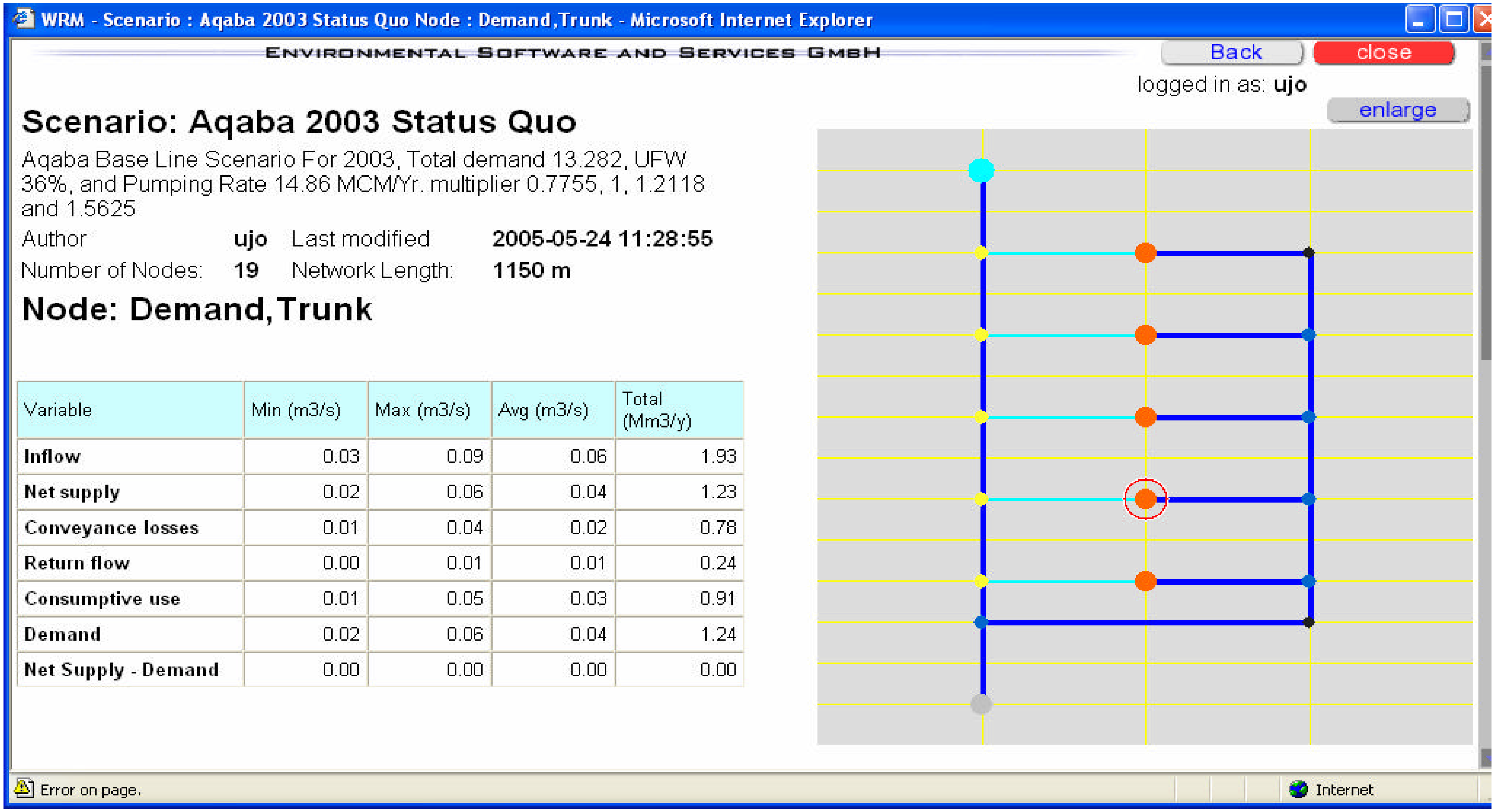


Figure E.7: Daily Analysis of Water Demand and Supply for the High Level Node for the Base Line Scenario for 2003.


WRM - Scenario : Aqaba 2003 Status Quo Node : Demand,Trunk - Microsoft Internet Explorer

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Scenario: Aqaba 2003 Status Quo

Aqaba Base Line Scenario For 2003, Total demand 13.282, UFW 36%, and Pumping Rate 14.86 MCM/Yr. multiplier 0.7755, 1, 1.2118 and 1.5625

Author **ujo** Last modified **2005-05-24 11:28:55**

Number of Nodes: **19** Network Length: **1150 m**

Node: Demand,Trunk

Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow	0.03	0.09	0.06	1.93
Net supply	0.02	0.06	0.04	1.23
Conveyance losses	0.01	0.04	0.02	0.78
Return flow	0.00	0.01	0.01	0.24
Consumptive use	0.01	0.05	0.03	0.91
Demand	0.02	0.06	0.04	1.24
Net Supply - Demand	0.00	0.00	0.00	0.00

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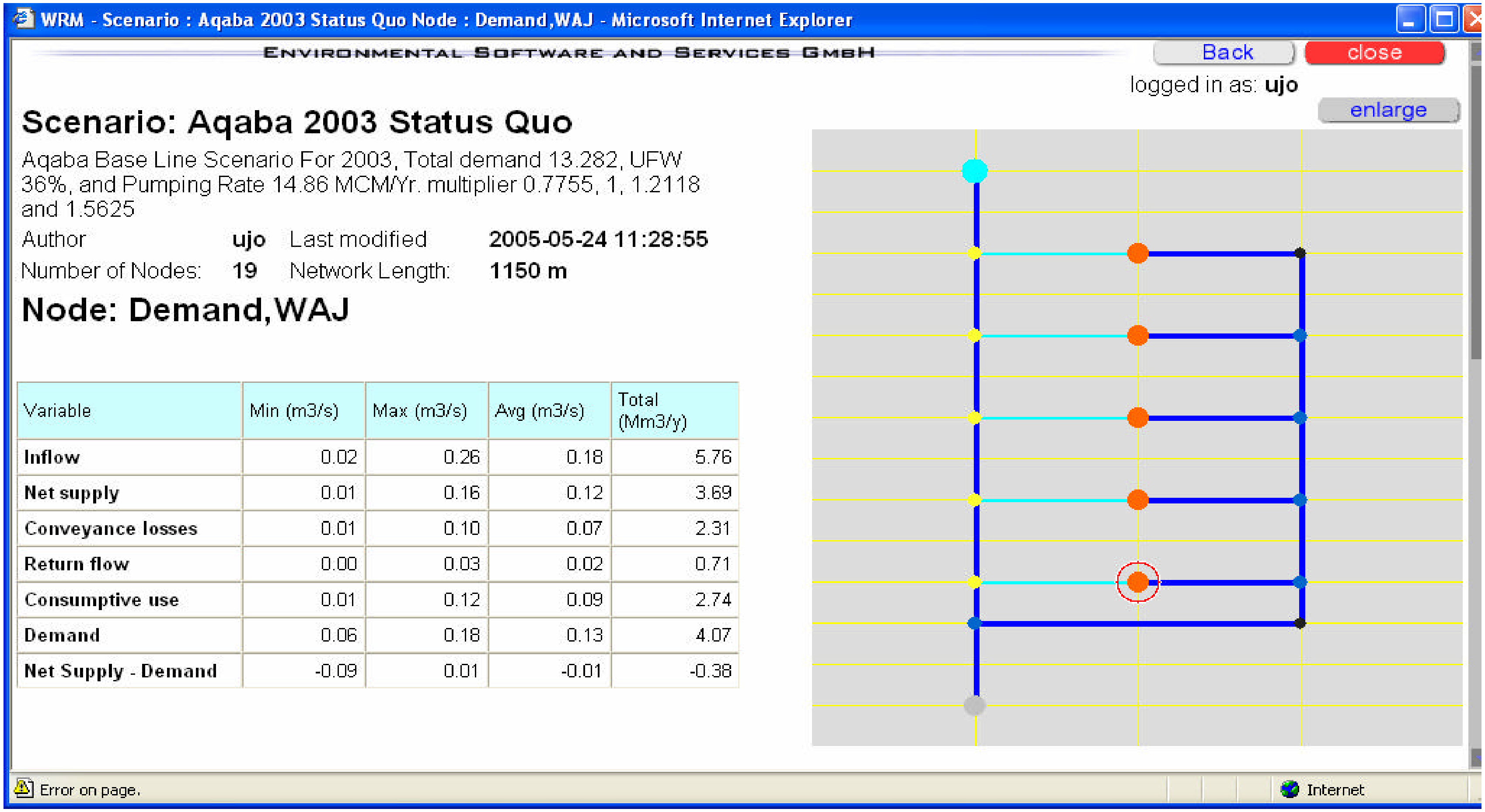
Figure E 8: Daily Detailed Analysis of Water Demand and Supply for theMain Trunk Node for the Base Line Scenario for 2003.

Figure E.9: Daily Analysis of Water Demand and Supply for the Main Trunk Node for the Base Line Scenario for 2003



WRM - Scenario : Aqaba 2003 Status Quo Node : Demand,WAJ - Microsoft Internet Explorer

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Scenario: Aqaba 2003 Status Quo

Aqaba Base Line Scenario For 2003, Total demand 13.282, UFW 36%, and Pumping Rate 14.86 MCM/Yr. multiplier 0.7755, 1, 1.2118 and 1.5625

Author	**ujo**	Last modified	**2005-05-24 11:28:55**
Number of Nodes:	**19**	Network Length:	**1150 m**

Node: Demand,WAJ

Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow	0.02	0.26	0.18	5.76
Net supply	0.01	0.16	0.12	3.69
Conveyance losses	0.01	0.10	0.07	2.31
Return flow	0.00	0.03	0.02	0.71
Consumptive use	0.01	0.12	0.09	2.74
Demand	0.06	0.18	0.13	4.07
Net Supply - Demand	-0.09	0.01	-0.01	-0.38

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Figure E10: Daily Detailed Analysis of Water Demand and Supply for the WAJ Node for the Base Line Scenario for 2003.

