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The Hashemite Kingdom of Jordan
National Planning Council

FEASIBILITY STUDY

ZARQA - RUSEIFA

WATER DISTRIBUTION, SEWERAGE AND STORMWATER SYSTEMS

INVESTIGATIONS, PRELIMINARY ENGINEERING DESIGN, FINANCIAL, AND SOCIO - ECONOMIC ANALYSIS REPORT

MALCOLM PIRNIE, INC.
in association with
JOUZY & PARTNERS

1980
Amman - Jordan

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December 22, 1980

His Excellency President
Dr. Hanna Odeh
National Planning Council
Amman - Jordan

Re.: Feasibility Studies of the Municipal Water Distribution Improvements and Sewerage and Stormwater Drainage Systems in Zarqa and Ruseifa, Jordan

Dear Dr. Odeh,

In accordance with our Agreement, we are pleased to submit the Investigations, Preliminary Engineering Design, and Financial and Socio-Economic Analysis Report. The tables and figures are bounded separately in the Appendix and the plates are in the Map Atlas.

This Feasibility Study developes a comprehensive program for staged construction of wastewater and storm drainage facilities and improvements to the public water distribution systems in Zarqa and Ruseifa. The primary objective is to provide for the basic human needs in the two communities.

The recommended project and its costs are summarized in Chapter 12.

We wish to thank the NPC Staff, the Ministry of Municipal, Environmental, and Rural Affairs, the Municipalities of Zarqa and Ruseifa, and the many others who have assisted us during this project.

Respectfully Submitted,

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INVESTIGATIONS, PRELIMINARY ENGINEERING
DESIGN, AND FINANCIAL AND SOCIO-ECONOMIC
ANALYSIS REPORT

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1.0 INTRODUCTION

1.1 Background

Zarqa is located about 20 km northeast of Amman. It is the second largest city in Jordan with a 1979 population of about 216,000 and has a projected annual growth rate of about 3.5 percent until 2000. Ruseifa, which shares a common town plan border with Zarqa, had a 1979 population of about 62,000 and a similar projected annual growth rate. These cities are shown in Figure 2.1.

The Zarqa-Ruseifa area is one of the principal industrial centers as many of the larger industries in Jordan are located within the two cities. Many industries are on the banks of the Zarqa River. The industries include: breweries; soft drink bottling works; food industries; weaving industries; phosphate production; a tannery; and various chemical industries. At present the wastewaters from these industries discharge to the nearest wadi with a minimum degree of treatment or no treatment at all.

Neither city has a general system for wastewater collection and treatment. At present, both cities are totally dependent on cesspools for wastewater disposal. These have become increasingly inadequate and unacceptable both from health and other environmental considerations.

The need for an expanded stormwater drainage system is also evident in both cities. The present systems are rudimentary at best, consisting of gutters and streets sloped to drain to the wadis. Many of these wadis are not large enough to accommodate the flows and flooding results. In addition, some streets do not have natural outlets and remain flooded for days after a heavy rain. During the rainy season, the cesspools tend to become overloaded and drain to these low areas and pollute the ponded waters.

The existing water supply and distribution system in Zarqa was substantially reinforced in mid-1960 and expanded to some extent during the past 12 years. The existing water distribution system in Ruseifa was built in 1963 with an additional supply completed in 1978. The existing system has not kept pace with growth since that date. At present, newer portions of Zarqa built at elevations higher than the existing service reservoirs are not served by a distribution system. The system expansion has not kept pace with growth. At present the supply of well water to the system is adequate but, like Amman, future water supply may be a problem.

1.2 Authorization

On January 6, 1980, an Agreement was signed between the National Planning Council of the Government of the Hashemite Kingdom of Jordan (herein "NPC") and Malcolm Pirnie, Inc. (herein "MPI") for consulting engineering services for Feasibility Studies, Final Design and Supervision of Construction of the Municipal Water Distribution Improvements, and Sewerage and Stormwater Drainage System in Zarqa and Ruseifa, Jordan.

The United States Department of State, Agency for International Development (herein "USAID") furnished MPI Letter of Commitment No. 278-022402 on January 16, 1980 which stated that USAID would pay all U.S. Dollar costs of the Feasibility Study.

In accordance with Section 5.3 of the Agreement, the effective starting date of the project was 10 calender days after the effective date of the letter. Thus, the effective starting date of the Agreement was January 26, 1980. In order to expedite the project, NPC and USAID agreed that work done after the MPI/NPC Agreement date of January 6, 1980 would be eligible for payment.

On January 5, 1980, MPI and Jouzy & Partners (herein "Jouzy") signed an agreement for associate consulting engineering services. Jouzy has provided the required in-country engineering and administrative services from its Amman, Jordan Office.

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On January 23, 1980 MPI confirmed its authorization to Jouzy to start work on January 6, 1980, the date of the MPI/NPC Agreement.

1.3 Purpose and Objective

The purpose of this Feasibility Study is to develop a comprehensive program for staged construction of wastewater and storm drainage facilities and improvement to the public water distribution systems in Zarqa and Ruseita.

The principal objective of this study is to provide for the basic human needs in the two communities. To this end, recommendations for phased investment in water, wastewater and storm drainage will take into account the special and immediate requirements of areas with high population densities, high incidences of waterborne diseases, and greatest inadequacies in present service.

1.4 Scope of Work

The scope of work includes the following:

- Planning Area definition and population forecasts.
- Survey of the existing socio-economic and health condition of the cities.
- Definition of the existing environmental condition.
- Evaluation of the existing water distribution system and engineering feasibility studies relative to future needs.
- Engineering feasibility studies relative to future wastewater collection and treatment systems.
- Evaluation of the existing stormwater drainage system and engineering feasibility studi relative to future needs.
- An industrial wastewater survey and sampling program to characterize existing and project future industrial wastewater loads.
- Engineering feasibility studies relative to industrial wastewater pretreatment and direct discharge requirements.
- Preliminary rate analysis of the alternative projects to investigate various phased investment programs.

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- Evaluation of the health and environmental conditions with alternative projects.

- Recommendation of a phased development project.

- Recommendations relative to the financing and implementation of the recommended project.

1.5 Report Organization

The report consists of the following five separately bound volumes:

- Summary Report.

- Investigations, Preliminary Engineering Design, and Financial and Socio-Economic Analysis Report.

- Industrial Effluents Treatment Report.

- Appendix to the Investigations, Preliminary Engineering Design, and Financial and Socio-Economic Analysis Report.

- Map Atlas for the Investigations, Preliminary Engineering Design, and Socio-Economic Analysis Report.

For ease of reading the report all reference material such as tables, figures, and plates have been separated from the text and can be found in the Appendix and Map Atlas. By such a separation the reader will be able to continuously return to the reference material as it is discussed in the text.

2.0 PLANNING CONSIDERATIONS

2.1 Planning Area

The scope of work defines the planning area as the Town Plan area of Zarqa and Ruseifa. The term "Town Plan area" refers to the land use plans prepared by the Ministry of Municipal, Rural and Environmental Affairs for the cities of Zarqa and Ruseifa. The Town Plan area contains most of the present population of the two cities. The planning area is shown on Figure 2.1. The planning area, Town Plan area, and municipal boundaries are shown on Plates 2.1 to 2.3.

On the basis of discussions with the National Planning Council, it was agreed that the army base which borders Zarqa to the east would also be included in the planning area. Consequently, the wastewater flows from the army base will be included for planning purposes, but neither a water distribution system nor a sewage collection system will be planned within the base itself.

The planning area also includes the industrial complex located south of Zarqa at Awjan Esh Sharqi. Because industrial development is presently occurring beyond the boundary of the Zarqa Town Plan area, the planning area has been extended to permit consideration of serving future industrial development.

The Town Plan area for Ruseifa is generally limited to those portions that are presently urbanized, and does not include adjoining areas where development is now occurring and is likely to occur in the future. For this reason, the planning area has been extended northward of the Ruseifa town plan area a distance of approximately one kilometer. This extension includes the labor housing project to be built north of Yajuz Road. The Amman-Zarqa highway has been selected as the southern boundary of the planning area in the vicinity of Ruseifa. The settlement called Al Musheirfeh, which was recently annexed by Ruseifa, has also been included in the planning area.

There are additional areas tributary to the Zarqa River between Ruseifa and Amman's Ain Ghazal wastewater treatment plant, but on the basis of discussions with the National Planning Council, these areas have not been included. The excluded areas are the Marka Housing Project, the Shnellar Refugee Camp and Technical School, and the Ain Ghazal industrial area between Amman and Ruseifa.

In addition to the Town Plans for Zarqa and Ruseifa, there is also a proposed land use plan for the Zarqa region by the Amman Urban Region Planning Group (AURPG). The planning area encompasses the AURPG plan area except for the communities of Hashemiyeh and Sukhnah, and the petroleum refinery, all to the north of Zarqa. These areas have been excluded from the planning area by the National Planning Council definition.

2.2 Planning Period

The scope of work specifies that the planning period shall be through the year 2000 with the proposed projects to be implemented according to a phased investment program. Implementation Phase I is to serve needs through 1990. Needs through the year 2000 are to be met through subsequent construction phases. Because certain facilities such as components of the wastewater treatment plant and trunk sewers are usually designed to serve for a longer period than 20 years, the design for these facilities takes into consideration needs through the year 2020 and saturation population.

2.3 Population Trends

The national census of population and housing, conducted in November 1979, reported the population of Zarqa and Ruseifa as 215,687 and 49,622 persons, respectively. In the case of Zarqa, the population was more than double the 96,080 persons reported by the previous census in 1961, for an average annual rate of growth of 4.5 percent. For Ruseifa, the population increased by more than 44,000 over the 1961 population of about 5,500, for an average annual rate of growth of 13 percent. Also included in the planning area is Al Musheirfeh, with a 1979 population of 12,052 persons, and a sparsely inhabited area along the Amman-Zarqa highway between Zarqa and Ruseifa with an estimated population of 1,300 persons. The total present population of the planning area is approximately 278,700 persons.

Between 1961 and 1979 the population of the East Bank increased at an average annual rate of 4.85 percent. At present, the crude birth rate is estimated to be between 45 and 50 births per 1,000 and the crude death rate is estimated to be between 9 and 12 deaths per 1,000, for a natural growth rate of between 3.3 and 3.6 percent. Also

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contributing significantly to the growth of the East Bank population has been the influx of refugees from the West Bank and Gaza strip during the hostilities in 1948 and 1967. Other demographic factors include a high rate of out-migration of Jordanians to the oil-producing Gulf countries, offset by the in-migration of workers from developing nations. The movement of immigrants to the cities, accompanied by internal migration from rural areas, has resulted in a rate of urban growth that is higher than that of the East Bank as a whole.

2.4 Population Projections through the Year 2000

The AURPG has projected the population of Zarqa and its satellites (Ruseifa, Al Musheirfeh, Hashemiyeh, and Sukhnah) in five-year increments through the year 2000 as follows:

1979	281,500 persons
1985	350,000
1990	410,000
1995	502,000
2000	616,000

The projections are based on average annual rates of growth during the five-year increments that range from 3.22 to 4.18 percent. The projections represent a modified extrapolation of recent trend with the assumption of a lower rate of in-migration and a slightly lower birthrate.

For the purpose of the feasibility study, the AURPG projections have been adopted with some modification. Because the AURPG planning area includes potential industrial growth areas to the north of Zarqa not included in the feasibility study, the AURPG projection has been adjusted downward to 390,000 persons in 1990 and 550,000 persons in the year 2000. This projection implies an average annual rate of growth of 3.48 percent over the 20-year planning period or approximately equal to the present rate of natural increase.

2.5 Present Population Density and Distribution

Because the detailed tabulations from the 1979 census will not be available until mid-1980, it was necessary to estimate population density and distribution in the planning area through the use of aerial

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photographs. The planning area was subdivided into areas or subunits of similar and homogeneous development patterns, and by means of 1979 aerial photographs, estimates were made of the number of dwellings per hectare in each subunit. Without detailed information as to variation in household size throughout the planning area, the average household size of 6.98 persons per household reported by the 1979 census was employed throughout. Density estimates by subunits range from 190 to 525 persons per hectare with an average density of about 350 persons per hectare. In estimating density, the vacant land within a subunit was not included, so as to more accurately reflect the density of the built-up portions. Thus, the estimate also indicates density as it will likely exist once the subunit approaches saturation development, assuming a continuation of the prevailing development pattern. The current population of each subunit was computed from the estimates of density, percentage of built-up land, and total land area. These estimates are required for spatial disaggregation of the flows.

2.6 Land Use Plans and Zoning

The Town Plans for Zarqa and Ruseifa, as well as the proposed land use plan by the AURPG were consulted to determine the location of future residential and industrial development. Both Zarqa and Ruseifa have local planning committees, empowered to prepare master plans, but because of the lack of technical staffs, the Ministry of Municipal, Rural and Environmental Affairs has prepared land use and street plans (or town plans) for both municipalities. The town plans designate land use according to four categories or zones of residential use, ranging from Zone A (the largest lot size) to Zone D (the smallest lot size). There are also commercial, industrial, public, and agricultural classifications. A general description of the Town Plan recommendations follows.

The Zarqa Town Plan designates the existing shopping district as a commercial zone with fairly limited commercial zones elsewhere in the city. Zone D, the highest density residential zone, is generally confined to existing high density areas such as Janna'ah and the area north of the commercial district. The lower density residential zones, Zones A and B, predominate elsewhere in the city. The industrial zone is confined principally to Awjan Esh Sharqi, south of Zarqa. The Zarqa River floodplain is designated for agricultural use.

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The Ruseifa Town Plan is generally confined to those areas that are largely built up at present. Residential Zones B, C, D are represented, with the greatest portion of the city designated for the higher density zones C and D, and a smaller area on the south bank of the Zarqa River designated Zone B. The area designated for commercial use is fairly limited, and the industrial zone applies largely to the phosphate processing facilities and a narrow strip north of the Shnellar Camp in Musheirfeh. As in Zarqa, the plan designates the Zarqa River floodplain an agricultural zone. The only other significant open space area is the pilgrims' area in Musheirfeh, north of the Shnellar Refugee Camp.

The proposed land use plan for the Zarqa Region by the AURPG is generally consistent with the two town plans, although the AURPG plan encompasses a larger area. Unlike the town plans, the AURPG plan does not specify different densities for residential areas. The Zarqa River floodplain is designated an agricultural area. Other major open space areas are the phosphate mine south of Ruseifa (for which land restoration is proposed upon exhaustion of the mine in the mid-1980s) and other phosphate company properties to the north of Musheirfeh. A major feature of the AURPG plan is a proposal that the army camp which lies immediately east of Zarqa and prevents the eastward expansion of the city, be converted to municipal and public uses such as a commercial center, government buildings, and educational and recreational facilities.

2.7 Potential Saturation Population

Estimates of saturation population for the subunits were obtained by the following procedure. The Town Plans for Zarqa and Ruseifa, as well as the proposed land use plan by the AURPG, were consulted to determine the areas of future residential development. The various zoning requirements regarding lot size, coverage, and building heights within the four residential zones were taken into consideration as an indication of future densities. The regulations proved to be of limited usefulness, however, because they do not specify the maximum number of dwelling units that can be built within a structure. Using assumptions of average dwelling unit areas of 100 m^2 or less yielded potential densities in excess of 500 persons per hectare, which is

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substantially greater than average conditions at present. Therefore, it was assumed that future development within each subunit would be similar in character to existing development. Thus, the densities of built-up portions that were estimated from aerial photographs (Section 2.5) were the basis for estimating the theoretical saturation population of each subunit. This approach yields an estimated saturation population for the planning area of 795,300 persons.

2.8 Disaggregated Population Projections

For the purpose of determining the spatial distribution of future water demands and wastewater flows, the projected increase in population through the year 2020 was disaggregated among the subunits of planning area. In the absence of information about specific development projects or the intentions of land owners in the planning area, an assumption was made that growth would occur with nearly equal likelihood in most of the subunits, with the amount of increase being approximately proportional to the area of vacant land available. In the case of those subunits that are more remote from existing settlements and physical infrastructure (roads and water supply), a less than average increase was assumed. As a result of this analysis, the projected populations for Zarqa and Ruseifa are:

	1990	2000	2020*
Zarqa	294,900	421,100	565,600
Ruseifa**	91,100	125,200	229,700
Total	386,000	546,300	795,300

* Planning area saturation population

** Includes Musheirfeh

Population projections, particularly those for areas such as Zarqa and Ruseifa which are characterized by dynamic growth, are necessarily subject to much uncertainty. Among the factors that could affect the overall growth of the planning area would be a resumption of in-migration of refugees in the event of renewed hostilities over the occupied West Bank. On the other hand, a resolution of the Palestinian statehood issue could possibly result in the out-migration of some refugees from the planning area. A third factor would be unexpected changes in the rate of economic development in the planning area. A fourth factor would be a change in attitude about family size and family planning.

2.9 Economic Forecasts

Various sources have been consulted to obtain information or forecasts on future economic development in the planning area. An interministerial committee is currently organizing for the preparation of the 1981-85 National Five-year Plan. Five-year planning involves a selection of development projects and an allocation of financial resources from internal and external sources to social welfare and infrastructure projects. No projects have thus far been identified for the planning area during the 1981-85 period.

The AURPG has designated areas within the Amman Region for future industrial development. Significant industrial development is expected to occur at Sahab (several kilometers south of the planning area), and also at Hashemiyeh in the vicinity of the petroleum refinery (to the north of the planning area). The AURPG also designates the area of Awjan Esh Sharqi for continued industrial development. The AURPG has not attempted to forecast specific types of industrial activity, but it does expect that limited water resources will prevent the establishment of heavy water-using industries. The fact that the national government must authorize new withdrawals from the aquifer will have a significant influence on the types of new industries that locate in the planning area.

Small industrial operations (furniture manufacture, cabinetry) account for much of the industrial activity in the Zarqa-Ruseifa area at present and would be expected to do so in the future. These enterprises are generally not significant water users. In view of the rather high annual rate of population growth, the construction industry will constitute a significant portion of future economic activity in the planning area.

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3.0 SOCIO-ECONOMIC AND HEALTH CONDITIONS

3.1 Socio-economic Factors

A socio-economic study was conducted as part of the overall feasibility study. The study was to serve the following purposes:

- o determine income distribution of planning area residents as input for ability-to-pay analysis
- o identify areas characterized by predominantly low-income population as basis for determining project phasing
- o determine attitudes toward water use that are likely to affect future levels of consumption
- o determine attitudes of residents regarding the need for a sewer project.

3.1.1 Family Income Distribution

The households of the Zarqa-Ruseifa area are generally characterized as low and middle-income families. Heads of households are mostly unskilled laborers or semi-skilled workers who are employed in the construction industry, in local manufacturing industries, retail shops, the civil service, or at the army base. In contrast to the nearby capital city of Amman, Zarqa and Ruseifa have a much smaller proportion of residents in the professional and managerial occupations and in the upper levels of government. Consequently, the proportion of the population in the upper income groups is very small, compared to Amman.

Information on income characteristics of households in the planning area is extremely limited. The recent census of the population in November 1979 included certain questions on socio-economic characteristics such as educational attainment and occupation, but no questions regarding individual or family income were asked. (It has generally been the policy of the Department of Statistics not to ask questions about income in the census or in special surveys.)

In 1974-75 the Royal Scientific Society conducted an income survey of 17,000 families, obtaining usable returns from 15,000 families. Based on the data obtained from that survey, the recent Jordan Urban Project (Halcrow-Fox and Assoc., Jouzy and Partners) estimated the 1973 distribution of monthly family income in urban areas as shown in column 1 below.

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Percentile	Urban Household Income Distribution Column 1: 1973 Monthly Income (JD)	Column 2: 1978 Monthly Income (JD)
10th	22	50
20th	30	70
30th	35	81
40th	40	92
50th	44	102
60th	51	116
70th	60	138

Assuming a rate of increase in family incomes equivalent to the average growth in Gross National Product from 1973 to 1978, the Halcrow-Fox study obtained the estimated 1978 income distribution shown in column 2. Commenting on the results thus obtained, the Halcrow-Fox study notes that the estimates for the lower percentiles may be on the high side because it is believed that incomes at the lower end of the distribution have not increased as rapidly as those of the middle or upper income groups.[1]

For the purpose of this feasibility study, it has been assumed that family income distribution in Zarqa and Ruseifa is approximately similar to the 1978 income distribution of urban households derived by Halcrow-Fox from the 1974-75 survey by the Royal Scientific Society. The following estimates of income distribution, increased by 8 percent per annum to 1980, will be used in the analysis of ability to pay in Chapter 10.

