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INTERNATIONAL CONSULTANTS IN ENGINEERING, ARCHITECTURE, PLANNING, AND MANAGEMENT

PN-AAH-376

ENVIRONMENTAL ASSESSMENT
ON
AMMAN WATER AND SEWERAGE PROJECT

Contract No. AID/otr-C-1628

Work Order No. 1

July 21, 1978

7183

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Attention: Mr. James G. Cassanos

Gentlemen:

Re: Contract No. AID/otr-C-1628
Work Order No. 1
Amman Water and Sewerage

We have received your comments dated June 21, 1978, pertaining to our May 19, 1978 draft report on the referenced project. Consideration has been given to all of these comments during preparation of the final report.

We are transmitting 25 copies of the final report in accordance with Work Order No. 1. Please advise us if you have any comments or questions.

It has been a pleasure working with you on this project.

Sincerely,

STANLEY CONSULTANTS, INC.

L. Lynn Pruitt
Study Manager

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DESCRIPTION OF THE PROPOSED PROJECT

Introduction

The city of Amman is the capital of the Hashimite Kingdom of Jordan and is located on the upper reaches of the Zerqa River basin. The Amman Water and Sewerage Authority (AWSA) is an autonomous local authority which has acquired the assets and liabilities of both the Water and Sewerage Departments of Amman Municipality. Control of AWSA is vested in a seven-member Board of Directors, composed of the Lord Mayor as chairman, three members from the Amman Municipal Council, one member from the National Planning Council, one from the Natural Resources Authority, and one from the private sector. The Lord Mayor is responsible to the Prime Minister for the activities of the Board. AWSA has authority for developing and maintaining water supply, water distribution, sewage collection, and sewage treatment works for the city of Amman. Major expansion and improvement of these facilities are proposed. Location of the proposed projects is shown on Figure 1.

Funding for the proposed projects will be obtained from various international funding agencies including the United States Agency for International Development (AID). Although AID is not participating in all portions of the projects, all of the projects being considered by AWSA are interrelated and act upon the same hydrological system. Consequently they are all considered in this environmental assessment.

Water Supply

The water supply project consists of the treatment and transmission of water from King Talal reservoir to the city of Amman. The reservoir is located approximately 35 kilometers (km) northwest of Amman and has a live storage capacity of 48 million cubic meters (Mm^3). The reservoir is an impoundment of the Zerqa River downstream of the city of Amman. Originally, King Talal Dam was developed to provide irrigation water for the Jordan Valley Authority. The dam is in the final stages of completion, but the reservoir will not be filled until 1979 or later.

The initial stage of the water supply project is to withdraw 12 million cubic meters per year (Mm^3/yr) from King Talal reservoir. After treatment and supplying some villages enroute, 10 Mm^3/yr will be transported to Amman via a 25 km long, 800 millimeter (mm) diameter pipeline. Capacities of the major project features have been increased by 40 percent to meet peak demands and operating fluctuations. Operation will be limited to 20 hours per day to avoid the peak electrical demand time. Physical facilities consist of the following:

1. On the southern shore of King Talal reservoir will be located a floating intake structure. Capacity of the intake is 1.364 cubic meters per second (m^3s) at a head varying from 70 to 120 meters (m) which allows for possible future expansion. From the intake, water will be pumped to a pretreatment plant.
2. The pretreatment plant consists of chlorination, coarse screening, storage and a pumping station to lift the water to the main water treatment plant. Provision is made for subsequent addition of microscreens. The pumping station and pretreatment facilities are sized at 0.682 m^3s at a head of 319 m. Water hammer protection is provided.
3. Raw water enters the water treatment plant at presedimentation basins, these are followed by cascade aerators and the addition of a coagulant, flocculation, and sedimentation. The final steps are rapid sand filtration, chlorination, and storage. Provisions have been made for feeding activated carbon for taste and odor control. Capacity of the water treatment plant is 0.650 m^3s. Filter backwash water is clarified with the overflow going to the presedimentation basins. No formal plans have been proposed for disposal of underflow from the backwash clarifier and sedimentation basins. One informal proposal suggested disposal of this sludge by discharge downstream of King Talal Dam. Housing will be built on this site for the operation and maintenance staff of the water treatment plant and related facilities.

4. Water will be conveyed from the water treatment plant to the city of Amman via a 800 mm pipeline and two pumping stations. The first pumping station is located at the water treatment plant and the second is at an intermediate point. Capacity of the pumping stations is 0.650 m^3s at heads of 301 and 210 m, respectively. The pipeline can convey 1.300 m^3s which allows for future expansion. The pipeline is to be buried for its entire length and provisions have been made for water hammer protection. The pipeline terminates at two storage facilities, each with a capacity of 10,000 cubic meters (m^3). These reservoirs will be located just nortnwest of Amman and will be connected to the Amman water distribution system.

Water Distribution System

AWSA has an ongoing program of water distribution system extensions. The projects currently being considered would extend the existing water distribution system by the addition of approximately 207 km of water mains and house connections.

Sewage Collection Systems

As with the water distribution system, AWSA has an on-going program to extend the sewage collection system in Amman. This project includes 225 km of sewers and service connections.

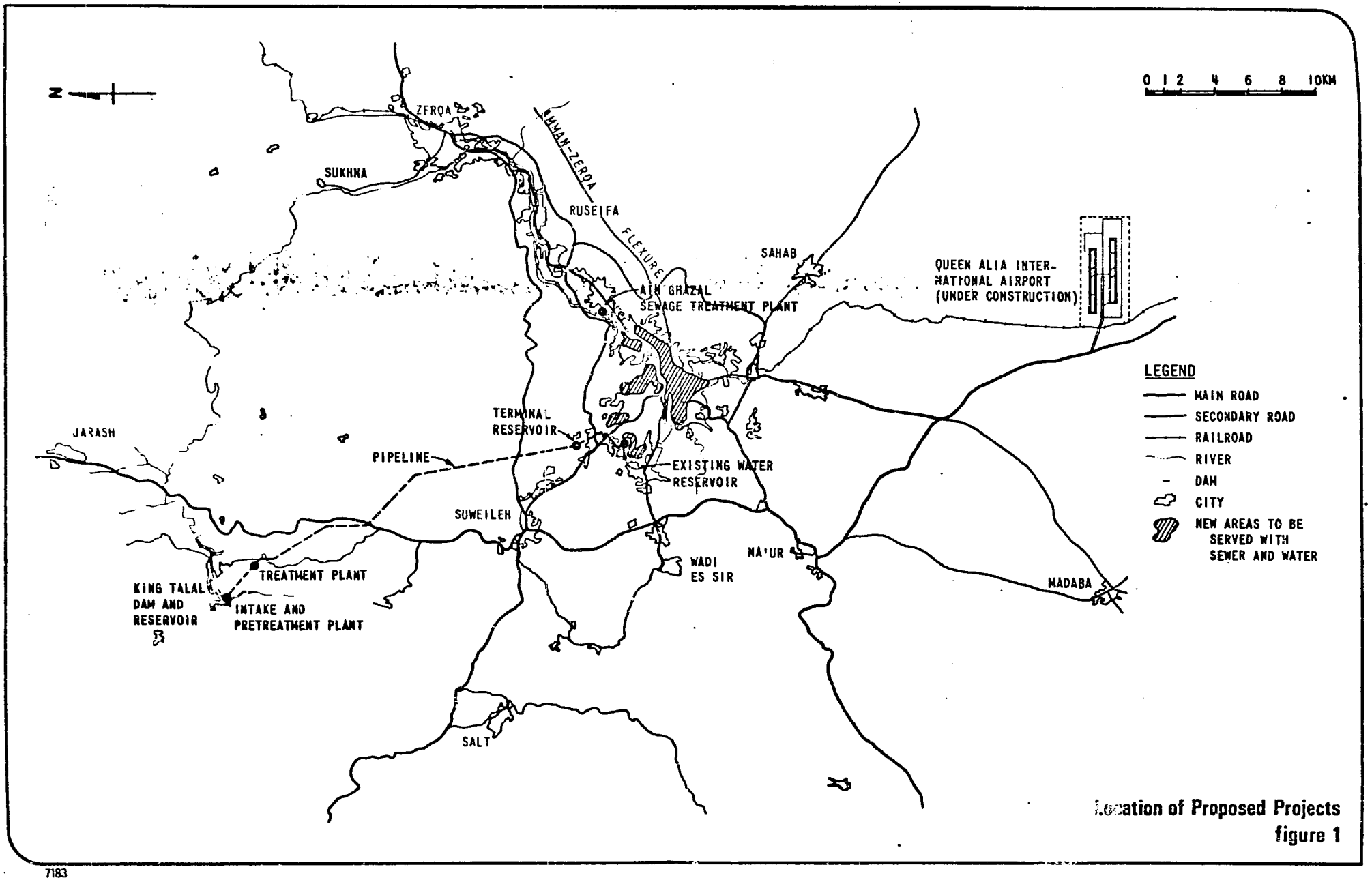
Sewage Treatment Plant

The city of Amman is currently served by a secondary wastewater treatment plant at Ain Ghazal. This plant is in need of additional sludge handling facilities and minor improvements to the treatment process equipment. Further study of sewage treatment requirements is being performed for AWSA. The draft report submitted in January, 1978, recommends the following:

1. Construction of a new anaerobic digester with a volume of 6,000 m^3 and upon its completion, refitting of the existing anaerobic digesters.

2. Installation of a mechanized grit removal system prior to the comminutor. Presently, grit is removed manually at this point.
3. Replacement of the existing nonfunctional flow recorder with a new instrument.
4. Installation of new sludge pumps.
5. Provision of new compressors for the return sludge air lifts.
6. Replacement of existing gas meters.
7. Provision of three automatic samplers and a portable sludge level detector.

An April, 1978 report presented to AWSA recommends the use of mechanical sludge dewatering by filter belt presses. This recommendation supercedes the recommendation in the January, 1978 draft report for sludge drying beds. All of these improvements are to be at the present Ain Ghazal sewage treatment plant site.



Location of Proposed Projects
figure 1

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PURPOSE OF THE PROJECT

Amman is the largest city in Jordan with a present population of at least 700,000. Although less than half of the population is connected to the water distribution system, everyone in the city is supplied by the water pumped from municipal wells. The nonconnected population depends upon water tanker service, roof tanks, and temporary connection to neighbors who are connected to the water distribution system. Probably less than 15 percent of the population is connected to the sewage collection system. Those persons not connected discharge their wastewater to septic tanks and cesspool systems. As described hereinafter, ground water hydrology allows rather rapid transmission of cesspool leachate to the ground water system.

This ground water system currently provides a total of about 18 Mm^3/yr as the water supply for the city of Amman. The current rate of pumping from the ground water aquifers exceeds the reliable yield of the aquifers. Studies have indicated that an additional source of supply is necessary immediately. The only readily available water supply source is the King Talal reservoir. Water supply from this reservoir is proposed to enable the reduction of the ground water supply to the safe yield level and to provide a better quality water for consumption.

Extension of the water distribution system will allow more people to be served through a pressurized system, thus decreasing some of the hazards involved with water tankers, roof tanks, and intermittent system pressure. Extension of the sewage collection system will eliminate some of the leachate from cesspools, thus reducing the amount of degradation of the ground water supply.

Additional sludge handling capacity is required at the sewage treatment plant to maintain proper operation. The existing anaerobic digesters are inadequately sized to handle existing solids loads and are operating at less than the design detention time. The majority of the digested sludge is currently disposed of in liquid form by trucking to the municipal dump. A small portion is dewatered on the sludge drying

beds. The city of Amman would like to discontinue the practice of dumping liquid sludge. Anticipated increases in sludge production will further exceed the sludge handling capability of the sewage treatment plant. The proposed filter belt presses will greatly reduce the quantity of sludge to be handled and will result in a more readily manageable material for disposal. The other items proposed to be constructed under the project at the sewage treatment plant are intended to improve plant maintenance and operation.

EXISTING ENVIRONMENTAL SETTING WITHOUT THE PROJECTS

The projects previously described are physically located in the city of Amman, near King Talal Dam and along the 25 km pipeline route. To properly assess the impacts and environmental characteristics of the projects requires examination of the entire hydrological system affecting the water supply. The hydrological unit, including ground water, is basically the Zerqa River basin from its headwaters to King Talal Dam. The following description includes some areas outside of the Zerqa River basin when these areas will affect either the importation or exportation of water from the basin.

Almost all of the drainage area lies within the governorate of Amman. Along the northern portion of the drainage basin the Zerqa River serves as a boundary with the governorate of Irbid which contains the narrow northern portion of the drainage basin.

Land

Topography - The eastern part of the study area is a gentle rolling plateau with increasing slopes to the west. The maximum elevation is 1,086 meters (m) above mean sea level at the western part of the area. The western portion of the area is characterized by rugged mountainous features with extreme topographic relief. It is not uncommon for slopes to range between 40 and 60 percent in these more rugged areas.

There are many wadis (nonperennial streams) draining the area and tributary to the Zerqa River. Drainage area for the entire Zerqa River basin is 4,031 square kilometers (km^2). The portion above Sukhna (excluding Wadi Dhuleil) is known as the Amman-Zerqa basin with a drainage area of 635 km^2.

Soils - Within the study area there are two major soil classifications. These classifications are the Zonal Soils and the Azonal Soils. The Zonal Soils are comprised mainly of the Red and Yellow Mediterranean soil types. Basically these soils occur in areas where rainfall averages

from 250 to more than 350 mm per year. The Mediterranean soils are important for agricultural production and have a relatively high natural fertility.

The second major soil classification is the Azonal Soils. This classification occurs at the eastern edge of the study area and contains the following specific soil types: Grumosols, Reqosols, and Lithosols. These specific soils are predominately clay, sand, gypsum, basalt, and various other rock. In general, they have limited or little value for agricultural uses.

Geology

General Description - The geology of the Amman-Zerqa basin in northwestern Jordan is comprised of Mesozoic-Cainozoic sediments. These sediments form a series of aquifers and aquicludes which are important to the water supply in the Amman region.

Geological mapping of the area was performed in the 1950's and 1960's. The following general description of the aquifers is presented to give an overview of the water-bearing formations. More specific information may be found in referenced documents, specifically those by Mudallal and Parker.

The Amman-Zerqa flexure (syncline) is an important geologic feature in the study area which provides a hydraulic barrier to the movement of ground water. The flexure is located adjacent to the Zerqa River near Amman as shown on Figure 2. Geologic formations in the region generally slope to the east but are intercepted by the Amman-Zerqa flexure. The flexure causes a ground water storage area along the north and west side of the divide.

Amman-Wadi Sir Aquifer System - The primary outcrop in the Amman-Zerqa basin is the Amman-Wadi Sir aquifer system (designated as B1-2, A7). This system, which is known as the "upper aquifer," is an unconfined limestone formation.

The Amman-Wadi Sir aquifer system is made up of the chert-chalk aquifer of the Amman formation (B1-2) and the limestone of the Wadi Sir formation (A7). These two formations are hydraulically interconnected

throughout most of the study area and are considered as a unit. Outcrops of the Amman-Wadi Sir system occur throughout much of the basin.

Sand layers occur at the contact zone of the two formations which comprise the upper aquifer system. Joints, fractures, folds, and solution channels occur irregularly throughout the system and affect the productivity of the aquifer. Direct recharge occurs from rainfall over the outcrop areas. There is some indirect recharge of the aquifer system from seepage, surface runoff, and floods in wadis which occur in the formations.

The alluvium and wadi fill deposits follow the major wadis and plateau gravel layers within the region. This is mainly made up of gravel, sand, and silt with direct recharge from rainfall or indirect from surface water flows in the wadis or subsurface flows from adjacent ground water fields. In the Amman area, the gravel deposits overlie the chert of the Amman formation resulting in a highly productive aquifer. The gravel deposits become very thin in the Zerqa area and the productivity of this aquifer decreases. The underlying Amman-Wadi Sir formation is also eroded in the Zerqa area reducing the yield. The alluvium and wadi fill formation is considered herein as a part of the upper aquifer.

Hummar Aquifer - The "lower aquifer" or Hummar formation (A4) is separated from the upper aquifer by the A5-6 aquiclude. The Hummar formation is composed of a highly fractured, crystalline, and coarse grained dolomitic limestone. It outcrops in a narrow band at a high elevation a short distance west of Amman. The aquifer, which is artesian, has historically had a high piezometric (ground water) level with good productivity. However, in recent years "mining" of the aquifer has lowered the piezometric level significantly. The permeability of the aquifer is reasonably good in the Amman area, but it is reduced significantly around Zerqa because of the presence of marl in that area. Limits of the aquifer are also restricted because of the Amman-Zerqa flexure which forms a hydraulic barrier to ground water movement.