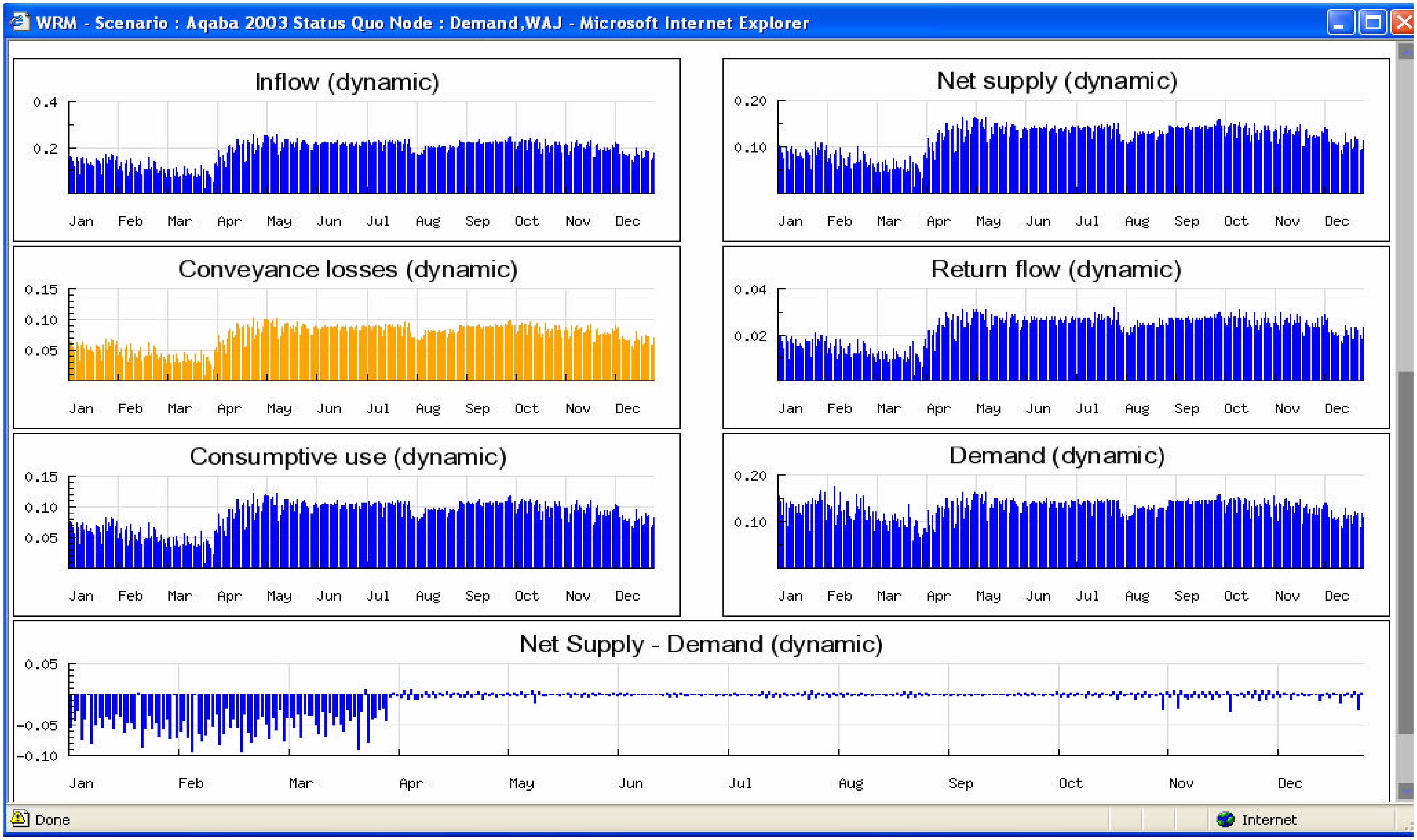
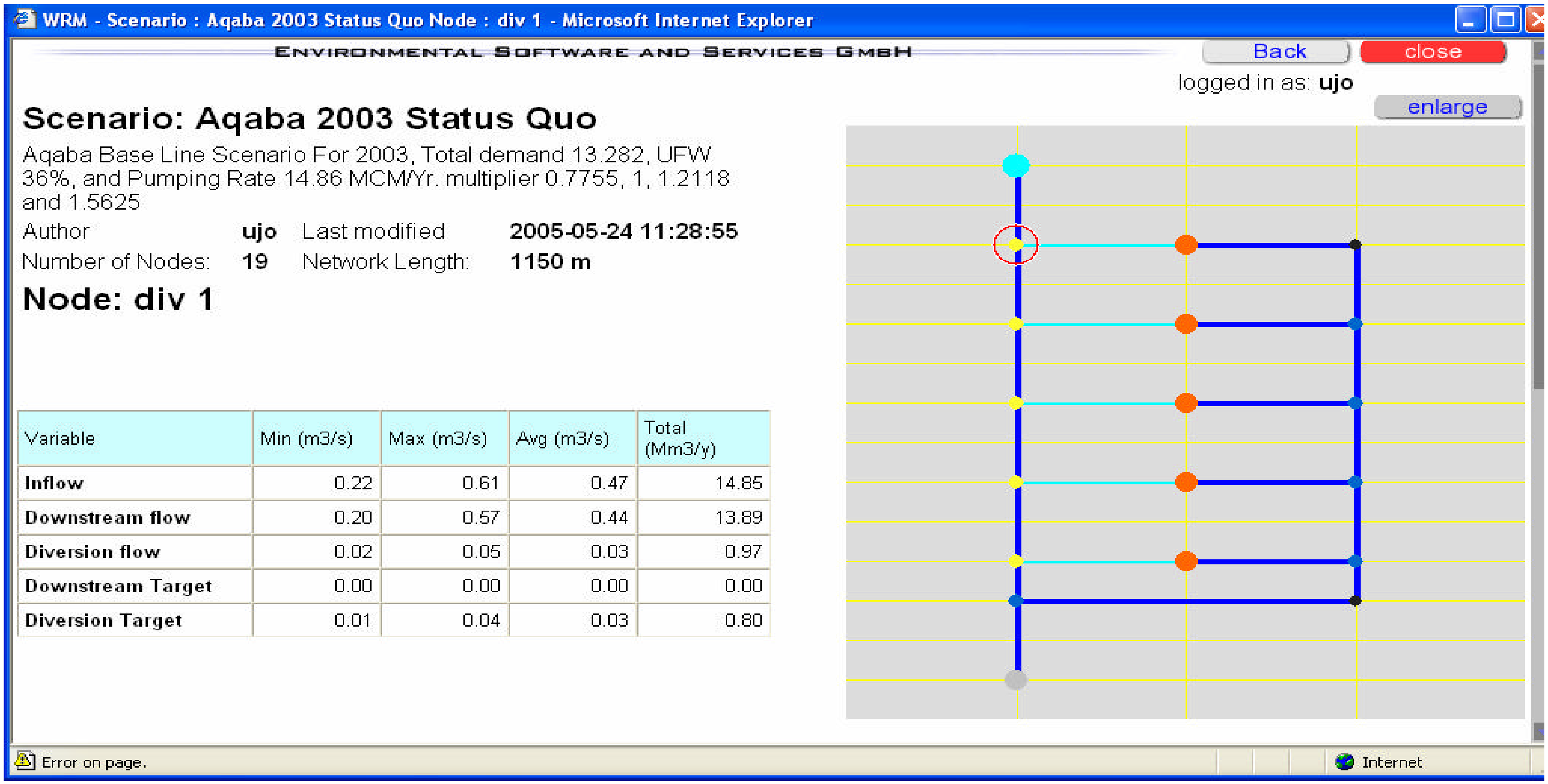


Figure E.11: Daily Analysis of Water Demand and Supply for the WAJ Node for the Base Line Scenario for 2003



Scenario: Aqaba 2003 Status Quo

Aqaba Base Line Scenario For 2003, Total demand 13.282, UFW 36%, and Pumping Rate 14.86 MCM/Yr. multiplier 0.7755, 1, 1.2118 and 1.5625

Author	ujo	Last modified	2005-05-24 11:28:55
Number of Nodes:	19	Network Length:	1150 m

Node: div 1

Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow	0.22	0.61	0.47	14.85
Downstream flow	0.20	0.57	0.44	13.89
Diversion flow	0.02	0.05	0.03	0.97
Downstream Target	0.00	0.00	0.00	0.00
Diversion Target	0.01	0.04	0.03	0.80

Figure E.12: Daily Detailed Analysis of Downstream and Diversion Water Flow for the Diversion Node No. 1 for the Base Line Scenario for 2003.

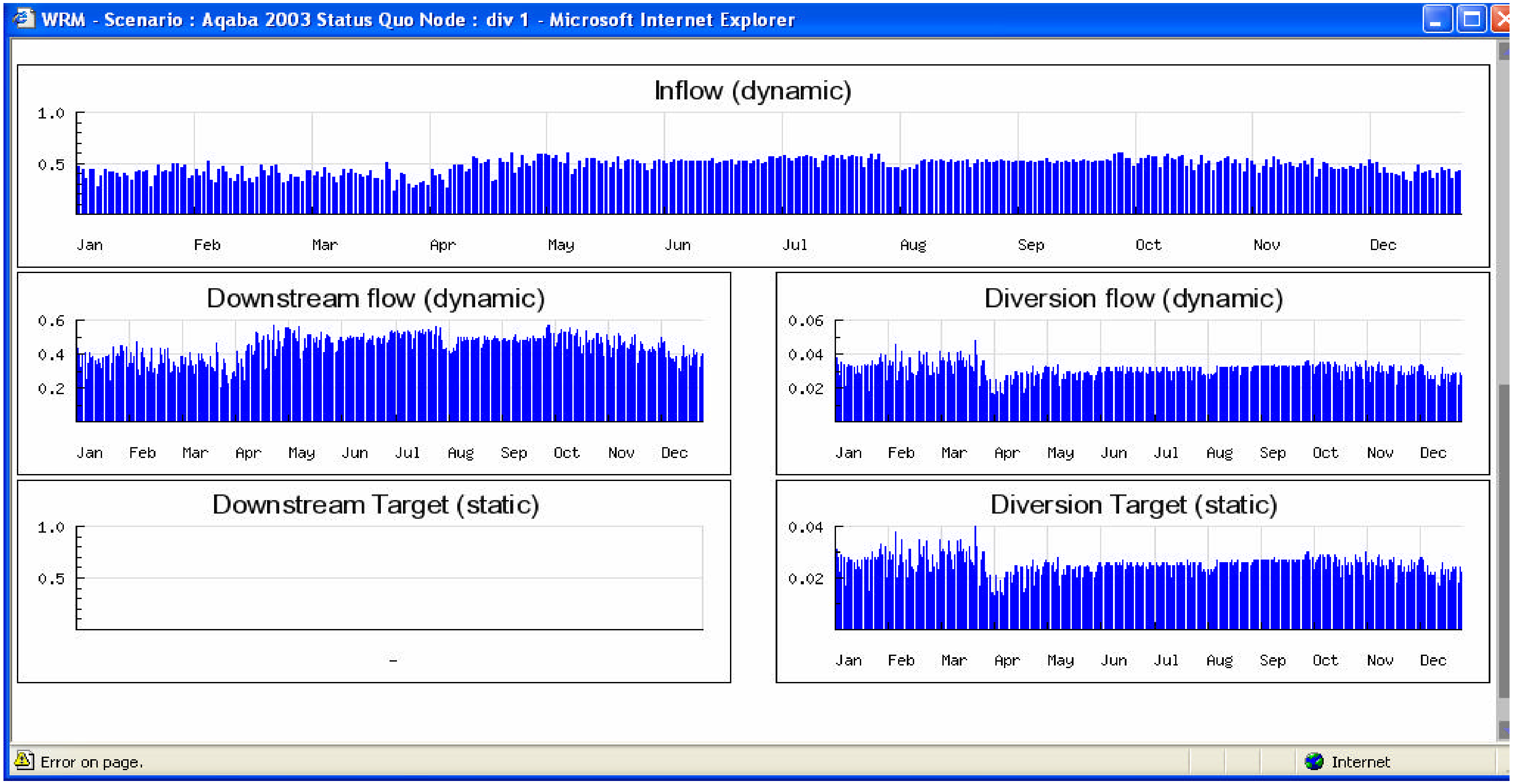
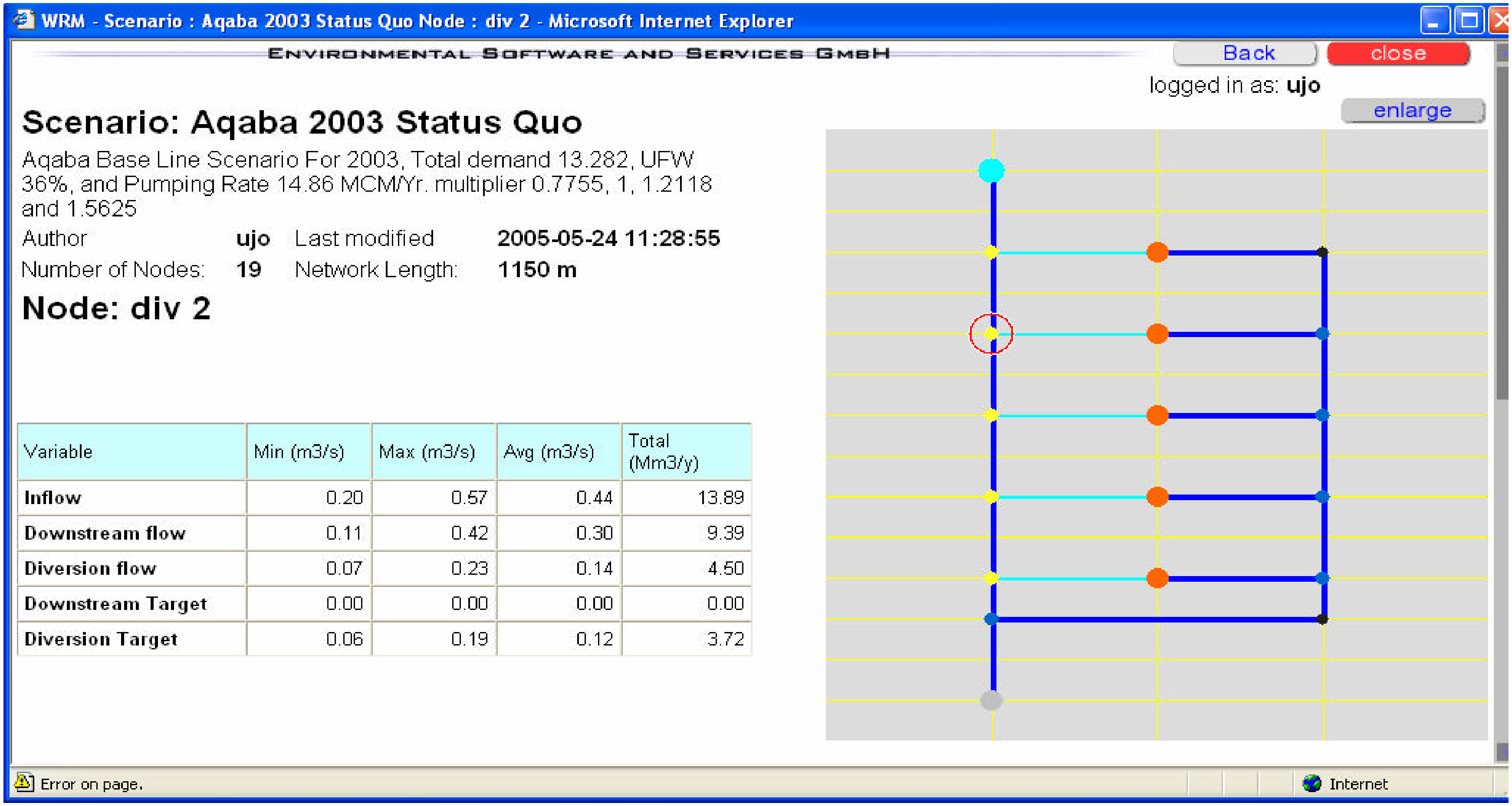