Percentile	1980 Household Monthly Income (JD)
20th	82
40th	107
60th	135
80th	205

The Halcrow-Fox study also conducted a household survey in several low-income areas of the Amman metropolitan area, one of which was the Janna'ah section of Zarqa. Of the 86 households interviewed in Janna'ah, 82 gave information on monthly household income.[2] About 35 percent of the families reported incomes of less than 60 JD per month, while 27 percent reported incomes in excess of 100 JD per month.

3.1.2 Low-income Areas

In an effort to identify areas characterized by predominantly low-income households, the use of data from the 1979 census was considered. Although the census takers did not ask questions about income, information was obtained on socio-economic variables that usually correlate well with income such as education. In general, the higher the educational attainment of the head of the household, the higher the family income. The number of persons per room in a household (a measure of crowding) generally correlates negatively with family income. Information on rent obtained by the census was considered to be of doubtful value because (1) only about 30 percent of households in Zarqa are renters, (2) rent control may tend to distort the correlation between income and rent, and (3) there are doubts about the accuracy of the responses. A request was made to the Department of Statistics for a cost estimate to perform a special hand tabulation for a random sample of 15 percent of the blocks in the planning area. Computer tabulation of the above data will not be possible until mid-1980 when the Department's computer becomes available. A hand tabulation of random sampling was not included in the scope of this report and the Department could not perform the work within the time frame required.

An alternative method of identifying the low-income areas is to conduct a sample survey, obtaining estimates of mean family income for various sectors of the planning area. This approach was rejected because it was felt that unless the means for the various subareas exhibited wide differences, large samples would be needed in order to be certain that the differences among the sample means were statistically significant. It was also thought that in a large sample survey designed to ask only a few questions of each household (including income), it would be impossible for the interviewer to establish rapport with the subjects and it would be very difficult to obtain accurate responses on the sensitive subject of income.

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The method chosen for characterizing subareas of the planning area according to economic status is a variation of the Delphi technique. A panel of individuals, using maps of the planning area, independently recorded their judgments as to economic status. Among the panel members was a staff member of the Directorate of Health, the public health specialist, the socio-economic consultant and a town planner. In the case of the first panel member, the characterization was based on familiarity with the planning area; in the case of the other members of the panel judgments were based on windshield and walk-through surveys of the area.

The classifications by the various panel members were compared and were found to be in substantial agreement. The composite map of areas according to economic status is reproduced as Plate 2.1 - 2.6.

One observation that was made by several of the panel members is that the planning area does not exhibit the degree of spatial segregation of socio-economic groups that is found in European or American cities. Dajani has reported a similar phenomenon in parts of Amman.[3] Some areas, especially those occupied by squatters, can be characterized as low or lower middle-income areas. But in other areas the process of renewal and replacement that is occurring often results in a modern dwelling of above average cost and inhabited by an upper-income family being situated next to older mud brick structures occupied by families of lower income. Thus, in many instances, it is not possible to assume a high degree of homogeneity within a given sub-area.

3.1.3 Attitudes toward Water Consumption

A survey consisting of in-depth interviews was conducted with twenty households in Zarqa and six households in Ruseifa. A description of the survey is presented in Appendix 3.1 the pertinent findings are summarized below.

There is no perceived shortage of water or problem of availability; the primary constraint on water consumption is the limited capacity of cesspools. Upper-income families use more water than lower-income families. Low-income persons tend to bathe less frequently than upper-income persons. For example, low-income persons may bathe once every ten days while upper-income persons bathe daily and, in the summertime, more than once a day. Upper-income persons bathe more frequently because of the greater convenience of having a hot-water heater and modern tubs and showers.

In low-income families, the young tend to use more water than the old. Older persons who are poor are very careful with water (especially those who come from rural areas where water is scarce), whereas their offspring who have attended school use more water to maintain cleanliness.

Clothes washing machines seem to be in use in most households regardless of income. All of the households sampled had a clothes washing machine and all respondents seemed to want to own other water-using appliances.

The squat toilet is used primarily by middle- and low-income groups, whereas flush toilets are used primarily by upper-income households. Lower-income families doubted they would be able to convert to a flush toilet because they cannot afford to do so, and because they have very limited space.

Respondents believed they would use more water to clean, wash, and bathe if cesspools were replaced by a municipal sewerage system. The estimated increase in consumption ranged between 10 and 15 percent.

3.1.4 Attitudes toward Municipal Sewerage

The twenty-six families who participated in the in-depth interviews were asked whether they favored a municipal sewerage system or continued reliance on the present method of cesspool disposal. All families, regardless of income, favored a sewerage system in Zarqa and Ruseifa. And all families indicated that they would be willing to pay whatever is required of them in order to eliminate cesspools. (No information could be given to the interview subjects as to the likely user charge, their expressed willingness to "pay whatever is required" is probably hyperbole.) Lower-income families were most concerned about whether the landlord or tenant would pay.

Although both upper and lower-income groups wanted sewers, they seemed to favor sewers for different reasons. The lower-income families believed that sewers will save them money, time, and effort in having their cesspools pumped, and avoid the municipal fines for dumping water in the street. The upper-income families seemed to be more concerned with problems of odor and disease.

In a separate social survey of Janna'ah residents (a low-income area of Zarqa), 58 percent of the households surveyed cited sewage disposal as a major disadvantage of their neighborhood.[2]

3.2 Health Conditions

A study of health conditions in the Zarqa-Ruseifa area was conducted as part of the overall feasibility studies. The purpose of the study was threefold:

(1) To identify areas having a high incidence of water-borne diseases, with the objective of setting priorities for project phasing

(2) To establish the status of present health conditions as a basis for assessing the impacts of the proposed projects

(3) To predict changes in health conditions that are likely to result from the proposed projects.

The full report of the health study is contained in Appendix 3.2 The principal findings regarding existing conditions are summarized below.

The health study emphasized gastrointestinal diseases because this category of health problems is often related to inadequate water supply and sewage disposal systems. Attention was also given to other water-based diseases, and to related health issues such as toxic substances from industrial discharges, and nitrate concentrations in the water supply.

3.2.1 Gastrointestinal Diseases

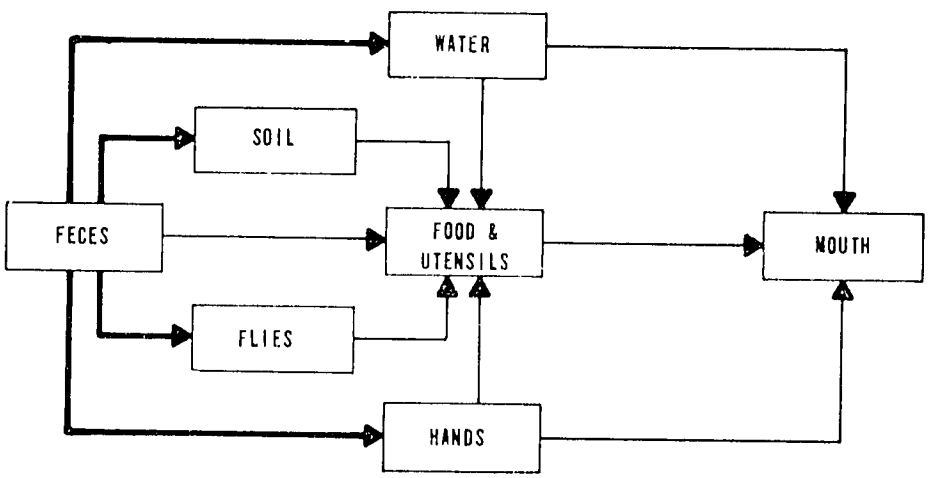
Human excreta and sewage contain a variety of micro-organisms such as bacteria, viruses, and protozoa. Raw sewage, for instance, is estimated to contain 1 million bacteria per milliliter. Some of these micro-organisms are disease-producing (pathogenic), causing illnesses ranging from mild food poisoning and diarrheas to extremely serious diseases such as infectious hepatitis, typhoid, and cholera. (Poliomyelitis and Coxsackie viruses, although not a cause of gastrointestinal illnesses, may also be present in human excreta.)

Health statistics for the Zarqa-Ruseifa area in 1977, 1978 and 1979 were obtained from the Directorate of Health in Zarqa. A review of the statistics on water-borne diseases by the public health specialist indicated that the reported cases very probably represent a significant undercount of the actual frequency of gastroenteric diseases. This impression was confirmed by the directorate staff who observed that physicians may not be reporting some cases, particularly of the less severe ailments such as enteropathogenic diarrhea.

	Number of Reported Cases		
	1977	1978	1979
Typhoid	-	53	35
Paratyphoid	-	23	6
Cholera	50	23	6
Infectious Hepatitis	-	32	30
Dysentery	-	-	1

That enteritis and diarrhea are more common than the statistics suggest is indicated by an analysis of national mortality data. Age-specific causes of death (East Bank, 1974) implicated enteritis and diarrhea in 36 percent of deaths of infants less than one year old; 26 percent of deaths for children aged one through four years; and 16 percent in all age categories combined.[4] Another survey of hospital admission statistics indicates that diseases of the digestive system are the leading health problem, accounting for 18 percent of all admissions.[5]

The improper handling and disposal of excreta and sewage can result in the transmission of these diseases via a number of fecal-oral routes as indicated by the diagram. Those pathways in which water supply, sewage disposal, and stormwater drainage may be implicated are indicated by bold lines, with other pathways indicated by light lines.



FECAL-ORAL ROUTES OF DISEASE TRANSMISSION

In Zarqa and Ruseifa, sewage is disposed of in cesspools which, because of shallow soils, are often excavated from rock of very limited permeability. If not pumped out periodically, the cesspools, commonly about 4 m^3, eventually become full and begin to overflow. Overflows occur more frequently during the rainy season. Sewage from cesspools overflows into yards and streets, where it may collect in puddles, or it may be carried by stormwater runoff to low-lying, poorly drained areas of the city where it ponds for extended periods of time. Cesspools in the vicinity of a wadi or natural drainageway may have an overflow pipe for direct discharge to surface waters.

These conditions may facilitate the transmission of disease in several ways. Liquid sewage from cesspools percolates through the rock fissures and eventually reaches the groundwater aquifer where contamination by pathogens may occur. In the Zarqa-Ruseifa area, there are two aquifers, an unconfined upper aquifer and a confined lower aquifer, the two being separated by an aquiclude. Because of direct recharge by cesspool effluent, the upper aquifer gives evidence of pollution, the lower aquifer, less so. The upper aquifer is used principally for irrigation and industrial process water where bacteriological purity is less critical. The lower aquifer is the principal source of public water supply and at the present time is of adequate quality. Water extracted from the public wells is chlorinated, which provides adequate protection as long as the chlorination process is reliable and effective.

Contamination of the potable water supply may also occur within the distribution system, and in Zarqa-Ruseifa this is a very likely possibility. Verbal information from the Directorate of Health in Zarqa indicates that the water in the distribution system gives frequent evidence of bacteriological contamination. The results of laboratory analyses of samples taken from various points in the distribution system during 1979 are summarized below:

Zarqa: 121 out of a total of 445 samples (27 percent) yielded a value for coliform organisms of 2.2 MPN/100 ml or more.

Ruseifa: 23 out of a total of 132 samples (17 percent) yielded a value for coliform organisms of 2.2 MPN/100 ml or more.

Testing for residual chlorine at various points throughout the distribution system during 1979 produced values ranging from about

1.0 mg/l at the point of chlorination to zero at the peripheral parts of the distribution system. Not uncommonly the problem of contamination is found to be associated with leaky and corroded water pipes and faulty joints that exist in the older parts of the system. This condition permits the entry of contaminants into the distribution system at times when the water pressure is interrupted for any reason. Fortunately, pressure in the system is normally continuous, although repair and replacement of pipes requires interruption of service in certain sections from time to time. Contamination may then occur by the infiltration of groundwater from soils saturated with sewage from cesspools.

Although pressures are maintained in the distribution system most of the time, the fear of water shortages during an extended drought has encouraged much of the population to employ some form of in-house water storage, such as galvanized roof tanks, barrels or other miscellaneous containers. This practice is also a potential pathway for disease. Roof tanks are often left uncovered, subject to contamination from external sources, and they are not generally cleaned or properly maintained. Water stored in barrels or other containers may become contaminated by unclean hands or utensils.

Present sewage disposal practices in Zarqa and Ruseifa may result in transmission of disease by other routes. The collection of sewage from overflowing cesspools in puddles and low-lying areas permits transmission of pathogens by flies and other vectors. Children, who may be attracted to the ponded water, may also risk infection if their hands become soiled during play.

There are, of course, other fecal-oral routes for gastrointestinal disease not involving the water supply, sewage disposal and stormwater drainage. Irrigation with polluted water from the Zarqa River (Zarqa is downstream from the Amman Wastewater Treatment Plant) or groundwater from the underlying aquifer may result in transmission of pathogens via the soil-food link. Although the risk of infection via this route can be greatly reduced by thorough washing and disinfection of leafy vegetables, it is unlikely that this precaution is practiced by every family. Poor hygienic practices and overcrowding among the poor are also undoubtedly implicated in the transmission of diseases. Lack of

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awareness, particularly among the lower socio-economic groups, about the need for handwashing before eating and food preparation, and other food handling precautions, contributes to the spread of infection. Bathing in polluted water such as the Zarqa River is another potential source of infection. Because of these multiple pathways of disease, it is not possible to determine the extent to which the lack of adequate sanitation systems is implicated.

3.2.2 Other Water-based Diseases

In addition to the water-borne diseases are water-based diseases such as malaria and schistosomiasis, in which the intermediate host depends on the availability of water. Malaria occurs from time to time in Jordan, but its incidence has been dramatically reduced since the institution of an international eradication program in 1956. The few identified cases are attributed to expatriates or to citizens returning home from work abroad.[3] Cases of the parasitic disease schistosomiasis have been reported in Jordan, usually among migrant agricultural workers who have come to Jordan from nations where the disease is more prevalent. A 1977 survey reported that 8 percent of foreign workers had urinary schistosomiasis. Colonies of vector snails have been reported and the Ministry of Health is taking measures to destroy snail colonies as they are discovered.[3]

3.2.3 Toxic Substances

There are several industries in Zarqa-Ruseifa, some of which have wastes containing heavy metals such as chrome and mercury and other toxic substances. In the absence of comprehensive studies and reliable analytical data on the presence of these substances in the drinking water supply, it is not possible to express a candid opinion on the degree of health risk. The potential hazards involved in the use of water contaminated by toxic industrial wastes cannot be ruled out. A more likely hazard than contamination of the aquifer is an eventual accumulation of toxic substances in the King Talal Reservoir.

3.2.4 Nitrates

Nitrates are a product of the decomposition of human wastes; in Zarqa and Ruseifa, cesspools are one source of nitrates and aquifer recharge by cesspool effluent may increase nitrate concentrations. The presence of excessive nitrates in drinking water can be hazardous to infants under three months of age. Under certain circumstances, nitrate

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can be reduced to nitrite in the gastro-intestinal tract; the nitrite then reacts directly with hemoglobin to produce methemoglobin, with consequent impairment of oxygen transport.

The World Health Organization permissible limit of nitrate concentration in drinking water is 45 mg/l. A preliminary study of 110 wells in the metropolitan region of Amman during 1973 to 1975 revealed that most producing wells along the Zarqa River are threatened by increasing concentration of nitrate (6). More than 43 percent of the wells tested had a nitrate concentration in excess of 45 mg/l.

More recent studies (7) indicate high nitrate concentrations near the Zarqa River, particularily around workshops and industrial locations. Frequent observations have shown the consistent high levels of nitrate percolating mainly into the shallow aquifer in the region. In general, the nitrate concentrations in the shallow aquifer averaged more than 100 mg/l. A study of the nitrate concentrations in the lower aquifer shows a sharp drop in nitrate concentrations to about 10 mg/l. These wells demonstrate that the lower aquifer is protected hydrogeologically from nitrate percolation.

There has been little reported occurrence of methemoglobinemia. This is believed to be due to: 1) the municipal wells are in the lower aquifer, 2) physicians may fail to associate the symptoms with high nitrate concentrations, and 3) the general custom of breast feeding of infants.

3.3 Criteria for Priority Staging

The objectives of the feasibility study, as defined in the agreement, specify that the consultant make recommendations for location and phasing of water and sewer services, taking into consideration the frequency of water-borne diseases, the adequacy of existing water and sewerage services, and areas with low-income population.

3.3.1 Health Criteria

There are severe limitations inherent in basing project priorities on present health conditions. The available health statistics do not permit identification of geographic areas of the Zarqa-Ruseifa area having high, low, or average incidence of water-borne diseases. Secondly, they do not permit identification of the method by which exposure to disease occured. Of the several possible fecal-oral routes by

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which gastroenteric diseases are transmitted (water supply contamination, food, hands), only some are amenable to control through improved sanitary systems, while others involve control of vectors such as flies and rodents, or changes in personal hygienic practices. Consequently, it was concluded that it is not possible to identify those areas of greatest health risk on the basis of available health statistics or other sources of information.

3.3.2 Adequacy of Existing Systems

The second criterion considered is the adequacy of existing water and wastewater disposal systems. Almost all residents of the planning area have access to piped-in public water supply, with the exception of some households located at higher elevations who must rely on water tankers for their supply. It is reported that pressures are maintained in both systems at all times and that the present supply is adequate. Consequently neither community is without water service for extended periods of time, as is the case in Amman.

Much of the distribution system has, however, been built through individual initiative and reflects the expediency of this type of ad hoc construction. Renovation of the system according to rational principles would reduce leakage and improve pressures (the latter becoming important if roof tanks are to be eliminated eventually). Portions of the Zarqa distribution system have suffered severe corrosion and these mains are currently being replaced. Bacterial contamination within the distribution system has also been observed.

Wastewater disposal in the planning area at present is by means of cesspools and the problems caused by this method of disposal have been cited previously. The problems of odor and cesspool overflow occur throughout the planning area, and are indicative of the inappropriateness of this method of disposal in a community of high population density and poor subsurface conditions. No data are readily available that would permit identification of areas having the most frequent or severe problems. Criteria that might have a high predictive value in identifying the most critical problem areas are related to absorption capacity and pollution risk, and include the following:

- o areas of shallow bedrock and low soil permeability
- o areas with steep slopes
- o areas of highest population density

- areas with the oldest systems
- areas in proximity to shallow wells or surface water
- systems that employ direct surface water discharge.

Of these criteria, population density and age of systems are the easiest to apply and will be taken into consideration in the selection of priority areas.

3.3.3 Low-income Areas

The projects under investigation are characterized as "basic human needs" projects. Because the need for a safe water supply and effective sewage disposal cuts across all income groups, it might be argued that the public health criterion is more valid than income. Two exceptions may be raised. If the proposed sewerage system results in substantially lower costs than the present disposal system, the savings will be more significant for low-income groups than for upper-income groups. At the outset of the study, this outcome is not immediately clear, however. Secondly, if the improvements lead to increased water consumption and, if one assumes the consequence to be improved sanitation among low-income families, then greater health benefits might be expected. A third reason for using low income as a criterion, would be the possibility that limited financial resources will prevent extension of sewerage to all urbanized parts of the planning area, in which case, upper income areas could be given lower priority than low-income areas. One drawback to a scheme that gives priority service to low-income areas in that such areas in Zarqa and Ruseifa are widely scattered and thus the cost per household served would be higher than for a compact service area which expands incrementally.

3.3.4 Selected Criteria

Because most of the planning area households are presently served by public water, priority will be given to improving water service to those households that are not adequately served. Elsewhere, modifications will be made to the distribution system to correct present deficiencies and to meet projected water demands. Installation of sewers in narrow footpaths will likely require replacement of existing water pipes, with staging determined by phasing of sewer construction.

The criterion selected for phasing of sewer construction is based on the optimization of benefits to costs. Benefits will be simply expressed in terms of cost per persons served. As indicated in Section 3.3.1, there is not sufficient information available to express benefits by subareas in terms of a reduction in the incidence of disease.

The criteria for phasing of the stormwater projects are discussed in Chapter 8.

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Best Available Document

The B1/2 unit overlies the A7 and consists of chalk, marl, limestone, chert, and phosphate beds that range in thickness from 80 to 115 meters. The cherty portions of the formation are characteristically folded and commonly are found in the study area, especially in the vicinity of Zarqa. In addition to its important aquifer characteristics, the B1/2 unit provides economic benefits through the mining of phosphorus. Two of the larger mines are located south of Ruseifa. These mines, as well as other exposures of the phosphatic beds, may increase phosphorus loadings to surface waters by runoff.

The A4 or Hummar formation forms the lower confined aquifer and is separated from the upper aquifer by 75 to 100 meters of massive limestone. The A4 unit mainly consists of 40-60 meters of crystalline, dolomitic limestone that is occasionally highly fractured. It gradually thins out and becomes increasingly marly towards Zarqa which decreases its water bearing properties. Outcrops of the A4 formation occur northwest of Zarqa at Sukhnah and Nimra.