Basalt Aquifer - Basalt formations occur in the northern portion of the study area and contribute to the ground water supply by direct hydraulic connection with the underlying gravel aquifer. The Basalts

are sponge-like formations which tend to be restricted in their aquifer productivity by zones of fine fractures and fissures. A ground water mound in southern Syria disperses ground water south into northern Jordan. Some of this ground water finds its way to the Dhuleil ground water field and the aquifers of the Amman-Zerqa basin. Little direct recharge is added to the Basalt system in Jordan, however, there is some indirect recharge from numerous wadis which have eroded into the Basalt formation. This recharge is believed to be of small quantity.

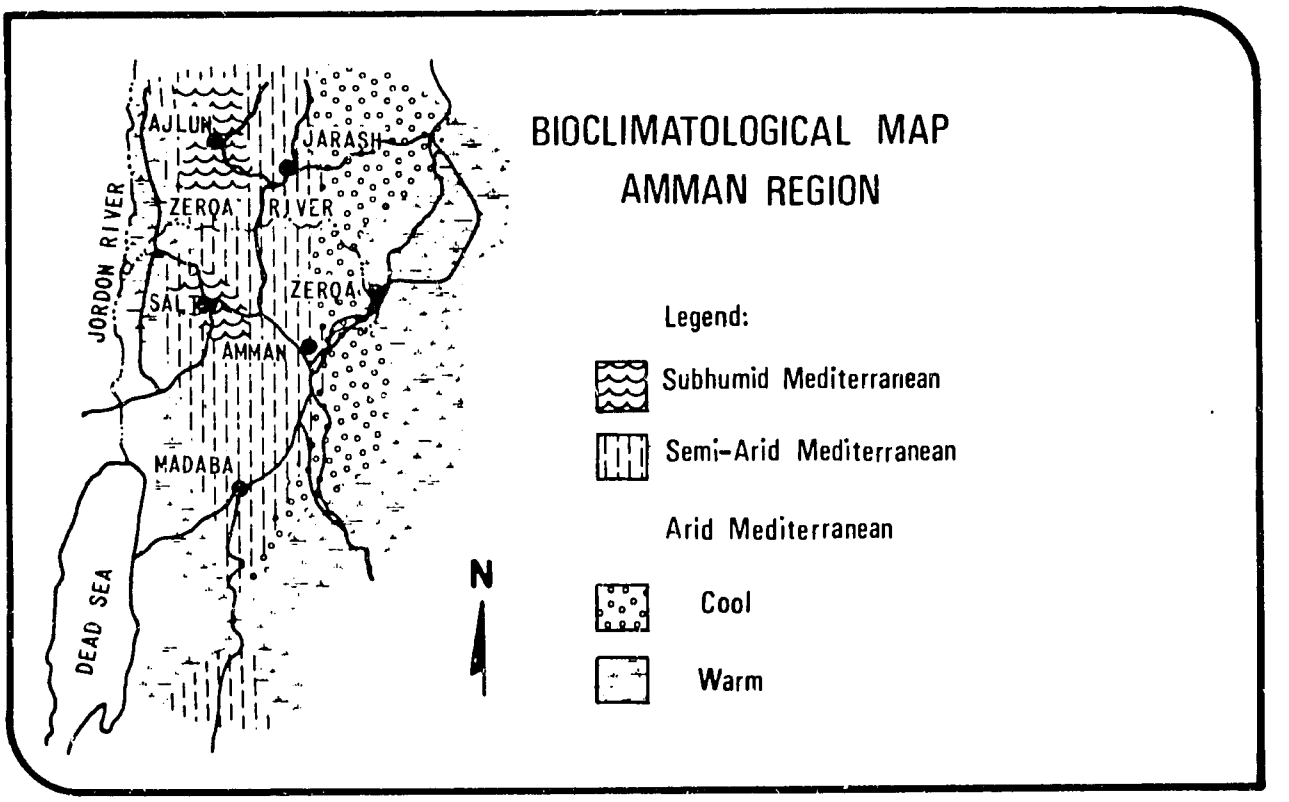
Atmosphere

Climate - Within the area of the Zerqa River basin three distinct climatic conditions prevail. The following description of these bioclimates is taken from Report 37, "Physiographic Regions of East Jordan as Related to Land Use" by Dr. Abdul Raheem Talli.

1. Subhumid Mediterranean - average annual rainfall is more than 600 mm, the different temperatures characterizing a cool variety and a warm variety. It covers two regions, Ajlun and Salt. The total area is about 650 km^2.
2. Semi-Arid Mediterranean - average annual rainfall between 300 and 600 mm. This bioclimate covers three main geographic zones: Irbid-Amman, Madaba, and Karak-Shaubak. The total area covers about 4,550 km^2.
3. Arid-Mediterranean - the average annual rainfall is between 150 and 300 mm.
   a. The cool variety covers the eastern slopes of the Ajlun range and the Amman-Madaba plateau; it is transitional between the semi-arid and arid bioclimates and is characterized by the Mafraq and Jiza locals.
   b. The warm variety covers the steppe portion to the west and east of the highlands from north to south. This bioclimate is characterized by Zerqa.

   The total area covered by the Arid-Mediterranean bioclimate is approximately 10,600 km^2.

A breakdown of eastern Jordan by distinct bioclimates reveals: 1.16 percent subhumid; 8.34 percent semi-arid; 19.02 percent arid, and 71.48 percent Saharan. Only the Saharan bioclimate does not occur within the confines of the Zerqa River basin.



Air Quality - No air quality data are available for the study area. Other than transportation sources, there are only a limited number of potential air pollution sources within the study area. Only a few industries and two power generating stations use combustion processes. Since petroleum products are the primary fuels utilized, even combustion sources do not contribute any significant amount of air pollution.

Wind borne dust is the most commonly observed air pollutant. In some localities this condition is exacerbated by mining operations.

Field reconnaissance has shown three point sources of significant, visible air pollution. In each case, the effect of the pollutant source is primarily local, and the total area affected is dependent upon wind conditions. There is a cement manufacturing plant in Suweileh. A phosphate mining operation near Ruseifa contributes dust blowing off

of large stockpiles in addition to the actual mining and processing operations. The third source is a combination of smoke, particulates, and odors from the burning of refuse at the Amman municipal dump.

Human Systems

Agriculture - Within the approximately 2,000 km^2 (Zerqa basin minus Wadi Dhuleil) of the Zerqa River basin, agriculture is a dominant user of land. In 1975, within the Amman Governorate, approximately 675 km^2 were devoted to crop production. In addition, approximately 60 km^2 were used for tree production. Together these agricultural uses accounted for better than 35 percent of the total land within the governorate. Due to the severity of the topography in the governorate, it is estimated that only 60 to 65 percent of the total area could be utilized for agricultural or urban uses. Much of the remaining 40 to 45 percent of the land has been designated as open grazing lands and is utilized throughout the year.

It is believed that crop production areas are generally maximized within the Amman Governorate and that as urban uses expand, it will be at the expense of agricultural areas.

Urban Areas - The single most dominant feature in the Zerqa River basin is the Amman-Zerqa urban complex. The exact physical size and population is not known; however, a 1975 population estimate indicates approximately 880,000 to 980,000 people. This urban complex comprises approximately 3 percent of the country's land area and was estimated to contain 62 percent of the country's population, 75 percent of the country's building area, and 74 percent of the country's industrial establishments.

Other urban areas within the Zerqa River basin are much smaller by comparison. The two major areas are Jarash and Suweileh. The 1975 population estimates for these two communities were 9,500 and 15,000, respectively.

Industries - Almost all of the industries within the study area are located between the municipalities of Amman and Zerqa. Limited information is available regarding environmental characteristics of the

industries. Table 1 contains the name and reported characteristics of those industries which are known to discharge wastewater to surface streams. The location of these industries is shown on Figure 2.

Most industries rely upon their own wells for water supply. A lack of water quality data for private wells makes an initial determination of the amount of nitrates or total dissolved solids (TDS) not possible. Water usages and demands are available for some of the industries, but the amount of wastewater discharges can only be inferred from these data. Characteristics of wastewater discharges from the industries have been investigated, but without wastewater flow information, pollution loads on the stream can not be determined.

The major industrial wastewater discharge is from a slaughter house in Amman. This is the only industry which discharges its wastewater to a municipal wastewater treatment system.

Known information on wastewater quality discharges from industries is given in Table 2. This information has been gathered by the Jordan Natural Resources Authority (NRA) and the Royal Scientific Society. AWSA, in conjunction with NRA, is currently preparing for a comprehensive industrial wastewater discharge survey, which should provide detailed information within one year. The information in Table 2 is qualitative only, because industrial wastewater flows are unknown.

Analysis of Table 2 gives an indication of the types of pollutants discharged from the various industries. Basically, the data cover inorganic constituents, oxygen demanding substances, and, in some cases, metals and toxic substances. Most inorganic compounds are present because they were originally present in the water utilized by the industry. Some industries increase the levels of TDS and sodium chloride. These two constituents are important because they affect the suitability of the discharge water for irrigation. The presence of oxygen consuming substances, as indicated by the levels of ammonia and chemical oxygen demands (COD), can alter the characteristics of the receiving stream, making it unsuitable for either irrigation purposes or livestock watering until natural purification processes have removed these pollutants.

TABLE 1

INDUSTRIES AND WATER CONSUMPTION

Name	Type	Code[1]	Water Consumption[2] 1975 (m^3/day)	Water Consumption[2] 2000 (m^3/day)
Jordanian Electric Power Co.	Power generation	1	400	710
United Industry Corp.	Battery manufacturing	2	235	630
Jordan Ice and Aerated Water Co., Ltd.	Pepsi-Cola bottling	3	740	3,015
Transjordan Minerals Research	Phosphate processing	4	205	2,055
	7-Up bottling	5	495	10,685
	Royal Crown Cola bottling	6		
	Marble factory	7		
Jordan Worsted Mills Co.	Textiles	8	330	495
	Steel mill	9		
	Textiles	10	135	1,350
Jordan Dairy Co. Ltd.	Dairy products	11	40	605
Jordan Tanning Co. Ltd.	Leather goods	12	820	1,370
Jordan Paper and Cardboard Factory Co.	Paper	13	575	1,095
Jordan Refinery	Petroleum products	14	3,150	5,755
	Leather goods	15		
Amstel Beer	Brewery	16	85[3]	
	Dairy products	17		
Arab Beer	Brewery	18		
Imperial	Textiles	19		
Eagle Liquor	Liquor, blending, & bottling	20	240[3]	

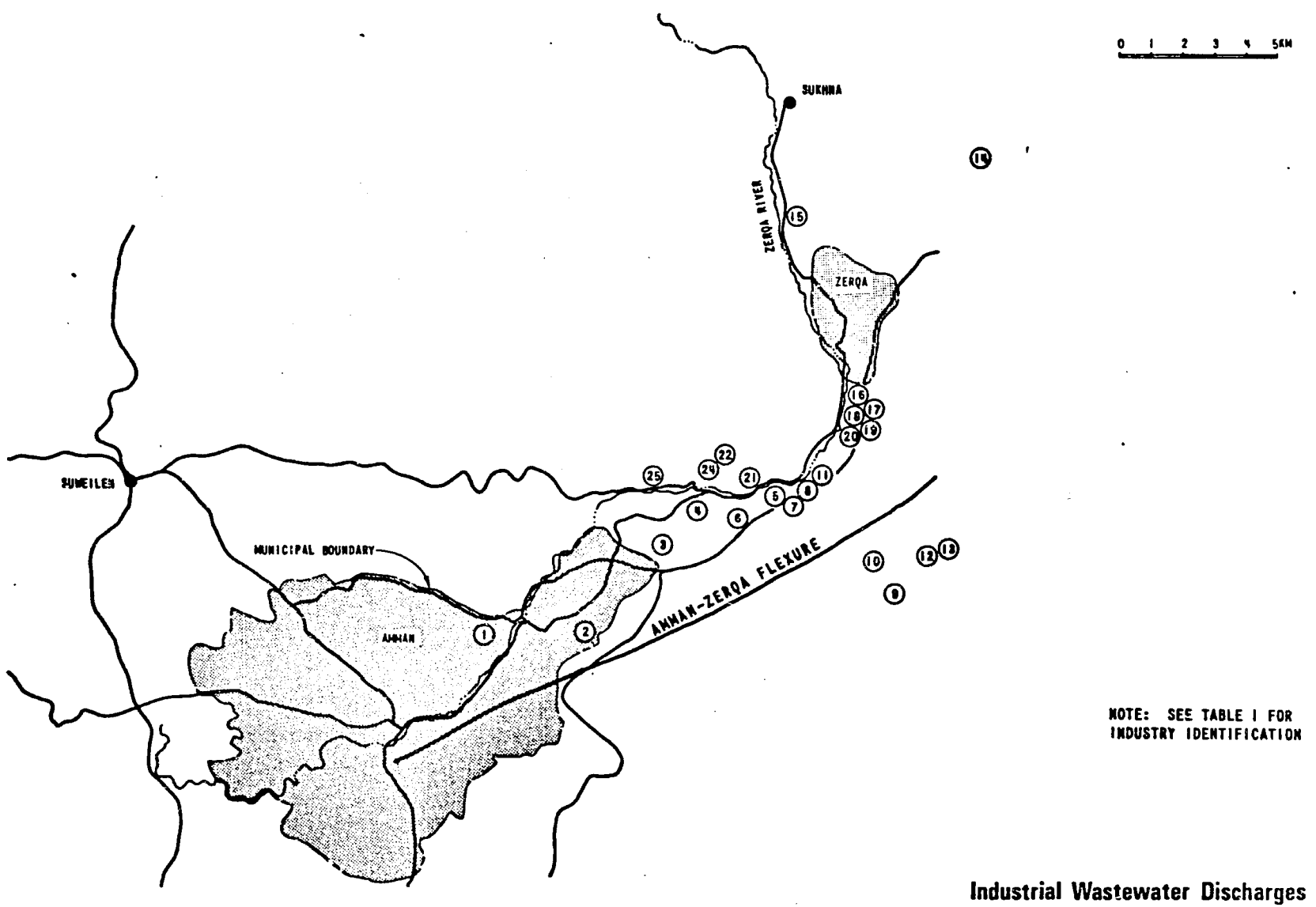
TABLE 1 (continued)

Name	Type	Code[1]	Water Consumption[2] 1975 (m^3/day)	Water Consumption[2] 2000 (m^3/day)
King Hussein Industrial City	Paints	21	550	12,330
King Hussein Industrial City	Detergents	21		
King Hussein Industrial City	Cosmetics	21		
King Hussein Industrial City	Biscuits	21		
Surf	Detergents	22		
Orient Star	Liquor, blending, & bottling	24		
Transjordan Mines	Phosphate mining	25	1,370	10,960

[1] Refers to location on Figure 2.

[2] From "VOLUME VI - DOMESTIC/INDUSTRIAL WATER DEMAND," "NATIONAL WATER MASTER PLAN OF JORDAN," Agrar-und Hydrotechnic GMBH, 1977.

[3] "Wastewater Disposal and Stormwater Drainage for City of Zerqa - Preliminary Design Report," SCAN PLAN Coordinator A/S and Jouzy & Partners, 1975.



Industrial Wastewater Discharges
figure 2

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TABLE 2

INDUSTRIAL WASTEWATER CHARACTERISTICS

Constituent Analyzed	Concentration Range (mg/l)
Magnesium, Mg	2.4 - 1,140
Calcium, Ca	0.0 - 6,010
Potassium, K	5.0 - 900
Sodium, Na	44.0 - 7,500
Chloride, Cl	50.0 - 37,200
Total Dissolved Solids	520 - 59,800
Phosphate, P_2O_5	Trace - 35
Sulphates, SO_4	0.0 - 4,170
Nitrate, NO_3	3.7 - 705
Chemical Oxygen Demand	1.9 - 46,260
Iron, Fe	0.005 - 27.0
Copper, Cu	0.005 - 3.5
Lead, Pb	0.019 - 0.45
Nickel, Ni	0.023 - 0.20
Aluminum, Al	0.3 - 7.6
Zinc, Zn	0.01 - 15
Cadmium, Cd	0.0 - 0.3
Manganese, Mn	0.01 - 0.5
Chromium, Cr	0.009 - 1.03
Mercury, Hg	2.0 - 8.0[1]
pH	2.6 - 11.4

[1] Field inquiries have disclosed that mercury determinations are probably in error.

Source: Based upon data collected by the Royal Scientific Society and Natural Resources Authority.