Figure E.13: Daily Analysis of Downstream and Diversion Water Flow for the Diversion Node No. 1 for the Base Line Scenario for 2003.



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Aqaba Base Line Scenario For 2003, Total demand 13.282, UFW 36%, and Pumping Rate 14.86 MCM/Yr. multiplier 0.7755, 1, 1.2118 and 1.5625

Author **ujo** Last modified **2005-05-24 11:28:55**

Number of Nodes: **19** Network Length: **1150 m**

Node: div 2

Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow	0.20	0.57	0.44	13.89
Downstream flow	0.11	0.42	0.30	9.39
Diversion flow	0.07	0.23	0.14	4.50
Downstream Target	0.00	0.00	0.00	0.00
Diversion Target	0.06	0.19	0.12	3.72

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Figure E.14: Daily Detailed Analysis of Downstream and Diversion Water Flow for the Diversion Node No. 2 for the Base Line Scenario for 2003.

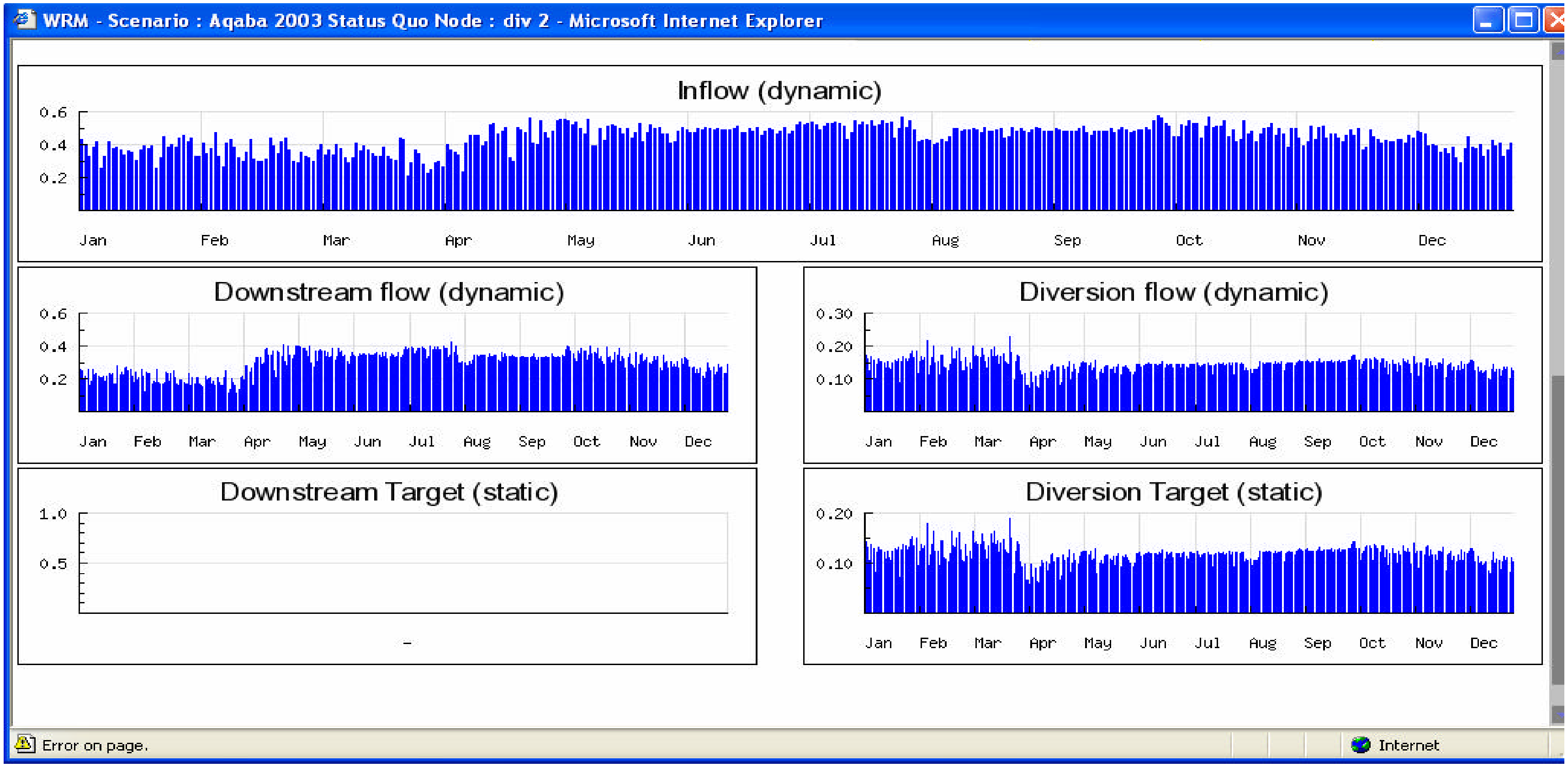
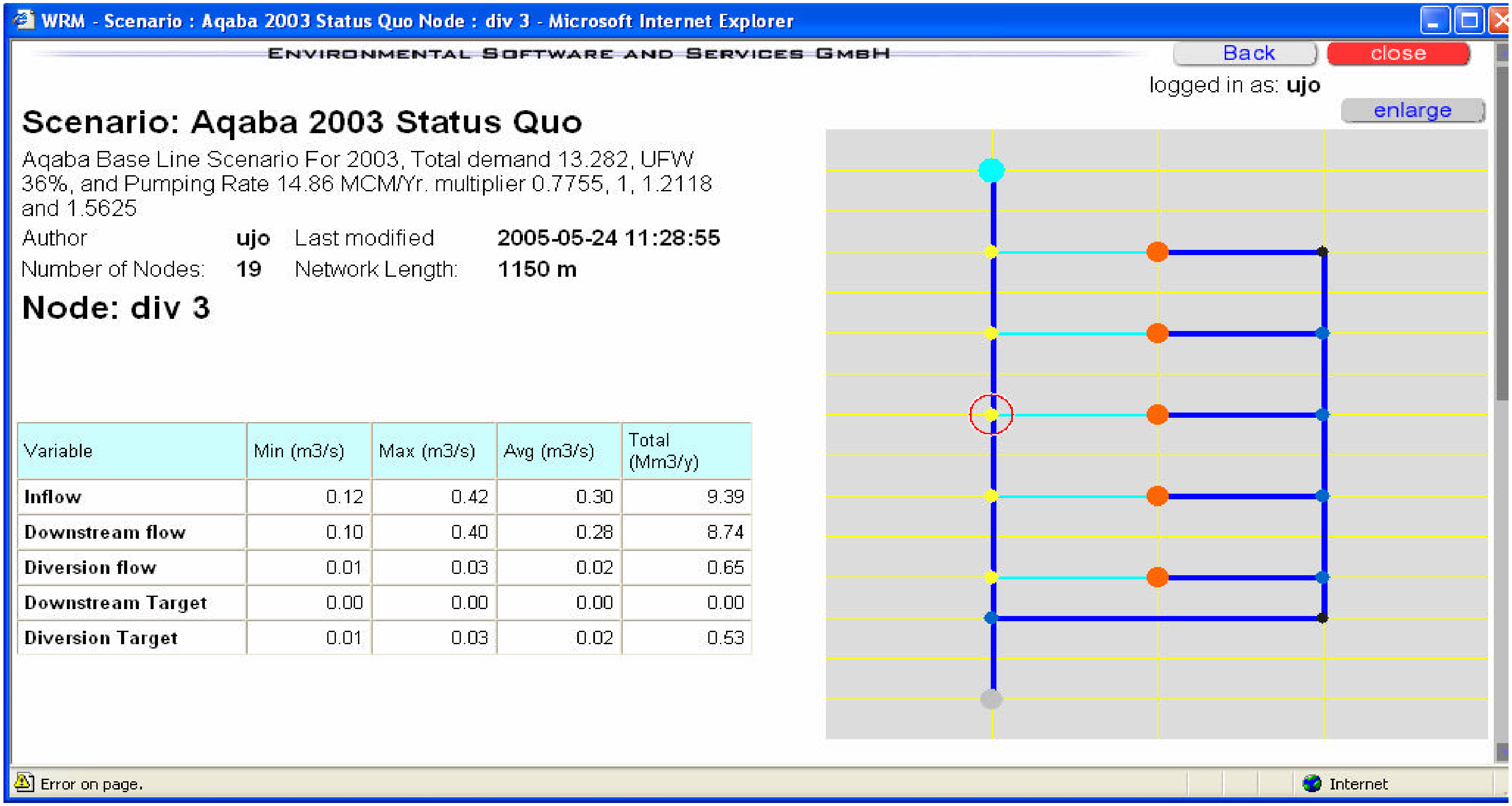


Figure E 15: Daily Analysis of Downstream and Diversion Water Flow for the Diversion Node No. 2 for the Base Line Scenario for 2003.


WRM - Scenario : Aqaba 2003 Status Quo Node : div 3 - Microsoft Internet Explorer

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Scenario: Aqaba 2003 Status Quo

Aqaba Base Line Scenario For 2003, Total demand 13.282, UFW 36%, and Pumping Rate 14.86 MCM/Yr. multiplier 0.7755, 1, 1.2118 and 1.5625

Author	**ujo**	Last modified	**2005-05-24 11:28:55**
Number of Nodes:	**19**	Network Length:	**1150 m**

Node: div 3

Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow	0.12	0.42	0.30	9.39
Downstream flow	0.10	0.40	0.28	8.74
Diversion flow	0.01	0.03	0.02	0.65
Downstream Target	0.00	0.00	0.00	0.00
Diversion Target	0.01	0.03	0.02	0.53

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Figure E.16: Daily Detailed Analysis of Downstream and Diversion Water Flow for the Diversion Node No. 3 for the Base Line Scenario for 2003.