In addition to these older sediments, recent alluvial deposits cover much of the study area near the Zarqa River and associated side wadis. The composition and depth of the deposits vary considerably, but 30 to 50 meters of material can occur in the area from Zarqa to Sukhnah. Alluvial deposits are known to provide for subsurface flow of the Zarqa River during summer months when the river becomes dry.[1]

The dominant geological structure in the area is the Amman-Zarqa syncline, which begins southwest of Amman and plunges northeastward to Zarqa. The syncline is responsible for the marked topographic relief to the northwest and southeast of the Zarqa River where slopes of 20 to 30 percent are common. In addition, the syncline has an important effect on ground-water flow as it controls the direction of flow from west to east. With the exception of the B1/2 unit, all formations are parallel to the syncline. The slope of the northwest limb has an average slope of 3 to 5 percent, while the southeast limb has slopes of 20 to 40 percent.

Associated with the syncline is the Amman-Zarqa flexure, which is a transition zone between the syncline and anticline. The flexure occurs southeast of the Zarqa River in association with a system of faults, and serves as the southeast boundary of both aquifers. Folding and faulting activities within this area have created a zone that is more permeable than other bedrock areas.

Previous soil mapping of East Jordan has categorized soils of the study area as mainly yellow Mediterranean (YM) and Red Mediterranean (RM) soils.[2] The YM soils are extensive throughout the area from Amman to Zarqa. Red Mediterranean soils occur at the extreme western boundary of the study area and continue westward to the Jordan River. To the east of Zarqa, soils are classified as grey desert soils which are infertile and contain high concentrations of salts.

The effect of precipitation on soil-forming processes is responsible for the major differences between the YM and RM soils. Red Mediterranean soils have developed in areas where rainfall averages more than 300 mm per year, while YM soils formed under drier climatic conditions (150 to 300 mm per year). Consequently, leaching of soluble materials has occurred to a lesser extent in the YM soils. They are characteristically shallow to bedrock where the occur on steep slopes. However, YM soils that have developed in the valleys and along the base of hillsides generally are deeper than the sloping soils as a result of deposition from upland erosion. These soils have free calcium carbonate accumulation within 30 centimeters (cm) of the surface. The pH of YM soils can be expected to range from neutral to moderately alkaline, depending on the depth to carbonates. In addition, these soils have a high corrosivity potential for uncoated steel because of salt accumulations throughout the profile.

The RM soils have similar characteristics, but are usually leached to a greater depth than the YM soils. Depth to carbonates is usually greater than 30 cm, and the profile may show signs of clay accumulation. As with the YM soils, RM soils are shallow to bedrock where they occur on steep slopes.

Both the RM and YM soils are extensively used for agricultural production in Jordan because of their natural fertility. Although irrigation would increase yields and enable a greater variety of crops to be grown, especially on YM soils, precipitation is usually adequate for most small grain crops. The most important agricultural soils within the study area are the alluvial soils found along the Zarqa River and side wadis. Their fertility, depth and proximity to irrigation water make these soils extremely desirable for high-yielding agricultural production. Furthermore, the relatively level alluvial soils have less erosion potential than the adjacent upland soils. Unfortunately, tracts of marginal sloping soils have been put into

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agricultural production as population pressures increased over the years. Erosion from these areas is a serious issue which decreases yields and aggravates water quality problems.

Most soils in the Zarqa-Ruseifa area are poorly suited for individual on-site wastewater disposal systems which rely on subsurface soil absorption. The densely developed hillsides have very shallow soils, and as a result, many disposal systems are constructed with little or no soil beneath the disposal area. Consequently, wastewater reaches the ground water without adequate treatment and contaminates the upper aquifer.

Where slopes are less than 12 percent, the YM and RM soils should be suitable for land application of wastewater or sludge provided that rock is deeper than one meter from the surface. Although no permeability data are available for these soils, it is expected that both possess favorable hydraulic properties for land application of wastes. Salt concentrations in the soil and waste may limit loading rates, depending on crop tolerances to salts. Other soil properties such as pH, cation exchange capacity and grain size distribution should be investigated prior to waste applications.

4.3 Climate and Air Quality

Climate within the study area is characteristic of the western fringes of the inland desert, where conditions are generally arid. The most distinctive feature of the Zarqa-Ruseifa climate is the concentration of rainfall in the cool winter and the drought conditions of the summer. Records indicate that from 1937 to 1973 annual rainfall in Zarqa ranged from 39 mm to 280 mm and averaged 131 mm, and in Ruseifa it ranged from 42 mm to 303 mm and averaged 155 mm, with virtually all of the rainfall occuring between the months of October and April.[1] The coldest and hottest months in the study area are January and August, respectively, with the recorded temperature range extending from 2.5°C to 39°C and a mean annual temperature of 17°C.[2,3] The average annual relative humidity at the Amman airport is 52 percent.

Air quality data are not available for the study area. However, the Zarqa-Ruseifa region contains a variety of industrial facilities including: beverage plants; phosphate mining and processing; paint and detergent production; textile plants; pulp and paper processors;

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dairies; distilleries; and chemical and petroleum refiners. These industries, in conjunction with motor vehicle emissions and wind-borne dust, comprise the significant sources of suspended and settleable particulate matter which is the main air pollutant associated with the study area.

4.4 Water Resources

Water resources and their limited availability are a major concern in the Zarqa-Ruseifa region. This concern can be largely attributed to several factors affecting the region's water resources. As previously mentioned, the area is characterized by a dry arid climate. Rainfall is concentrated in the winter months, with the summer months generally receiving no rainfall. In addition, wide fluctuations in annual rainfall make water planning efforts very difficult. Intermittent streams, known as wadis, are common in the study area and constitute the major portion of surface water system. These streams, including the Zarqa River above the Sukhnah springs, dry up during the summer months. During this period surface water is unavailable to the Zarqa-Ruseifa area except through several local springs. The primary water source for the study area is groundwater.

The study area's water resources are composed of three major features: the upper and lower groundwater aquifers; the Zarqa River; and the King Talal Reservoir. Each of these components is discussed separately below.

4.4.1 Ground-water Resources

Ground water in the Zarqa-Ruseifa area occurs mainly in two aquifers. The shallow, upper aquifer is unconfined and as such, the water level is free to rise and fall in response to seasonal fluctuations. The lower aquifer is separated from the upper by a layer of massive limestone. This is a confined condition in which the water level fluctuates in response to piezometric pressures.

Recharge to the upper aquifer occurs by direct and indirect infiltration of rainfall, and by artificial recharge from sewage effluent, leakage from public water supply lines, cesspools and by return irrigation water. VBB [1] estimates that 20 million cubic meters per year (Mm^3/y) infiltrates to the upper aquifer by natural recharge, and

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28 Mm^3/y by artificial recharge. Some recharge takes place by direct infiltration throughout the Zarqa-Ruseifa region where outcrops of the B1/2 and A7 formations commonly occur. However, larger volumes of water reach the upper aquifer by indirect infiltration through alluvial deposits of the Zarqa River and associated side wadis.

Unlike the upper aquifer, recharge of the A4 formation occurs mainly by direct infiltration in the outcrop areas. Outcrops of the A4 formation northwest of Amman are the major recharge zones for the lower aquifer. Total recharge of this aquifer was estimated as 5 Mm^3/y by VBB.

Groundwater flow in both aquifers is controlled for the most part by the Amman-Zarqa syncline and flexure. From the areas of recharge, water flows northeastward along the syncline until Awajan, where the flow then turns northward. The primary natural discharge area for both aquifers occurs at Sukhnah Spring, approximately 7 km northwest of Zarqa. At one time this spring was the source of the perennial section of the Zarqa River, but because of heavy withdrawals in recent years, the river runs dry during late summer. However, investigations by VBB indicate that subsurface flow continues in the streambed during the summer.

Other important springs in the area include Ras el Ain, Zarqa, Ruseifa and Zarbi Springs. Each of these springs discharges water only from the upper aquifer. The Ras el Ain Spring, located west of Amman, forms the headwater of the Zarqa River. Average annual flow from this spring during the period 1937-1967 was 100 liters per second (l/s); however, current flow rates are probably less as a result of increasing withdrawals. The Zarqa Spring, which at one time had the highest average flows of all springs in the area, now becomes dry during the summer. Although there are no recorded flows for the Ruseifa Spring, VBB has estimated a mean flow of 2 Mm^3/y. The Zarbi Spring has a mean flow of 19.7 l/s. Total mean spring flow estimates for the entire Upper Zarqa area is 15.4 Mm^3/y from the above springs plus several smaller springs and seeps. (2) The springs have experienced marked flow reduction during recent years.

Several studies have attempted to define a water balance for the Upper Zarqa Basin. The more recent projects have estimated ground-water withdrawals from 160 producing wells in the area as about 31.6 Mm^3/y from the upper aquifer and 9 Mm^3/y from the lower aquifer. (3) Since

total recharge to the lower aquifer is estimated as about 5 Mm^3/y, it appears that there is an overdraft of approximately 4 Mm^3/y from the lower aquifer. Apparently, the resources of the upper aquifer are not being overexploited as a result of the large amount of artificial recharge. Some of this artificial recharge is in fact coming from wells which penetrate the lower aquifer and ultimately recharge the upper aquifer. Consequently, long-term water level observations of the lower aquifer have shown declines of up to 10 meters per year, while the upper aquifer level has stayed essentially the same. (4) It has been estimated that total safe yield from both aquifers is 20 Mm^3/y, based on 25 Mm^3/y of natural recharge and 5 Mm^3/y of baseflow at Sukhnah Spring. (5)

Depth of wells varies considerably from the shallow, hand-dug wells along the Zarqa River, to wells deeper than 200 meters which withdraw water from the lower aquifer. Of 162 wells producing in 1976, 123 penetrated the upper aquifer and 39 the lower aquifer. Many of the wells that were drilled into the lower aquifer remove water from both aquifers. In the area from Ruseifa to Zarqa most wells are shallow, hand-dug holes (less than 20 meters) with yields less than 10 cubic meters per hour.

Ground-water quality of the upper aquifer in the Zarqa-Ruseifa area has been degraded recently as a result of urban and industrial growth. Chemical analysis of well water during 1976 noted significant increases in total dissolved solids (TDS), chlorides and nitrates when compared to earlier tests (1971). (6) These parameters are used generally as indicators of domestic sewage contamination. The mean values of upper aquifer wells in the Zarqa - Sukhnah area sampled during 1976 for the VBB report had average nitrate concentrations of 36.6 milligrams per liter (mg/l), chlorides of 187 mg/l, and TDS of 790 mg/l. Analysis of ground water was not conducted prior to urbanization of the area; however, it has been estimated that under natural conditions chloride content was 20 milligrams per liter (mg/l) or less and TDS was about 230 mg/l. (7) The World Health Organization (WHO) has set the maximum allowable nitrate concentration in drinking water at 45 mg/l. Although the VBB analysis indicates ground-water nitrate concentrations of 36.6 mg/l, it is reasonable to assume that concentrations have increased since 1976 because of additional urban development, and are approaching or have surpassed WHO recommendations.

Bacteriological data are scarce for wells in the area. Limited studies of 46 wells from Amman to Zarqa indicate that 20 wells had more than 16 coliform bacteria per 100 milliliters on a statistical basis (most probable number).[8] WHO standards recommend that maximum levels of coliform bacteria should not exceed 16 organisms per 100 ml in drinking water. For this reason all municipality water is chlorinated before distribution.

4.4.2 Zarqa River

The Zarqa River and its tributaries comprise the only significant running water environment in the region. The headwaters of the Zarqa River are located just west of Amman and flow northeast to Zarqa. From Zarqa, the river changes course and flows north to Sukhnah, where it is met by Wadi Dhuleil, a major tributary. Turning westward the river continues until it flows into the Jordan River. Located throughout the Zarqa-Ruseifa area are springs which feed into the river. These springs include the Ras el Ain Spring, just west of Amman; the Zarbi, Ruseifa, and Zarqa Springs in the Zarqa-Ruseifa area; and the Nimra, Husayya, and Sukhnah Springs in the Sukhnah area. In recent years, increased withdrawal from these springs and the aquifers supplying them has resulted in considerable reductions in their discharge levels.

Flow records from the Sukhnah gaging station indicate that the mean monthly flow for the Zarqa River at Sukhnah Springs is 733.6 m^3/hr, with a maximum flow of 1303 m^3/hr (occurring in November 1969), and a minimum flow of zero. On several occasions (October 1978 and September 1979) there was no flow at the gaging station. With the exception of the zero base flow, this information was obtained from records previous to 1976, which is significant since water demand in the Zarqa-Ruseifa area has increased markedly over the past several years. In addition, the Zarqa River is intermittent from its headwaters to Sukhnah, with the river drying up during the arid summer months.

The only available stream flow information for the vicinity of the City of Zarqa are calculated data from the "National Water Master Plan of Jordan," which predicts annual flows of 33.52 Mm^3/y for a wet year and 24.24 Mm^3/y for an average year. Comparison of this data with the Sukhnah gaging station records reveals significant differences. The predictions for the Zarqa vicinity are three to four times greater than

the Sukhnah records. The higher flows estimated for the Zarqa area may be accounted for by the Zarqa River's intermittent flow between Zarqa and Sukhnah, with virtually zero flow for eight to nine months annually. In addition, when surface flows do occur in the Zarqa area, the flow is dramatically reduced by irrigation projects, evaporation, and upper aquifer recharge via river bed seepage.

Analysis of the Zarqa River water quality is difficult due to the general lack of data pertaining to the river's water quality characteristics. For this reason the discussion concerning water quality will be general.

The various industries in the study area and the Amman sewage treatment plant are continuously discharging nitrogen compounds, oxygen demanding substances and a variety of inorganic compounds, including heavy metals.[9] Agricultural runoff from irrigation contributes phosphorus and nitrogen compounds and pesticides. In addition, the runoff from the phosphate mines in the Ruseifa area is heavily laden with phosphorus compounds. Deposits of nonsoluble pollutants on the stream bed occurs annually, since all of the above mentioned discharges originate along the intermittent section of the river. When the river flow increases during the wet season, these deposited pollutants are then carried downstream, causing a higher pollutant load at this time of the year.[10]

Pollution of the Zarqa River is of concern because the river is a source of both potable and irrigation water. Agricultural efforts in the study area require irrigation and the Zarqa River is the only source presently capable of providing sufficient quantities for such projects. Shallow river bed wells in conjunction with deeper wells (approximately 200 meters) in the area are utilized for a variety of purposes including industrial and agricultural activities, as well as drinking water. One well of particular significance is located in the vicinity of the Amman sewage treatment plant. This well is employed to fill tanker trucks, which then distribute the water for domestic use. The effluent from the sewage treatment plant enters the river at this point. There is no indication that any precautions are taken to determine if the well's water is safe to use as potable water. Public health hazards caused by the utilization of the Zarqa River for agricultural projects and as drinking water are a very real problem for the inhabitants of the study area.

One report has suggested using the Zarqa River for fisheries.[11] The sites discussed by that report are located below the King Talal Reservoir, and although these sites are a considerable distance from the study area, the water quality of the Zarqa River would have a significant effect on such a fisheries project. The numerous discharges that are currently released into the Zarqa River in the study area would probably have an adverse impact on any fisheries in the Zarqa River.

4.4.3 King Talal Reservoir

The King Talal Reservoir, formed by the damming of the Zarqa River in its lower course, is located between the Balqa and Ajlun Mountains, southwest of Jarash. It has an estimated storage capacity of 48 to 52 million cubic meters (MCM) and at maximum pool level covers an area of 2.6 square kilometers (Km^2).[12] The reservoir provides water for the East Ghor Canal and is intended to furnish water for irrigation projects.[13] It has also been projected that the Amman-Zarqa area may receive a portion of its drinking water from the King Talal Reservoir.

However, significant water quality problems associated with the King Talal Reservoir threaten to jeopardize all of these uses. The waters flowing into the reservoir via the Zarqa River contain a variety of pollutants, including phosphates, industrial wastes (toxic end-products), treated and untreated sewage, and heavy metals. The influx of phosphorus compounds into the reservoir results in eutrophication, with related dissolved oxygen problems and algae blooms. The eutrophic conditions combined with the presence of numerous pollutants will severely impact the reservoir's water quality. The impact of the reservoir's poor water quality is not limited to irrigation and potable water uses. It will additionally restrict or eliminate the potential for fisheries projects.

4.5 Ecosystems

4.5.1 Terrestrial

The study area is located in a transition zone between two distinct habitat types: the Mediterranean Region and the Saharo-Siadian Region. Generally covering a small portion of the study area, the Mediterranean Region is typified by the Amman area. This area is capable of supporting forests and agricultural activities, primarily

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because of the annual rainfall it receives, approximately 250 mm to 400 mm. Natural forests occuring in this region are composed of oak, pine, juniper, wild olive, and cypress.[1] However, severe reductions in the size of these natural forests have occurred as land is cleared for industry , agriculture, lumber, and firewood. Government sponsored programs have successfully reforested some areas, principally with pine. Where agricultural activities occur crops and their associated weeds have supplanted the indigeneous flora communities. Over-utilization of these lands is another major problem, particularly during droughts when overgrazing by goats frequently results in extensive damage to the plant life and severe soil erosion.

The Saharo-Sindian Region is the most extensive habitat type found in the study area. This habitat, also referred to as steppe grassland or brushy steppe, is characterized by dwarf shrubs and herbaceous species. Utilized principally as grazing lands, the annual rainfall in this area generally ranges from 40 mm to 250 mm.

Within these two habitat types are agricultural lands that are concentrated in the river bottoms. Virtually all of the agricultural lands are located along the Zarqa River, which is used for irrigation. The crops consist primarily of vegetables (tomatoes, onions and peppers). Encroachment in the river bottom areas by the industrial and residential components of the region has resulted in substantial reductions in the availability of land for agricultural uses.

Major wildlife forms native to this region, have been extirpated from the study area, as a result of industrial, agricultural, mining and residential development. In addition, uncontrolled hunting between 1930 and 1960 and overgrazing by livestock resulted in the extermination of many of Jordan's larger game mammals, including the Arabian oryx, Onager and Asiatic lion.[2] The mammals most likely to occur in the study area include the hare, shrew, bat, and several varieties of rodents.[3] Other forms of wildlife occuring in the study area include: birds (pigeons, ravens, grouse, partridges, quail and hawks); reptiles (lizards, snakes, skinks and chameleons); and amphibians, such as frogs in the wet areas along the Zarqa River. No endangered species are believed to exist in the Zarqa River basin.[4]

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4.5.2 Aquatic

The significant aquatic ecosystems in the study area are the Zarqa River and the King Talal Reservoir. The Zarqa River, known locally as Wadi Seil or Seil Zarqa, provides a running water environment for the region. Currently, the flow of the river is intermittent during the summer months from Zarqa to Sukhnah. Discharges from the Amman sewerage treatment plant and the numerous industrial facilities along the river have severely impaired the river's water quality.[5]

Specific information on fish and invertebrates such as populations or a species listing, is not presently available. However, it is reported by the University of Jordan that fish and invertebrates do inhabit the Zarqa River. Major freshwater fish species, that are indigenous to Jordan and can be expected to inhabit running water environments, include carp, tilapia, barbel and Nile catfish. It has been suggested that fisheries development in Jordan should include the construction of cement tanks for the cultivation of carp at the Sukhnah springs.[6] However, in terms of commercial and recreational fishery activities, the Zarqa River is currently of no importance.

Since the King Talal Reservoir (KTR) is still filling,* information pertaining to its water quality and fisheries potential is incomplete. However, as several reports have indicated, the water quality of the KTR is already substantially impaired and it appears that this condition will worsen as the reservoir reaches capacity.[7] The King Talal Reservoir's poor water quality is directly attributable to the heavy pollution of the Zarqa River, which was dammed to form the KTR. Eutrophication of the reservoir has been observed (1978) and is expected to continue, since the natural background phosphorus levels of the Zarqa River are more than adequate for the development of such conditions. In addition, seasonal changes in the thermal stratification of the reservoir effect the availability of algal nutrients.[8] The hypolimnion or deep water layer will probably be devoid of oxygen during the summer and fall, thereby limiting the volume of water available for fisheries use. The Jordan Valley Authority advises that there has been no effect on the carp brought in for recreational purposes due to pollution in the reservoir.

* Filled winter 1979-1980.