Heavy metals in the wastewater discharges to the Zerqa River are a matter of concern since the construction of King Talal Dam. The presence of a reservoir to act as a sink for these substances may have an effect upon water quality within the reservoir. Included among the metals and toxic substances are pollutants which, in relatively low amounts, are hazardous both to plants and animals, including man. Potential problems with heavy metals in reservoirs come about because of bioconcentration and presence of the metals in bottom sediments. Concentrations of pollutants in aquatic plants or animals may be many times that of the water because biological processes have concentrated the pollutant within the organism. When introduced into a reservoir, metals have a tendency to be incorporated into the bottom sediment. Microbial action in the bottom sediment can resolubilize the metal making it available for bioconcentration; this is the basic action of mercury contamination of fish.

In summary, most industries in the Amman area provide goods for consumption within Jordan. Most goods produced are household related. The industries provide their own water supply and generally discharge wastewaters without treatment to surface waters. An increase in water demand is anticipated as well as an increase in the amount of wastewater discharged. The quantity and quality of the wastewater presently discharged is not definitely known. Available qualitative analysis of wastewater shows the presence of pollutants which could have a significant effect on water use in the basin.

Constructed Facilities and Activities - Development is currently occurring in the Amman Governorate at an extremely high rate. It is estimated that since 1971 the region has been growing at an annual rate of nearly 6 percent. Prior to 1971, the Amman region received large numbers of political refugees as a result of political strife in 1967. Since 1971, the immigration of political refugees has slowed; however, significant immigration from within the country is continuing to occur.

As a result of continued immigration, Amman is experiencing significant activity. Housing is extremely limited and expensive,

particularly for the moderate and low income people. An indicator of this is shown in the "Social Soundness Analyses of the Amman Water and Sewerage System" prepared by Jarir S. Dajani in 1978 as a part of this total environmental analysis.

A major concern with much of the current development is that it is occurring without the benefits of city utilities, particularly sewer and water. It is also occurring at scattered outlying locations making future utility distribution and collection systems most inefficient.

The Ain Ghazal sewage treatment plant serves the sewered portion of Amman and discharges treated effluent to the Zerqa River. The treatment processes consist of a comminutor, pre-aeration and grit removal, primary sedimentation, conventional activated sludge, secondary clarification, and chlorination. Primary sludge is pumped directly to anaerobic digesters, while waste activated sludge is thickened in gravity thickeners prior to digestion. Presently, nearly 90 percent of the liquid sludge from the anaerobic digesters is trucked to the municipal dump. The plant was designed to handle a flow of 60,000 m^3/day and BOD_5 loadings of 18,000 kilogram/day (kg/day). Present plant loads are 12,000 m^3/day and 8,600 kg/day of BOD_5. To avoid extremely long detention times, only half of the hydraulic capacity of the plant is being utilized. Even this modification results in detention times much greater than those designed. The organic loading is almost at the design point for half of the plant.

The above circumstances result in the plant being operated at the lower limits of a conventional activated sludge system. The extremely long detention times result in a partially digested sludge being wasted to the anaerobic digesters. In addition, the size and general state of repair of the anaerobic digesters limit the sludge handling capacity to approximately the present sludge loads. The plant has a number of minor operational problems which occasionally affect the overall efficiency of the plant on a short-term basis. These difficulties include malfunctioning diffusers, problems in maintaining blower capacity, and breakdown of the grit removal mechanism.

Water

Surface Water - The only significant surface water feature in the study area is the Zerqa River and its tributaries. The Zerqa River rises in the area just west of Amman and flows east and northeast to Zerqa where it changes direction to the north. Just north of Sukhna, it is joined by a major tributary, Wadi Dhuleil, and turns westward, continuing until it meets the Jordan River. The upper reach of the Zerqa River (known locally as Wadi Seil) is an intermittent stream, with little or no flow during the dry season, until it reaches Sukhna. From Sukhna downstream springs and other ground water flows contribute increasing amounts of water to the base flow of the stream.

There are stream flow gaging stations at Sukhna, the bridge on the new road to Jarash, Deir Alla, and on Wadi Dhuleil at Sukhna. Only the gages at Deir Alla and on the Jarash Road Bridge have periods of record greater than 10 years. A number of studies have been made to determine the stream flow characteristics of the Zerqa River based upon available stream flow data by correlation with precipitation records, which is available over a far longer period. Predicted stream flow and drainage area for the gaging stations as given by "The National Water Master Plan of Jordan," is given in Table 3.

TABLE 3

PREDICTED FLOWS - ZERQA RIVER

Gage	Location	Drainage Area (km^2)	Predicted Flow (Mm^3/yr) Wet Year	Average Year	Dry Year
AL2	Deir Alla	3,430	141.6	93.2	57.6
AL1	Old Jarash Bridge	3,250	105.5	67.4	40.0
AL11	New Jarash Bridge	3,150	91.5	61.7	39.0
AL3	Sukhna	635	35.9	25.3	17.5
AL4	Ain Ghazal Bridge	163	9.8	7.3	5.5

Source: National Water Master Plan of Jordan.

Water quality characteristics of the Zerqa River are not readily available. In 1976, a number of water samples were taken to determine the suitability of the water quality for a water supply. The results of these samples, as given in "Amman Water Supply from King Talal Dam," are shown in Table 4. Water quality in the Zerqa River for two days in 1977 as presented in "The National Water Master Plan of Jordan" is presented in Table 5. No bacteriological or radiological data are available. The results given in Table 5 reflect stream conditions during high flow periods, but after the first half of the rainy season.

TABLE 4

WATER QUALITY - ZERQA RIVER AT JARASH ROAD BRIDGE

Parameter	Value	Parameter	Value
Ca	98 mg/l	HCO_3	268.4 mg/l
Mg	41.1 mg/l	SO_4	192 mg/l
Na	144.9 mg/l	NO_3	6.2 mg/l
K	16.4 mg/l	Total cations	300 mg/l
SO_2	14.5 mg/l	Total anions	730.6 mg/l
Cl	237.8 mg/l	TDS	1,031 mg/l
CO_3	11.1 mg/l	pH	7.9 units

Source: Amman Water Supply from King Talal Dam.

Analysis of the variation in stream flow with the season and the nature of wastewater discharges indicates that stream water quality is likely to be highly variable. The Ain Ghazal sewage treatment plant and the downstream industries are continuous contributors of oxygen demanding substances, nitrogen compounds, and a variety of inorganic pollutants including heavy metals. In the area from Amman to downstream of Sukhna, return flow from irrigation will contribute both nitrogen and phosphorus compounds and pesticides. Since the municipal and industrial discharges occur in the area where the stream is intermittent, nonsoluble pollutants will be deposited on the stream bed

TABLE 5

ZERQA RIVER QUALITY

Constituent	Unit	Abdoun		Treatment Plant Asman Effluent		Downstream Treatment Plant		Before Phosphorus Mines Ruseifah		Ruseifah		Awajan Bridge		Zerqa Bridge Zerqa		New Jarash Bridge	
		Jan.'77	Feb.'77	Jan.'77	Feb.'77	Jan.'77	Feb.'77	Jan.'77	Feb.'77	Jan.'77	Feb.'77	Jan.'77	Feb.'77	Jan.'77	Feb.'77	Jan.'77	Feb.'77
E.C.	mmhos/cm	0.390	0.390	1.950	1.860	0.700	0.650	0.630	0.540	0.495	1.000	0.520	1.300	0.510	1.200	1.450	0.870
Total Dissolved Solids	mg/l	250	250	1.248	1.190	448	416	403	346	317	640	333	832	326	768	928	557
Calcium (as Ca)	mg/l	38.0	37.2	78.8	56.0	46.0	48.0	46.8	43.2	40.8	68.0	40.0	79.2	40.0	73.2	94.8	68.0
Magnesium (as Mg)	mg/l	2.9	3.6	23.3	29.2	8.5	5.2	5.3	5.8	5.6	9.2	4.1	216.7	5.3	15.6	40.9	16.5
Sodium (as Na)	mg/l	26.5	28.8	201.2	179.4	80.6	63.2	69.0	46.0	44.0	87.4	52.9	214.5	39.5	105.8	138.0	81.6
Potassium (as K)	mg/l	7.8	9.8	47.2	46.8	17.9	16.4	16.0	12.1	13.3	22.6	14.4	26.9	12.9	25.7	20.2	10.1
Chloride (as Cl)	mg/l	42.6	33.4	236.8	209.5	81.7	67.4	78.8	54.0	51.5	113.6	58.2	158.7	58.6	142.4	221.9	111.8
Sulfate (as SO_4)	mg/l	19.2	23.1	89.3	60.5	38.4	25.0	33.6	11.5	24.0	45.6	24.0	40.3	38.4	52.8	151.7	77.8
Carbonate (as CO_3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bicarbonate (as HCO_3)	mg/l	86.6	134.2	634.4	652.7	231.8	235.5	189.1	183.0	158.5	322.3	169.6	461.2	136.6	392.8	320.9	207.4
Total Cations		3.49	3.66	15.82	14.20	6.96	5.97	6.21	4.95	5.04	8.54	5.31	11.77	4.92	10.20	14.62	8.57
pH		7.75	7.35	7.65	7.50	7.95	7.48	7.00	7.75	7.60	7.65	7.30	7.80	7.98	7.85	7.25	7.30
Nitrate (as NO_3)	mg/l	28.9	11.5	52.3	0.8	25.0	3.7	21.3	8.8	21.3	1.8	19.2	0	18.3	1.8	13.3	17.3
Nitrite (as NO_2)	mg/l	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Carbon dioxide (as CO_2) free	mg/l	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Silicon dioxide (as SiO_2)	mg/l	7.7	12.5	24.6	28.0	12.9	12.4	10.8	11.3	7.7	15.2	8.3	22.0	9.3	17.0	14.5	12.1
Ammonium (as NH_4)	mg/l	4.5	3.2	50.8	22.9	6.0	1.4	8.0	1.4	8.7	1.4	12.5	16.5	6.6	18.3	3.1	2.1
COD	mg/l	21.8	186.2	158.0	1,146.6	1,325.7	803.6	858.9	607.6	526.6	803.6	533.9	1,313.2	134.4	1,528.8	70.8	176.4
Zinc (Zn)	mg/l	0.80	0	1.32	0	0	1.60	0.13	1.40	0	1.58	0	2.87	1.93	0	0.31	0.13
Cadmium (Cd)	mg/l	0.04	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.04	0.02	0.08	0	0.02	0.01	0
Lead (Pb)	mg/l	0.06	--	0.26	0.04	--	0.04	0.04	0.33	0.02	0.20	0.02	0.66	0	0.02	0.04	0
Iron (Fe)	mg/l	0.02	0	0	0.01	0.02	0.01	0.37	0.02	0.01	14.04	0.01	37.59	0.03	0.02	0.37	0
Chromium (Cr)	mg/l	0.22	0.03	0.08	0.04	0.02	0.06	0	0.08	0.04	0.08	0.04	0.25	0.27	0.04	0	0.04
Copper (Cu)	mg/l	0.13	0.02	0.04	0.03	0.08	0.04	0.02	0.03	0.05	0.06	0.08	8.35	0.08	0.06	0.01	0.04
Manganese (Mn)	mg/l	1.73	0.50	0.23	0.50	1.37	1.55	0.19	1.38	0.87	1.25	0.62	2.88	1.90	1.12	0.67	0.23
Aluminum (Al)	mg/l	0.04	0	0	0	0	0.01	0.83	0.02	0	7.08	0.01	31.66	0.04	0.01	0.33	0
Fluorine (F)	mg/l	0.01	0	0	0.01	0	0	0.36	0	0.01	7.80	0	17.60	0.05	0	0.35	0

Source: "National Water Master Plan of Jordan." Stream flow was 27,900 m^3/hr at Jarash Road Bridge in January 1977.

during the dry season. In addition, some of the dissolved pollutants will likely be left on the stream bed due to evaporation of stream water. Most dissolved pollutants will be carried along with the water which flows underground along the stream bed. During the dry season, the lower portion of the Zerqa River will have a relatively high quality water because almost all of the flow will be from springs or ground water sources. At the start of the wet season, increasing stream flows will resuspend and redissolve deposited materials, thus increasing the pollutant load which the stream is carrying. After this "flushing" of the stream bed, the additional stream flow will dilute the pollutants, but the higher stream flow will insure that the pollutants are carried downstream in a continuous flowing stream.

Since the King Talal reservoir is still filling, the effect of stream water quality upon water quality characteristics of the reservoir has not yet been observed.

Ground Water Supply - The water supply for the Amman-Zerqa basin currently is taken from the two ground water aquifers located in the region. A description of both the upper and lower aquifers was presented previously in this assessment.

Recharge of the two aquifers has been studied by several investigators in recent years. In the Amman area, recharge to the upper aquifer has been determined to be at least 10 Mm^3/year. Recharge to the lower aquifer in Amman has been determined to be between 2 and 3 Mm^3/year. Studies that comprise the entire Amman-Zerqa basin differ considerably. Recharge to the upper aquifer in the Amman-Zerqa basin has been estimated to range between 20 and 45 Mm^3/year, while recharge to the lower aquifer has been estimated between 5 and 10 Mm^3/year. The more recent projections made by Vattenbyggnadsbyran (VBB) favor conservative values at the lower end of these ranges.

Storage within the aquifers has been approximated. The upper aquifer in the Amman area has been estimated at a storage capacity of about 250 Mm^3. Within the entire Amman-Zerqa basin, the upper aquifer storage is projected to be between 500 and 750 Mm^3. Estimates for the storage in

the lower aquifer have not been refined to any great extent. In the Amman area, values between 50 and 100 Mm^3 have been projected. For the entire basin, estimates range from 150 to 1,500 Mm^3.

Current pumping rates from the upper and lower aquifers are fairly well defined. From the upper aquifer, about 13 Mm^3/year are being withdrawn in the Amman area. This is coupled with about 5 Mm^3/year from the lower aquifer in the Amman area. These two quantities represent the total supply of AWSA. Within the entire Amman-Zerqa basin, including Amman, pumpage from the upper aquifer ranges between 27 and 31 Mm^3/year with an additional 9 to 10 Mm^3/year drawn from the lower aquifer.

Transmissivity values are difficult to calculate from available pumping tests because of the heterogeneous nature of the aquifers. Transmissivity values for the upper aquifer range from less than 10^{-4} to greater than 10^{-2} m^2/sec. The higher values are found in wells located in the alluvial deposits. Average values of transmissivity for the upper aquifer are in the range of 10^{-2} to 10^{-3} m^2/sec. For the lower aquifer, pumping test information is more scarce but the results indicate transmissivity values basically are the same as the upper aquifers but with the average being more in the range of 10^{-2} to 10^{-4} m^2/sec.

Well yields also vary considerably throughout the basin. The higher yielding wells in the upper aquifer are located near the Amman-Zerqa flexure. This is especially true where the flexure is close to Wadi Seil, thus allowing additional recharge of the aquifer. Most of the wells of this category are around 200 meters deep. Shallower wells along the Wadi Seil are normally low-yielding. Wells located in areas of alluvial deposits such as the large outcrop area south of Zerqa usually are high producing wells. Yield figures range from zero to slightly in excess of 200 m^3/hr.

Piezometric pressure is essentially equal for the two aquifers in the Amman-Zerqa region. Originally the lower aquifer was artesian but heavy pumping over the last few years has lowered the piezometric level by 50 to 100 meters. The elevation of the water table in the

upper aquifer has experienced minor reductions in recent years. The current rate of withdrawal from the upper aquifer appears to be only slightly more than the available recharge. Fluctuations in the two aquifers occur throughout any given year due to seasonal variations in rainfall and pumping rates.

Several springs produce water within the basin. Most notable of these are Nimra, Sukhna, and Zerqa. Nimra Spring is fed from the lower aquifer through a fault. Discharge from this spring has averaged 65 liters per second (lps), however, since 1970 the flows have decreased considerably. This is undoubtedly a reaction to the declining piezometric pressure in the lower aquifer. Sukhna Spring is fed from a combination of the upper and lower aquifers as they join an outcrop in that vicinity. Average flow from Sukhna Spring is slightly over 200 lps, however, since 1972, the production has decreased considerably to values less than 100 lps. Zerqa Spring is fed from the upper aquifer with an average discharge of slightly over 300 lps up through 1957. This spring has, however, essentially dried up with production being between 20 and 30 lps in the last few years. Other springs in the basin have experienced similar reductions.

Ecology

Flora - Within the study area there are three distinct physiographic regions, each with a somewhat different flora characteristic. The following descriptions of these regions were taken from Report 37 by Dr. Abdul Raheem Talli, "Physiographic Regions of East Jordan as Related to Land Use." The following description delineates these regions within the study area.