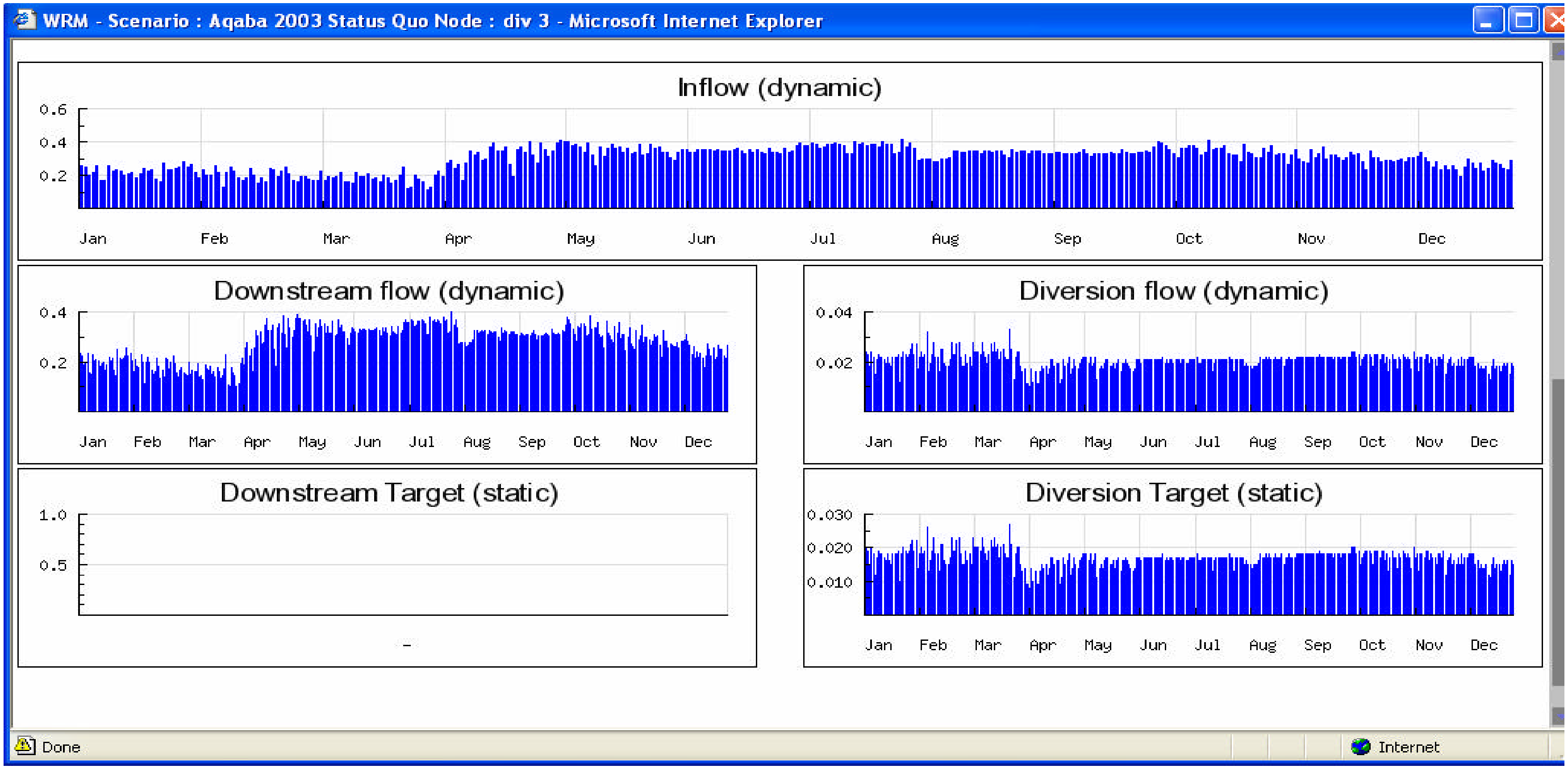
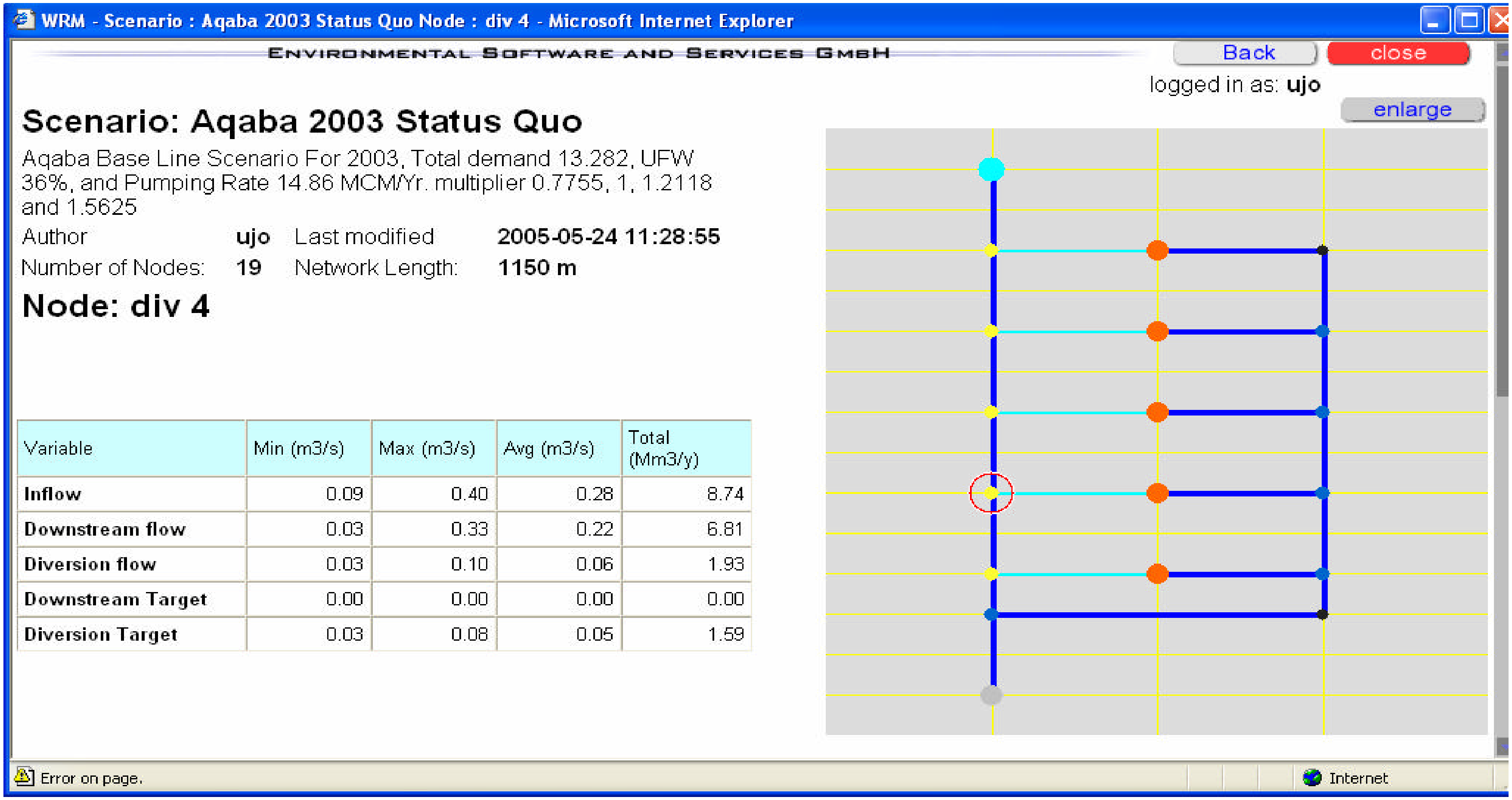


Figure E.17: Daily Analysis of Downstream and Diversion Water Flow for the Diversion Node No. 3 for the Base Line Scenario for 2003.



WRM - Scenario : Aqaba 2003 Status Quo Node : div 4 - Microsoft Internet Explorer

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Scenario: Aqaba 2003 Status Quo

Aqaba Base Line Scenario For 2003, Total demand 13.282, UFW 36%, and Pumping Rate 14.86 MCM/Yr. multiplier 0.7755, 1, 1.2118 and 1.5625

Author	**ujo**	Last modified	**2005-05-24 11:28:55**
Number of Nodes:	**19**	Network Length:	**1150 m**

Node: div 4

Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow	0.09	0.40	0.28	8.74
Downstream flow	0.03	0.33	0.22	6.81
Diversion flow	0.03	0.10	0.06	1.93
Downstream Target	0.00	0.00	0.00	0.00
Diversion Target	0.03	0.08	0.05	1.59

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Figure E.18: Daily Detailed Analysis of Downstream and Diversion Water Flow for the Diversion Node No. 4 for the Base Line Scenario for 2003.

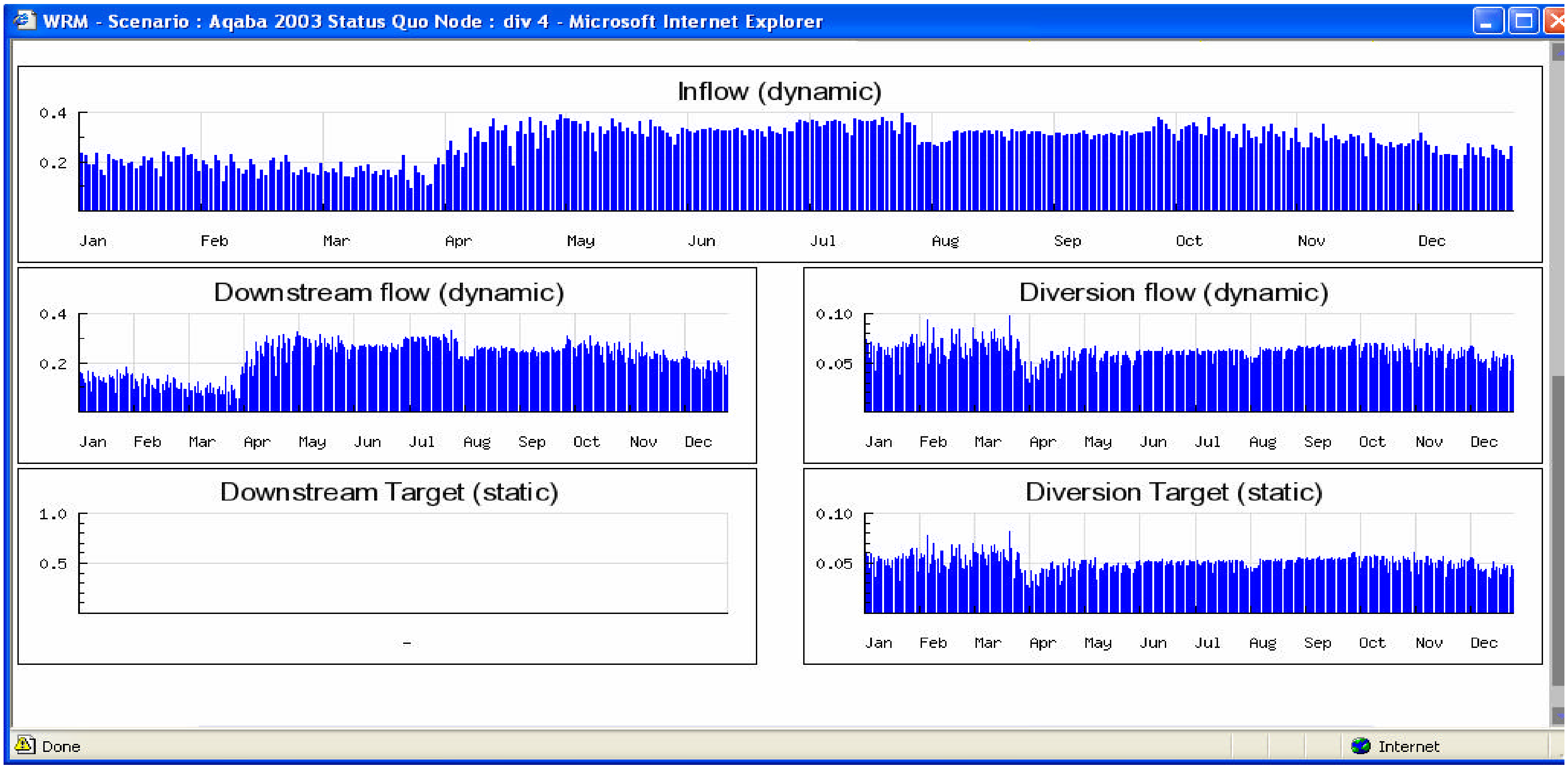

Figure E.19: Daily Analysis of Downstream and Diversion Water Flow for the Diversion Node No. 4 for the Base Line Scenario for 2003.