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4.6 Archaeological Resources

Human occupation of the area encompassed by modern-day Jordan has spanned a period of approximately 100,000 years from the lower Paleolithic through the Ottoman periods. Jordan contains some 800 known archaeological sites, including major sites from the Neolithic period, the Bronze Age, the Iron Age, the Hellenistic Age, the Nabatean Civilization, the Roman period, the Byzantine Empire, Early Islam, the era of the Crusades, and the Turkish occupation.[1]

Conversations with the director-general of the Department of Antiquities and the director of the American Center for Oriental Research (ACOR) indicate that, although excavations of limited scope have been conducted, the planning area has not been thoroughly or systematically studied.[2,3] Collections of prehistoric materials have been found along the Zarqa River and although intensive cultivation within the wadi has obliterated surface evidence, it is considered likely that alluvial deposition over time might contain paleolithic age materials at depths of several meters.[3] Some specimens of Late Bronze Age pottery (1600-1550 B.C.) have been found in Zarqa, and it is expected that Bronze Age material is likely to be found, even in built-up and paved over areas.[2]

A survey of sites in Eastern Palestine by Glueck[4] in 1937 lists four sites that are located within the planning area. Glueck describes one site, called Qereujat Hadid, as a large, completely destroyed site, spread over a considerable area. The site's location is indicated as several hundred meters south of the village of Zarqa on the east side of the Wadi Zarqa, near the Zarqa Spring. This location would appear to be the same as the present-day community of Janna'ah. Glueck reported the discovery of several Early Iron Age sherds, but found no ruins that could be attributed to that period. He judges the site to be a particularly important site in the Roman period.[5] On the west bank of the Zarqa River is a site called by Glueck Khirbet Umm Beida. Describing it as a small, completely destroyed site on the top of a hill, Glueck notes that the rujm were in such a ruined state that no conclusions with regard to their time of origin could be made, and no sherds were found to help indicate during which period or periods the site had been occupied. Glueck's description places the site near the western edge of the planning area.[6] A third site, called by Glueck er-Reseifeh, occupies a large, high hill north of Shnellar Camp and

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west of Musheirfeh. The site was once completely surrounded by a great wall, most of which has disappeared, but other stone structures remain. Glueck judges the construction to date from the Early Iron Age, and reports the discovery of sherds from the Early Iron Age (I and II), and early Byzantine and medieval Arabic periods.[7] The fourth site, which Glueck calls Rujm Wanani, appears to be present-day Jebel Faisal (west of the Shnellar Camp). The rujm is a small, completely destroyed block house situated on top of a hill. By it was found a small number of EI-I-II sherds and several Roman sherds.[8]

The Archaeological Map of the Hashemite Kingdom of Jordan indicates that the Roman Road from Busrah in Syria to Aqaba passed through Zarqa and Ruseifa. The precise location of the road in these two communities is not known, but it is expected to be near the present-day Amman-Zarqa Road and the Wadi Zarqa. The map also shows a historic structure in central Zarqa called Qasr Shibib.[9]

4.7 The Man-Made Environment

4.7.1 Land Use Patterns

The cities of Zarqa and Ruseifa form an urbanized corridor that extends northeasterly along the Zarqa River from Amman. The original impetus for Zarqa's growth is attributed to the presence of the army base which borders the city on the east, with initial settlement occurring between the army base and the Zarqa River. Over the years the city has grown in a northerly and westerly direction, and to a lesser extent to the south. The City of Ruseifa was initially a settlement on the steep southern slopes of the Zarqa River and its growth has been stimulated, in part, by the development of the phosphate mines to the south. Over the past 10 to 15 years, the two cities have acquired their linear configuration as urbanization, usually squatter settlements, has proceeded along the slopes north and west of the Zarqa River.

The Zarqa River, which has long been under cultivation, is subdivided into numerous small farms that produce vegetables for the region. Over the years, industrial development has encroached on the agricultural land of the wadi between Zarqa and Ruseifa, most likely to take advantage of the shallow groundwater aquifer as a source of water

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supply and the proximity to the old Amman-Zarqa highway. In recent years, government agencies have tended to discourage further industrial development along the Zarqa River, and newer industries are now locating on the upland areas south of Zarqa that are served by the new Amman-Zarqa highway.

Much of the commercial activity in the planning area is concentrated in the central business district of Zarqa, an area of about 50 hectares directly east of the army camp. Elsewhere in the planning area, smaller scale commercial activity is found intermingled with residential uses. Open space uses such as parks or conservation areas constitute only a minor fraction of the total land area in Zarqa and Ruseifa.

4.7.2 Building Types and Urban Development

The cities of Zarqa and Ruseifa exhibit a variety of urban settlement patterns, reflecting different topographic conditions, historical origins, and the effects of subsequent redevelopment. The older areas of Zarqa, built on a gently sloping terrain, are organized in a grid-iron layout with blocks ranging in length from 120 to 200 meters and depths of 50 to 100 meters. A typical block is further divided by narrow footpaths, generally one to two meters in width, which provide access to dwellings on the interior of the block. The characteristic housing type in these areas is the typical Arab court-style house, a rectangular walled area with a single-story dwelling (occasionally two stories) along one side and an open court for laundry and other domestic activities. Some of the older dwellings are of mud-brick construction, and over time these have been modified, improved, or replaced with modern construction materials such as concrete block and poured concrete. Around the perimeter of the block are usually two-story and occasionally three-story structures of modern poured concrete construction often with stone facing. The first floor of the structure is often devoted to some type of commercial activity while the upper floors are usually occupied as residences. Some high-rise construction (3 to 5 stories) has begun to occur in central Zarqa, presumably the result of rising land values as the city grows and matures. In the newer areas on the north side of Zarqa, residences are more likely to be free-standing, individual structures placed in the middle of the building lot. The newer dwellings are of poured concrete,

column-and-slab construction with block walls, usually two stories in height with provisions for additional stories at some future date. This process of incremental construction is a characteristic one for many families for whom no mechanism of housing finance exists; consequently the homeowner builds in stages as his personal savings permit.

Ruseifa and those areas of Zarqa on the west bank of the Zarqa River are, in large part, squatter settlements built on areas of rugged terrain with slopes ranging from 10 to 20 percent. The street patterns are generally more random than in central Zarqa, reflecting the difficult terrain and the ad hoc, expedient process by which these settlements have developed. As in some of the older parts of Zarqa, many dwellings do not front on a public street, but obtain access via narrow footpaths that penetrate the larger blocks. Because of the limited financial resources of the squatters (and the impossibility of obtaining mortgage financing on illegal development), dwellings are built in stages, often one floor at a time. Densities are characteristically about 300 to 350 persons per hectare.

4.7.3 Transportation

Because of the limited financial resources of much of the study area population and the high import duties placed on automobiles, car ownership is not widespread among families in Zarqa and Ruseifa, but generally confined to upper and middle-income households. The compact nature of the two cities makes walking feasible for many persons and fixed-route service taxis are available for longer trips. Consequently, motor vehicle traffic is fairly light on most streets with the exception of the central business district and a few major thoroughfares. In some areas of Zarqa and in many areas of Ruseifa the streets have not yet been paved.

CHAPTER 4

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5.0 WATER DISTRIBUTION

5.1 Existing System

5.1.1 Municipal Supply

The Zarqa water supply is from groundwater extracted from wells located to the north of the city along the Petroleum Refinery Road. There are three wells, known as S14, S14A and S16 which have the following characteristics:

Source	Capacity	Diam	Total Depth	Static Water Level
S14	300 m^3/hr	12" Casing	238 m.	70 m.
S14A	300 m^3/hr	10" Casing	281 m.	74 m.
S16	130 m^3/hr	10" Casing	113 m.	58 m.

A new well with an estimated capacity of 150 m^3/hr is being drilled on the southeast side of the city near the vegetable market. It will be connected to the reservoir on Jebel Al Abiad which is under construction. The new well has a 12" casing and was initially sunk to a depth of 80 m. The static water level was 18 m. The first tests showed high nitrates in the water. This was not unexpected since the well had been sunk only as far as the upper aquifer. The well is now being sealed from the upper aquifer and driven into the lower aquifer.

After the new well becomes operational, the total supply capacity will be 880 m^3/hr which is 21,120 m^3/d. These are maximum capacities as governed by the well pumps. The well pumps are generally close to the sustained capacity of the well.

The Ruseifa water supply is from groundwater extracted from two wells located near the Zarqa River. Well No.1 is on the south side of the wadi near the Hussein Industrial City mosque and well No. 2 on the north side of the wadi in farm land about 1 km northwest of well No. 1. Each well has a pumping capacity of about 150 m^3/h , thus, the total supply capacity is 7,200 m^3/day.

5.1.2 Industrial Supply

Industrial supply is from both the municipal systems and private wells. Records at the municipal water departments show that, in 1979, 607 m^3/d was supplied to industries from Zarqa and 69 m^3/d from Ruseifa.

During the industrial survey, we inquired concerning the amount of water which was supplied to each industry from private sources. Some industries had good data on their water use and others were uncertain. Based on evaluation of the information received, it is estimated that private industrial use, in 1979, was 4604 m^3/d in Zarqa and 2955 m^3/d in Ruseita

5.1.3 Treatment and Water Quality

Since the water for both Zarqa and Ruseita is groundwater, the only treatment is chlorination. The normal dosage is 1.5 to 2.0 mg/l. The chlorine dose applied in emergency cases is 2.5 mg/l. Testing for residual chlorine is carried out routinely at various points throughout the distribution system. In general, test results range from 1.0 mg/l near the point of chlorination to 0 at the peripheral parts of the distribution system.

The bacteriological quality is checked routinely by the Ministry of Health at the sources and at the taps in various location in the cities. The analyses are performed according to the World Health Organization (WHO) standard. In 1979, about 27 percent of the Zarqa samples showed bacteriological contamination. The Ruseifa analyses for 1979 indicated that 17 percent of the samples were contaminated. The majority of Zarqa samples were taken during the summer months when there was a cholera problem. These samples are taken at customer taps and are a good indication of the tap water quality of the sampled customer.

In general, each customer has a roof tank to store water for emergency use. House plumbing is arranged so that the water from the mains flows to the roof tank. In many cases, the tanks are open. These tanks are a source of contamination. Thus, the water sampled at the customers tap is not a true indication of the water quality in the distribution system. Other possibe sources of bacteriological contamination are the leaky and corroded water pipes in the older parts of the cities and failure to disinfect after pipes repair.

When contamination is found, remedial action includes increasing the chlorination dosage to the system and/or requesting that the individual tanks be cleaned and covered. However, it must be concluded that bacterial contamination do exist in both systems.

Chemical analysis show that all well water is within the WHO drinking water standards and the Total Dissolved Solids range between 400-750 mg/l and pH from 7.00 to 8.00. The most recent chemical analyses for the Zarqa and Ruseifa wells are shown in the Table 5.1. These analysis were taken in 1 77 and illustrate the infrequency of testing. There are no standards for boron and we believe that the chemical quali of the water currently supplied to Zarqa and Ruseifa is satisfactory. The source of all operating wells is the lower aquifer and, thus, the pollution present in the upper aquifer does not generally enter the water supply system.

It has been reported by the National Resources Authority (NRA) that fluoride levels in the upper aquifer have reached about 0.5 mg/l. Nitrate concentrations in the lower aquifer have been reported by NRA as about 10 mg/l. The chemical testing does not check for either of these problem contaminents. It is recommended that they be added to the list of constituents for which testing is conducted.

No data exists with respect to heavy metals, carcinogens, and other potentially toxic materials. However, there are potential hazards involved in using water that has possible industrial contamination. In view of the present extent and projected future expansion of industries in the planning area, this potential problem warrants consideration.

5.1.4 Population Served

Nearly the entire population of the cities derives its water supply from the public water systems in one way or another. Residents who are not supplied with water directly depend upon connections to their neighbors. In Zarqa, those at elevations higher than the water storage reservoirs are supplied from tank trucks. Thus, the population served in Zarqa is about 215,000 and in Ruseifa is about 61,000.

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5.1.5 Existing Physical Facilities - Zarqa

The existing physical facilities are shown on Figure 5.1 and Plates 5.1 through 5.6.

The current supply for Zarqa is from the three northern wells through two 16-inch transmission mains. The supply pumps take suction from a 500 m^3 concrete ground level reservoir and convey the water toward Zarqa. One 5000 m^3 (No.1) and one 500 m^3 (No.2) ground level concrete storage reservoirs float on the system. In addition, one 5000 m^3 (No.4) reservoir is being built on Jebel Al Abiad. Storage is also provided in the roof tanks.

There is also a 500 m^3 elevated tank (No.3) located near the hospital. This tank was damaged during the 1970 civil strife and is not serviceable. It could be incorporated into the existing system but there are no plans to do so.

The supply pumps operate until both tanks are full. Then pumping is discontinued and the tanks drain to about one quarter full. Each tank has a full-time watchman who controls the tank level by directing the supply pump operator by telephone.

Detailed information about each tank is as follows:

Item	Tank No.1	Tank No.2	Tank No.3	Tank No.4
Ground Elevation - m	658	642	620	699
High water level - m	666	650	635	706
Low water level - m	660	644	630	701
Capacity - m^3	5,000	500	500	5,000

Except for tank No.3, each of these tanks is in serviceable condition and can be expected to provide service until year 2000 assuming continued routine maintenance.

A new supply and storage system is under construction for the southern area of the city. Completion is anticipated by the end of 1980. The new well near the vegetable market will supply a 5000 m^3 reservoir on Jebel Al Abiad. This new system will be on a hydraulic

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gradient of 705 m which is about 50 meters higher than the present system. The systems will be valved-off because of the different pressures. An emergency interconnection will be provided. It is anticipated that pressure reducing valves will protect the distribution network below elevation 630 m.

The existing transmission and distribution system in Zarqa has the following pipe quantities:

16-inch diameter	11,090 m.
12-inch diameter	3,800 m.
8-inch diameter	9,810 m.
6-inch diameter	14,695 m.
4-inch diameter	2,820 m.
3-inch diameter	6,145 m.
2-inch diameter	12,915 m.
TOTAL	61,275 m.

The 16-inch pipe is steel and pipe 4-inch and smaller is galvanized steel. The 6,8 and 12-inch size are either steel or ductile iron and are generally in good condition. About 21 km of the Zarqa network was constructed in 1965.

The city provides distribution lines in the streets. Individual owners must then run the house services and connect to the distribution lines. Because of the dense housing and footpath arrangement, many house services are over a hundred meters long and serve many houses. A considerable portion of the delivery network is comprised of these small lines.

Most of these lines are currently on top of or very close to the ground surface. These lines corrode easily and have considerable faulty joints. It is reported that the pipes are galvanized before threading. Hence, many leaks occur at the joints. It is possible to see leaks or evidence thereof throughout the planning area. There is no incentive for the lines to be repaired because the water is lost prior to metering.

About 12-15 km of the galvanized steel mains are replaced each year and about 3-4 km of new mains greater than 2-inch diameter are installed for extensions.

5.1.6 Existing Physical Facilities - Ruseifa

The Ruseifa existing facilities are shown on Figure 5.1 and Plates 5.1 through 5.6.

Like Zarqa, Ruseifa has two pressure zones. Well No. 1 pumps through a 6-inch line to a circular elevated storage tank on the south side of the city. The tank has a 250 m^3 capacity and a flow line of elevation about 680 m.

Well No. 2 pumps through two 6-inch lines to a 500 m^3 ground level reservoir on the west side of the Musheirfeh area. The tank has a flow line elevation of about 750 m. Also connected to the same system is a 500 m^3 ground level reservoir located north of the Zarqa River on the west side of Jebel Al Shamali. This reservoir has a flow line of about 705 m. Pumping to these tanks is controlled by watchmen and telephone as in Zarqa. All tanks are in serviceable condition and, with proper routine maintenance, should last until the year 2000.

Ruseifa has about 23,500 m of steel pipes of the following sizes:

8-inch diameter	150 m.
6-inch diameter	13,500 m.
4-inch diameter	5,000 m.
3-inch diameter	2,600 m.
2-inch diameter	2,300 m.
TOTOAL	23,550 m.

The pipelines between Well No. 2 and the reservoir at Musheirfeh and at North Ruseifa are new and were completed in 1978.

In addition to this piping, like Zarqa, a considerable portion of the distribution network is comprised of galvanized steel house services less than 2-inches in diameter. These small galvanized pipes experience the same problems as Zarqa, namely corrosion and leakage.

5.1.7 Operation and Maintenance Procedures

The Zarqa water department was established in 1938 is an integral part of the Municipal Organization but became semi-detached in 1965. Its Director, who manages all the affairs of the water

department, is, in common with other department heads, responsible to the Mayor. Under authority of the National Municipal Ordinance, the Municipal Council issues necessary administrative regulations and has responsibility for the water rates. (See Appendix 5.1).

The water department has a present staff of 162 and employs additional daily labor when required. (See Table 5.2). This staff is of sufficient size and training to operate the existing system.

The accounts of the water department are kept separately from the Municipal accounts. Water department employees are subject to Municipal Civil Service Regulations.

All water services are metered. Meters are owned by the Municipality and are serviced in its workshop. The workshop can handle from 25-30 meters per day. Meters are mainly of two makes, Kent (English) and Doris (Syrian). The Kent is the disc type and the Doris is the propeller type. The disc type are more accurate but more susceptible to becoming clogged by sand particles. For the last few years, Zarqa has been installing the propeller type.

The water section of Ruseifa is a part of the Municipality but it maintains separate accounts. Like Zarqa, the National Municipal Ordinance governs rules and rates.

The staff of the water section are 32 in number as shown in Table 5.3. The staff is weak with respect to training of the management personnel and is less than adequately prepared in some specialized areas.

All water services are metered in Ruseifa. The meters are owned by the customers and no workshop for repair or testing is available. There are no standard types of meters and, presumably, the customers install the cheapest type. When the meter stops recording, the customer is required to have it repaired at a private repair shop. These meter ownership, testing, and repair practices leave much to be desired. It is believed that the total metered water sales could be inaccurate.

All repairs to the systems are done by the Municipality staff. Major repairs of pumps or electric motors are done at supplier's workshops.

5.1.8 Water Losses

A comparison of the total water sales and total pumpage for recent years is shown below:

Year	Water Sales (m^3)/yr	Total Pumpage (m^3)/yr	Percent Unaccounted-for-water
Zarqa			
1977	2,735,136	4,854,040	43.7
1978	3,013,121	5,313,750	43.3
1979	3,101,231	5,883,562	47.3
Ruseifa			
1977	596,593	970,970	38.0
1978	561,680	868,910	25.0
1979	538,558	642,730	16.2

Based on this data, the unaccounted-for-water average about 40%. There were well problems in Ruseifa in 1979 and the data is estimated. The total pumpage data are based on measurements generally made by relatively new venturi type flow recording devices. Sometimes, estimates are made by the time the pumps operate. This data is believed to be reasonably accurate. The water sales are based on meters which are known to have problems.

It is estimated that half of the losses in the system occur mainly in the distribution network and house services. The other half or 20% is considered as meter under-registration and meter stoppage.

For a water-short country, this level of unaccounted-for-water is unacceptable. The level of unaccounted-for-water in a well managed system is between 10 to 15%. It is believed that the level of unaccounted-for-water can gradually be reduced to 20% by the year 2000. Reduction beyond this level to a value of 10 percent should be a goal but it may not be achieved within the planning period.

The steps in obtaining this reduction are: (1) institute improved metering practices, (2) have a leak survey conducted, and (3) phased replacement of easily corroded pipe materials. Items (1) and (3) will require gradual implementation. Item (2) should be done by one large survey.

With regard to improved metering the following is suggested:

Zarqa

(1) An attempt should be made to eliminate the sand particles which clog the disc type meter. Areas such as sand traps, cleaning the suction reservoir, and improved pipe repair methods could be explored. If these are unsuccessful, then the propeller type can be used with the realization of lower accuracy.

(2) Continue testing meters at about 5 years intervals or less. Average USA testing frequency is about 5 years but experience and test results will indicate the proper interval in Zarqa.

Ruseifa

(1) Acquire ownership of the meters and establish a test and repair shop.

(2) Ownership of the meters could be accomplished by purchasing and installing a predetermined number of meters each year. Gradually, the city will own all the meters.

(3) Commence efficient operation of a meter test and repair facility.

It is suggested that both municipalities consider a leak survey. Leak surveys are accomplished in several ways. Leak survey crews can inspect the system with geophones or electrical detector equipment and listen for service and distribution system leaks. A comprehensive survey can be accomplished by subdividing the system into districts and controlling and measuring the flow into such districts for at least 24-hr and comparing the night rate to the total 24-hr use. If the night rate indicates high usage which cannot be explained satisfactorily, leakage probably exists. By a process of further subdividion, the location of the high night rate can be discovered.

Measurement of flows is accomplished by recording pitot meter readings over a 24-hr period. Qualified speciality firms are customarily retained to carry out the leak survey since the work is quite technical and the normal water department is not equipped or properly staff.