According to the report, 1.16 percent of Eastern Jordan belongs to the subhumid, 8.34 percent to the semi-arid, 19.02 percent to the arid, and 71.48 percent to the Saharan bioclimates.

Physiographic Regions - Amman-Zerqa Basin

1. Mediterranean Region - This region comprises the area of northern and southern highlands from the Syrian border to Hagib Station in the south. It includes the important forest areas of Jordan and the bulk of the cultivated lands.

The main forest tree species is Quercus coccifera and Quercus aegilops. Average annual rainfall varies between 250-600 mm. Approximate area about 8,000 sq.km. half of it is steep slopes and forest lands. This region is not yet managed according to land use suitability. Soil and water losses are heavy under the affects of land mis-use.

2. Grassland - This is the northern extension of the brush vegetation region. The average annual rainfall is about 200 mm over most of the region except the area between Amman and Madaba which receives more. This area of higher rainfall is mostly under cultivation. Pon sinaica, Poa bulbosa, and Carex stenophylla form the dominant cover and protect the soil. This region is devoid of shrubs and therefore very few plants of the better perennial grasses exist.

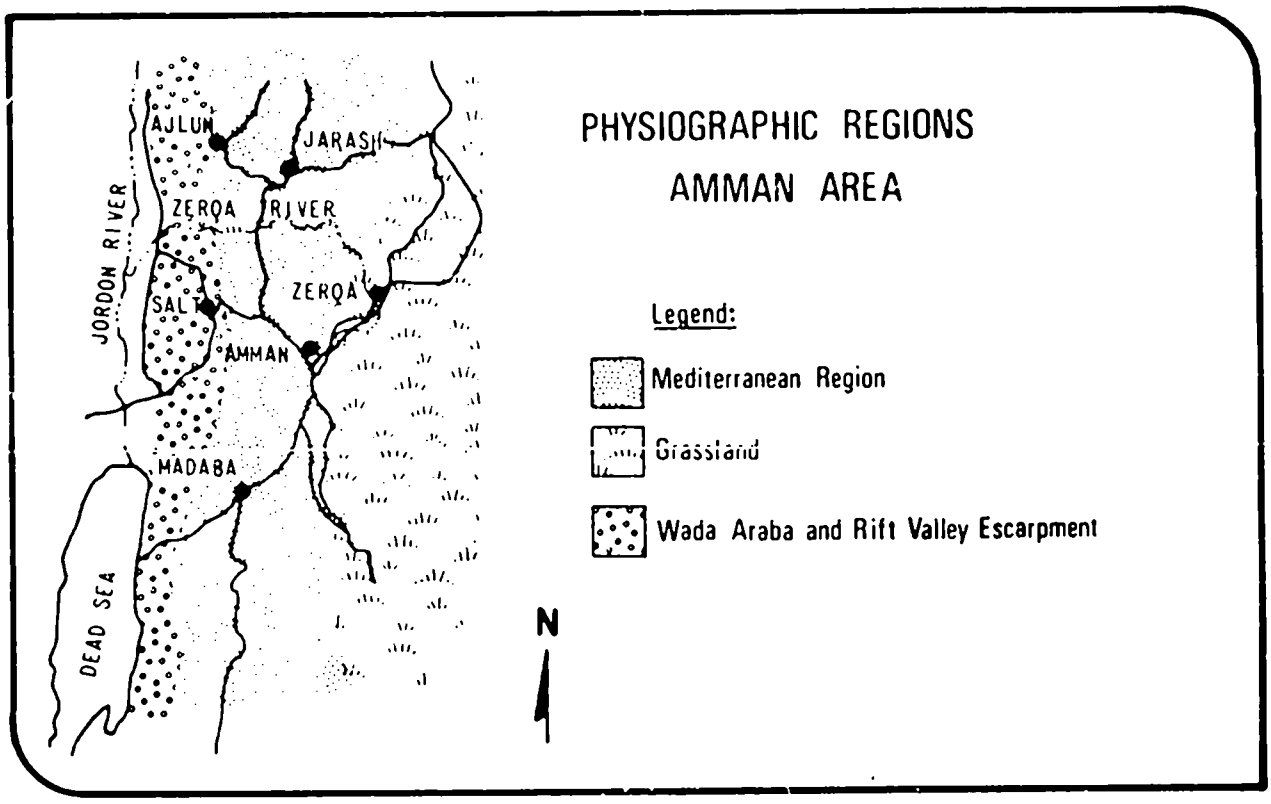
   In recent years vast tracts of area northeast of Amman have been plowed up by tractor either to be planted by grain crops which rarely are harvested and as in the Wadi Dhuleil region or as irrigated farms where artesian water is available (more than 300 sq. km. of range land were plowed in this region). This region has good potential as range land supplemented by community farms and pastures especially where ground water is available. Water spreading systems and check dams on wadis can utilize the runoff water to raise winter crops and forages. Range land should be put under proper management and developed by reseeding, etc.

   Unfortunately, this region is suffering from wind and water erosion since the soil mantle cover has nearly disappeared.

3. Wadi Araba and the Rift Valley Escarpment - This region includes the escarpment area between the western edge of the forest region and the Jordan Valley extending to include Wadi Araba in the south. Wadi Araba includes that portion of the Jordan Valley geological rift from the south of the Dead Sea to the Gulf of Agaha.

   It forms a narrow strip as a transition zone to better rainfall area in the eastern highlands due to climatic conditions imposed by the Jordan Valley rift. Annual rainfall is below 100 mm. Perennial grasses are sparse and erosion is severe and most of the area is devoid of vegetation and soil. The escarpment is characterized by steep dissected mountain slopes dropping rapidly to the west with high elevation gradient.

   This region has low priority for improvement as range land. Limited work can be practiced to improve natural vegetation on side and mouth of wadis through water spreading and utilization of water runoff collected in wadis and streams.



Fauna - The agency involved with the fauna of Jordan is the Royal Society for the Conservation of Nature (RSCN). This agency was contacted to provide information on the fauna in the Zerqa River basin. Two facts were quickly learned. First, specific species known to inhabitate the study area have not been compiled as investigations have not been conducted. Second, there were no endangered species known to inhabitate or frequent the Zerqa River basin.

Without benefit of specific species, the RSCN did discuss the probable make-up of the fauna within the study area. Because man and his activities have so dominated the entire study area for several centuries, the most probable fauna is that which adapt most readily to change. It was indicated this would be the most common and numerous of the species in the country.

Cultural Factors

Archeology - As a Kingdom, Jordan was established in 1946; however, civilizations have resided in this portion of the world for thousands of years. Because of this rich historical culture, the country has taken a positive position towards archeology and, in particular, the identification and possible preservation of major findings.

The country is so old that potential archeological sites are everywhere. An archeological survey conducted in conjunction with development of the King Talal reservoir project revealed 12 previously unidentified sites within the reservoir area.

The potential exists for any area to contain some remnants of past civilizations. Precautions must be taken to identify potential sites and catalog findings to determine historical significance. A recommendation to assure identification is made in the section entitled "Direct Impacts on the Human Environment."

Recreation - Historically, recreation has not been a significant factor in the lives of the people in Jordan. As the country continues its development and the population becomes more affluent and has more time, recreation is gaining in importance and interest. Presently, facilities are limited and scattered, with many areas having no formal facilities available to them.

In the vicinity of the King Talal reservoir there are two major national parks. These facilities, Dibbin National Park and Jarash National Park, encompass several hundred square kilometers and provide limited recreational opportunity to the population in the region.

Ecological Relationships

Quality Changes in Surface Water Resources - The quality of the water in King Talal reservoir will begin to change as the reservoir fills. Pollutants carried by the Zerqa River and retained within the reservoir will alter water quality within the reservoir and, thus, the discharge for downstream irrigation purposes. The characteristic of most importance is the trophic state of the reservoir. The trophic state will be determined by the amount of nutrients available for phytoplankton growth.

The Amman wastewater discharge and high nitrate levels within the stream will provide sufficient nitrogen compounds. The total amount of phosphorus in the stream has not been determined. However, the Amman sewage treatment plant contributes 168 kilograms (kg) of total phosphate (as phosphorus) daily. Although the entire wastewater flow does not always proceed directly to the reservoir, it may be assumed that all of the phosphorus in the discharge will reach the reservoir. Irrigation return flow from agricultural activities and wastewater discharges from the phosphate mining and processing operations near Ruseifa are other potential major contributors of phosphorus to the Zerqa River and King Talal reservoir.

A comparison of nutrient requirements for phytoplankton growth shows phosphorus to be the growth limiting nutrient. Phosphorus loading on the reservoir from the sewage treatment plant discharge alone is calculated to be 50 grams per square meter per year. According to work by Vollenweider, this loading exceeds the loading required to cause this reservoir to become eutrophic by a factor of at least 100. The magnitude of existing phosphorus loading to that required to limit eutrophic conditions indicates that control measures to reduce phosphorus loading on the reservoir would be ineffective. Thus, King Talal reservoir will become very highly eutrophic regardless of whether or not phosphorus removal is instituted at all wastewater discharges.

Although the reservoir will become eutrophic, the extent and type of phytoplankton growth will be influenced by, and perhaps limited by, the availability of micronutrients. The availability of micronutrients such as potassium, iron, molybdenum, and even vitamins has been shown to affect the growth of phytoplankton.

The reservoir will maintain a very high level of phytoplankton growth. The magnitude of growth may cause the hypolimnion to be devoid quantities of organic material (dead phytoplankton) to be deposited on the bottom of the reservoir and may cause the hypolimnion to be devoid of dissolved oxygen. The phytoplankton growth in the upper portions of the reservoir will cause dissolved oxygen levels to fluctuate, being high during the day and near zero at night.

Environmental conditions seem to favor the dominance of bluegreen algal blooms. Some species of bluegreen algae produce extracellular toxins. These toxins have been known to cause death of fish and livestock, including cattle. None of the standard water treatment processes, including chlorination, remove or inactivate the toxin. There is no method for predicting whether or not any of the toxic species of bluegreen algae will become dominant in the reservoir. Unless a toxic species is present in extremely large quantities, toxic effects will not occur.

Problems with algal blooms will occur on a periodic basis. Normally blooms occur during spring and fall. Because of the high eutrophic potential at King Talal reservoir, the spring bloom may maintain high growth rates through the summer.

Quality Changes in Ground Water Resources - Water quality from the two water supply aquifers serving the Amman area has been adequate for general domestic use until recent years. The only treatment required has been chlorination. There have, however, been some historic problems with bacterial pollution in the distribution mains because of deteriorating condition of the mains and intermittent supply to the various sections of the system. In 1976, 11 percent of all bacteriological tests were positive (indicative of a contaminated situation).

Recent studies indicate a deterioration in upper aquifer water quality. Locations of wells with significant water quality deterioration coincide with areas of heavy urban or agricultural development. Few other locations exist for development of wells with high productivity. Chlorides, total dissolved solids, and bacteriological indicators have increased to near or above the maximum permissible limits for drinking water. Nitrate levels in the upper aquifer are typically above 10 ppm. It is not unusual to find nitrate levels above 45 ppm, which is the allowable World Health Organization limit for drinking water.

Specific sources of ground water contamination are found throughout the basin. The upper aquifer outcrops throughout the developed area in the Amman-Zerqa basin. The highly fractured and fissured structure of the upper aquifer makes it highly vulnerable to pollution from external sources. With the exception of a limited amount of sewered area in the

city of Amman, most of the residences within the basin are served by individual cesspools. Seepage from the cesspools is often allowed to penetrate the upper aquifer where it receives very little natural purification. Domestic waste in Amman is very concentrated because of the relatively low water consumption rates. As a result, domestic wastewater releases have had a significant effect on pollution of the upper aquifer.

Industrial developments are located in the valley of the Amman-Zerqa basin primarily in the area between Amman and Zerqa. Little or no treatment of industrial waste is currently provided and the untreated discharges are allowed to enter the Zerqa River directly. Some industries discharge into small tributaries which results in the wastewater penetrating directly into the upper aquifer outcrop prior to mixing with the normal stream flows. Industrial and domestic wastes which reach the main channel flow over and through alluvial deposits which tend to follow the stream bed. These flows have less effect on ground water pollution than the cesspool seepage because of the small recharge area which is directly affected by the stream flow.

Agricultural developments in the basin are responsible for a certain amount of ground water pollution. Most of the intense farming areas are irrigated from water pumped from the Zerqa River or from springs in the area. Excess irrigation flows which are contaminated by agricultural chemicals and fertilizers find their way back into the river directly or indirectly through the alluvial deposits. Stream flows also are contaminated during flood flows which scour the farming areas located in the valley. Ground water in the upper aquifer is then degraded because of recharge from the polluted flood flows in the stream.

Water quality in the lower aquifer has been only slightly affected by pollution from the upper aquifer in recent years. Wells drilled through the upper aquifer have not been properly constructed to seal the connection through the aquiclude. Until recently, the piezometric pressure in the lower aquifer was considerably higher than that of the upper aquifer, causing any leakage to occur in the upward direction

with no significant impact on lower aquifer quality. Since 1976, the piezometric level in the lower aquifer has been essentially equal to that of the upper aquifer because of heavy pumping from the better quality source. Currently, the piezometric levels are still essentially equal, thereby providing more opportunity for flows into the lower aquifer from the more highly polluted upper aquifer. Some evidence of this has been noted. Connections between the two aquifers also occur at faults and a few other geologic features in the basin. Some deterioration in ground water quality also occurs by passage of the water through the limestone formations.

The current means of providing refuse disposal in the basin involves utilization of open dumps. Leachates from the dump enter the outcropping of the upper aquifer and contaminate the ground water supply. This is particularly true of the dump located northeast of Amman. In addition to the normal refuse, liquid sludge from the Amman sewage treatment plant is dumped at this location. The liquid waste readily penetrates the upper aquifer formation. Leachates from the liquid sludge are extremely high in nitrogen compounds, especially nitrate, and TDS. Since the dump is in close proximity to water supply wells used for domestic supply, the potential for contamination of these wells is very high. Continued over an extended period of time, a significant portion of the aquifer may become contaminated. There is no evidence of pollution of surface waters by runoff from the dump.

Population Dynamics - Because of the extremely limited aquatic habitat, neither large populations nor large species of fish are present. The aquatic food chain is limited by the absence of any large predator species. Freshwater fish do not comprise any major portion of human diet.

Within the study area, terrestrial habitats are severely impacted by human activities. Most areas capable of supporting animal life are utilized by domestic animals, such as cattle, sheep, and goats. Only true desert is available solely to wildlife. Terrestrial wildlife populations terminate with small predators and birds of prey.

Disease Vectors - Communicable diseases are generally classified as being transmitted by either human contact, air, food, water, or nonhuman vectors, such as animals and insects. Other than human contact, food and water borne diseases appear to be most important in Jordan. During recent epidemics of enteric diseases both food and water have been identified as modes of transmission. Besides the major epidemics, a number of minor epidemics of gastroenteritis and/or bacterial dysentry occur each year. In addition, amoebic dysentry appears to be endemic.

Epidemics of major enteric diseases such as cholera and typhoid fever are uncommon because the diseases are not normally present in the population. The human waste-water-food relationships which contribute to the transmission of the enteric diseases are at least partially due to the need to utilize all available water because of the semi-arid climate. Contamination of the present water supply source occurs by leaching of pollutants from cesspools and septic tanks into the ground water stra a or directly into temporarily depressurized water mains.

Although the water supply is chlorinated, there are a number of possible sources of contamination in the water supply system. Most of the population still receives its water from tankers. Even though sanitary procedures are required, contamination of water tankers has occurred. The water delivered from tankers is generally stored in a roof tank, occasionally for periods of over one week. Even the water distribution system is subject to contamination during dry periods. At these times, it is not possible to maintain water pressure in all portions of the system. When the water mains are empty, the possibility of infiltration of polluted ground water exists. There does appear to be some correlation between epidemics of gastroenteritis and periods of high water demand, when system depressurization is more common.

Food crops are generally irrigated by and/or washed prior to marketing by potentially polluted water. Ground water used for agricultural purposes may be polluted as described above. Most surface waters are also contaminated by human wastes. This is at least partially due to the inability of the present wastewater collection and treatment systems to fully serve the population.

RELATED ACTIVITIES

Urban Planning

The Amman Governorate presently finds itself in a position not too uncommon to any major urban center in the world. The governorate has experienced phenomenal growth since 1961. At that time, Amman was a community of approximately 250,000 persons; now it is the center of commerce, industry, and government for the entire country, and the governorate population exceeds 1.5 million people. The growth and development of Amman has been so rapid that much development has occurred without benefit of planning or capacity for providing even marginal city services (sewer and water). Now steps are being taken to provide the services and to direct the development.