WRM - Scenario : Aqaba 2003 Status Quo Node : div 5 - Microsoft Internet Explorer

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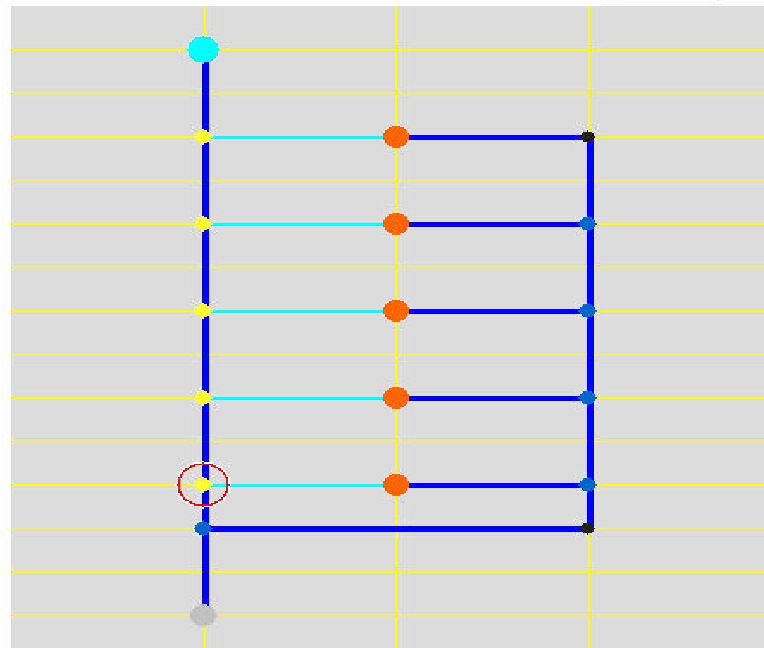
Scenario: Aqaba 2003 Status Quo

Aqaba Base Line Scenario For 2003, Total demand 13.282, UFW 36%, and Pumping Rate 14.86 MCM/Yr. multiplier 0.7755, 1, 1.2118 and 1.5625

Author **ujo** Last modified **2005-05-24 11:28:55**

Number of Nodes: **19** Network Length: **1150 m**

Node: div 5



Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow	0.02	0.33	0.22	6.81
Downstream flow	0.00	0.12	0.03	1.05
Diversion flow	0.02	0.25	0.18	5.76
Downstream Target	0.00	0.00	0.00	0.00
Diversion Target	0.06	0.18	0.13	4.07

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Figure E.20: Daily Detailed Analysis of Downstream and Diversion Water Flow for the Diversion Node No. 5 for the Base Line Scenario for 2003.

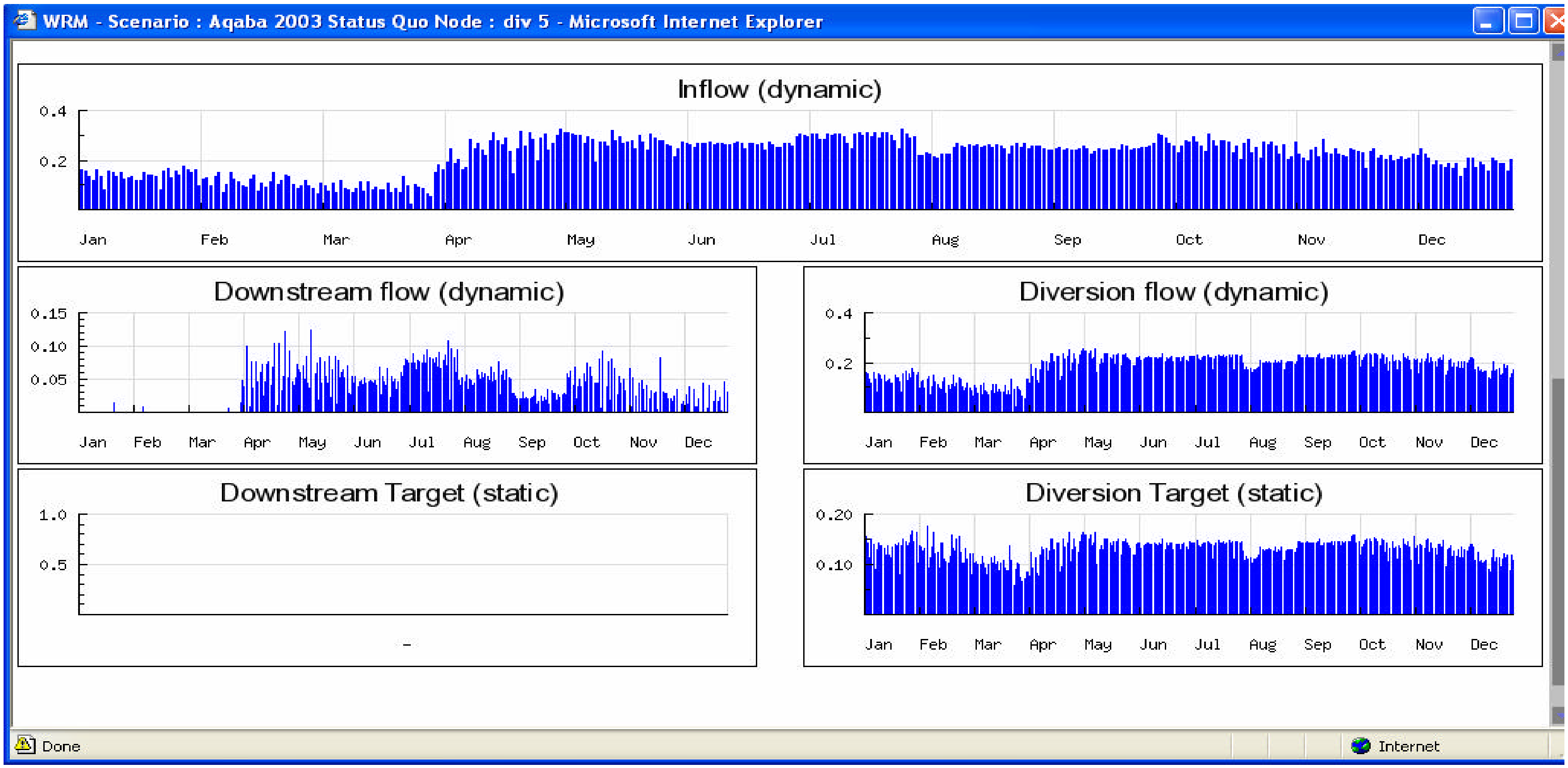
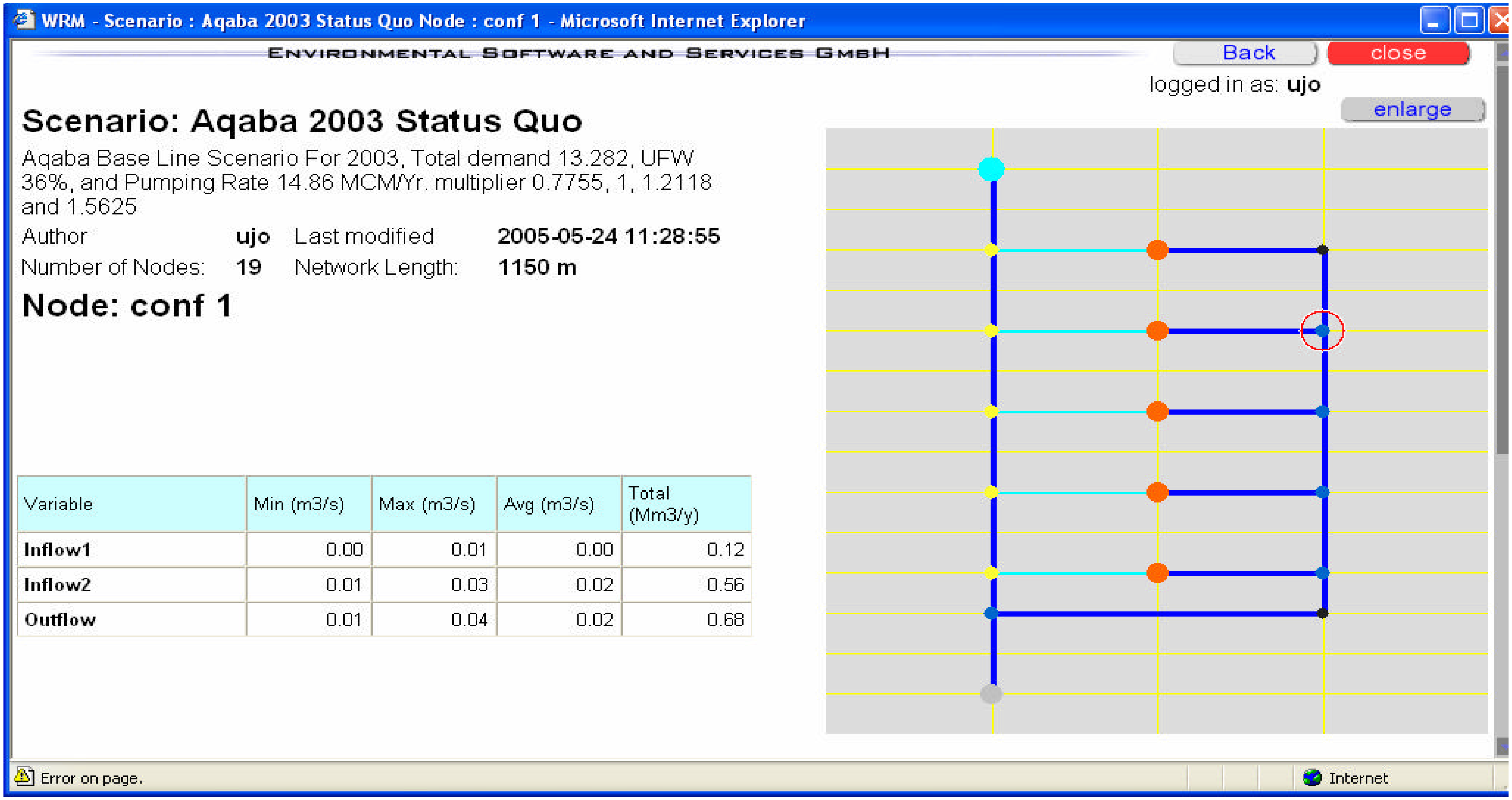


Figure E.21: Daily Analysis of Downstream and Diversion Water Flow for the Diversion Node No. 5 for the Base Line Scenario for 2003.



WRM - Scenario : Aqaba 2003 Status Quo Node : conf 1 - Microsoft Internet Explorer

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Scenario: Aqaba 2003 Status Quo

Aqaba Base Line Scenario For 2003, Total demand 13.282, UFW 36%, and Pumping Rate 14.86 MCM/Yr. multiplier 0.7755, 1, 1.2118 and 1.5625

Author	**ujo**	Last modified	**2005-05-24 11:28:55**
Number of Nodes:	**19**	Network Length:	**1150 m**

Node: conf 1

Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow1	0.00	0.01	0.00	0.12
Inflow2	0.01	0.03	0.02	0.56
Outflow	0.01	0.04	0.02	0.68

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Figure E .22: Daily Detailed Analysis of Water Inflow and Outflow for the Confluence Node No. 1 for the Base Line Scenario for 2003.