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An order of magnitude cost estimate for a leak survey of Zarqa is JD 50,000 and Ruseifa is JD 20,000. The survey would take about 6 months.

5.2 Water Demand Projections

5.2.1 Historical Data

Listed below is a summary of the historical data for the past few years:

Year	Service Connection No.	Annual Quantity Pumped m^3	Average Daily m^3	Max Daily m^3	Max to Average Daily
Zarqa					
1970	15,361	2,724,330	7,464	8,773	1.17
1971	16,021	2,920,210	8,001	9,579	1.19
1972	16,909	2,967,930	8,131	9,108	1.12
1973	18,251	2,469,790	9,506	10,728	1.13
1974(1)	18,872	3,679,705	10,081	10,345	1.03
1975	19,445	3,905,645	10,700	11,379	1.06
1976	20,203	4,134,599	11,32[illegible]	12,885	1.14
1977	21,617	4,854,040	13,299	14,154	1.06
1978	22,436	5,313,750	14,558	16,151	1.11
1979	23,665	5,883,562	16,120	16,500	1.02
Ruseifa					
1977	4,716	970,970	2,660	(2)	
1978	5,500	868,910	2,380	(2)	
1979	6,100	642,730(1)	1,761	(2)	

(1) There was some defect in the well pumps and the quantity is estimated.
(2) Data not available.

5.2.2 Projected Domestic and Commercial Use

In Zarqa, the 1979 population was 215,687 and the average daily pumped quantity was 16,120 m^3. The average daily per capita pumped quantity was 75 liters. This includes all water use: domestic, commercial and industrial. Meter records indicate that 607 m^3 per day were sold to industrial users.

For Ruseifa, the 1979 population was 61,674. Using the 1978 average daily pumped quantity (2,380 m^3) since the 1979 pumped quantity was estimated, the average per capita pumped quantity was 39 liters including industrial use.

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The 1979 Ruseifa industrial sales were 69 m^3 per day . Assuming the 1978 industrial sales were close to 1979, the per capita pumped quantity for domestic and commercial use was 37 l/c/d.

In Section 5.1.8, it was shown that unaccounted-for-water was about 40%. It is believed that about one-half of that amount is used but not registered on the meters. The other 20 percent is considered leakage.

The various daily per capita quantities for Zarqa and Ruseifa can be summarized as follows:

	Zarqa	Ruseifa
Total Pumped Quantity	75 l/c	39 l/c
Industrial Sales	3 l/c	2 l/c
Dom.& Comm. Pumped Quantity	72 l/c	37 l/c
Estimated Leakage (20%)	15 l/c	7 l/c
"Actual" Dom. & Comm. Use	57 l/c	30 l/c

For planning purposes, the following assumptions are made concerning future water use:

1. Increased water use allowance - one l/c/d per year will be added each year to allow for increased use from increased bathing and washing machines. The total additional allowance to the year 2000 will be 21 l/c/d. The report by Dr. Nasir (Appendix 3.1) elaborates on the younger generations use of more water.
2. Toilet flushing allowance - A one-time allowance of 10 l/c/d will be added to allow for increase water use due to a water-borne waste disposal system. A standard flush toilet uses about 15 liters per flush and a person uses it at least twice per day. The 10 l/c/d allowance assumes that a portion of the population will continue to use a squat slab system and allows for sewer service to less than the total population.

With these assumptions, the Zarqa year 2000 domestic and commercial per capital demand is estimated as follows:

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1.	"Actual"1979 use	57 l/c/d
2.	Increase Water Allowance	21 l/c/d
3.	Toilet flush allowance	10 l/c/d
	Subtotal	88 l/c/d
4.	Unaccounted-for-water	22 l/c/d
5.	Demand	110 l/c/d

The Ruseifa per capita use, based on available data, is about one-half the Zarqa use (30 vs 57). We believe that, assuming an adequate water availability, this relationship will not continue. Therefore, for the planning purposes, we have assumed that the 1979 use would have been 45 l/c/d. With this assumption, the year 2000 domestic and commercial per capita demand is estimated as follows:

1.	"Actual" 1979 use	45 l/c/d
2.	Increased Water Allowance	21 l/c/d
3.	Toilet flush allowance	10 l/c/d
	Subtotal	76 l/c/d
4.	Unaccounted-for-water	19 l/c/d
5.	Demand	95 l/c/d

Studies recently undertaken in relation to the planning and development of other water supply systems for Jordan show a wide range of estimates of potential levels of present and future consumption and demand for domestic use. Estimates for towns and cities range between 65 to 85 liters per capita per day. The estimates for the year 2000 vary from 100 l/c/d to 120 l/c/d. Our estimates compare favorably with the projections of others.

Using the same method and assuming the 1990 unaccounted-for-water is 30 percent, the 1990 per capita domestic and commercial per capita demand is 111 l for Zarqa and 94 for Ruseifa.

5.2.3 Projected Industrial Use

The 1979 industrial water use is based upon the following assumptions:

1. 1979 and 1980 water meter readings for those industries supplied by Municipal water.
2. Estimates by industry for unmetered private wells (only one industrial well is metered).
3. Our estimates (based on production and similar uses) for those industries that do not meter.

These estimates are summarized as follows:

	1979 Industrial water use - m^3/d		
	Municipal	Private	Total
Zarqa	607	4,604	5,211
Ruseifa	69	2,955	3,024
TOTAL	676	7,559	8,235

A detailed list by industry is presented in the Industrial Effluents Treatment Report.

The projected industrial water demands are based on the following considerations:

1. 1984 production in accordance with industry estimates.
2. Production from existing industries would parallel planning area projection growth until plant capacity was reached. In plants of unknown capacity, it was assumed that capacity would be reached in the year 2000.
3. Limited water conservation until the sewage treatment plant begins operation (1984).
4. Cooling water recycle and other water conservation measures will be implemented by the year 1990 for those industries receiving wastewater service.
5. Undeveloped areas zoned industrial will develop from 1980 until saturation which is assumed at 2020. Water use for these new industrial areas is based on current water use per hectare with conservation measures, 32.9 $m^3/d/ha$.

Using these assumptions, the projected industrial water demand is as follows:

	Projected Industrial Water Demand - m^3/d		
	1990	2000	2020
Zarqa	6,306	9,030	14,212
Ruseifa	5,962	6,199	6,199
TOTAL	12,268	15,229	20,411

It is anticipated that much of the industrial supply will continue to come from the private supplies. Discussion with the industries has indicated that all but the Eagle Distillery and the Oriental Mineral Water Factories estimate that no additional municipal supply will be needed. Thus, the total future industrial use from municipal supplies is calculated as follows:

	Estimated Industrial Use From Municipal Supplies (m^3/d)		
Zarqa	1990	2000	2020
Existing Use	607	607	607
New Development	1,850	3,700	7,400
Eagle Distillery	4	89	89
Subtotal	2,461	4,396	8,096
Ruseifa			
Existing Use	69	69	69
Or't. Min. Wat. Fact.	104	104	104
Subtotal	173	173	173
TOTAL	2,634	4,469	8,269

5.2.4 Projected Total Demand

The projected total demand until 2020 consists of the domestic and commercial demand, industrial use, and the unaccounted-for-water allocable to the industrial use. Assuming that the water allowance increase continues at 1 l/c/d per year, the 2020 Zarqa and Ruseifa per capita demands are about 135 and 120 l/c/d respectively. The total served population are:

	1990	2000	2020
Zarqa	294,900	421,100	565,600
Ruseifa	91,100	125,200	229,700
TOTAL	386,000	546,300	795,300

The total estimated municipal demand is derived as follows:

	Total Estimated Municipal Demand m^3/d		
	1990	2000	2020
Zarqa			
Dom. & Comm.	32,734	46,321	76,356
Industrial	3,516	5,495	10,120
Subtotal	36,250	51,816	86,476

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	Total Estimated Municipal Demand - m^3/d		
	1990	2000	2020
Ruseifa			
Dom. & Comm.	8,563	11,894	27,564
Industrial	247	216	216
Subtotal	8,810	12,110	27,780
TOTAL DEMAND	45,060	63,926	114,256

The 1990 estimates reflect an unaccounted-for-water reduction to 30 percent. The 2000 and 2020 estimates reflect 20 percent unaccounted-for-water.

5.2.5 Future Supply

The total estimated demand can be compared to the existing supply, assuming the new Zarqa well is operational, as follows:

	Comparison Total Demand vs Existing Supply (m^3/d)		
	1990	2000	2020
Zarqa			
Demand	36,250	51,816	86,476
Existing Supply	21,120	21,120	21,120
Deficiency Subtotal	15,130	30,696	65,356
Ruseifa			
Demand	8,810	12,110	27,780
Existing supply	7,200	7,200	7,200
Deficiency Subtotal	1,610	4,910	20,580
TOTAL DEFICIENCY	16,740	35,606	85,936

This data indicates that the existing supply will have to be increased by 159,226 and 403 percent to meet the 1990, 2000 and 2020 demand, respectively. If the unaccounted-for-water were reduced to 20 percent by 1990, the supply deficiency would be about 11,700 m^3/d.

It is beyond the scope of this study to determine the source of the new supply. It is believed that the future supplemental supply will come from the Azrak pipeline which is being constructed on the east side of the planning area or from the East Ghor/Amman pipeline which can be connected to the Azrak pipeline if pumping from Azrak is discontinued. The logical connection point for supplemental supply is a joint connection near Awjan esh Sharqi.

Discussions in October 1980 with the Amman Water and Sewer Authority and the Jordan Valley Authority (JVA) indicated that they plan to supply, on the conservative side, an additional 7.2 million m^3/yr from the Azrak project in early 1981 and an additional 45 million m^3/yr by the end of 1982 to the greater Amman-Zarqa region. The supplemental water required by 1990 for Zarqa and Ruseifa is about 80% of the Azrak supply or 10 percent of the East Ghor Main Canal (EGMC) supply. The JVA plans to have additional supplies available by 1990 from either the Maqarin Dam or a second phase of the EGMC project.

5.3 Design Criteria

5.3.1 Design Period

Water systems contain many large and costly structures that require a long time period to construct and that are not easily expanded. They also include buried pressure conduits that cannot be readily enlarged. Consequently, the principal system components are made large enough to satisfy the needs of the area served for a reasonable time into the future.

As a general practice, feeder mains and interior distribution piping are designed for 50 years. In this case, the saturation population is used. Transmission facilities are easily expandable facilities and generally designed for about half that period. In accordance, with the Agreement, these are designed for the year 2000. These will be examined for phasing so that the Phase I facilities will be adequate for 1990.

5.3.2 Range of Pressures

An adequate distribution system must be able to furnish the necessary flow of water to various points in the system at the pressure necessary to satisfy the normal requirements for each customer. As most of the houses have a roof tank, the pressures at the fixtures in the house is governed by the height of the roof tank.

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Many of the buildings in Zarqa and Ruseifa have 2 and 3 stories. Assuming a 3 story building, the design height would be 10 meters.

A pressure at the customer's service of 1 atmosphere (34 ft/ 10.5 meters of water) would be sufficient to serve the roof tanks. If the roof tanks were eliminated, then the pressures should be more in line with conventional systems. As a guide, conventional systems are designed for 25 to 30 psi (2 Atm) minimum at the distribution main. The distribution system will be designed to maintain this conventional pressure range in the distribution system.

Conventional system design should be such that pressures in excess of about 120 psi (8 Atm/85 meters) should be avoided. Pressures above this range are harmful to conventional plumbing fixtures. As long as the pressure is controlled by the roof tank, there is no problem. The distribution system will be designed to keep the maximum pressures within this limit.

Therefore, the desirable range of pressures at the customers service is 2 to 8 atmospheres (25 to 120 psi/21 to 85 meters).

5.3.3 Peaking Factors

The average ratio of maximum daily flow to average daily flow for the past 10 years has been 1.0. The major reason for this is the relatively low per capita water use. Water is carefully used for the basic human needs such as drinking and bathing. There is no significant seasonal demand variation for such items as gardening. We have assumed that this ratio will increase to 1.3 during the life of the facilities.

There is no data available for the ratio of peak hour to maximum or average day. As long as there is significant roof storage, the ratio will remain low. We have assumed that the ratio of maximum hour demand to average daily demand will be 1.6 as long as roof storage remains.

One of the items used in estimating the 2020 average daily per capita flow was a continued increase of the per capita use by 1/c/year. If we assume that this increase does not extend past the year 2000, the design peaking factors increase to 1.5 and 2.0 for maximum day and

maximum hour. If this maximum hourly rate is used to design the distribution system then roof tanks would not be required.

An addition of these two factors yields a too conservative design. Therefore, the factors of 1.3 and 1.6 will be used in the design of the distribution system.

5.3.4 Storage Requirements

It has generally been found that the most economical combination of pumping, distribution piping, and storage tank capacity results when a given area is supplied at the average rate of demand on the maximum day from the source of supply and equalizing storage is provided within the distribution system to supply the difference between the rate of supply and the instantaneous rate of system demand. Additional storage may also be provided for fire protection and for an overall reserve to maintain supply during temporary emergency outages until standby units can be placed in service.

The volume of storage required to equalize peak demands usually is a function of the magnitude and duration of the peak demands and the rate of supply to the distribution system. When the rate of supply is at the average rate on the maximum day, the volume ranges from about 15 percent of the average rate on the maximum day for large urban systems and higher amounts for small suburban systems.

For the year 2000 condition, the Zarqa and Ruseifa conditions with the existing storage are as follows:

<u>Zarqa</u>

Existing Municipal Storage	- m^3	10,500
Roof Tanks - estimate	- m^3	5,000
Total available storage	- m^3	15,500

Average rate on maximum day (year 2000) - 52,135 m^3/d x 1.3 = 67,775 m^3/d

Percent average rate 15,500/67,775 x 100 = 23%

Ruseifa

Existing Municipal Storage	- m^3	1,000
Roof Tanks - estimate	- m^3	1,500
Total available storage	- m^3	2,500

Average rate on maximum day (year 2000) - 12,186 m^3/d x 1.3 = 15,840 m^3/d

Percent average rate $\frac{2,500}{15,840} \times 100 = 16\%$

In addition to the equalization storage, it is generally prudent to provide 25 percent general reserve in additional storage. Assuming an average equalization rate of 15 percent, the required total storage is 20 percent (15 ÷ .75) o the average rate on maximum day. Zarqa already complies with the 20 percent criteria and Ruseifa needs an additional 659 m^3. This would be required near year 2000.

Another generally used guideline is that enough total storage should be provided to supply 6 hours of flow on average day. With the 1.3 peaking factor, this is 4.6 hours or 19 percent of maximum day flow. Thus, the calculation based on equalization storage agrees with this guideline.

Ideally, distribution storage should be located at the opposite side of the distribution system from the source of supply. This configuration permits two-way supply to the system during periods of peak demand. In large systems, hydraulic and safety considerations usually will result in the placement of portions of the total storage volume at two or more locations.

5.3.5 Fire-Fighting Requirements

There are no fire-flow standards for Jordan. Building construction, in general, is of block, brick, or mud which presents no great fire hazard. Thus, no special provision will be made for fire-flow facilities except for the commercial areas and high value district where fire hydrants are currently available and would be extended as necessary. There are no fire hydrants in Ruseifa and a limited number of hydrants in Zarq Like most parts of Zarqa and Ammon, the fire trucks carry their own supply of water.

Accepted fire-flow practice in the United States is that storage and distribution networks are designed to serve either the peak hour or maximum day plus fire-flow requirements, which ever is greater. In large urban areas, the peak hour requirements are usually greater than the maximum day plus fire-flow.

In the Zarqa high value area, the fire hydrants are spaced at about 100 meter intervals. The fire trucks carry their own water supply. The pumper trucks can pump at about 60 m^3/hr (250 gpm). For supply, the pumper take water from the hydrants into the truck tanks and then repump.

The 5000 m^3 reservoir serves the high-value district. To fulfill only the maximum day requirement, the reservoir will not be required since the maximum day requirement is available from the source of supply.

Keeping 25% reserve, 3750 m^3 (990,000 gal) would be available for fire-flow. Assuming a maximum of 4 hydrants for any fire, and 4 hours of duration, the flow available for each hydrant would be 235 m^3/hr (1000 gpm). Therefore, there would be sufficient storage to fight a fire.

5.3.6 System Considerations

Distribution system piping should be arranged in a gridiron pattern so that the required flow to any point of significant demand can be supplied from at least two directions. In addition to minimizing the overall headloss across the distribution system, this configuration limits the extent of the area that must be taken out of service for the maintenance or repair of a section of pipe.

The gridiron pattern will consist of feeder and branch mains. The classification of a given main is dependent upon its location and function within the overall system.

All intersections between feeder mains and all intersections between branch mains should be completely valved. In the case of an intersection between a feeder main and a relatively small branch main, the branch main should be valved.

Air and vacuum relief provisions are required at high points and blow-off valves at all low points of the distribution system.

Thrust blocks should be provided at all dead ends and at all bends over 7 degrees.

5.3.7 Minimum Pipe Size

The minimum size of main lines for the distribution system is 50 mm (2"). This size line can serve about 450 people. This size line could be used in footpaths. House services should be between 12.5 mm (½") and 25 mm (1") depending on the size of the household.

5.3.8 Pipe Materials and Appurtenances

The existing systems consist of steel, ductile iron, and galvanized steel pipes.

Experience has shown that the steel pipes and the joints of the galvanized steel pipes corrode in 5 to 10 years. Since 1965, cement-lined ductile iron pipe has been used with satisfactory results.

Recently polyvinyl chloride (PVC) pipe has become available from local manufacturers in pressure ratings up to 10 atmosphere (150 psi) working pressure. High density polyethylene pipe has also been used in Jordan. When compared to PVC pipe, it is more flexible and unaffected by heat until it ignites. However, the material is 15 percent higher in cost, ignites easily, and has a lower hydrostatic design stress capability.

Both the Water Supply Corporation and the Amman Water and Sewerage Authority (AWSA) have had experience with plastic pipe. We discussed the use of plastic pipe with both of these agencies.

The advantages and disadvantages of cement-lined ductile iron pipe when compared to plastic pipe are as follows:

- Material Cost - The estimated material cost per meter of pipe material is:

Size	Ductile Iron J.D.	Plastic (PVC) J.D.
2-inch	2.000	1.000
4-inch	5.000	2.700
6-inch	7.000	5.750
8-inch	9.500	9.000

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- Installed Cost - The estimated total installed cost per meter is:

Size	Ductile Iron JD	Plastic (PVC) JD
2-inch	16.000	15.000
4-inch	20.000	17.700
6-inch	24.000	22.800
8-inch	27.000	26.000

- Pressure rating - The DI pipe has normal working pressure of 24 Atm (350 psi) as against 16 Atm (235 psi) for the strongest (Class 16) plastic pipe.

- Familiarity - the municipal workers in both Zarqa and Ruseifa are familiar with ductile iron.

- Proven record in Zarqa and Ruseifa - The two municipalities are satisfied with the ductile iron pipe.

- Discussions with representatives of the Water Supply Corporation and AWSA indicated that they have had several poor experiences with plastic pipe. These problems were mainly leaks attributed to water hammer, workmen unfamiliar with joints, brittleness of pipe exposed to sun, and problems obtaining fittings.

- With plastic pipe, the actual cost of laying and joining the pipe (exclusive of material) is less than ductile iron but there are additional costs for storing and care in handling, better backfill, deeper excavation because of less strength, and higher failure rate during contractor hydrostatic testing.

- Plastic pipe has higher operation and maintenance costs because of more frequent breaks.

The only advantage of plastic pipe is that the material is cheaper than ductile iron. Because of the range of pressures and experience of the Water Supply Corporation and AWSA, we recommend that the use of ductile iron be continued. The engineers of both agencies believed this to be the correct choice. The cost estimates presented are based upon supply from the USA.

For house services, the galvanized steel pipe has experienced corrosion within 5 to 10 years after installation. An alternative is the use of plastic pipe. The galvanized steel is more expensive than the plastic. The plastic has less strength than steel. Discussion with the Water Supply Corporation and AWSA indicate that they have also had poor experience with plastic house service.

Both agencies are now using galvanized steel house services. The Water Supply Corporation current standard is galvanized steel which meets the following (1) British Standards Institution Specification for Steel Tubes and Tubulars Suitable for Screwing to BS 21 Pipe Threads including Appendix A, the copper sulfate test, (2) the pipe is hot-dipped after threading, and (3) is medium series. It is believed that the galvanized steel pipe which has had a less than satisfactory record did not meet these rigid standards.

Based on the experiences of the Water Supply Corporation and AWSA, we recommend use of galvanized steel house services. The cost estimates are based upon the use of this material. It is available from local manufacturers.