One of these steps was the creation in 1977 of the Amman Urban Regional Planning Project. The principal products of the project are to be:

1. A Regional Development Plan timed to begin with the National Five Year Plan 1981-1985.
2. A Planned Development System for making intersectional and intergovernmental policy decisions concerning the development of the region and its relation to national development objectives.
3. Jordanian Technical Capacity to conduct planned regional development.

The technical and implementation arm of this project is the Amman Urban Regional Planning Group. Their sphere of influence is a 30 km radius from the center of Amman. Their principal problem is to channel and promote orderly growth and development in an area which until now has been allowed to develop unabated and uncontrolled. The most positive aspect beyond the creation of the project is that the central government is taking a positive position on the necessity of developing the necessary plans and controls.

Urban Development

In addition to the general growth and development in the Amman Governorate, there are at least four major new facilities either under construction or in the final planning stages which, when completed, will provide significant impact or will act as catalysts for additional growth and development. Individually, each will require major services. Collectively, the impact is very significant and all are outlying from the center of Amman.

The first of these new facilities is the Queen Alia International Airport. This facility is presently under construction and upon completion will tend to generate and attract development. The facility is located approximately 25 km south and slightly east of Amman. The evidence of the drawing power of such a facility is illustrated by a major housing project in the final stages of construction located in the vicinity of Na'ur approximately 15 km south and slightly west of Amman. This facility is being built by Alia Airlines for its personnel.

A second major facility presently in the final planning stages is a major industrial park complex to be located between Sahab and El Matalla. This complex is located approximately 15 km south and slightly east of Amman. It is located north and east of Queen Alia International Airport. There is no direct transportation link between this site and the airport.

The third major planned development is located approximately 15 km north and slightly west of Amman in the vicinity of Abu Naseir. This facility, which is in the final planning stages, is for a planned community of approximately 40,000 persons. Originally, this community was intended to be self-sufficient. However, present thinking is that it will probably serve as a "bedroom" community for the Amman area.

The final major planned improvements which will impact regional development are the provisions for increased utilities in the refugee camps at Baqa, Zerqa, and Wahdat and El Hussein in Amman.

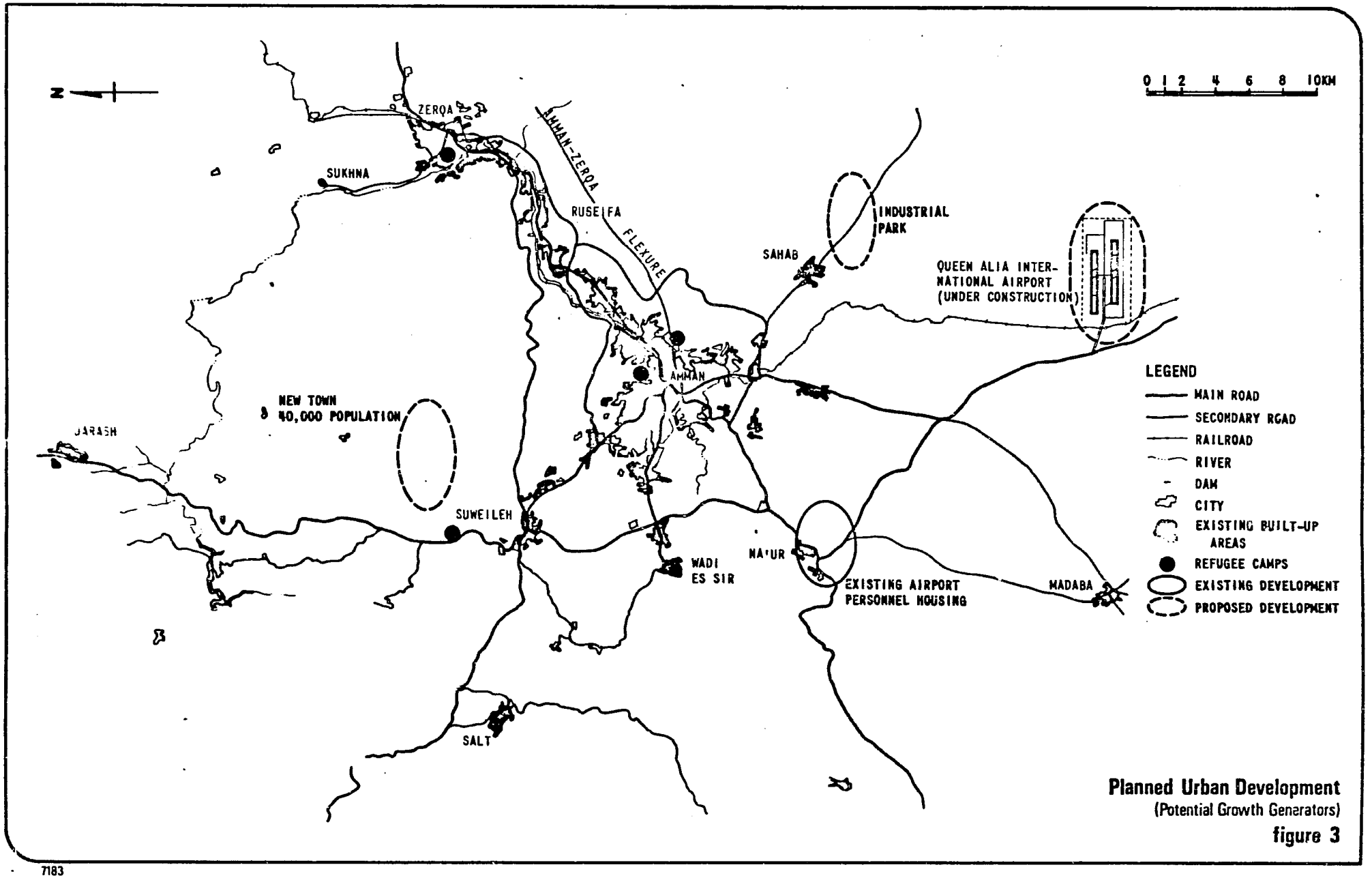
All of the previously discussed planned development will necessitate significant improvements to the basic infrastructure in the Amman

urban area. All of these developments are within the Zerqa River basin, therefore, all will discharge their wastes and draw their water from the same services. Furthermore, all the facilities are outlying, necessitating the further extension of the various service networks. Lastly, all the planned facilities are, in themselves, major enough to either draw or spinoff additional development which must also be served. As mentioned, all of these major developments are either in the final planning stages or under construction. In all probability all of these developments will be various stages of completion prior to the implementation of the land use plans and development controls which are being developed by the Amman Urban Regional Planning Group. Until plan implementation, development in the Amman Governorate will continue in its present uncontrolled nature. This type of growth will continue to create major problems in providing adequate utility service. It is recommended that governmental agencies assist where possible with the efforts and actions of the Amman Urban Regional Planning Project. Any delay in developing their principal products will only further delay developmental guidelines and controls. Figure 3 delineates the general location of these planned developments in relation to the Amman metropolitan area.

Other Sewage Treatment Plants

The communities of Jarash and Zerqa are presently providing for sewage treatment plants. The city of Jarash plans to have construction underway on a secondary wastewater treatment plant very soon. This plant will discharge its effluent to Wadi El Jarash, which is tributary to the Zerqa River a few kilometers upstream of the reservoir. Estimated flows for the study period are presented in Table 6. The effect of this wastewater discharge upon water quality in either the Zerqa River or the reservoir should be minimal. Levels of biodegradable substances are low enough to not affect stream quality, and there are no industries in Jarash which discharge toxic substances.

A secondary wastewater treatment plant has also been proposed for Zerqa. However, the preliminary engineering for this project is going to be revised to include the Ruseifa area, and possibly some of the



Planned Urban Development
(Potential Growth Generators)
figure 3

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TABLE 6

JARASH WASTEWATER FLOW PROJECTIONS

Year	Estimated Population Served	Wastewater Discharge (m^3/day)
1980	11,070	720
1990	15,400	1,155
2000	20,500	1,740

Source: "Sewage Treatment Plant for City of Jarash-Volume 5, Special Conditions of Contract, Functional Specifications," Scan Plan Coordinator A/S and Jouzy and Partners.

industries, in the sewage treatment plant service area. At least several years will elapse before a sewage treatment plant is operational in Zerqa. Because Zerqa is a much larger community, and the Zerqa River is an intermittent stream at this location, the wastewater discharge from this plant will have an effect upon water quality in the Zerqa River for some distance downstream of the discharge. Projected flows for the Zerqa sewage treatment plant without any industries are given in Table 7.

TABLE 7

ZERQA WASTEWATER FLOW PROJECTIONS

Year	Estimated Population Served	Wastewater Discharge (m^3/day)
1980	249,000	11,200
1985	314,000	15,700
1990	397,000	21,800
1995	499,000	29,900
2000	623,000	40,500

Source: "Sewage Treatment Plant for City of Jarash-Volume 5, Special Conditions of Contract, Functional Specifications," Scan Plan Coordinator A/S and Jouzy and Partners.

Effluent from the proposed Zerqa treatment plant will increase the flow in the Zerqa River by the amount of wastewater treated. There will also be net increases in loadings of oxygen demanding substances, nitrogen, and phosphorus on the stream. Although presently some small amounts of raw sewage are discharged to the stream and leachates from cesspools carry some nitrogen and phosphorus to the stream, the amounts currently being discharged to the Zerqa River are much smaller than those which will be discharged by the sewage treatment plant.

Population and Growth Characteristics

Sources and Projections - The availability of significant historical population data is extremely limited. The country had a census in 1961. Since that time, several special surveys or partial census studies have been made. The problem, however, is that the data are not comparable as study areas are different, etc.

Because the data are lacking, it has been necessary for contracted consultants to develop some projection for engineering purposes. Presently, there are two main projections for the Amman Governorate which are being used for basic facility planning purposes.

The first is the projection of VBB, a Swedish firm which is doing much of the utilities planning for Amman. This projection calls for a moderately declining annual rate of population growth from 5 percent in 1975 to 3 percent by the year 2005.

The second major population projection for the Amman Governorate is from the "National Water Master Plan." This projection was developed by the German consulting firm of Agrar-und Hydrotechnic GMBH and various local Jordanian ministries. This projection calls for a higher annual growth rate throughout the period to 2005.

The details for both these projections will be shown in the next section. In discussing both sets of projections with the Amman Urban Regional Planning Group (AURPG), they felt neither were very responsive or totally comprehensive. It was the opinion of AURPG that both projections were based on past trends and were not responsive to what was

believed to be major limiting factors. These factors are primarily water availability and transportation systems. AURPG is currently working on plans for the Amman Governorate. A part of this work will be development of population estimates using physical factors as a part of the limiting criteria for population projections.

Population Projections-VBB - The projections from VBB indicated a declining annual rate of population increase from 5 percent in 1975 to 3 percent in 2005. Specific numbers were available for the city of Amman; however, governorate population had to be derived. The following table shows the estimated population.

TABLE 8

POPULATION PROJECTION COMPARISONS
AMMAN, AMMAN GOVERNORATE
1975-2005

Year	Amman[1]	Amman Governate Projection A[1]	Amman Governate Projection B[1]
1975	626	1,300	1,242
1980	780	1,620	1,483
1985	950	1,973	1,788
1990	1,129	2,345	2,087
1995	1,320	2,742	2,573
2000	1,550	3,220	3,003
2005	1,800	3,739	3,410

[1] In thousands.

Source: VBB 1976 Feasibility Report and Stanley Consultants, Inc.

The Amman Governorate Projection A was developed maintaining the relationship of the city of Amman to the governorate. In 1975, the city of Amman contained 48 percent of the total population of the governorate.

Projection B for the governorate utilizes the total water demand and per capita daily consumption projections to derive the population. The

1976 Feasibility Study by VBB developed total water demand for Amman and the remainder of the governorate. Also included was a projection for per capita daily consumption from 1975 through 2005. These estimates were combined to derive the population for the remainder of the governorate.

Population Projections-National Water Master Plan - Projections from this document provided annual growth rates for the cities of Amman and Zerqa through the year 2005. To arrive at a total population for the governorate, an annual growth rate had to be assumed for the remaining portion of the governorate. Also for purposes of comparison, the 1975 populations for Amman, Zerqa, and the governorate were taken from VBB estimates. The following table details the population projections.

TABLE 9

POPULATION PROJECTIONS
AMMAN, ZERQA, AMMAN GOVERNORATE
1975-2005

Year	Amman[1]	Zerqa[1]	Remainder of Governate[1]	Total[1]
1975	626	260	414	1,300
1980	799	316	492	1,607
1985	1,020	385	584	1,989
1990	1,271	457	700	2,428
1995	1,584	543	840	2,967
2000	1,973	645	1,007	3,625
2005	2,459	766	1,208	4,433

[1] In thousands.

Source: National Water Master Plan and Stanley Consultants, Inc.

To arrive at the above projections, the master plan indicated annual growth rates to 1985 of 5.0 and 4.0 percent for Amman and Zerqa, respectively. From 1985 to 2005, the annual growth rates for Amman and Zerqa were 4.5 and 3.4 percent, respectively. The annual rates of 3.5 percent to

1985 and 3.7 percent annually from 1985 to 2005 for the remainder of the governorate were developed by Stanley Consultants, Inc.

Projection Comparison - Table 10 shows the comparisons between the VBB projections and those from the National Water Master Plan.

TABLE 10

POPULATION PROJECTIONS - AMMAN, AMMAN GOVERNORATE
1975-2005

	Amman[1]		Amman Governorate[1]		
Year	VBB	Master Plan	VBB Projection A	VBB Projection B	Master Plan
1975	626	626	1,300	1,242	1,300
1980	780	799	1,620	1,483	1,607
1985	950	1,020	1,973	1,788	1,989
1990	1,129	1,271	2,345	2,087	2,428
1995	1,320	1,584	2,742	2,573	2,967
2000	1,550	1,973	3,220	3,003	3,625
2005	1,800	2,459	3,739	3,410	4,433

[1] In thousands.

Source: Stanley Consultants, Inc.

As shown in the table, the projections from the National Water Master Plan are much higher than those used by VBB for engineering of the basic utilities. The projections were discussed with representatives from the AURPG to ascertain their opinion as to validity. It was the opinion of AURPG that based on the several practical surveys and studies conducted for various reasons since 1971, the Amman region (35 km radius) has been growing at an annual rate in excess of 5.5 percent. This would mean that the entire Amman Governorate would probably approach an annual growth rate of approximately 5 percent. For this reason, plus their familiarity with the governorate, AURPG tends to support population

projections in line with those presented in the National Water Master Plan. As mentioned previously, AURPG is developing projections for their planning jurisdiction taking a variety of physical limiting criteria into consideration. When completed in 1980 or 1981, these projections may provide greater insight as to capabilities of the area to properly support various populations.

From the standpoint of this environmental assessment, it is assumed that the two population projections represent an operating range. Within the next few years, the city of Amman and its immediate environs will probably exceed the growth projected by VBB. However, if the annual rates are maintained as projected in the National Water Master Plan, economic (jobs) and physical facilities will have to be developed to support that level of growth. This degree of development is not readily apparent now.

PROJECT RELATIONSHIP TO CURRENT AND PROPOSED PLANS, POLICIES, AND CONTROLS

Land Use Plans, Policies, and Controls

The project, as described previously, will ultimately be totally within the planning jurisdiction of the Amman Urban Regional Planning Group (AURPG). Prior to the formation of this group in 1977, the project would have involved the city of Amman and the Department of Municipalities and Rural Affairs. These agencies were contacted to determine any conflicts between the proposed improvement and any on-going policies or controls. It was quickly evident that there were no direct conflicts, and, generally, the regulations which were on record were not being enforced. As located, there are no elements of the water supply project, intake, pretreatment plant, treatment plant, pipeline, or terminal storage facilities which will conflict or create incompatible land use relationships.

Resource Use Plans, Policies, and Controls

The only direct relationship this project may have with established resource plans is the current irrigation efforts in the Jordan Valley. Presently, the Jordan Valley Authority (JVA) is concluding the first of a three-stage program ending in the year 2000, to increase irrigation potentials for crop production in the Jordan Valley. The development and construction of the King Talal Dam were under the auspices of the JVA for the sole purpose of providing irrigation water to the Jordan Valley.