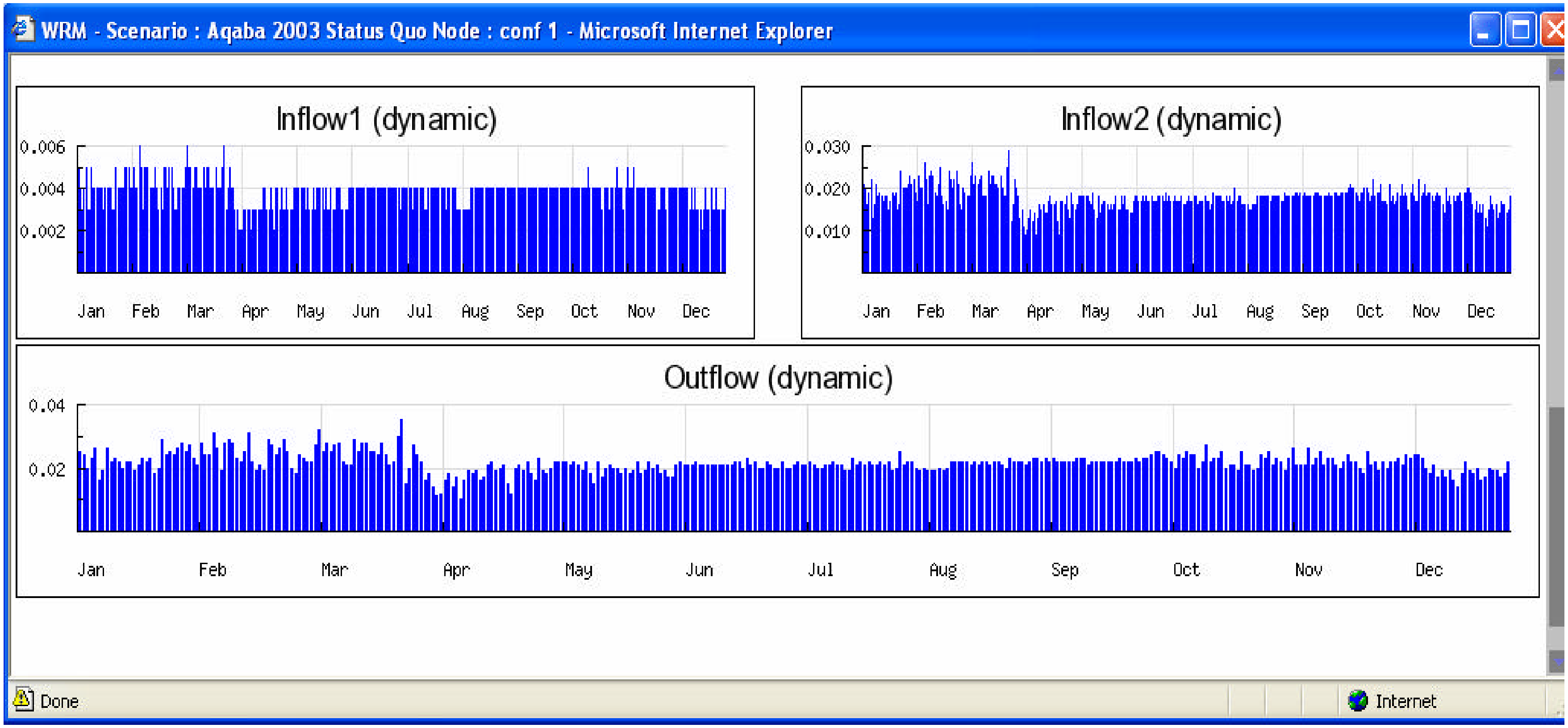
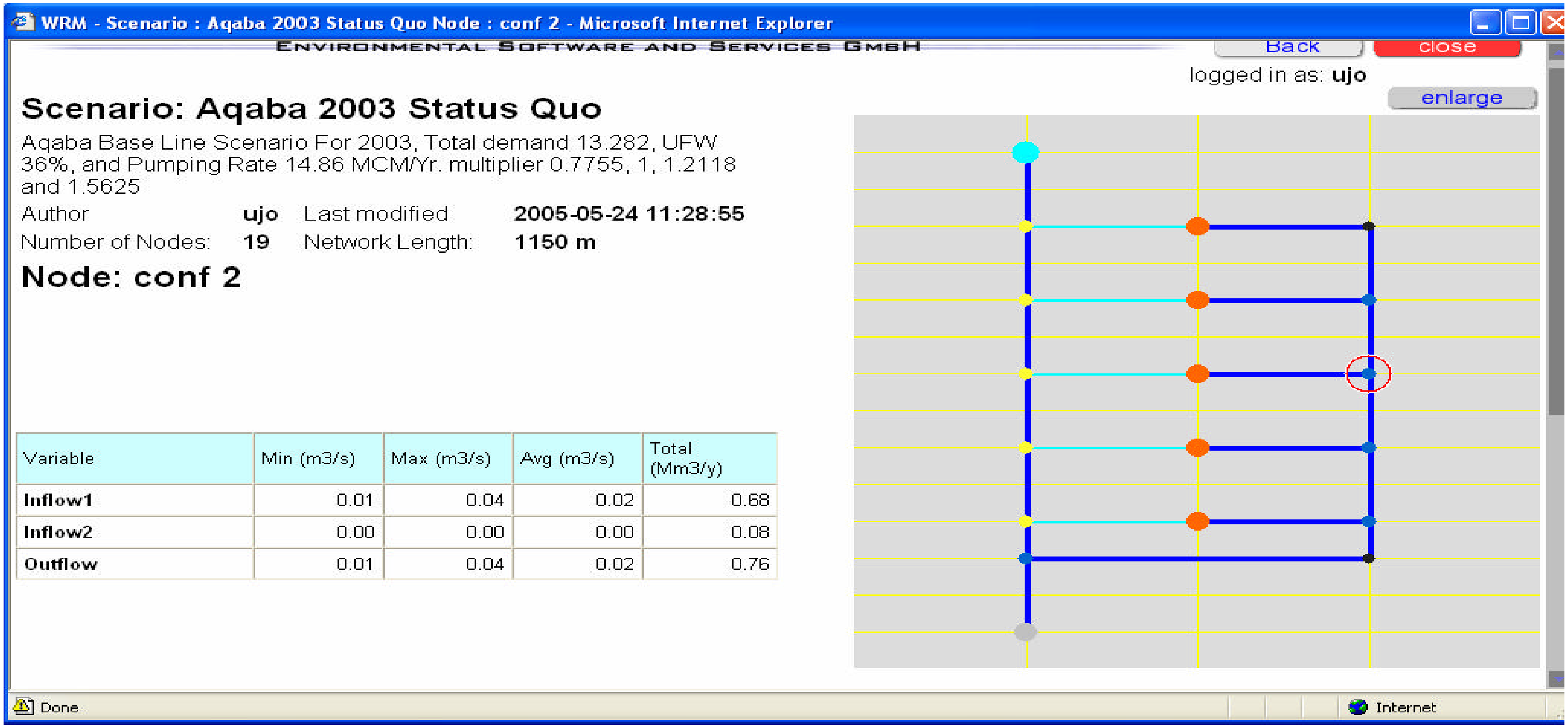


Figure E.23: Daily Analysis of Water Inflow and Outflow for the Confluence Node No. 1 for the Base Line Scenario for 2003.



Scenario: Aqaba 2003 Status Quo

Aqaba Base Line Scenario For 2003, Total demand 13.282, UFW 36%, and Pumping Rate 14.86 MCM/Yr. multiplier 0.7755, 1, 1.2118 and 1.5625

Author	**ujo**	Last modified	**2005-05-24 11:28:55**
Number of Nodes:	**19**	Network Length:	**1150 m**

Node: conf 2

Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow1	0.01	0.04	0.02	0.68
Inflow2	0.00	0.00	0.00	0.08
Outflow	0.01	0.04	0.02	0.76

Figure E.24: Daily Detailed Analysis of Water Inflow and Outflow for the Confluence Node No. 2 for the Base Line Scenario for 2003.

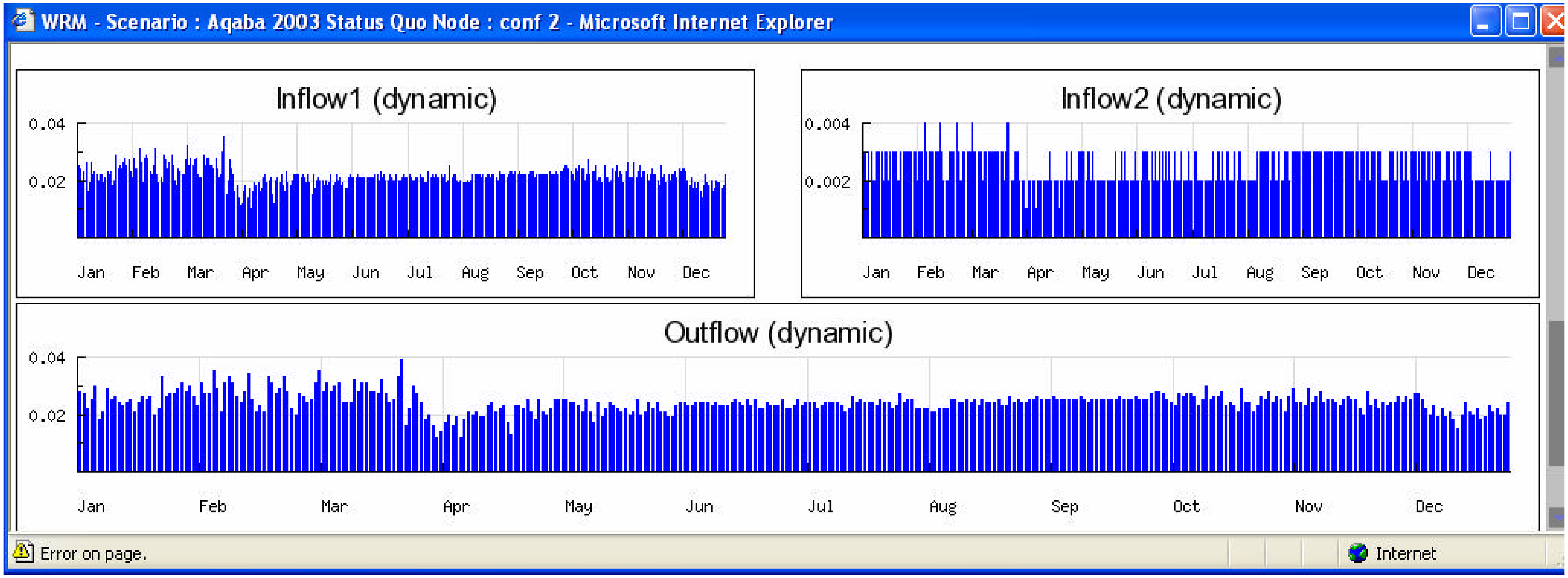
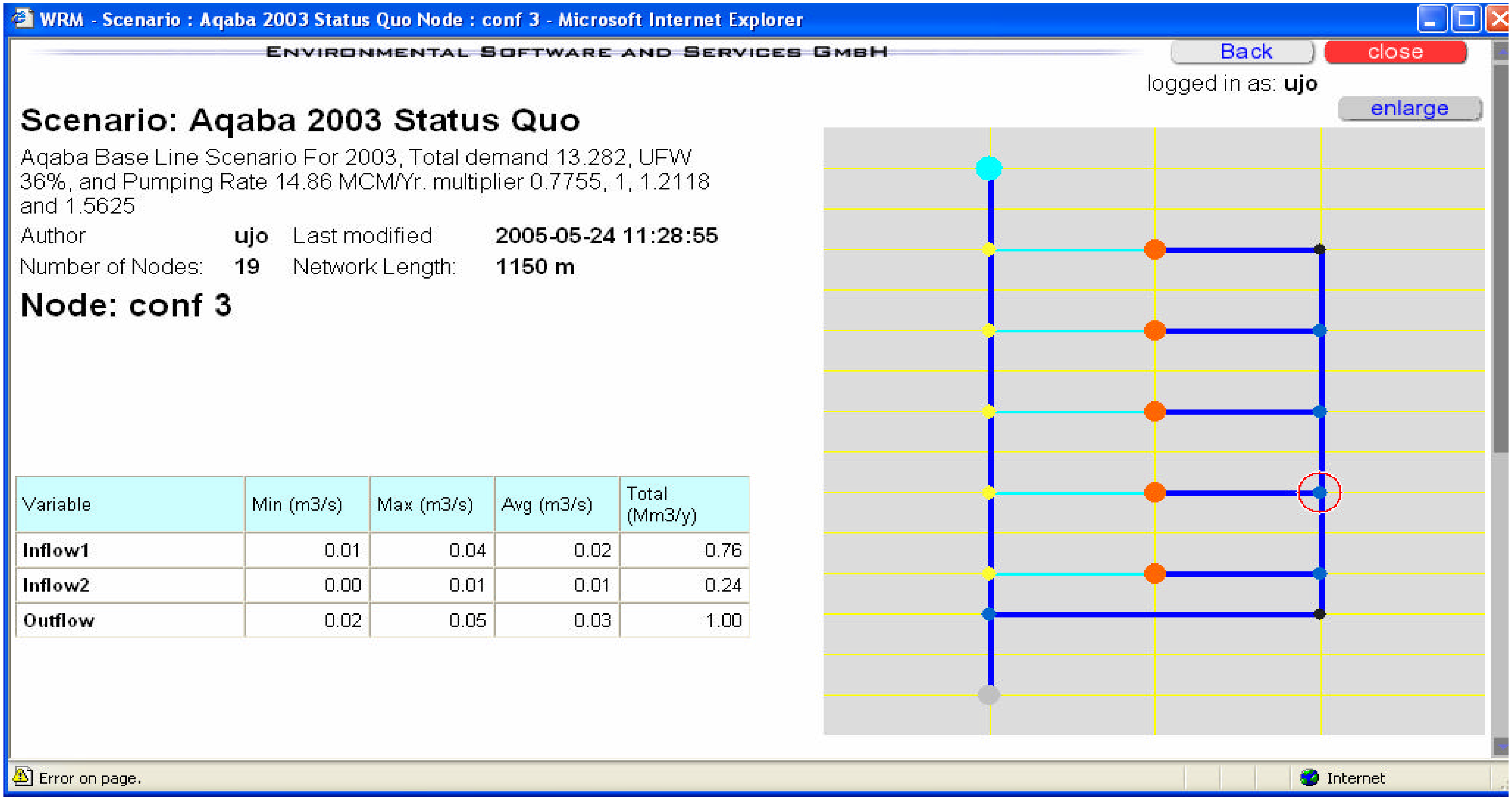