Line and sectionalizing valves should be gate valves of iron body, bronze mounted, double disc, and should have a non-rising stem for manual operation with a valve wrench. The valves should be directly buried with metal valve box. Minimum operating pressure for valves should be determined in accordance with the pressure services requirements.

Customers service connections to the main should be made with a threaded corporation stop. For ductile pipes, a saddle and ferule is to be made with a tapping machine. The customer service lines should be sized on the basis of accepted water works practices.

Standardizing on one or two makes of meters would minimize spare parts storage. The standard meter should be durable, accurate and of materials having a low scrap value to minimize pilferage. Meters should be located in locked steel box where they will not be subject to vandalism or accidental damage.

Care must be taken when planning and constructing water lines. Other utilities along the route must be identified and located both vertically and horizontally before trenching to minimize damage. During construction, this usually will be accomplished by test pits dug in advance of trenching operation.

It is recommended that every commercial service such as sewers, water pipes, electric cables, and telephone cables be allocated a specific location in the street, especially in the currently undeveloped areas. These standard locations should normally be strictly adhered to in order to facilitate crossing points between different kind of service and to avoid interference between the same.

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This, together with the preparation of as-built plans, will minimize conflicts with or by other utilities in the future.

5.3.9 Roof Tanks

The roof tanks are a health hazard since they provide a means of water supply contamination. Ideally they should be eliminated but this does not appear feasible. The use of roof tanks and other home storage methods such as barrels is apparently based on a fear of water shortage. Even though Zarqa now has a continuous water supply, we believe that most residents may not be completely confident in it adequacy. In addition, the internal piping is arranged to flow-through the tank.

Given that it is impractical to eliminate the roof tanks, it is suggested that the municipalities increase their efforts to have the tanks kept clean and covered. This is mainly an enforcement problem. Experience indicates that the tank covers are frequently not properly placed on the tanks. This allows such contamination as airborne particles and bird droppings to enter the tanks. It also provides a place for mosquito breeding. The covers could be inspected by the meter readers at the same time as the normal meter reading.

When an adequate supply and distribution system is available, there may be a gradual reduction in the use of the roof tanks. Since the storage calculations have utilized the roof tank capacity, additional storage will be required if the effort to eliminate the tanks is successful.

5.4 Zarqa Design

5.4.1 Useable Existing Facilities

In Zarqa, all the existing pipelines are useable except for one very old 12-inch steel pipe which is laid across building lots in the vicinity of the hospital. This line was not considered in the network analysis. It should be removed from service since it may have leaks or locations where polluted groundwater can enter the system when the water is shut-off.

The concrete storage reservoirs are useable until 2000 assuming routine maintenance. The pumps, motors, and chlorinators are serviceable providing they are properly maintained. A budget item has been included in the estimated financial statements for replacement as required.

Other improvements required to bring the system up to acceptable standards are:

1. New master meter needed at north well supply.
2. Isolating valve near Zarqa River Bridge to separate the north and south distribution systems.

5.4.2 Pressure Zones - Zarqa

The main reservoir in Zarqa is at an elevation of about 645 m and the lower end of Zarqa near the road bridge is 570 m or a total difference of elevation in the system of about 75 m or about 110 psi static pressure. The majority of the area served is at elevations from 600 m to 640 m or about 60 psi. This is satisfactory for the main portion of the City.

The new reservoir on Jebel Al Abiad has an elevation of about 700 m. It is anticipated that this reservoir will serve the area of the city west of the river. The ground elevation near the Zarqa River is about 570 m. The total elevation differential is 130 m which is about 185 psi. Thus, areas with ground elevations below 615 m should not be served from the 700 m gradient. The recommended maximum static pressure is 85 m. During system design, separate pressure zones will be created using pressure reducing valves.

5.4.3 Design Methodology - Zarqa

There are several methods of hydraulic analysis available. The degree of accuracy of the available data and system configuration must be considered.

We have selected the Method of Sections for distribution system analysis. This method is particularly useful for preliminary studies of large and complex distribution systems with the supply from one direction. The method is to cut the distribution network by a series of section lines in the general direction of flow. Estimates are then made of how much water must be supplied beyond each section. The capacity of the available pipes in the general direction of flow is calculated and new pipes are added to provide the required capacity. The analysis is based upon the average hydraulic gradient across the system. Excessive velocities are avoided to minimize the possibility of water hammer.

For a further explanation, the reader is referred to Section 13-7 of Volume 1 of "Water and Wastewater Engineering" by Fair, Geyer, and Okun.

The City of Zarqa was divided into about 60 separate zones for which the water demands were calculated on the basis of per capita flow and the spatial disaggregation of population. Industrial demands were added as appropriate.

Because of the supply configuration, the area was divided into two areas of analysis. One section is the major portion of the existing city north and east of the Zarqa River. The other section is the other less populated section west of the Zarqa River and south of the bridge.

For older distribution lines, the "C" valve (roughness coefficient) in the Hazen-Williams formula ranges from 70 to 100. For new cement-lined the values are 140 or above. We have used 100 as an average value for the entire system.

5.4.4 Zarqa - 1990 Design

The design of the Phase I facilities for Zarqa is based on furnishing adequate facilities for the year 1990 demands.

The major thrust of the Phase I improvement will be

1. Additional Supply
2. Reinforce Existing System
3. Expansion to New Areas

In Section 5.2.5, it was shown that the total supply deficiency for Zarqa was 15,130 m^3/d in 1990 and 30,696 m^3/d in 2000. Also for Ruseifa, the total supply deficiency for Ruseifa was 1,610 m^3/d in 1990 and 4,910 m^3/d in 2000. The total supply deficiency was 16,740 m^3/d in 1990 and 35,606 m^3/d in 2000. This data demonstrates that acquisition of a new supply must be part of Phase I. Because it is a major facility but one that can be easily paralleled, the design life is 20 years. Also, because it is a joint (Zarqa and Ruseifa) facility, it is discussed in the Zarqa section. The cost will be proportioned to Zarqa and Ruseifa on the basis of design flow.

The common pipeline will run from the connection to the East Ghor/Amman - Azrak pipeline near Awjan esh Sharqi to the vicinity of the Zarqa River. From there, the line will continue to the Jebel Al Abiad reservoir but this will be considered a Zarqa distribution line.

The design capacity of the line should be based maximum daily flow. For both cities, this totals 46,300 m^3/d (35,606 x 1.3). The estimated hydraulic gradient in the East Ghor/Amman - Azrak pipeline will be elevation 758 m. This is based on the hydraulic gradient necessary to serve Amman. This gradient will also be sufficient to serve the Jebel Al Abiad and the majority of Ruseifa. It will not be able to serve the Musheirfeh reservoir.

The 758 m gradient is the minimum that can be expected in the pipeline. In most cases, the gradient will be more. Therefore, pressure reducing valves will be required on all take-offs that do not serve the higher areas of the city or the reservoir.

Based on analysis of the available pipe sizes, a 24-inch pipe size has been selected.

The question then, is, how to proportion the cost. The percent of design flow for Zarqa in 2000 is 86.1. For the purpose of this report, we have assumed that Zarqa pay 80 percent of the cost of the common line since all costs are not directly proportional to flow.

In the existing parts of Zarqa, there are several incomplete distribution network loops. There are also several areas of the city where there is poor flow distribution between the existing 4-inch branch mains. We recommend that the network be reinforced to strengthen flow to these areas.

The developing areas are principally south and west of the existing population center. In Phase I, provision is made to serve three areas from the new 24-inch connection. Initially, service will be from the new well. The major facility to serve this new area in the proposed 12-inch pipeline along the west bank of the Zarqa River to the vicinity of Hai ez Zawahreh. Distribution loops proceed westward from this line to serve the new development. Because this line is fed from the elevation 700 m hydraulic gradient, there are some low areas where pressure reduction is required. The municipality is planning to establish a high service area about 630m elevation. Therefore, when the areas below elevation 630m should be in a low or normal pressure zone.

A 16-inch line is also proposed for the east side of the river. This line is proposed to run from the proposed 24-inch northward to the southern extent of the currently built-up area of Zarqa. As the area north of Zarqa developes, less and less of the existing northern well supply will be available for the southern areas of the city. The proposed 16-inch line will make the new supply available to the southern areas of the city.

The proposed Phase I improvements are as follows:

Pipe Size (inch)	Length (km)
24	3.0*
16	4.0
12	6.0
10	1.0
8	5.0
6	10.0
4	30.0
2	22.0
Total	81.0

* 80% of supply line

The major lines are shown on Figure 5.1 and all lines are shown on Plates 5.1 to 5.6.

5.4.5 Zarqa - 2000 Design

The design for adequate service to year 2000 is defined as Phase II. The major component of Phase II design are:

1. Phased expansion to keep pace with anticipated growth, and
2. Transmission mains to convey the new supply to those areas now deficient because of new growth nearer the existing well supplies.

The major portion of the expansion between 1990 and 2000 will occur by continued growth west of the city. There will also be some expansion north of the city. The westward expansion will be accommodated by a major (8" & 12") pipeline along the western edge of the anticipated growth. This line will close the loop initiated by the 12-inch line along the west side of the river in Phase I. A distribution network is planned between these lines.

An additional 16-inch will be required on the east side of the river to increase supply to the city as the northern area grows.

The proposed Phase II improvements are as follows:

Pipe Size (inch)	Length (km)
16	5.0
12	4.0
8	9.0
6	5.0
4	10.0
2	40.0
Total	73.0

The major lines are shown on Figure 5.1 and all lines are shown on Plates 5.1 to 5.6.

5.5 Ruseifa Design

5.5.1 Useable Existing Facilities

In Ruseifa, all lines are serviceable and have been included in the distribution system analysis. The reservoirs are considered serviceable until year 2000 with proper maintenance. Budget allowances will be made for routine replacement of pumps, meters and chlorinators.

The improvements required to bring the existing system up to acceptable standards are:

1. To strengthen it by new network.
2. To standardize on meters and provide a meter workshops.

5.5.2 Pressure Zones-Ruseifa

The existing Ruseifa system operates on two separate hydraulic gradients. The system from Well No.1 operates from the 250 m^3 reservoir with a flow line of elevation 680 m. The reservoir is located on the high ground south of the old Amman-Zarqa highway. The minimum elevations served by this tank are about 600 m. Therefore, no pressure problems are anticipated.

Well No. 2 pumps to two reservoirs. The controlling reservoir is the 500 m^3 structure located in the Musheirfeh section. It has a flow line elevation of 750 m. It is sufficiently high to serve the surrounding area. The section of Musheirfeh north of the tank near the Zarqa River drop to elevation 642 m. The differential from the tank flow line to this area exceeds the maximum allowable pressure established in the design criteria (85 m). Therefore, areas below elevation 665 m must be served through pressure reducing valves.

The 500 m^3 reservoir in the vicinity of Yajoz road is also served by Well No.2. It's flow line elevation is 706 m. It currently serves an area where the low elevation of the densely populated area is generally above 620 m. Therefore, there are no anticipated high pressure problem. There are isolated cases of customers below this elevation near the river. These should be handled as an individual basis. The tank is also sufficiently high to handle the majority of the area south and north of the Yajoz road.

In the future, Ruseifa should continue to operate on the same two pressure system. The Musheirfeh system should operate as a high service system. The remainder of the municipality should operate from the 705 m gradient. The pressure from the future connection should be sufficient to supply this tank. The 680 m flow line tank will also be on the same gradient. The elevations are sufficiently close in elevation that the 680 m tank will not be "locked-out" of the system.

5.5.3 Design Methodology - Ruseifa

The configuration of Ruseifa is different than Zarqa. Analysis of its system was done by considering it as a long transmission main with successive take-off. Analysis of the smaller area was done by the Method of Section.

5.5.4 Ruseifa - 1990 - Design

The design of the Phase I facilities for Ruseifa is based on furnishing adequate facilities for the year 1990 demand.

The improvements will be required in four areas:

1. Additional supply
2. Reinforce existing system
3. Expansion to new areas
4. Improved metering practice

In Section 5.2.5, it was shown that Ruseifa would have a supply deficiency by 1990. Section 5.4.4 describes the design of this line. It concludes that Ruseifa should be allocated 20% of the cost of the 24-inch pipeline.

In the existing parts of Ruseifa, there are several incomplete distribution network loops. Even with completion of the loops, there will still be areas with poor flow because of insufficient branch mains. The proposed Phase I facilities will remedy this situation.

The new development is expected to occur adjacent to the existing area. In the Musheirfeh area, it will be north and towards the river. In the "old Ruseifa" area, it will be eastward south of the old Amman-Zarqa highway. North of the river, it will start to fill-in the Jebel Al Shamali area.

The major facilities are shown on Figure 5.1. All facilities are shown on Plates 5.1 to 5.6. These facilities are sized to serve the saturation populations for the areas which they serve.

The 12-inch line will make the new supply available to the area of Ruseifa between the existing wells and the municipality eastern border. The 12-inch line north of the eastern section of the city and the 8-inch line through the existing development north of the river are the start of the major northern loop.

The proposed Phase I improvements are as follows:

Pipe Size (inch)	Length (km)
24	0.6*
12	3.0
8	1.3
6	3.3
4	12.0
2	20.0
Total	40.2

* 20% of supply line

It is also recommended that the municipality acquire ownership of the meters and institute adequate test and repair procedures.

It is recommended that the Musheirfeh system continue to operate as a high service area supplied by Well No. 2. An emergency interconnection should be made so that the pumps which supply the Musheirfeh area could take suction from the new supply if necessary.

5.5.5 Ruseifa 2000 Design

The design for the year 2000 consists of completing the loop to serve the Jebel Al Shamali area and the proposed housing project north of Yajoz road with a 6-inch line. This is the remaining section of the 12-inch and 8-inch line discussed in the previous section. The improvements also include a 700 m^3 reservoir which was discussed in Section 5.3.5.

There are no streets shown on the base map for the areas that are expected to develop between 1990 and 2000. The major areas are

Jebel Al Shamali and Hai Al Aradieh. We have included an estimate for these areas based on the pipeline density in the developed areas.

The proposed Phase II improvements are a 700 m^3 reservoir plus the following pipelines:

Pipe Size (inch)	Length (km)
6	1.0
4	4.0
2	10.0
Total	15.0

5.6 Cost Estimates

The estimated construction costs for the recommended projects in 1980 JD are as follows:

Phase I		
Zarqa		JD 2,230,000
Ruseifa		1,080,000
	Total	JD 3,310,000
Phase II		
Zarqa		JD 1,725,000
Ruseifa		325,000
	Total	JD 2,050,000

The details of the cost estimates are given on Tables 5.4 and 5.5. Appendix 5.2 discusses the basis of the cost estimating procedure.

5.7 Recommended Implementation

There are three classes of water distribution improvements when viewed with regard to implementation:

- The supply, feeder and branch mains
- The pipeline to reinforce the network and handle expansion
- The lines in the footpaths and house service replacement which will only be practical as the sewer program progresses. These are essentially sewer construction costs service they are necessitated by the sewer construction.

For Zarqa, we have allocated JD 1,000,000 for those pipelines which are for network reinforcement plus growth. These are essentially all the 2- and 4-inch lines. These would be constructed between 1981 and 1990 at JD 100,000 per year (June 1980 cost).

For Ruseifa, we have allocated JD 100,000 for construction of the reinforcement and expansion. This is about one-half the 2- and 4-inch lines. Because the Ruseifa system is weaker, about 85% of the 2- and 4-inch lines are planned for immediate replacement. We have also allocated JD 150,000 for new meters from 1981 to 1990.

5.8 Local and Foreign Costs

As required by the Agreement, all costs are divided into foreign and local costs. The material is allocated on the basis of its manufacturing location. Labor, except for foreign manufactured machinery and supervisory personnel, is considered a local cost.

The Phase I and Phase II local and foreign costs are summarized as follows:

	Local (JD)	Foreign (JD)	Total (JD)
Phase I			
Zarqa	1,182,000	1,048,000	2,230,000
Ruseifa	540,000	540,000	1,080,000
Total	1,722,000	1,588,000	3,310,000
Phase II			
Zarqa	915,000	810,000	1,725,000
Ruseifa	195,000	130,000	325,000
Total	1,110,000	940,000	2,050,000

The detailed breakdown is given in Tables 5.6 and 5.7.

NOTE:

The pipe sizes have been given in inches in this chapter. The equivalent sizes in the metric system are:

Size Inches		mm	Size Inches		mm
1	-	25	10	-	250
2	-	50	12	-	300
3	-	75	15	-	400
4	-	100	20	-	500
6	-	150	24	-	600
8	-	200			

6.0 SEWER SYSTEM

6.1 Existing Wastewater Disposal Practices

6.1.1 Sanitary Sewage Disposal

At present, there are no publicly-owned wastewater collection and treatment facilities in either Zarqa or Ruseifa. Sanitary sewage is generally disposed of in privately-owned, on-site systems constructed by the homeowner. The responsibility for industrial wastewater disposal has been left to each individual industry. Because of the rapid growth of the two communities plus the industrial development, more emphasis has been placed on disposal per se than on achieving adequate treatment prior to discharge.

The cesspool or pit privy is the disposal system most commonly used by the homeowner. The relatively soft, easily excavated rock found at or near the ground surface throughout most of the planning area facilitatesthe construction of unlined pits at low cost, while the small building lots, steep slopes and soil conditions all mitigate against the construction of either conventional or mound type septic systems. Although no data have been obtained regarding the porosity of the rock or the percolation rates achieved in the pits, field observations indicate that the wastewater moves rapidly into the bedding planes and interstices of the rock formation and either filters downward into the groundwater or appears as seepage where the bedding planes outcrop on downstream slopes. The grey to black color of the seepage and the odors generated when it is ponded in depressions indicate that the degree of treatment achieved during its passage through the rock is low. The relatively high concentration of nitrates in the ground waters of the upper aquifer indicate that the levels of treatment achieved by present disposal practices are inadequate to protect the groundwater against contamination.

The destiny of development in portions of Zarqa and Ruseifa is such that cesspools are frequently located under the buildings which they serve. The odors emitted from these pits enter the homes through their floors and the floors above the pit remains damp.

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Although the vast majority of property owners utilize cesspools, wastewater from some homes is discharged directly to the Zarqa River. In Ruseifa, a number of privately-owned sewers have been constructed down the face of the rock cliffs to the water's edge.

Even in homes with cesspools, a significant volume of wastewaters may be discharged to the nearest ditch, street or footpath. A common complaint of families interviewed during this study is that many people throw wash water (sullage) into the streets and footpaths to avoid overloading their cesspools. This practice results in muddy footpaths, odors, and general nuisance conditions throughout the more densely developed sectors of the planning area. It has reportedly been the cause of many arguments and ill feelings between neighbors.

6.1.2 Industrial Wastewater Disposal

With relatively few exceptions, the industries located along the Zarqa River discharge untreated wastewaters directly into the river. Industrial establishments located at some distance from the Zarqa River dispose of their wastewaters by a variety of methods including discharge to cesspools, ponds, and small drainage ditches.

A detailed discussion of existing industrial disposal practices is given in the Industrial Effluents Treatment Report.

6.1.3 Septage Disposal

The municipality of Zarqa owns and operates eight tank trucks for pumping out cesspools. An estimated 32 privately-owned tank trucks also operate in Zarqa and in Ruseifa which has no municipal fleet.

There were 29,765 metered water service in the two municipalities at the end of 1979, and it is estimated that there are over 30,000 cesspools. If all of the cesspools are pumped out semi-annually, each of the estimated 40 trucks in the area must service an average of five systems per day over a 300 day operating year. While Dr. Nasir's report (See Appendix 3.1) indicates cesspool pump-outs average about 4 per year, discussion with the Municipality Engineer indicates that this number is high but may apply to certain limited localities. It is estimated that a semi-annual pump-out is a more realistic figure for the planning area average. The need for more frequent pump-outs is reduced by disposal of sullage and grey water in the streets.

Septage collected by the tankers is reported to be disposed of by dumping at a government-approved site located along the Zarqa-Azrak road about 25 km from the city.

Zarqa charges JD 2.500 per four-cubic meter truck load while private operators charge from JD 3.000 to JD 5.000 per load. The charge for pumping out a 2 m^3 cesspool varies from JD 1.25 to JD 2.5 depending upon the tank truck service used.

6.2 Service Areas and Served Population

6.2.1 Methodology

In order to design the sewer system, the planning area must be divided into subareas along drainage basin lines with consideration given to natural divisions between existing population centers. An estimate must also be made of the population which can be economically included in a sewer system.

In preparing service population estimates, it was assumed that small clusters of houses located at a distance from population centers and homes on streets with numerous vacant lots could not be economically served during any phase of the project.