In discussions with JVA, it was learned that the reservoir has a capacity of 57 Mm^3. A breakdown of that capacity is: 9 Mm^3 dead storage and 48 Mm^3 for irrigation. Provisions were made to raise the dam 10 meters after 10 years to compensate for sediment in the reservoir. Now, however, the breakdown of the total reservoir capacity has been changed. The following is the new allocation: 9 Mm^3 dead storage, 10 Mm^3/year water supply to Amman, 2 Mm^3/year for rural villages between the reservoir and Amman, and 36 Mm^3/year for irrigation.

It was learned from the Department of Agriculture and JVA that the 12 Mm^3/year of water allocated to Amman and the existing villages will have some impact on agricultural production. Both the Department of Agriculture and JVA indicated that the 12 Mm^3/year could irrigate approximately 12,000 donums (1,200 hectares) of land annually. Their estimates indicate that, if irrigated, this area could return annually 100 JD per donum. This estimate represents a potential loss of agricultural production equal to 1.2 million JD annually by diverting the 12 Mm^3/year of water for domestic use to the Amman area. The counter argument is that the 12 Mm^3/year of water supplied to Amman and existing rural villages will be used to enhance the quality of life for many residents who work at a variety of jobs which make a variety of products which in all probability would exceed the monetary value of the agricultural products. No one has attempted to quantify the monetary value of the water supply for domestic use.

What must be remembered is that the principal purpose of the reservoir is for irrigation; to impinge significantly on this purpose could have lasting effects on the agricultural potentials of the Jordan Valley. This trade-off must be considered each time requests arise for additional water supply regardless of the potential user.

PROJECT RELATED IMPACTS

As described in preceding sections, this project will have impacts on many sectors of the human environment. This section will identify and discuss these impacts and their effects.

Air

Air Quality - There will be some short-term effects on the air quality in the vicinity of the projects during construction. At any given time, there may be significant increases in airborne dust and particles. This will continue to occur throughout the construction of all the facilities and until such time as the disturbed areas have been revegetated. After revegetation, the air quality in the vicinity of the projects should return to preconstruction conditions.

The area affected by the periodic deterioration of air quality will be in the immediate vicinity of the construction sites. It is felt that residents beyond one kilometer will experience no noticeable changes in air quality. As most of the major facilities are situated in undeveloped areas, the impact on the population will be limited. This condition is different at the Amman end of the pipeline. More persons will potentially be affected, and efforts, as practical, should be taken to reduce the quantities of dust during construction. In addition, revegetation of the disrupted areas should be done as quickly as possible.

Weather Modifications - No impacts.

Fish and Wildlife

Discussion with the Royal Society for the Conservation of Nature (RSCN) provided guidance as to the degree this project will impact the fish in the Zerqa River and the wildlife in the vicinity of the water supply facilities.

Information on fish, populations, species, etc., was not available from RSCN and to their knowledge no formal fish census has been conducted in the Zerqa River. Regardless of species, the anticipated impacts on the existing fish population are twofold. First, as water supply is increased to Amman and as a larger percentage of the urban population is connected to the sewer system, flows will increase in the Zerqa River. The opportunity does exist for this increased flow to be contaminated as much of the flow

will be effluent from the treatment plants at Amman, Zerqa, and Jarash. Therefore, water quality could impact any fish population in the river. The potential impact on existing fish populations in the Zerqa River are not considered to be significant enough to warrant alterations to the projects under consideration by this assessment.

The second impact, although not related to the projects under consideration, is the changing nature of the river at King Talal reservoir. It is anticipated the fish in the Zerqa River is a population which requires flowing water to properly breed and multiply. Though most of the fish population in the river could live in the reservoir, in all probability they would not be able to reproduce, as these species require the riffle action of flowing water. The reservoir does not contain this type of habitat. Through stocking and proper management, fish species requiring the habitat provided by the reservoir could be introduced.

The impact on the wildlife is believed to be less than the impact on fish. Again, the RSCN was contacted to provide information as to probable species expected in the area of the water supply improvements. No specific information was available. A general description of probable wildlife to be found was given in earlier sections of this report. It was learned that in all probability no rare or endangered species are known to be in the general area of the construction.

The proposed project will require approximately 17 hectares of land for major facilities. These specific areas will be developed to such a degree that it will be unusable as wildlife habitat. This will require any wildlife currently in this area to relocate. Due to the remote nature of this area and the availability of adjacent similar habitat, this relocation can occur naturally with no significant impacts or effects on the local wildlife populations.

The 25 hectares of land utilized for the pipeline will be disrupted, but upon completion of the installation will be returned to a near-natural state. Any wildlife currently using this area will be temporarily dislocated into adjacent habitat. However, after revegetation the land utilized for the pipeline could again serve as wildlife habitat.

Water

Drinking Water Quality - The basic water quality characteristics of King Talal reservoir have been described previously. The expected highly eutrophic state of the reservoir may have important impacts upon finished water quality and operation and maintenance of the water treatment plant.

Heavy algal blooms will cause difficulties with operation of some treatment processes. The large increase in solids represented by the algal cells will require heavier prechlorination and greater amounts of chemical coagulants to effectively settle the cells. Even with effective sedimentation, it has been found that heavy algal growths in raw water cause far shorter filter runs than normal. This will mean an increase in the amount of backwash water required. Many species of algae contribute taste and odors to water supplies. To overcome this problem, it will be necessary to feed activated carbon, for which provision has been made in the treatment facility.

Because of the possibility of obtaining a very highly eutrophic state within the reservoir, there is a probability that strains of bluegreen algae may develop which excrete an exotoxin. The nature of the exotoxin varies from species to species, but they have been identified as being the probable cause of contact dermatitis in humans and poisoning of livestock, fish, and birds. There have been documented cases of algal poisonings in the Middle East. There have been no cases of human mortality associated with ingestion of water containing bluegreen algae. There are unsubstantiated reports of gastroenteritis epidemics associated with heavy algal blooms in water supplies. Normal water treatment processes have no effect on the nature of the exotoxin.

It must be emphasized that the occurrence of an algal exotoxin in the raw water is only a remote, but real, possibility. While it can be shown that the reservoir will be highly eutrophic, and that there is a high probability that bluegreen algae will be a dominant species during some of the year, it is unknown whether any specific exotoxin producing bluegreen algae species will dominate as would be required to have an impact upon the quality of the water supply.

Changes in Water Quality - The water supply project and extension of the sewage collection system will both contribute to higher flows through the sewage treatment plant. Projected sewage treatment plant flows as presented in Table 11 are based upon the same criteria as used by VBB with the following exceptions:

1. The connected population will be 95 percent of the total population in year 2000.
2. The population projections are those of Table 9.
3. Sewage flow from the camps increases from 25 lpcd in 1980 to 50 lpcd in 2000.

TABLE 11

PROJECTED SEWAGE FLOWS - AMMAN

Year	Connected Population	Percent of Total Population	Sewage Flow (Mm^3/yr)	Percent of Water Demand	Water Demand (Mm^3/yr)
1980	439,000	55	8.0	37	21.9
1985	663,000	65	15.2	51	29.8
1990	953,000	75	26.4	60	44.1
1995	1,346,000	85	44.7	70	63.6
2000	1,874,000	95	71.1	82	86.4

Source: Stanley Consultants, Inc.

Although a proportionally larger segment of the population is projected to be connected to the sewer system, the impact of cesspools upon ground water quality will remain significant. At present, all sewage except 4.3 Mm^3/yr is discharged to cesspools. Since the amount of unaccounted-for water is high, the best estimate of sewage discharged to cesspools is 6 to 9 Mm^3/yr. If 80 percent of the water demand in Table 11 becomes sewage, then the amount of sewage discharged to cesspools will remain in the same range of flow as present until after the year 1995. If the population connected to the sewer system does not increase as projected, the impact upon ground water quality will be more severe.

Immediately downstream of the sewage treatment plant, the volume of flow in the Zerqa River will be increased. During dry weather, the flow will continue for a greater distance before disappearing into the upper aquifer. When flows from both the sewage treatment plants at Amman and Zerqa total approximately 46,000 m^3/day, there will be continuous dry season stream flow from the Ain Ghazal sewage treatment plant to King Talal reservoir. This should occur between 1985 and 1990. At that time, self-purification of the stream will become an important factor in stream water quality and possibly in reservoir water quality. During the dry season, sewage treatment plant discharge will comprise a larger proportion of the stream flow and is more likely to reach the reservoir during this season.

A preliminary analysis of the self-purification capabilities of the Zerqa River during the dry season was performed using available stream data and assuming that secondary treatment would be provided for Amman, Ruseifa, and Zerqa.

Approximate water quality characteristics of the Zerqa River just upstream of the King Talal reservoir as given by this analysis are:

1. The oxygen demanding substances, BOD and NH_3, have been oxidized during the time of travel to the reservoir.
2. The original bacterial population discharged in the sewage treatment plant effluents has died off.
3. The ammonia originally present in the sewage treatment plant discharges (110 mg/l as nitrogen) has been oxidized to nitrate. The total nitrate concentration in the Zerqa River will be approximately 50 mg/l, as compared to the present concentration of 6 mg/l.

The Zerqa River between Ain Ghazal and Sukhna will suffer decreased water quality. In this portion of the stream, dry season stream flow will consist almost entirely of wastewater discharges. Water quality in this area will be characterized by low or absent dissolved oxygen concentrations, odors, and possibly bacterial contamination. Conditions will become worse if the anticipated secondary treatment is not provided.

Undesirable conditions presently exist during the dry season but for a shorter distance due to infiltration of the total flow into the upper aquifer. Only advanced wastewater treatment will improve water quality in the Ain Ghazal-Sukhna reach. Water quality may tend to limit the present practice of withdrawing water for irrigation, livestock watering, and domestic use from the stream in this area.

During the wet season, stream water quality will be improved along the entire stream from Ain Ghazal to King Talal reservoir due to increased dilution.

Solid Wastes

Additional solid wastes will be generated both by the water treatment plant and the sewage treatment plant. Both will have adverse impacts on the human environment.

Solids generated by the water treatment processes will be a new type of solid waste for the area. Waste sludges will be generated by sedimentation basins and filter backwash water. Filter backwash water is to be settled with the overflow returning to the water treatment plant and the underflow to be disposed of. Currently, the plans for the project do not show the means of disposal of the sludges. The Amman Water and Sewerage Authority (AWSA) has verbally indicated that the method of disposal will be discharge to the downstream side of King Talal Dam. This concept is not economically or technically feasible because of the long distance and rugged terrain. Additionally, the sludges will contain inorganic chemical solids, inert solids from the raw water, and a small amount of biodegradable material. The major effect of direct discharge of this sludge would be to deposit heavy amounts of these solids immediately downstream of the area where they are discharged. As the stream flows fluctuate, these materials would be washed further and further downstream. Since almost all of the flow downstream of King Talal Dam is to be utilized for irrigation, the presence of these solids could have an effect upon the use of the water for irrigation purposes. The solids, when applied with irrigation water, would modify the texture of the soil and affect soil pH.

Because of the expansion of sewage collection system, there will be an increase in the total amount of solids generated at the sewage treatment plant. The sludge dewatering facilities proposed will reduce the total volume of sludge that must be handled. The dewatered sludge will be more suitable for disposal in the municipal dump than the liquid sludge now being handled. It has been proposed that the dewatered sludge be utilized as a fertilizer and/or soil conditioner on agricultural land. Sludge disposed of in this manner must be applied on lands, and at such times, as to prevent erosion of this material to the streams. Disposal of sludge on agricultural lands would greatly decrease the amount of nitrate leached to the upper aquifer, as compared to the present method of sludge disposal.

Noise

As with air quality, noise will also be a factor. However, this will also be primarily during the construction of the facilities and will be limited to the usual working hours. Upon completion of the project, the treatment facilities and pumping station will create a certain amount of continuous noise. This impact is felt to be negligible as these facilities are all situated in areas with little or no resident populations.

Energy Supply and Natural Resource Development

Electrical Energy Transmission - As a part of the water supply project, it will be necessary to provide electrical supply to the pretreatment plant, treatment plant, and pump stations.

The responsibility for the line was initially with the Jordan Electrical Authority. However, they are responsible for only the selling of bulk power. The installation and distribution of the power is the responsibility of the Jordan Electrical Power Company (JEPCO). Representatives of JEPCO, their consultant, Kennedy and Donkin, were contacted to determine specifics on the electrical supply facilities.

The electrical supply will come from Amman to the various facilities, generally following the pipeline routing. The electrical supply will be 33 kV double circuit line carried on 14 m lattice steel structures. There

will be electrical substations at each of the water facilities to step the current down to workable voltage. The reason for 33 kV is to provide power in excess of water facility demands in order that surplus power could be available to electrify the smaller villages along the transmission route from Amman. It was indicated by JEPCO and confirmed by the Jordan Electrical Authority that provisions had been made in their current program for generating the 33 kV to supply the proposed water facilities.

The impacts of the electrical supply line are expected to be minimal. Visually, the line will be noticeable, but the height of 14 m should help as this is not extremely tall. The lattice steel structure is not extremely noticeable. Since much of the route is rural undeveloped area, the line should not pose a major visual impact. Routing of the line parallel to the pipeline is desirable because only one corridor is needed, thereby limiting total disruption of the area.

The major concern and potential impact will occur as the line passes through the governmental reforested area in the vicinity of the King Talal reservoir. It will be necessary to remove the trees for a corridor width of 90 m to assure no conflicts with the transmission line. Removal of the trees will necessitate the planting of appropriate shrubs and grasses to reduce soil erosion. It is estimated that the pipeline and transmission line will pass through 5 to 7 km of governmental reforested lands.

Land Resource Development - The pipeline, transmission line, and water supply facilities will disrupt either totally or partially 42 hectares of land. Of this total, 17 hectares will be utilized for structures and grounds for the pump stations, treatment, and water storage facilities. The current use of this land is estimated to be evenly divided between grazing and agricultural uses. This project will remove these 17 hectares from present uses and convert them to more intense use.

The 25 hectares used for the pipeline and power line corridor will also impact current uses. Three to four hectares are situated in urban areas and will not adversely impact adjoining property. This area generally follows existing streets and roads and will be located in the right-of-way of these facilities.

The pipeline and power line will pass through 5 to 7 km of governmental reforested lands. This will necessitate clearance of 45 to 65 hectares of land for proper clearances. If this area is properly planted with shrubs and grasses to control erosion, the impact will be negligible.

Seven to eight hectares of grazing land will be affected by the pipeline corridor. Upon completion of the facility and revegetation, this area could once again be used for grazing.

Lastly, the pipeline will remove an estimated seven to nine hectares of land from agricultural production. This land will not be able to be used for this after completion of the facilities. However, the land could be utilized for grazing after revegetation.

With the exception of the loss of 15 to 16 hectares of agricultural and grazing land, the impacts to renewable resources are felt to be minimal.

Land Use and Management

Land Use Changes - The proposed project will create the changing of present land use patterns in the vicinity of the specific improvements. In all cases, this change will be from rural or nonintensive uses to more intense land utilization. It is felt that these changes can be accommodated without any undue impacts. The type of development which is proposed is such that it could be accommodated in rural areas without significantly altering the rural nature of the area. Furthermore, the type of proposed development is such that it should not generate any additional "spin-off" development to impinge further on the rural nature of the area.

Public Land Management - Presently, the government owns or has control of the lands around the reservoir and the sites for the intake/pretreatment plant, treatment plant, pumping stations, and the terminal reservoirs. In addition, they have or will have control of the 10 m wide right-of-way for the length of the pipeline route. It is advantageous that this land is under public control especially as it relates to future potential use, particularly at the King Talal reservoir.

Protection of Environmentally Critical Areas - The primary concern is for proper treatment and precautions during construction of the areas with excessive slopes. The locations of all major structures are such that with

nominal construction precautions and prompt revegetation upon completion, erosion will not pose a significant problem. This situation is not true for construction of the pipeline. The pipeline route, though well situated, still must travel through areas with slopes in excess of 50 percent. Because of the nature of the soils, erosion will be severe if construction precautions are not implemented. Proper trench backfilling and compaction is critical as well as construction of dikes and water retention structures to control the flow of the runoff down the route of the pipeline. If this is not done, erosion will soon expose the pipe and will cause massive erosion problems. Upon completion of the construction, it is imperative that the disturbed areas be revegetated with appropriate shrubs and grasses as quickly as possible.

Redevelopment and Construction in Built-up Areas - The final 3 to 4 km of the pipeline will pass through the developing portions of Amman. As planned, this construction will occur primarily within the rights-of-way to several streets. During construction there will be times of inconvenience and disruption to local traffic. This disruption should occur primarily during the working day, and the construction site should be left in a safe condition during nonworking hours. Upon completion of the pipeline, the disrupted surfaces should be replaced, limiting the impacts to short-term duration.