Figure E.25: Daily Analysis of Water Inflow and Outflow for the Confluence Node No. 2 for the Base Line Scenario for 2003.



Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow1	0.01	0.04	0.02	0.76
Inflow2	0.00	0.01	0.01	0.24
Outflow	0.02	0.05	0.03	1.00

Figure E.26: Daily Detailed Analysis of Water Inflow and Outflow for the Confluence Node No. 3 for the Base Line Scenario for 2003.

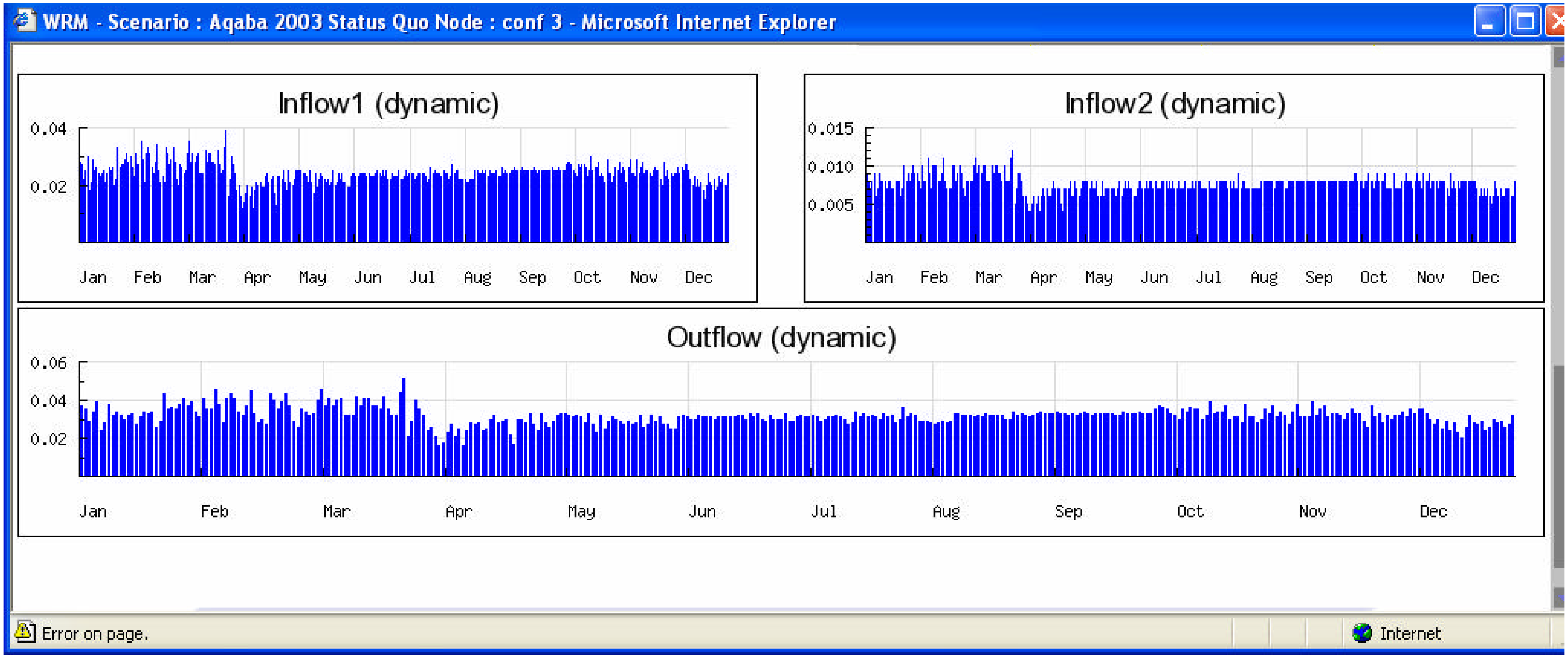


Figure E.27: Daily Analysis of Water Inflow and Outflow for the Confluence Node No. 3 for the Base Line Scenario for 2003.

WRM - Scenario : Aqaba 2003 Status Quo Node : conf 4 - Microsoft Internet Explorer

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Scenario: Aqaba 2003 Status Quo

Aqaba Base Line Scenario For 2003, Total demand 13.282, UFW 36%, and Pumping Rate 14.86 MCM/Yr. multiplier 0.7755, 1, 1.2118 and 1.5625

Author	**ujo**	Last modified	**2005-05-24 11:28:55**
Number of Nodes:	**19**	Network Length:	**1150 m**

Node: conf 4

Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow1	0.00	0.03	0.02	0.71
Inflow2	0.02	0.05	0.03	1.00
Outflow	0.03	0.07	0.05	1.71

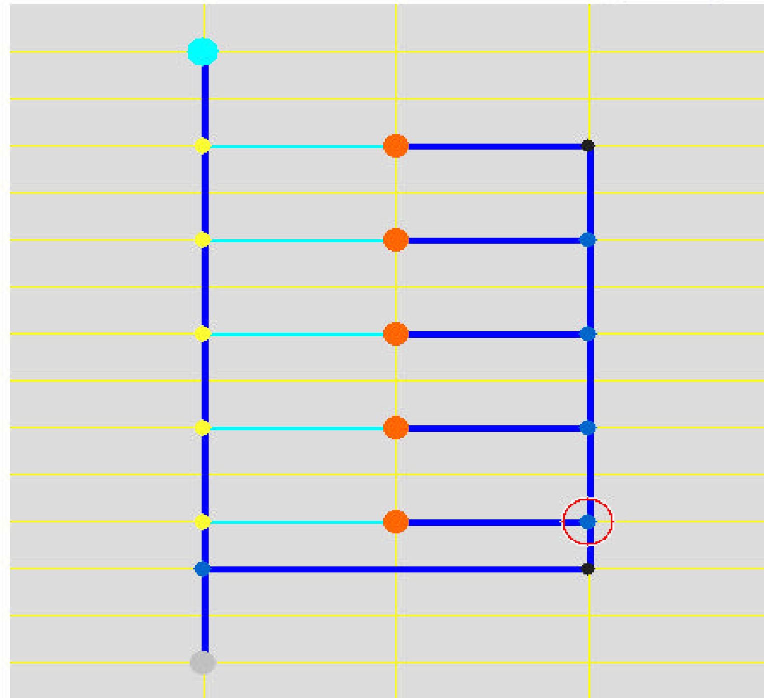

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Figure E.28: Daily Detailed Analysis of Water Inflow and Outflow for the Confluence Node No. 4 for the Base Line Scenario for 2003.