In determining the extent of the initial phase collection sewer project, the follow criteria have been used:

- Small clusters of houses located at some distance from existing centers of population will not be sewered during the initial phase.
- Streets on which more than half of the developable lots have been built upon will be sewered during the initial phase.
- Small sections of heavily developed areas which drain into undeveloped land will not be sewered during the initial phase if an extensive amount of sewering is required within the undeveloped area.
- No collection sewers will be constructed to serve homes on large lots within the agricultural areas along the Zarqa River. Where such homes are in close proximity to a proposed trunk sewer and the owner wishes to connect to the system, a connection stub will be provided at the nearest manhole for his use.

Aerial photographs taken in 1979 were used in conjunction with the above criteria to estimate the extent of the collection sewer system. The sewer system design prepared by Scan Plan Coordinator and Jouzy & Partners in 1975 was reviewed using these photographs t determine where new development has occurred since that date. A preliminary sewer system layout was prepared for Ruseifa using the 1976 series 1:2,500 scale topographic map with a 1 meter contour interval.

Even though the planning area contains large amounts of vacant land suitable for development which is projected to experience a very rapid rate of population growth throughout the next 40 years, it is still anticipated that there will be some areas in the process of developing during all stages of the project. Thus, it is anticipated that even in the year 2020, some people living within the planning area will not be served.

6.2.2 Planning Area Subdivision

The planning area has been subdivided into 21 subareas as shown in Figure 6.1. A brief description of each subarea plus factors governing served population follows:

- Subareas I and II are located in Zarqa and drain toward the Zarqa River. The southeasterly portion of Subarea I is currently developed to approximately 90 percent of its saturation population while the northerly and westerly portions contain large tracts of vacant land. Subarea II is presently developed to approximately 85 percent of its saturation density throughout. Wastewaters from both subareas could be conveyed by gravity to a trunk sewer along the river.

- Subarea III, IV, and the Army Base are located on the easterly side of Zarqa and drain toward the northeast to the Wadi Saida - Subarea III presently contains about 25 percent of the City's total population and is developed to about 95% of its saturation population. The southerly portion of Subarea IV contains a small area which currently approaches saturation destiny while the east-central portion as far north as the municipal [illegible] field is developing rapidly into a middle and upper income residential area. The northerly section of this subarea contains mostly vacant land and includes an area zoned for new industrial growth along the Refinery Road. The Army Base lies directly east of subareas III and IV and has a resident population of approximately 35,000 including soldiers and their families.

Wastewaters from all three subareas will have to be collected at a point near the northeast corner of the city and pumped over the divide to a trunk sewer in Subarea I or treated at a separate treatment plant along Wadi Saida.

- Subareas V and VI are located on the westerly side of the Zarqa River. Subarea V is too sparsely developed to consider the construction of sewers at present, but is projected to develop a rapid rate over the next 20 years. Subarea VI contains a densely developed strip of housing along its easterly edge while its westerly portion is nearly vacant Both of these subareas drain directly to the Zarqa River through a number of relatively deep drainage courses.

- Subarea VII is located on the easterly side of the Zarqa River and is traversed in a north-south direction by the new Amman-Zarqa highway and the railroad. The portion of this subarea between the highway and the river contains a refugee camp and a very densely developed grouping of low income homes. The Army Base occupies a small portion of the subarea east of the highway while the remainder of the area is essentially vacant land.

- Subarea VIII is located on the westerly side of the Zarqa River in the Awjan Al Gharbi area. A number of Industries including two breweries and a distillery are located along the edge of the river. Scattered clusters of homes and small commercial establishments are found on the westerly side of the main road which parallels the river. The density of development in the westerly portion of the subarea is not sufficient to justify the installation of collection sewers at present. However, a few streets adjacant to the main highway could be sewered to a trunk sewer running along the road. The wastewaters from the industries along the road are relatively strong and should be collected and treated in any proposed sewerage project.

- Subareas IX and X lie on the easterly and southerly side of the Zarqa River where it bends to the north. Subarea IX encompasses the area drained by the Wadi Hajar and is very sparsely populated at present. The southeasterly portion of this subarea contains the Jordan Ceramic Industry Co., the Jordan Match Co., and Leather Products Company, while the Jordan Paper and Cardboard Co., is situated on the ridge between subareas IX and X. Approximately 3300 meters of trunk sewer would be required along the Wadi Hajar from its confluence with the Zarqa River at a point

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near the ceramic and match factories to serve these industries. As described in the Industrial Effluents Treatment Report there is little justification for constructing such as extensive amount of sewer for these industries at this time.

- Wastewaters from the Jordan Paper and Cardboard Co., together with those from the Jordan Tannery Co., and the Jordan Army Blanket Factory and a number of smaller industries could be collected in a trunk sewer running through Subarea X. In addition, a small densely developed area near the Zarqa River could be served.

- The southerly portion of Subarea X is zoned for future development and could be served by future extension of the subtrunk sewer

- Subarea XI encompasses the area around Wadi Ushsh on the easterly side of the Zarqa River. Approximately 100 homes have been built along a ridge adjacent to the wadi but the density of development is not sufficient to warrant a subtrunk and collection system in Phase I.

- Subareas XII and XIII are located along the west side of the Zarqa River in the Awjan Al Janubi area. A number of industries are located in these areas including the Oriental Mineral Water Factories (7-Up), the Jordan Dairy, and the Jordan Worsted Mills. There is a densely developed residential area along the Zarqa River in both subareas. These areas are considered sufficiently developed for service in Phase I.

  A government housing project is currently being constructed north of the Yajoz road in Subarea XII. The project is presently served by subsurface disposal methods. When the project has developed sufficiently and the amount of developed areas have expanded northward, the project would be served by extension of the Subarea XII subtrunk.

- Subarea XIV is situated on the southerly side of the Zarqa River and consists almost entirely of vacant land. When sufficient development occurs to justify the provision of sewer service, a subtrunk sewer could be constructed from this subarea to a trunk sewer on the northerly side of the river.

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- Subarea XV encompasses the land which drains to a deep, steep-sided drainage channel on the northerly side of the Zarqa River. Although a few homes have been built on the sides of this channel, the area is largerly undeveloped. The construction of a subtrunk sewer along the drainage channel will be difficult and expensive and should not be undertaken until more development occurs in the area.

- Subarea XVI includes the central portion of Ruseifa on the southerly side of the Zarqa River plus a large area of open-pit phosphorous mines. The developed portion of the subarea is located along an east-west oriented ridge. The most densely populated area lies on the southerly side of the ridge and drains to a low point or pocket at the edge of the open-pit mine area where a pond of stagnant surface runoff and septage forms during wet weather. Sewage from this area will have to be pumped over the ridge to a trunk sewer along the Zarqa River.

  The development on the northerly side of the ridge consists of a larger number of homes and commercial establishments as well as the municipal office building and the principal mosque. This area naturally drains toward the river although the portion of the northerly slope in the easterly section of the subarea is separated from the river by a rocky cliff.

  The large area occupied by the phosphate mines is practically undevelopable in its present state. This area is proposed for parks and open space under the current plan prepared by the Amman Urban Regional Planning Group (AURPG).

  It is estimated that approximately 75 percent of the properties in Subarea XVI could be served during the initial phase of any proposed sewerage project, and that most of the remaining homes, would receive service as partially developed streets reach saturation densities.

- Subarea XVII is located on the northerly side of the Zarqa River in Ruseifa and encompasses the Hussein Industrial City and a densely developed residential area. It is estimated that nearly one-third of this subarea has been developed to saturation density and the remainder is being developed at a rapid rate.

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Approximately 70 percent of the present population could be served by a system of gravity sewers during the initial phase of the proposed project.

- Subareas XVIII and XIX are located in the northwesterly corner of the planning area. Both subareas are almost totally undeveloped at present and contain extensive mining areas. Area XIX is designated as open space by the AURPG. The Phosphate Company currently operates screening and drying facilities at a complex located in subarea XVIII but expects to close this facility in 1981. The only wastewater generated by this facility results from the operation of air scrubbers. These waters contain sand, silt, dust and other inorganic particles that should not be discharged to the sewerage system.

- The Jordan Yeast Factory is located in Subarea XIX and discharges a wastewater with a high BOD and suspended solids content. In order to provide sewer service to this industry, over 3000 meters of sewer would have to be constructed through vacant lands and farms along the railroad to a point near Ruseifa where it would connect to the trunk sewer serving that area. As described in the Industrial Effluents Treatment Report, the cost of this sewer would be considerably in excess of the cost of a local industrial waste treatment plant. Thus, this sewer should not be built until sufficient development takes place along its route to justify it.

- Subarea XX encompasses the Musheirfeh area of Ruseifa in the extreme westerly portion of the planning area. Approximately one kilometer of relatively vacant land separates this area from the main population center of Ruseifa and many streets in Musheirfeh have houses along one side only. The construction of sewers for this area should probably be deferred.

6.2.3 Served Population

Estimates of the current and projected total and served population for each of these subareas are shown in Table 6.1. The estimates of the served population will be used in design of the sewer system. The total and served populations for the planning area summarized as follows:

Year	Total Population	Served Population	Percent
1990	421,000	272,500	64.7
2000	586,300	419,700	71.6
2020	840,300	697,000	82.9

6.3 Quantities And Characteristics of Sewage and Industrial Wastewater

6.3.1 Domestic and Commercial Sewage

Per capital domestic and commercial sewage flows can be expected to correspond closely to the per capita water consumption figures presented in Chapter 5. Per capita water consumption usually includes some water used for washing cars, watering gardens and other purposes which do not result in the production of sewage. In preparing the estimates of per capita sewage flow, it has been assumed that approximately 80 percent of the water delivered to consumers will be returned to the sewer system. (1) A separate allowance has been made for groundwater infiltration and inflow of stormwater through manhole lids and illicit roof and court yard drains. This allowance generally depends upon the area of the system and increases with age because of pipe deterioration (2).

The projected per capita water consumption in leters per day and corresponding sewage flow are:

	ZARQA				RUSEIFA			
Year	Water Use	Sewage Flow	Infil/ Inflow	Total Sewage Flow	Water Use	Sewage Flow	Infil/ Inflow	Total Sewage Flow
1984	72	58	8	66	60	48	8	56
1990	78	62	10	72	66	53	10	63
2000	88	70	10	80	76	61	10	71
2020	108	86	14	100	96	77	14	91

In preparing these projections, it has been assumed that the sewerage system would be in operation by the beginning of 1984 and, thus, the initial projections relate to that year. It should be noted that industrial process wastewater flows are not included in the per capita flow figures presented, but are discussed separately.

Five-day biochemical oxygen demand (BOD_5) and suspended solids (SS) concentrations in sewage from domestic and commercial sources are expected to be relatively high as a result of low per capita water use. A per capita contribution of 60 grams per day of both BOD_5 and SS, when used in conjunction with the projected per capita sewage flows from each community, results in concentrations of these constituents in the wastewater as follows:

Year	ZARQA Per Capita Sewage Flow l/d	ZARQA BOD_5 mg/l	ZARQA S.S. mg/l	RUSEIFA Per Capita Sewage Flow l/d	RUSEIFA BOD_5 mg/l	RUSEIFA S.S. mg/l
1984	66	909	909	56	1,071	1,071
1990	72	830	830	63	952	952
2000	80	750	750	71	845	845
2020	100	600	600	91	659	659

These BOD_5 and SS concentrations are similar to those experienced at the sewage treatment plant in Amman.

The total sewage flow, BOD and SS loads from domestic and commercial sources in any given year will depend upon the number of people served by sewers in that year. The service population estimates presented in Table 6.1, have been used in conjunction with the per capita sewage flow, BOD and SS figures to develop total domestic and commercial flow, BOD and SS estimates. These estimates are detailed in Table 6.2.

6.5.2 Industrial Wastewaters

Industrial wastewater discharges are described in detail in the Industrial Effluents Treatment Report. Estimates of industrial wastewater quantities and characteristics have been made with the following assumptions:

- Industries will not enact major water conservation measures such as recycling cooling water until the public sewer system is in operation and they are required to pay for treatment services. Thereafter, conservation measures will be implemented rapidly and will be in effect by 1990 for those industries served.

- Industrial production at existing industries and corresponding wastewater discharges will increase at the same rate as population growth until the production capacities of these industries are reached.

- New industries will locate in areas zoned for such development and growth will proceed at a uniform rate between 1980 and 2020.

Not all of the industrial wastewaters are expected to be discharged to the sewerage system. Some industries such as the ceramic tile factories produce wastewater which is primarily composed of sands, cement dust and other non-biodegradable products resulting from polishing and grinding operations. These wastewaters can best be treated on-site and the water recycled rather than disposed of in the sewers. Other industries have such limited flows and are located so far from populated areas that their wastes are more economically disposed of cesspools until more development occurs to justify the construction of an expensive sewer.

For the planning area, the total estimated flow, BOD_5, and SS to the municipal sewerage system from industries are shown in Table 6.3.

6.3.3 Total Wastewater Flows and Characteristics

For the planning area, the total estimated flow, BOD_5, and SS to the municipal sewage system are as follows:

Year	Average Flow m^3/d	BOD_5 Kg/d	S.S. Kg/d
1984	21,700	18,700	14,700
1990	24,200	24,100	19,200
2000	41,200	37,000	30,900
2020	81,100	57,400	50,600

The breakdown by subarea is given in Table 6.4.

It should be noted that the data presented in Table 6.4 is based upon the assumption that all those areas with sufficient present population to warrant the construction of sewers would received sewer service during the initial stage of the project. The quantities and characteristics of wastewaters resulting from any number of alternative initial stage projects can be obtained by adding together the corresponding flows, BOD and SS for the combination of subareas which make up each alternative.

6.4 Sewer System Design Criteria

The design criteria and pipe material utilized for the preliminary engineering design are consistent with modern engineering practice. A detailed discussion of these topics is presented in the Appendix.

The major features of the design criteria are:

- Design period based on useful life of facility
- Gravity sewers sloped to prevent deposition of solids.
- Domestic and commercial flow peaking factor based on experience at typical treatment plants and reduces as contributory population increases.
- Force mains minimum velocity designed to prevent solids deposition.
- Large pumping stations have separate wet and dry wells.

6.5 Trunk Sewer and Treatment Plant Alternatives

6.5.1 Alternative Treatment Plant Sites

The 1975 report on wastewater disposal for Zarqa recommended construction of a sewage treatment plant on a 13.7 hectare site occuping both sides of the Zarqa River near the northwesterly corner of the city. The plant was to utilize the trickling filter process of secondary wastewater treatment and was to be constructed in two phases.

The first phase was designed to serve an estimated population of 350,000 at an average daily flow of 19,250 m^3/d in 1990, while the second phase called for expansion of the plant to serve a population of 455,000 at a flow of 29,575 m^3/d in 2000. Because of the limited area available, the design of the second phase facilities called for the construction of a large box culvert to carry the Zarqa River through the site and permit the use of the area over this culvert for the construction of a portion of the sludge drying facilities.

The inclusion of Ruseifa in the proposed sewerage project plus the numerous industries located in the Ruseifa area results in an increase in the projected flow reaching the treatment plant in 1990

and 2000 to 24,200 m^3/d and 41,200 m^3/d respectively. Furthermore, it is projected that, by the year 2020, the volume of wastewater requiring treatment will have increased to approximately 81,000 m^3/d. The 13.7 hectares available at this site is not adequate for the construction of a cost effective treatment plant of the capacity required to provide service to the Zarqa-Ruseita area for any reasonable period of time beyond 1995 and, thus alternative plant sites must be considered. (See Chapter 7).

Two alternative plant sites have been investigated as shown in Figure 6.2. Alternative site A is located along the Zarqa River approximately 1.6 kilometers north the original plant site. This site contains approximately 28.5 hectares of land on the east side of the River along the Zarqa-Sukhnah Road and an additional 9.5 hectares along the westerly bank of the stream. The site is currently used for agricultural purposes and a large barn used for raising chickens is located in the middle of the area. The site slopes gently from the road toward the river. Preliminary investigations indicates that wastewater entering the site from a trunk sewer along the road could flow through the plant by gravity.

Alternative site B is situated to the northeast of Zarqa on a 34 hectare tract of nearly level land located immediately north of an Army ordnance depot between the railroad and the road to Hashimiyeh. A treatment plant located at this site would discharge to the Wadi Saida. Because of the level nature of the terrain in this area, a raw sewage pumping station would be required at the plant influent. The site is currently owned by the Army.

Both alternatives sites are large enough to accomodate expansion of the treatment plant to serve well beyond the year 2000. The two sites offer three possible alternatives for sewering the planning area.

Alt. 1- Treatment of all wastewaters at Alternative Site A.

Alt. 2- Treatment of all wastewaters at Alternative Site B.

Alt. 3- Treatment of those wastewaters which flow by gravity to the Zarqa River at Site A and those that drain naturally to the Wadi Saida at Site B.

As has been discussed previously, all sections of the planning area except Subareas III, IV and the Army Base drain naturally to the Zarqa River and could be served by a system of gravity trunk sewers constructed along the stream to Alternative Site A. Subareas III, IV and the Army Base drain toward the Wadi Saida near Alternative Site B. The projected average daily wastewater flows which drain by gravity to each site are shown below:

Year	ALTERNATIVE SITE A (ZARQA RIVER)	ALTERNATIVE SITE B (WADI SAIDA)
1984	15,300	6,400
1990	15,800	8,400
2000	27,100	14,100
2020	57,200	23,900

6.5.2 Alternative Sewerage Schemes

Three alternative trunk sewer systems corresponding to the three possible treatment schemes are shown in Figures 6.3, 6.4, and 6.5. Under Alternative 1, all wastewaters would be treated at Site A on the Zarqa River. Wastewaters from Subareas III, IV and the Army Base which drain toward the northeast to the Wadi Saida would be intercepted at a major pumping station located just north of the Zarqa municipal well field and pumped over the divide to a gravity trunk sewer in Subarea I where it would flow to a sewer running along the easterly side of the Zarqa River to the plant site. Wastewaters from the Ruseifa area would be collected by a system of trunk sewers extending westerly along the River.

The main pumping station serving Subareas III, IV and the Army Base would be designed for an average daily flow of 11,900 m^3 and a peak flow of 23,900 m^3/d. Three 225 Horsepower (Hp) pumps, each with a capacity of approximately 12,500 m^3/d at a total dynamic head of about 68 m, would be installed. Two of these pumps would deliver the maximum daily flow of 23,900 m^3 while the third would be a stand-by unit. The station would discharge through a 500 mm diameter force main.

Shortly before the year 2000, the station would be expanded to double its initial capacity by the addition of two more pumps, and a second, 500 mm force main would be installed parallel to the original pipeline.

Under Alternative 2, shown in Figure 6.4, wastewaters from Subareas III, IV and the Army Base would flow by gravity to a treatment plant located at Site B. Wastewaters from the Ruseifa area and from the remainder of Zarqa except Subarea I and V would be collected in a trunk sewer system similar to that proposed under Alternative I and conveyed to a major pumping station located on the east side of the Zarqa River about 1300 meters downstream from the bridge on the Zarqa-Ruseifa road. Wastewaters from Subarea I would be conveyed to this pumping station via a gravity trunk sewer running south. Sewage from Subarea V would be collected at a point on the westerly side of the river and pumped to the trunk on the easterly side. The main pumping station would discharge its wastewaters through a 900 mm diameter force main to the gravity trunk sewer near the Army Base where they would flow to a raw sewage pumping station at the proposed plant site.

As in Alternative I, the main pumping station would be designed to accomodate a doubling of its capacity in about the year 2000. Initially, the station would contain three, 450 Hp pumps, any two of which would be capable of pumping a maximum daily flow of 57,000 m^3/d through a 900 mm diameter force main at a total dynamic head of 65m. In or about the year 2000, two additional pumps of the same capacity would be installed, and a second, 900 mm force main constructed parallel to the first one.

Under Alternative 3, shown in Figure 6.5, the wastewater from subareas III, IV and the Army Base would flow by gravity to the treatment plant located at Alternative Site B, while those from the remainder of the planning area would flow by gravity to a second treatment plant at Site A. No major pumping stations would be needed under this alternative except, of course, the raw sewage pumping station at the influent to the treatment plant at Site B.

6.5.3 Cost Comparison

The capital and operating cost (including maintenance) estimates of the facilities performing equal functions of the three alternatives in thousands of JD are:

Item	Alt. 1	Alt. 2	Alt. 3
Capital	14,165,900	14,151,700	14,889,300
Operation and Maintenance	311,400	374,400	295,600

The capital cost includes a 44 percent allowance for contingencies, engineering and other indirect costs. (See Chapter 9). The treatment plant costs are based upon trickling filters with anaerobic digestion and sludge drying beds.