Neighborhood Character and Continuity - See the "Social Soundness Analysis of the Amman Water and Sewerage Systems" by Jarir S. Dajani which was done in conjunction with this environmental assessment.

Impacts on Low-Income Populations - See the report referenced above.

Historic, Architectural, and Archaeological Preservation - Discussions with the Department of Antiquities revealed that there are no known sites within the areas to be utilized for the construction of facilities for this project. It was stated that the areas around El Rumman and Tab Qira have been established sites for civilization for some millennia and that these areas should be investigated.

It is a recommendation of this assessment that an archaeological survey be undertaken in all associated areas where construction will take place. The basis for this recommendation is from a similar such survey done in the

area of the King Talal reservoir. This survey found 12 previously unknown archaeological sites. Similar sites will probably be found at construction sites for the proposed project. The opportunity should be given for proper surveying, identification, cataloging, and excavation as required of these areas prior to the initiation of project construction.

Outdoor Recreation - There were no outdoor recreation facilities considered as a part of this project nor were there any programmed in the development of the King Talal reservoir. Likewise, the construction of this project does not impact any existing recreation facilities.

In discussions with the RSCN, it was learned that the provision of recreation facilities is a reasonably new concept. This is closely related to the development of the country. It is the desire of RSCN that in the future provisions be made for recreation at King Talal reservoir. The facilities which are desired are only now being conceptualized. It is important that the necessary land be set aside for future recreation development. For this reason, governmental control of all lands adjacent to the reservoir is important to assure that future recreational opportunity may be available to the public.

Secondary Effects

Increased stream flows between Ain Ghazal and Sukhna will undoubtedly result in greater utilization of surface water for irrigation purposes. This can have beneficial effects by allowing the existing land to be more productive and bringing additional land into agricultural production.

Withdrawals for irrigation upstream of King Talal reservoir would have a detrimental effect upon the overall water supply scheme. Generally, less than 20 percent of the water withdrawn for irrigation is returned directly to this stream. Use of a substantial portion of the stream flow for irrigation would mean that there would be a correspondingly lesser amount returned to King Talal reservoir to be available for water supply recycling.

The public health aspects of using treated wastewater for agricultural purposes should be carefully considered. Present practices in the area are to utilize stream flow for irrigation and cleaning of vegetable crops

prior to marketing. This procedure results in microbial contamination of the crops and has been a factor in enteric disease epidemics. Modifications of irrigation practices and/or restrictions on the amount of water withdrawn may be required to deal with the health-related aspects of this practice.

ALTERNATIVES TO THE PROPOSED ACTION

The proposed projects, their planned extension in the future, and any alternatives to these projects have been evaluated while taking into consideration overall water quality and quantity needs within the study area. Developing adequate quantities of water for municipal use and protecting the quality of the water supply are major considerations.

Because of the immediate need for additional water supply for the city of Amman, the proposed water supply project utilizes the only readily available source of water. Despite some environmental risks, a suitable high quality finished water can be obtained. In the following section consideration will be given to where additional water supply should originate. Although decisions on this could affect the sizing of some components of the King Talal supply project, no modifications of these components is recommended. A reasonable chance exists that these components can be utilized to their full capacity in the future, and the financial investment involved is not great.

King Talal reservoir and ground water sources in the basin are not capable of meeting all domestic needs within the study area. Projected water demands for Amman and the Amman Governorate are given in Table 12.

TABLE 12

DOMESTIC WATER DEMANDS

Year	Per Capita (lpcd)	Population, Amman (1,000's)	Water Demand (Mm^3/yr)	Population, Amman Governorate[1] (1,000's)	Water Demand (Mm^3/yr)
1980	75	799	21.9	1,607	44.0
1985	80	1,020	29.8	1,989	58.1
1990	95	1,271	44.1	2,428	84.2
1995	110	1,584	63.6	2,967	119.1
2000	120	1,973	86.4	3,625	158.8

[1]For the total governorate including Amman.

Source: Stanley Consultants, Inc.

When examining Table 12, an important consideration is the per capita water use. It is very probable that the actual per capita use would be 120 lpcd now, if sufficient water were available. Per capita usage is now, and will be for some time, restricted by the amount of available water.

Since extensive recycling through King Talal reservoir may not be possible from a hydrological standpoint, alternatives to the proposed future water supply plan were considered because of a low return ratio through the sewage treatment plant and because of water quality considerations.

Proposed Future Water Supply

Consultants for AWSA (VBB) have recommended that initially 20 Mm^3/yr be obtained from King Talal reservoir for Amman. This has since been modified to 10 Mm^3/yr plus 2 Mm^3/yr to the rural villages. In 1985, an additional 12 Mm^3/yr would be obtained. In 1991, a reservoir on upper Wadi Wala would supply an additional 12 Mm^3/yr. In 1995 and 2001, additional supplies of 20 and 12 Mm^3/yr would be obtained from King Talal reservoir. Total water supplied by the year 2000 would be approximately 91 Mm^3/yr. This quantity is insufficient to meet the anticipated demand.

Environmentally, this proposal places a severe strain upon the natural purification processes necessary to provide good water quality in King Talal reservoir. The extent of recycling required to provide approximately 64 Mm^3/yr causes very substantial increases in the level of nitrates in the water.

Alternatives of a Significantly Different Nature

Basically, water is supplied to the entire study area by the Zerqa River and ground water resources. Both of these sources are limited in their capability. Recycling of water through the Zerqa River and King Talal reservoir for supply to Amman and other communities will increase the amount of water available, but is also limited by the changes in water quality caused by recycling. In addition, the recycling through the natural system involves water losses to agricultural uses and to the ground water table in areas where the water cannot be recovered to be used again.

One of the major environmental considerations is the quality of water which will be available from King Talal reservoir under recycling conditions. Recycling is not a significant factor for the initial water supply project from King Talal reservoir. Taking a second increment from the reservoir only 5 years after the first stage withdrawals does not allow sufficient time for environmental conditions within the natural system to stabilize.

Previously Considered Alternative Water Resources - A total of 10 alternative water supply projects was investigated by the VBB "Water Resources Study for Amman Water Supply," September, 1977. The possibility for utilizing sewage treatment plant effluent from Amman for irrigation, ground water recharge, and direct recycling was addressed in that report.

Utilization of sewage treatment plant effluent for irrigation in the Zerqa River basin could potentially reduce the amount of ground water which is currently extracted for irrigation purposes. Studies indicate that sewage treatment effluent characteristics would be marginally acceptable for most crops currently grown in the area. Since a major portion of the irrigation usage is consumptive, any withdrawals of water from the Zerqa River in the upper reaches would represent a direct reduction in the quantity of water available for irrigation in the Jordan River Valley from King Talal reservoir. The quality of water available from King Talal reservoir is expected to be better for irrigation than the sewage treatment plant effluent because of the dilution from ground water and flood flows.

Use of sewage treatment plant effluent for ground water recharge in the Amman-Zerqa area was not recommended. A high degree of treatment of the effluent would be required before usage in a recharge system. Otherwise the aquifer would soon become plugged and contaminated. Very little natural purification of the water can be accomplished within the aquifer system because of the fractured limestone formation. There is also the problem of potential additional deterioration of the upper aquifer water quality. The buildup of dissolved solids and nitrates which are not removed in the conventional sewage treatment process would be much more of a problem in the recharge system than with the King Talal diversion plan because of flood water dilution.

Direct recycling of sewage treatment plant effluent with additional tertiary treatment was considered as a last resort by VBB. The possibilities of contaminated water supply, cost of treatment, and public acceptance were considered too great to make this a viable plan.

In addition to the King Talal diversion plan, VBB studied nine other outside sources. Of these, the Upper Wala Dam project holds the most promise. This project would involve constructing a dam across the Upper Wala River system, about 40 km south of Amman. This potential site was investigated initially, in 1965 by Sir M. MacDonald and Partners, as a source for irrigation water. Potential supply from this source has been estimated at 12 Mm^3/yr, which could be transported to Amman as a municipal water supply. Consideration should be given to the possibility of locating the dam further downstream, thus including a much larger drainage area and substantially increasing the potential yield from this reservoir. The drainage basin of Wadi Wala is essentially undeveloped with few sources of pollution. The only competing water use in the vicinity is small agricultural developments with minimal irrigation at the present time. Detailed engineering studies should be started immediately to investigate the full potential of this surface water basin as a potential water supply for the city of Amman. It is anticipated that the water quality from Wadi Wala would be very good and would act to limit the buildup of dissolved solids and nitrates in the total Amman water supply system. This project is not recommended as an alternative to the proposed project because nearly 8 to 10 years would be required to develop the surface water supply from this source.

One of the potential sources studied by VBB which is designated as the Wadi Sir Dam was proposed at a location about 10 km west of Amman. It would collect both surface water runoff and base flow discharge from springs in the Wadi Sir area. The spring flow, which amounts to about 2 Mm^3/yr, is currently utilized by the cities of Wadi Sir and Amman. The additional 2 to 3 Mm^3/yr which would be available from this dam could be allocated for Amman and/or Wadi Sir if development occurs in that area. Consideration should also be given to locating the dam

further downstream allowing more additional drainage area. Because of the proximity of this Jordan River tributary to Amman, ultimate development of its supply should be considered. Initially the Wadi Sir Dam project was rejected because of its small net quantity of water to be developed. It could play a part in supplying water to a region which will have to utilize every potential source to maintain a sufficient water supply.

Three other sources, studied by VBB which deserve additional attention as potential ground water supplies for the Amman area, are: Qastal located about 25 km south of Amman, Baqaa located about 15 km northwest of Amman, and Swagha situated nearly 75 km south of Amman. These areas contain a ground water basin which has been identified as having yields of 4, 3.5, and 8.7 Mm^3/yr, respectively. Some of these supplies are currently committed for irrigation use. Additional studies are needed to investigate the full potential of these areas and determine if any excess would be available for transmission to Amman. At the present time, however, the potential supply from these areas is not large enough to warrant a recommendation as an alternative to the proposed project.

Springs located in the Amman-Zerqa River basin near Ruseifa and Sukhna were also included in the VBB studies. A review of the spring flow records indicate that flows from major springs in this area have decreased significantly in recent years These flows are also a part of the Zerqa River base flow and would add no additional supply to the system. A portion of the spring flows is currently used, and the balance would not be sufficient to warrant development for the city of Amman.

A dam has also been considered on Wadi Abdoun. This reservoir would result in storage for either aquifer recharge or as a surface water supply. Wadi Abdoun is the uppermost tributary of the Zerqa River and flows through a portion of Amman. The proposed dam site, which was studied by the Natural Resources Authority, would be located about 4 km southwest of Amman. This reservoir would not add to the total water resources available in the basin; however, it could provide a good quality water close to Amman. Estimated net yield is about 3 Mm^3/yr. Although this is not a significantly large quantity to act as a separate source, the Wadi Abdoun reservoir should be given additional consideration. The recent study by Binnie

and Partners, entitled "Prince Ali Dam" March, 1978, investigated the Wadi Abdoun source in some detail. It is recommended that further consideration of the Wadi Abdoun dam be delayed until the first stage water supply project from King Talal reservoir has been developed and in operation for a few years. If the water quality at King Talal reservoir is sufficient to allow additional withdrawals, there is no reason to develop the Wadi Abdoun site at a more expensive cost.

The two remaining sources considered by VBB include a surface water source at Zerqa Main and a ground water source from Azrak area. Both of these sources are high in total dissolved solids and would require extensive treatment for a domestic supply. Also, the better quality water in the Azrak area is already committed for various uses in that vicinity and the Irbid area.

Investigations have been carried out by the Food and Agriculture Organization of the United Nations on the deep sandstone aquifers of East Jordan. These studies indicate some potential for only small scale development of water supplies from the Kurnub-Zerqa sandstones in northwest Jordan. Current available information does not indicate the presence of favorable supplies for the Amman area.

Other Alternative Water Resources - Another potential source for water supply for Amman is ground water from the Basalt formation which outcrops over 11,000 km^2 in northern Jordan. Recharge to the Basalt system is from the high rainfall zone of the Jebel Druze Mountains in Syria. Over 22 Mm^3/yr are currently being pumped in the Wadi Dhulell area. The Basalt aquifer discharges flowing artesian water into the Hummar system (lower aquifer) in the Amman-Zerqa Basin. The Basalt aquifer also discharges into the Amman-Wadi Sir system northeast of Zerqa (upper aquifer). Flows from the Balalt system also discharge into other aquifers in adjoining basins. Some additional development of the Basalt system may be possible; however, this may have an effect upon the amount of water available for recharge to the upper aquifer in the Amman area.

Plans are currently being made for development of a major water resource project on the Yarmouk River. The Maqarin Dam would be 125

meters high and would have storage capacity of 200 Mm^3. Current plans include development of hydroelectric potential, irrigation for the Jordan Valley, and water supply for the Irbid area. Consideration is also being given to diverting domestic water supply to the Amman region. Present siting for the Maqarin Dam is in northern Jordan with a large percent of the reservoir area being located in Syria. Various international funding agencies, including the U.S. Agency for International Development, are expected to participate in this project.

Implementation - The proposed water supply plan should be modified to take advantage of alternative sources and to maximize water quality. Following the initial water supply development from King Talal reservoir, it is recommended that the second stage of water supply for Amman be obtained from the Upper Wadi Wala reservoir. Reconnaissance and feasibility studies of the Wadi Wala site should begin immediately. This reservoir would be a continuing source of high quality water supply at a reasonable distance from the city of Amman.

Utilization of the Wadi Wala source will also permit evaluation of King Talal reservoir for additional water supply. At the end of the evaluation, doubling the supply from King Talal reservoir may be possible using the same level of treatment as the initial development. Withdrawals from King Talal reservoir beyond this amount will probably necessitate the provision of sophisticated tertiary water treatment processes at the water treatment plant. For this reason, water supply sources from outside the basin may be more favorable. Some additional water supply may be available from the proposed Maqarin reservoir on the Yarmouk River. Further demands may require location of additional water supplies.

No Action

Since there are three separate projects under consideration, it is possible that no action could be taken on each project individually. The effects of eliminating the various combinations will be considered.

Case 1 - No project for water supply from King Talal reservoir - The only environmental benefits would be elimination of the short-term adverse environmental impacts and the long-term benefit of keeping the

land involved in agricultural and grazing production. These minor benefits are far outweighed by the importance of additional water supply for the city of Amman. Water demands for the capital city are currently in excess of the safe yield of the ground water aquifer systems. This is particularly true of the lower aquifer which has experienced reductions in the piezometric level of 50 to 100 m in the last few years. Storage within the aquifer formation is limited and will become depleted if the current pumping rate is continued. Pumping costs, including energy expenditures, will also increase as the piezometric levels drop.

The upper aquifer is currently being overpumped slightly in excess of its recharge capacity. Demands for water supply from this upper aquifer can be expected to increase rapidly as the piezometric level in the lower aquifer continues to drop. Unless other water supply sources are developed, the upper aquifer will soon become heavily exploited. Storage capacity in this aquifer is also limited while the recharge is essentially constant depending upon rainfall stream flows and other infiltration within the outcrop areas.

Quality of the water in the lower aquifer has remained good despite heavy pumping. In the upper aquifer, the quality of the water has deteriorated significantly within the last few years. Records indicate water quality has deteriorated markedly in areas of heaviest pumping. This deterioration will be further accelerated as pumping rates increase in the upper aquifer. Sources of pollution to the upper aquifer include seepage from cesspools and septic tanks throughout the populated areas of the Amman-Zerqa region. Industries and agricultural developments along the valley are also significant sources of pollution either directly to the upper aquifer or indirectly through contamination of the stream flows which also provide some recharge to the ground water system. The adverse environmental effects of no action in this case outweigh the environmental benefits, and it is recommended that this case of no action not be considered.

Case 2 - No extension of water distribution or sewage collection systems - There are no environmental benefits associated with this

case. Adverse environmental effects include:

1. Increasing potential health hazard as a greater proportion of the population is not connected to the water distribution system and relies upon water tankers and roof storage tanks for water supply.
2. A greater potential health hazard due to the continued use of an increasing number of cesspools, which lead to pollution of the ground water supply source and potentially serious local problems due to individual cesspools overflowing.

Not increasing the extent of the sewage collection system will make less imperative the addition of sludge digestion capacity at the sewage treatment plant. Possibly only rehabilitation of the existing digesters will be required. This no action alternative is not recommended.

Case 3 - No action on repairs and addition of sludge digestion capacity at the sewage treatment plant - The only environmental benefit would be the elimination of potential leachate from the sludge drying beds reaching the upper aquifer or the Zerqa River. Adverse environmental effects would include:

1. Lack of proper operation of the sewage treatment plant due to lack of repairs.
2. Increasingly overloaded sludge digesters which will result in only partially digested, and in some instances raw, sludge will be disposed of at the municipal dump.