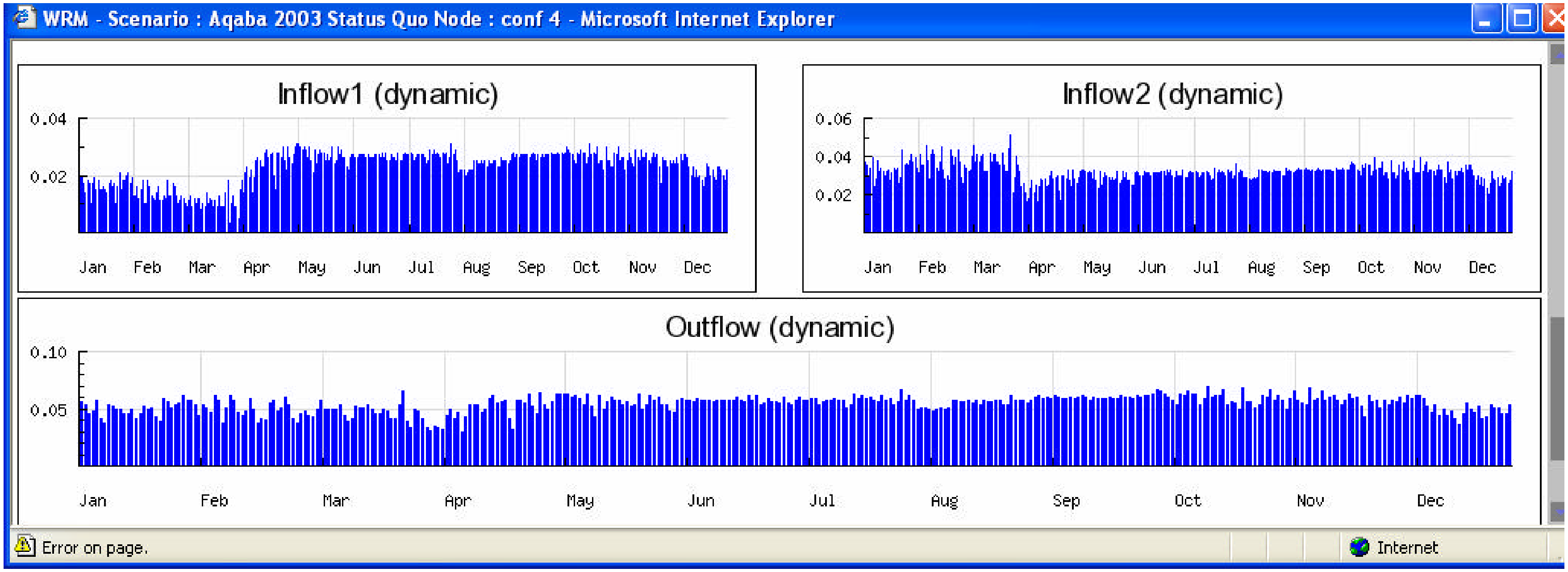
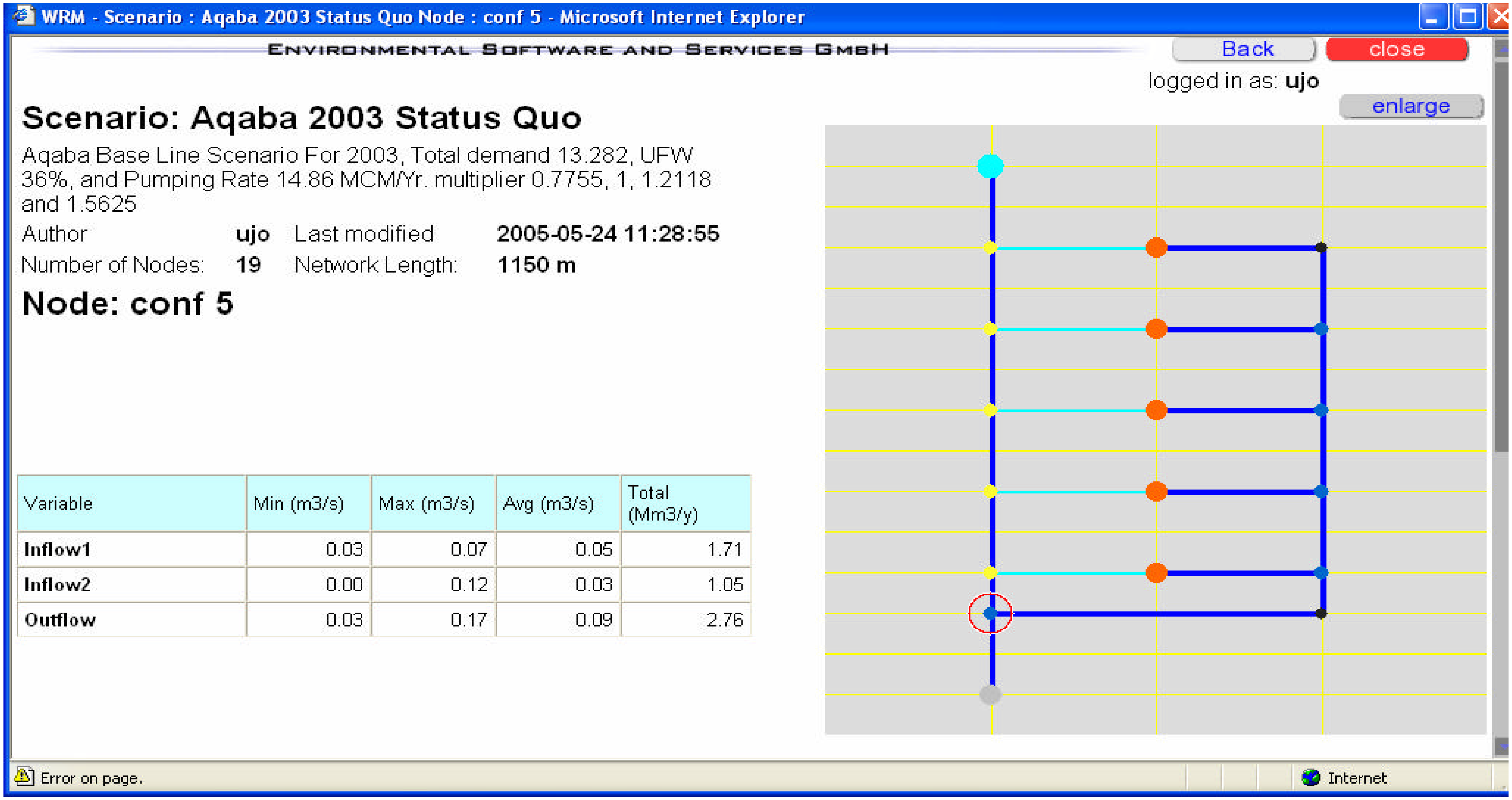


Figure E.29: Daily Analysis of Water Inflow and Outflow for the Confluence Node No. 4 for the Base Line Scenario for 2003.



Variable	Min (m3/s)	Max (m3/s)	Avg (m3/s)	Total (Mm3/y)
Inflow1	0.03	0.07	0.05	1.71
Inflow2	0.00	0.12	0.03	1.05
Outflow	0.03	0.17	0.09	2.76

Figure E.30: Daily Detailed Analysis of Water Inflow and Outflow for the Confluence Node No. 5 for the Base Line Scenario for 2003.

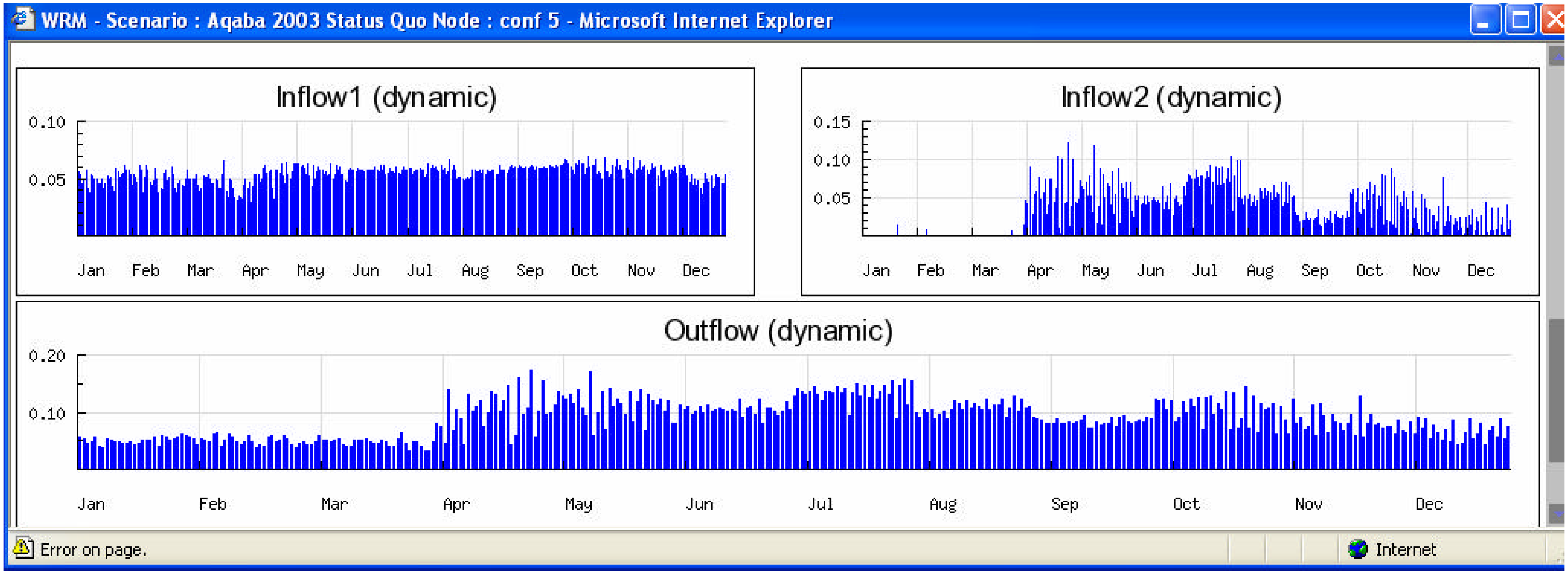


Figure E.31: Daily Analysis of Water Inflow and Outflow for the Confluence Node No. 5 for the Base Line Scenario for 2003.

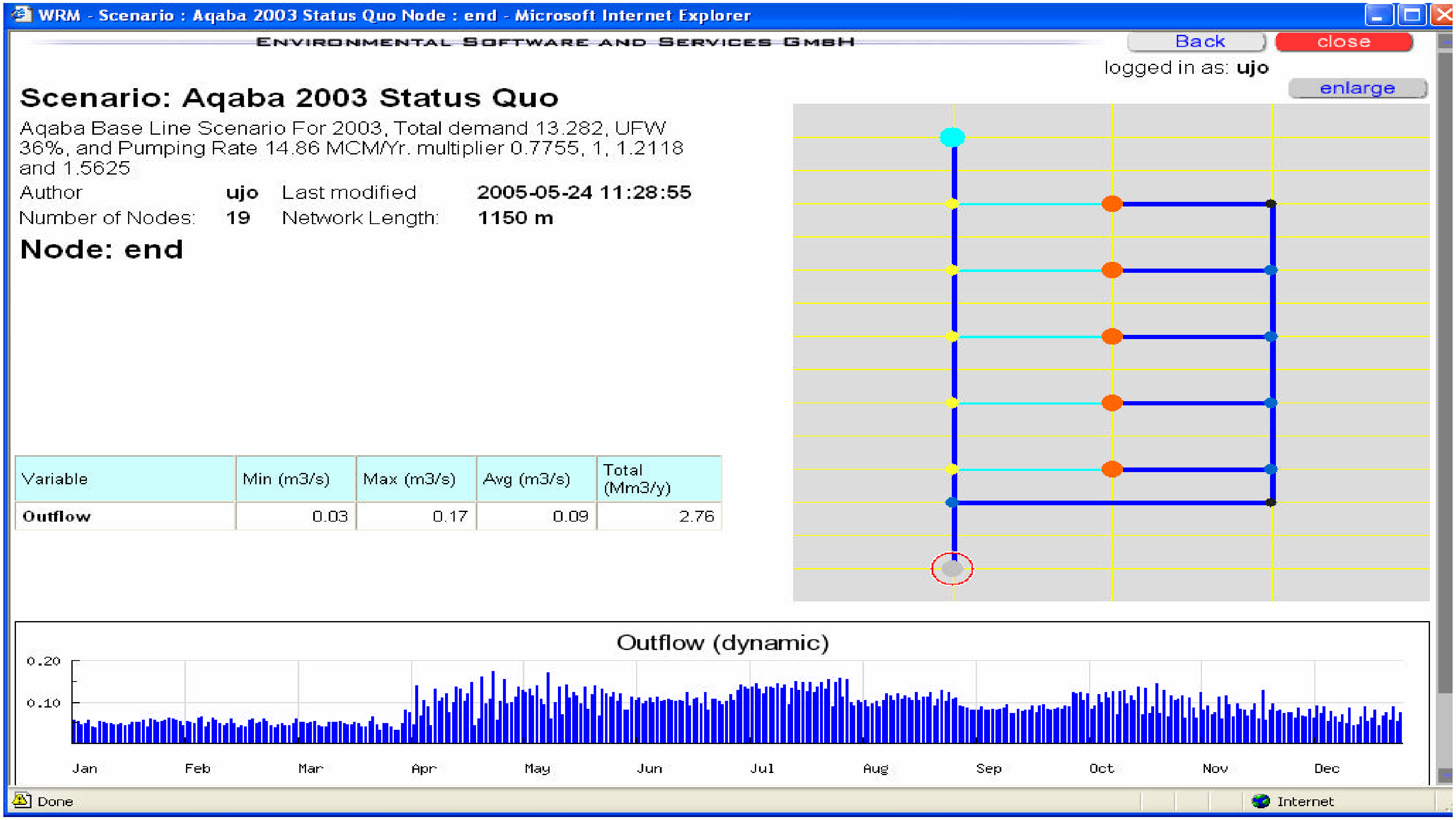


Figure E 32: Daily Detailed Analysis of Water Outflow for the End Node for the Base Line Scenario for 2003.

7.3

Water Resources Modeling, WRM

DSS

Multi-criteria analysis