This case of the no action alternative is not environmentally acceptable.

Case 4 - No action to provide water supply from King Talal reservoir and extension of water distribution and sewage collection systems - Environmental benefits consist of the elimination of adverse environmental effects associated with the supply project and retention of land used for the water supply project in its original usage. Environmental costs include the following:

1. Less water available for each person because even though the water distribution system is not being extended, all of the population receives their water from the municipal supply.
2. Increased health hazards due to a greater proportion of the population utilizing water tankers and roof storage tanks.
3. Increasing use of the ground water resource leading to its more rapid depletion, as described in Case 1.

The no action alternative described by this case is not recommended.

Case 5 - Eliminating extensions to water distribution and sewage collection systems and no improvements to sewage treatment plant - The environmental benefit consists of eliminating the possibility of leachate from the sludge drying beds reaching the Zerqa River. Environmental difficulties which will occur if the projects are not constructed are:

1. Continued usage of cesspools by an increasing proportion of the population resulting in continuing degradation of the ground water supply due to cesspool leachate.
2. Increased reliance on water tankers and roof storage tanks to provide water for the population with resulting health risks.
3. Difficulties in maintaining proper operation of the sewage treatment plant due to the lack of repairs.

Again, the no action alternative as described by this case is not recommended.

Case 6 - Elimination of water supply project and improvements at sewage treatment plant - Environmental benefits consist of the following:

1. Elimination of short-term environmental impacts associated with the construction of the water supply project.
2. Retention of land in its original usage that would have been used for the water supply project facilities.
3. Elimination of potential leachate from the sludge drying beds to the Zerqa River.

Environmental costs of eliminating these two projects are:

1. Increasing use of the ground water resource leading to its more rapid depletion, as described in Case 1.
2. Inability to maintain efficient operation of sewage treatment plant due to the lack of necessary repairs to process equipment.
3. Increasing sludge production will require the disposal of partially digested or raw sludge at the municipal dump.

No action on this combination of projects is not recommended.

Case 7 - Effects of taking no action on all three projects - The environmental benefits in this instance are the same as for Case 6. The adverse environmental effects are as follows:

1. Increasing use of the ground water resource leading to its more rapid depletion, as described in Case 1.
2. A greater proportion of the population will have to be served through water tankers and roof tanks with resulting health hazards.
3. A greater proportion of the population will utilize cesspools for sewage disposal resulting in both greater ground water contamination potential and increased probability of local health hazards due to malfunctioning cesspools.
4. Inability to maintain proper operation of sewage treatment plant due to lack of repairs to process equipment.

Again, this no action alternative is not recommended.

Summary - Although no action on one or a number of combinations of the three projects will result in some environmental benefits, in no case does the environmental benefit derived come close to equalling the adverse environmental impact of no action in that case. It is therefore recommended that the no action alternative not be considered for any of the projects.

Population growth within Amman is not expected to be significantly affected, at least through most of the study period, by following the no action alternative. People will continue to migrate to the city even in the face of less than desirable water and sewage facilities. There will, however, come a time when other urban areas will become more attractive if the current situation is allowed to perpetuate.

Postpone Action Pending Further Study

This alternative has all of the same negative impacts as the no action alternative. It does, however, have the advantage of allowing additional investigation into the water quality which can be expected in the King Talal reservoir. At the present time, the reservoir is in the initial filling process and the quality of the impounded water is not known. Projection of the expected quality is difficult because of the many unknown aspects of waste sources, geological conditions, soil erosion, flood flows, as well as reservoir characteristics. The postponement alternative would not only allow time for the reservoir to fill and the contents to equalize, but would provide opportunity for implementation of pollution control measures and related studies.

While the postponement alternative has advantages over the no action alternative, it still contains the negative impacts of not having adequate water quality and quantity available for the city of Amman for a number of years. This alternative is therefore not recommended.

Alternative of Different Design

The following alternative is presented as a means of maximizing known water supply sources. This alternative proposes the efficient recycling of Amman wastewater for potable use. Table 13 presents the projected sewage flows and loads for the study period. The hydraulic capacity of the Ain Ghazal sewage treatment plant is 60,000 m^3/day, which indicates the plant will have sufficient capacity through about 1987. However, the BOD_5 design loading is only 18,000 kg/day, and this will be exceeded prior to 1980. Increasing the BOD_5 loading above the design will cause the plant to malfunction; thus, studies to investigate provisions for additional sewage treatment plant capacity are needed now. It is recommended that studies for additional sewage treatment plant capacity also include studies on the further treatment of wastewater for reuse.

TABLE 13

PROJECTED AMMAN SEWAGE CHARACTERISTICS

Year	Flow (m^3/day)	BOD_5 (kg/day)
1980	26,000	30,800
1985	48,000	46,400
1990	79,000	63,600
1995	130,000	88,600
2000	204,000	121,900

Reuse of wastewater has the following advantages:

1. Almost all of the wastewater volume is available for reuse. When recycling through King Talal reservoir, water losses approaching 50 percent may be expected.
2. The required type of treatment would provide a water quality comparable to other available sources, with the possible exception of Wadi Wala.
3. The possible environmental problems due to eutrophic conditions in King Talal reservoir would be avoided.

However, there are substantial disadvantages:

1. This particular reuse arrangement has not yet been proven successful. Long-term health effects are uncertain, although probably not much different from those of recycling through King Talal reservoir.
2. Operation and maintenance of such a facility will be expensive and require highly skilled, trained operators.

Only more detailed study can compare this alternative to the others proposed. Even with direct recycling, both the first stage of King Talal supply and the Wadi Wala projects will be required to assure adequate water supply.

Compensate for Fish and Wildlife Losses

The project as proposed would disrupt wildlife in the areas of construction. The total area involved is approximately 42 hectares. Of that total, 17 hectares will be totally removed as potential habitat because of constructed facilities. The remaining 25 hectares could, upon completion of the project, revert back to habitat suitable for

upon completion of the project, revert back to habitat suitable for wildlife habitation. The loss of 17 hectares of habitat is not felt to be significant enough to warrant alternative considerations.

The effects on fish populations and habitats are somewhat more extensive but not considered to be any more significant. As discussed, the creation of the reservoir has significantly altered the habitat conditions of the Zerqa River within the limits of the reservoir. Present fish populations are adapted to a flowing water habitat. Many of the present species living in the river must have that habitat to properly reproduce.

The logical solution to the river habitat situation is to do nothing to alter the remaining flowing portions of the Zerqa River thereby assuring a fish population in the river. To compensate for the reduction in total fish population, the reservoir should be stocked with species suitable for impounded water. This would make available two distinct types of fish population and perhaps increase the benefits to the local population.

In discussions with the RSCN, it was learned that there is a long-range governmental policy to diversify the protein sources throughout Jordan. The desire is for equal reliance on sheep and goats, fowl, and fish. King Talal reservoir is being considered as a possible location for a fishery. Should plans proceed, the long-term potential problem of water quality in the reservoir must be considered in any plans. As has been discussed, the water quality may pose problems for even the local sport fish populations in the river and potential populations to be introduced in the reservoir. Continued monitoring of this potential problem is the only way to know the extent and degree of deterioration in water quality.

UNAVOIDABLE ADVERSE IMPACTS

The only unavoidable adverse impact will be the decrease in water quality due to recycling of water through King Talal reservoir as proposed for subsequent stages of water supply development for the city of Amman. Alternatives for decreasing the amount of recycling necessary are given in "ALTERNATIVES TO THE PROPOSED PROJECTS." Not only does the decrease in water quality due to recycling cause problems with maintaining a good quality water supply to the city of Amman, it affects the water quality of the entire reservoir. The major use of the water from the reservoir will be for irrigation purposes in the Jordan Valley. Table 14 presents estimated average annual concentrations of nitrates and total dissolved solids in the Zerqa River as it enters the reservoir. Since this is the major source of reservoir water, reservoir water quality will be essentially the same except for effects of sedimentation and evaporation.

TABLE 14

ZERQA RIVER WATER QUALITY

Year	Percent of Flow[1]	Nitrates (mg/l)	Total Dissolved Solids (mg/l)
1980	13	20	1,000
1990	34	45	1,020
2000	57	75	1,040

[1]Percentage of stream flow which is discharged from sewage treatment plants.

The information presented in Table 14 is based upon following the water supply plan proposed by VBB. The WHO limit for nitrates is 45 mg/l, which will be reached by about 1990. The 1,500 mg/l TDS allowable limits will not be reached during the foreseeable future. Decreases in TDS are

possible if substantial amounts of low (<1,000 mg/l) TDS water are imported to the basin; however, the average annual evaporation (about 2.0 m/yr) will tend to increase the concentrations.

Average annual figures do not show the entire magnitude of the problem. During the dry season, especially at the end of the season, there may be almost direct stream flows to the water intake because of lowered reservoir conditions. The seasonal variation in flow percent and quality is given in Table 15. During January through April, conditions are below, or the same, as the annual average condition. During the month of July, the driest month, nitrates and percent of streamflow, that is sewage treatment plant discharge, are nearly double the annual average.

TABLE 15

1990 ZERQA RIVER WATER QUALITY

Month	Percent of Flow[1]	Nitrates (mg/l)	Total Dissolved Solids (mg/l)
January	21	28	1,012
April	40	53	1,024
July	67	89	1,039
October	60	79	1,035

[1] Percentage of stream flow which is discharged from sewage treatment plants.

SHORT-TERM VERSUS LONG-TERM PRODUCTIVITY

Relationships Between Domestic Supply and Irrigation

As was discussed in preceding sections, there is a relationship between allocating water for domestic supply and for irrigation. As originally designed, the King Talal reservoir was built for solely irrigation purposes. As such, the system should operate for an indeterminate length of time with no significant changes in either quantity or quality of water available in the reservoir.

The allocation of water for domestic supply to Amman creates two distinct problems. The first is the commitment of the water resource for a different purpose. The water allocated to Amman will result in a reduction in agricultural irrigation in the Jordan Valley and a corresponding reduction in agricultural production. The decision for the allocation is a political one with the basic criteria being that the water can accomplish more in Amman than in the Jordan Valley.

The second problem is also political, but the ramifications are far more reaching. By allocating water to Amman and placing that water in a closed recycled system, the water quality in that system becomes a potential area of great concern. While data are not available to make definite projections, it is possible that the quality could deteriorate to the point that the entire volume contained in the reservoir may not be usable for either domestic supply or irrigation. Should this occur, the volume of water allocated to Amman would be lost, but so would the much larger volume be lost for irrigation purposes and the associated agricultural production.

It is a suggestion of this assessment that all precautions be taken to maintain a high degree of water quality, and that allocations to Amman be limited to the initial withdrawal for as long as possible. This delay will allow continuous monitoring of the water quality to determine the effects of recycling.

COMMITMENT OF RESOURCES

Identify Unavoidable Impacts

The project of removing water from King Talal reservoir, treating, and pumping the water to Amman does have some unavoidable, though not insurmountable, impacts as related to commitment of resources. The first is the commitment of 17 hectares of land to more intense utilization with the construction of project facilities. This is not felt to be a significant impact. Should at some future date the facilities prove unusable, the land could be reclaimed and used in much the same manner as currently utilized.

The second unavoidable impact is the reduction in potential agricultural irrigation as a result of allocating water for domestic supply. The 12 Mm^3/year allocated annually for domestic supply equates to 1,200 hectares of land in the Jordan Valley which cannot be irrigated. If at some future time or for some political reason the water currently allocated for domestic supply becomes available for agricultural irrigation, it can be applied to the available land in the Jordan Valley with no loss of agricultural productivity.

AVOIDABLE ADVERSE EFFECTS

General

The following describes adverse environmental effects of the proposed projects which can be mitigated by modifications and additions to the projects. Securing a good quality water supply will also require some modification of existing practices associated with the use of water in the study area. Industrial wastewater discharges comprise a potential pollutant source which could adversely affect the quality of the water supply. It will be necessary for the government to regulate the type and quantity of pollutants discharged from the industries and to maintain an on-going program of surveillance. In addition to the monitoring of industries, water quality monitoring at various points along the Zerqa River, from the two ground water aquifers, and within the reservoir should be begun as soon as possible. Data thus obtained will be useful in the final design of water treatment facilities and will serve to show trends and changes of water quality due to increased flows through the reservoir.

Water Supply Project

The following are proposed modifications to the water intake and water treatment plant:

1. Locate the openings on the water intake at levels below the surface of the water sufficiently deep to minimize the amount of algae taken into the water treatment system. The top of the intake opening should be at least 2 meters below the surface. This will help reduce the load of algal cells on the subsequent treatment processes allowing more efficient operation.
2. Filter backwashing facilities and sludge handling facilities should be adequately sized to allow for proper operation of the treatment processes under conditions of heavy algal loads into the treatment processes.
3. The proposed method of disposing of water treatment plant sludges is not environmentally acceptable. It is recommended that sludge dewatering facilities be provided. Filtrate from the dewatering operation can be returned to the head of the

treatment plant and the sludge cake should be disposed of in a landfill operation nearby. Mechanical dewatering by centrifuges, filter presses, or vacuum filters would be the most effective means of dewatering, but the use of sludge drying beds is an acceptable alternative.

4. Facilities for taste and odor control by activated carbon feed should be available during initial construction of the plant.

Sewage Treatment Plant

Besides the modification described below, consideration should be given to immediate assessment of future wastewater treatment requirements for the city of Amman. Although the present plant is currently doing an adequate job, the anticipated rapid increase in wastewater flows will severely overload this plant in the near future. Since provision of adequate wastewater treatment is essential to maintaining adequate water quality downstream and in the reservoir, immediate analysis of the situation is recommended.

Consultants retained by AWSA have recently recommended provision of mechanical sludge dewatering at the existing sewage treatment plant. Filter belt presses have been adopted as the type of dewatering equipment to be installed.

One of the major problems with mechanical dewatering equipment is the need for extensive maintenance of the machinery. Filter belt presses are an excellent choice from a maintenance standpoint. In addition, operation is relatively simple. The process will require the use of polymeric coagulents, which will be a high operating cost item. Also, the rate of polymer feed will have to be carefully controlled.

The report favoring mechanical dewatering does not address the disposal of the filtrate. Approximately 550 m^3/day of filtrate will be produced. This should be returned to the head of the sewage treatment plant as it is far too strong a wastewater for direct discharge. The 550 m^3/day will not cause a large increase in the hydraulic load on the plant, but the 3,000 kg/day BOD_5 loading of the filtrate represents a significant portion of the 18,000 kg/day BOD_5 capacity of the plant.

Final disposal of the sludge is to be in the municipal dump, with some reference that the dewatered sludge may be more readily acceptable for agricultural purposes. Disposal of sludge on agricultural land is preferable to disposal in a dump or landfill because the nitrogen compounds will not likely contribute to ground water contamination when utilized on cropland.

ENVIRONMENTAL AND RESOURCE DATA

General

Much of the assessment done in this report has been qualitative instead of quantitative because of a lack of basic data. Estimates and the use of professional judgment do not permit precise calculations of such items as water quality. Since water is a scarce resource in Jordan, the acquisition of all types of data required to manage this resource is important, especially in the study area.

Data Deficiencies

The following are areas where no data, outdated information, or insufficient data exist, as regard this assessment:

1. The uncertainty of population data for Amman and the surrounding area.
2. Lack of information on percapita water demand. Some information on per capita use is available, but the actual demand may be significantly higher. Even the per capita use data are approximate.
3. A lack of stream quality data for the Zerqa River.
4. No information on per capita sewage flows.
5. Insufficient data on industrial wastewater discharges.
6. Inadequate data on ground water levels, pumping rates, and water quality.

Recommendations

A water quality monitoring program should be instituted to obtain information on overall water quality in the Zerqa River and King Talal reservoir. It is expected that complete daily water quality analyses will be made on both the raw and finished water at the proposed water treatment plant. Besides these analyses, weekly or biweekly water quality data should be acquired for the Zerqa River just downstream of Ain Ghazal, downstream of Zerqa, and at the new Jerash bridge. Water quality analyses for the reservoir should be carried out biweekly or monthly and should include information on nutrients and phytoplankton.

A survey of industrial discharges is currently underway. As a result of this survey, some type of industrial discharge control will probably have to be instituted to protect the water quality. An industrial discharge surveillance program will be necessary.

Ground water monitoring is currently being conducted to a limited extent in the Amman-Zerqa basin. Additional monitoring points are needed to identify areas of ground water contamination and over-pumping.

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