Operating costs are based upon current prices for labor, chemicals and electrical power generated from sewage gas.

The details of these cost estimates are shown in Tables 6.5, 6.6 and 6.7 and in Appendix 5.2. Soil exploration data throughout the planning area is presented in Appendix 6.3.

In order to present a valid comparison of costs, the present worth of operating costs from 1984 through 2000 have been calculated (10 percent discount) for each of the trunk sewer and treatment alternatives. When added to their respective project costs, the total present worth associated with each alternative for the duration of the planning period is obtained. These amounts in thousands of JD are:

Present Worth	Alt. 1	Alt. 2	Alt. 3
Capital less Salvage	13,015,000	13,602,000	13,613,000
Operation and Maintenance	2,651,300	3,187,600	2,516,700
TOTAL	15,666,300	16,189,600	16,129,700

This demonstrates that Alternative 1 is the most economical. Based on economics and the qualitative factors presented in Chapter 7, the single plant on the Zarqa River, Alternative 1, is recommended.

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Design of the trunk and collection sewers will proceed on the basis of Alternative 1 implementation.

6.6 Collection and Subtrunk Sewers

6.6.1 Initial Service Area

The majority of the subareas are judged to have sufficient population density or industrial development to consider the construction of at least some collection sewers during Phase I of the project. These areas were selected on the criteria presented in Section 6.2. Construction of collection sewers was not judged economical in Subareas V, IX, XI, XIV, XV, XVIII, and XIX.

Subarea XX encompasses the community of Musheirfeh at the extreme westerly portion of the planning area and is considered a border-line case. Whether it should be included in the initial phase of the project will be considered later.

Except for the southerly portion of Subarea XVI in Ruseifa, all subareas for which collection sewers have been considered can be served by gravity to the proposed trunk sewer system. The wastewater from an estimated 1100 homes drains to a low point at the edge of the phosphate mine and will have to be pumped. A pumping station utilizing submersible pumps with a firm capacity 19 liters per second at a total dynamic head of approximately 20 meters is recommended. The station would discharge through a 150 mm diameter force main to a gravity sewer in the northerly portion of the subarea.

A summary of the collection and subtrunk sewer facilities considered for Phase I construction is :

Pipe	Length-meters
200 mm	195,450
250 mm	5,350
300 mm	6,820
400 mm	3,120
600 mm	160
	210,900
House laterals (Number)	26,850
Pumping Station	19 l/s
Force Main 150 mm	220 m

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This summary includes 8050 meters of sewer to serve the Musheirfeh area which may not be economically practical at this time. A detailed breakdown by subarea is given in Table 6.8 in the Appendix.

6.6.2 House Lateral/Connection Policy

Of particular concern, especially to homeowners in low income areas, is the extent to which the government is prepared to spend public funds to facilitate connection to the sewer system. The connection is made by installation of a tee or wye in the street sewer and construction of a pipe (house lateral) to the vicinity of the property line. A house connection is then constructed from the end of the lateral to the various sanitary facilities. The existing policy in Amman requires the homeowner to pay the construction cost of the house connection plus any internal plumbing modifications. The Amman Water and Sewerage Authority (AWSA) provides the homeowner with design drawings of the house connection and a list of contractors who have been approved to do such work. The homeowner then chooses a contractor from the approved list and contracts with him to install the pipe. In many cases, the homeowner is also required to install a 600 mm diameter manhole on the end of the house lateral sewer to serve as a clean-out and inspection point and to facilitate the connection of his plumbing to the system. The cost of connecting his plumbing to the manhole at the end of the house lateral sewer is, of course, also paid by the homeowner.

If the homeowner does not construct the house connection sewer within three months of the time he is notified of the need to do so, AWSA has the power to turn his water service off. However, AWSA has not implemented this policy. AWSA'S experience is that a much better hook-up rate was experienced in the poor areas compared to the rich areas. The poorer people are in need of sewers while the rich people generally have more land, less disposal problems, lower pumpout rates, and less annual cost. Dr. Nasir's report indicated that the surveyed families would pay "anything". However, even if willing or anxious, the funds still must be obtained. The practice of non-connection, if widespread, could defeat the purpose of the entire sewerage project.

In order to facilitate connections, it is recommended that as in Amman, the house lateral sewers be installed by the government as part of the sewer construction project. This is the usual practice in the United States since the house laterals are on public property. As a result of similar problems in other areas, the World Bank has agreed in several cases to finance house laterals as part of the total project cost. Discussions with USAID have also indicated that they would probably agree to include the house lateral cost if it were to finance the project

The question then arises as to whether the house lateral sewer should be built to a point just short of the property line or whether it should extend onto the homeowner's lot and include a terminal clean out manhole. The purpose of the terminal manhole is to facilitate connection from several locations on the houseowner's property to one central location. In many cases, the cesspool is below the squat slab outside the general living area and the kitchen is within the house.

In other cases, a terminal manhole is not a practical solution but the houseowner must make extensive internal plumbing changes. A very typical case is a row of common-wall houses with the courtyard and cesspool in the rear. The only access to the street sewer and house lateral stub is directly through the living area. It would be inappropriate to locate the terminal manhole in the center of the living area. A suggested solution is a terminal manhole or clean out near the cesspool.

The unusual case is a house with easy access to the sewer. In order for all houseowners to receive equal value, the following is suggested:

- For those situations where a terminal manhole is the appropriate solution, the project will include the construction of that manhole.

- For all other situations, the houseowner will receive an allowance equal to the average terminal manhole cost. This allowance will be paid after satisfactory connection to the system. The project will end the house lateral as close to the property line as possible with a stub.

Additional benefits to be gained by including the terminal manhole and extended house lateral in the project are:

- o Better quality control since the project will have adequate inspection
- o Lower overall cost because of economy of scale
- o Completion of all underground work before paving

The costs for the terminal manholes and allowance are separated from the general construction cost. The total estimated cost is JD 75 which is JD 25 for the house lateral extension and JD 50 for the manhole or manhole allowance.

6.6.3 Existing Water Lines

A factor which will affect the cost of constructing the collection sewer system is the necessity of relocating or replacing existing water lines. In most instances, sewers constructed in streets will be installed at sufficient depth to avoid conflict with the existing water mains. An allowance has been included in the unit costs for sewers in streets to account for expected delays in construction which inevitably occur when working in close proximity to existing utilities.

The construction of sewers in footpaths, however, is expected to present much more difficult problems. The common practice in Zarqa and Ruseifa has been for the municipality to construct distribution system mains only in the principal streets and for the homeowners to construct service connections from these mains to their homes. As a result, most of the footpaths contain a number of ½ to 1-inch diameter galvanized steel water service lines. For the most part, these service lines were originally installed on the ground surface or in trenches less than 10 cm deep. In an attempt to prevent erosion of the footpaths and to eliminate muddy conditions during the winter months, many of the home-owners have paved the footpaths with concrete. As a result, those water service connections which were originally installed on the ground surface are now encased in the concrete pavement. It will be extremely difficult if not impossible to break and remove the concrete for sewer trench excavation without destroying the water services. It is possible, in fact, that any contractor preparing a tender for the construction of the collection sewer system would include in his bid the cost of replacing

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all or a substantial portion of the existing water service lines in the footpaths. Inasmuch as it would not be good engineering practice to permit the contractor to replace or repair each individual water service line damaged during the course of his work with a similar line, and in view of the fact that major improvements to the exisitng water service system are comtemplated, it is recommended that new, publicly-owned water lines be installed in each footpath in conjunction with the construction of the sewer in that footpath.

The estimated cost of this work has been included in the construction cost estimates for the collection sewer system but is shown separately. It is recommended that one contractor be utilized for installation of the sewer and water lines in a given area. This will relieve the municipalities of many coordination problems.

6.6.4 Footpath Resurfacing

Another factor which must be considered in estimating the collection sewer costs is the necessity of resurfacing the footpaths to protect the pipe trench against erosion. As mentioned, many of the footpaths have been paved with concrete by the homeowners. The quality of the existing paving work is generally poor. Some paths are paved over their entire length while others are only partially surfaced. Little attention has been given to sloping the pavement to a central gutter, and, in many cases, sullage and rainwater running along the buildings and walls at the edges of the paths have eroded these structures. Where no paving exists, it is common to find a 10 to 30 cm deep erosion gully wandering from side to side of the path even though the ground may consist of soft, weathered rock.

Although sewer trenches in footpaths will be backfilled with compacted material, it will generally not be possible to achieve a surface over the trench which will resist erosion as well as the surrounding, undisturbed ground surface. As a result, runoff will tend to occur directly over the trench and rapidly erode away the backfill and expose the pipe. It is therefore, considered essential that the footpaths be surfaced with a minimum of 8 cm-3 inch of concrete to protect the sewer against washout. An allowance of JD3.5 per linear meter has been included in the cost estimates for sewers in footpaths to accomplish this work.

6.6.5 Estimated Cost

The estimated construction cost of the collection and subtrunk sewers considered for the initial phase of the project are summarized as follows:

Collection and Subtrunk Sewers	JD 8,629,000
Addition for House Lateral and Manhole	2,013,000
Water Mains	994,000
TOTAL (with Subarea XX)	JD 11,636,000

These costs include the street and footpath sewers, house lateral and terminal manhole costs, resurfacing of existing paved streets, concrete surfacing of the footpaths, and 50 mm water mains in the footpaths plus the house service reconnection. These estimates are detailed by subareas in Table 6.9.

It should be noted that the Musheirfeh area collection and subtrunk are included in these estimates. There are no costs for a collection system for the Army Base since it has been assumed that the Army will construct its own system. A metering chamber should be constructed on the Army Base effluent pipe to encourage the elimination of extraneous water. The basis for these costs are described in the Appendix Supplemental Material 5.2

6.7 Trunk and Collection Sewer Phasing

6.7.1 Basic Human Needs Concept

The construction of sewerage facilities in Zarqa and Ruseifa is considered to be a "basic human needs" project. The Agreement required that the sewerage program be time-phased to reflect the most urgent needs for services in terms of high densities, serious health problems and/or greatest inadequacies in present service. In Chapter 3, it was shown that low income and densely populated areas are relatively evenly spread across the planning area.

Specific areas with high incidences of disease could not be isolated. The available records indicate that enteric diseases are prevalent throughout the entire area and are probably as much related

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to contaminated water and food, which is distributed or sold to all people regardless of the area in which they live, as to a lack of adequate sewage disposal facilities.

Inasmuch as there are no public sewerage facilities in either Zarqa or Ruseifa, it is impossible to delineate those areas with the greatest inadequacies of sewer service. In general, however, areas of high population density have more difficulty in disposing of wastewaters in on-site cesspools than do those with more land area per dwelling. As has been noted, densities of over 450 people per hectare are common in many of the poorer areas of the planning area and cesspools are located under the floors of the dwellings for lack of other available space.

6.7.2 Other Factors

Although the phasing program must be designed to meet the basic needs of the people, other factors must also be considered. Industrial wastewaters contribute significant amounts of pollution to the Zarqa River which is used for swimming and bathing by numerous people. In addition, the industries can provide a significant proportion of the revenues needed to operate and maintain the sewer system and treatment plant during the initial years of operation by payment of sewer service charges. Any project phasing schedule must take into account the need to serve these industries as well as the people.

The nature of sewer projects is such that it is usually not economical to by-pass areas with moderate population densities to reach areas of greater density and need. Gravity sewer routes are governed by topography, and the cost of constructing sewers with sufficient capacity to serve future generations is high. It is usually necessary to serve as many properties along the sewer route as can readily be connected if the cost per person or property served is to be maintained at an acceptable level.

6.7.3 Economic Evaluation

In order to arrive at a cost-efficient program for phased construction, an economic evaluation has been made of various phasing schedules. A first step in this evaluation, consideration was given

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to the economics of constructing the principal trunk sewer along the Zarqa River from the proposed treatment plant to its intersection with the trunk sewer from Subarea I with sufficient capacity to serve through the year 2000 only, rather than until 2020 as originally proposed. Under this scheme, a second, parallel sewer would be installed in the year 2000 to provide the capacity needed through the year 2020. An analysis of anticipated peak flows and the topography along the sewer route indicates that a 900 mm diameter pipe would be required to serve through the year 2000, and a second 900 mm pipe would be added in that year to serve through 2020. In contrast, a single 1100 mm diameter sewer would serve for the full 40 year design period. A present worth analysis of the two alternatives indicates that the single 1100 mm sewer is more economical for all interest rates less than 13 percent. Therefore, the single pipe designed to serve for forty years is recommended.

For smaller diameter pipes, the factors which favor providing capacity for the year 2020 during the initial phase of the project are even more pronounced. Thus, it is concluded that the selection of a 40 year design period for the gravity trunk sewers is correct. This is not true, however, for force mains since the minimum flow velocity must be maintained. Larger diameter force mains require higher capacity pumps to provide the required 0.60 m/s minimum velocity. This requires larger electrical switchgear, more powerful electric motors and a number of other costly items. It also increases the detention time in the wet well. Thus, two parallel force mains are still recommended for the major pumping station on the northeast side of Zarqa.

As a second step in the evaluation of potential phasing programs, a "minimum" project was selected as the basis for comparison of alternative schedules. The "minimum" project consisted of just those trunk and collection sewer facilities necessary to serve Subareas I, II, III and IV in Zarqa. The construction costs for these facilities were determined, including the present worth of the operation and maintenance costs of the main pumping station serving

the easterly side of the city. Dividing by the estimated number of people served during the first year of operation of the project, (1984), the cost per person served is JD 72.83. The 1984 Army Base population (35,000) was not included since the Army intends to construct its own collection sewer system and may not be ady to connect to the system in that year. If it were included, the cost would reduce to JD 55.71 but this number does not include the cost of the Army Base collection system.

In order to determine the effect of adding additional facilities to serve more subareas, the cost of extending the trunk sewer system, by increments, to reach more subareas can be added to the cost of the collection sewers for those areas and divided by the number of people served by the added facilities. This figure can be compared to the cost per person for the "minimum" project to determine whether the incremental and total cost per person served exceeds the cost of the "minimum" project. Since treatment costs per person served can be expected to consistently decline as the required plant capacity increases, no costs for treatment were included.

The next logical subarea to add is Subarea VII. This subarea is adjacent to the "minimum" project area, can be served by gravity, and is densely populated. The incremental cost of service is JD 51.01. This is less than the cost per person for the "minimum" project. If Subarea VII is included in the project, a lower total cost per person served will result. The construction cost per person served for the new total project would be JD 59.17 compared to JD 72.83 for the project without Subarea VII.

If the trunk sewer system is extended still further to serve Subarea X, a major reduction in cost per person results. This is because Subarea X contains a number of large industries which can be served by a very low cost collection sewer system. In order to convert the industrial flow to an equivalent service population or "population equivalent", a figure of 66 liters per person per day, the estimated 1984 average per capita sewage production figure for Zarqa, was divided into the estimated daily industrial flow. Since the

industries in Subarea X are expected to significantly reduce their wastewater discharges soon after connection to the sewer system, the estimated 1990 industrial flow was used in the calculation. If the much higher, 1984 figure were used, a still lower cost per person served would result. The incremental per capita cost is JD 7.43 and over the total project cost is JD 53.32.

After adding the incremental costs of trunk and collection sewer facilities for the trunk sewer which run along the easterly side of the Zarqa River from the proposed treatment plant to Subarea X, the effect of constructing the trunk sewer along the westerly side of the river to Ruseifa was considered.

The first segment of this trunk sewer would cross the river and run south to the boundary between Subareas VI and VIII to serve the collection sewers in Subarea VI. The incremental construction cost of the trunk and collection sewers in Subarea VI is JD 80.39 per person and the addition of Subarea VI to the total project would increase the total construction cost per person served to JD 54.29. However, if the trunk sewer is extended upstream to the approximate mid-point of Subarea XIII, service an be provided to a number of industries along the river as well as homes in Subareas VIII, XII and XIII. The incremental cost of the trunk and collection sewers necessary to serve these areas is JD 39.86 per person and the total construction cost of the entire project up to that point is JD 52.16 per person.

Subarea XVII is the next area which could be served by a further extension of the trunk sewer. This subarea contains the Hussein Industrial City as well as a large number of low income families and, although the incremental cost is estimated at JD 55.99 per person served, the total cost per person served by the project up to and including that point increases by JD 0.2 a very minimal amount, to JD 52.36.

The extension of sewer service to Subarea XVI requires that the trunk sewer cross the river and run westerly along the base of a rock cliff to a point near the new bridge on the Zarqa - Ruseifa road. The incremental cost of serving this subarea is JD 64.90 per person served,

and the total cost per person served is JD 53.21, an increase of JD 0.85. However, Subarea XVI contains a large number of low income families and very high population densities.

The incremental cost per person served in extending the sewer system to serve Subarea XX, the community of Musheirfeh, is estimated at JD 92.72 and the increase in the total construction cost per person served amounts to JD 1.30. The population densities in Musheirfeh are not, at present, as high as in other sectors of the planning area. As a result, the cost per person for constructing collection sewers is high.

The incremental and total per capita construction cost of adding successive subareas is summarized as follows:

Add	Incremental Cost Per Person (JD)	Total Cost Per Person (JD)
Minimum	-	72.63
VII	51.01	69.17
X	7.43	53.32
VI	80.39	54.29
VIII, XII & XIII	39.86	52.16
XVII	55.99	52.36
XVI	64.90	53.21
XX	92.72	54.50

The details of these calculations are given in Table 6.10.

6.7.4 Shnellar Refugee Camp and Jebel Faisal

While the Shnellar Refugee Camp and Jebel Faisal are outside of the planning area, they could be served by the proposed trunk sewer system.

The Shnellar Refugee Camp is administrated by the United Nations Relief and Work Agency.

The 1979 population was 24,229. Present wastewater disposal facilities are cesspools. In order to serve the present population, gravity subtrunks and a collection system would convey the flow to a

point east of the Camp. A small pumping station would pump to the old Amman-Zarqa Road. A 250 mm subtrunk would carry the flow to Ruseifa and, thence, into the trunk sewer. Expansion of the treatment plant would be slightly earlier. The estimated construction cost of these facilities plus modifications to the trunk without Shnellar sewage is JD [illegible],050,000. This is a cost of JD 43.34 per person. If included, the total project cost would be JD 43.56. These estimates assume a collection sewer system. If public toilets were use, the cost would be less.

The Jebel Faisal area is across the old Amman-Zarqa Road from Shnellar Camp. At present, population is estimated at 3,200. This population is on the top of the hill along the road. The estimated 2020 population is 7,500 and it is anticipated that the growth will proceed down the hill towards the river.

In order to serve Jebel Faisal, a collection system and subtrunk sewer system must be built. The subtrunk would start at the southern base of the hill, run west to the Zarqa River and follow the river to Ruseifa. The estimated construction cost of these facilities is JD 250,000. The incremental cost is JD 78.13.

If both Shnellar Camp and Jebel Faisal are added to the total project, the per capita cost is JD 53.83.

6.7.4 Recommended Phase I Sewer System

Although the economic analysis indicates that the lowest cost per person served is achieved if the sewer system is constructed as far west as Subarea XIII during the initial phase, the basic human needs of homeowners in Subareas XVI, XVII and XX must be considered. A review of the 1979 aerial photographs shows that the population densities in large portions of Subareas XVI and XVII exceed 450 persons per hectare. Field investigations in both areas revealed sewage running down the streets and ponded in low areas, an indication that cesspools are not functioning. Children swim in the Zarqa River immediately downstream from the Hussein Industrial City wastewaters discharged in Subarea XVIII. The cesspools serving the industrial complex are polluting

the groundwater as evidenced by high concentration of heavy metals in samples taken from the Ori[illegible] Star Distillery well. The need for sewers in Subareas XVI and XVII is judged to be as great as, if not greater than the need in Subareas VI, VIII and XII for which a more economical system is possible. The increase in cost per person served which results from including Subareas XVI and XVII in the initial phase of the project is minimal. It is judged that the basic human needs in these subareas plus the necessity of preserving and protecting groundwater quality far outweigh the economic consideration associated with a small increase in system cost.

The incremental [illegible] serving the Mushbeirieh area (Subarea XX) is much higher than in any other area. The present population density is not as high as in most sections of the planning area. The same situation exists in [illegible] Faisal. The basic human need is not as great in these areas as in other sections of the planning area.

Certainly, there is a great basic human need for the Shnellar Camp. There is also the difficult question of the permanence of the camp. Over the next decade, the camp could either grow or reduce in size depending upon the political situation.

Based on these considerations, the recommended Phase I project will provide sewer service to the developed sections of Subareas I through IV, VI through VIII, X, XII, XIII, XVI and XVIII. The recommended sewer system is shown in detail on Plates 6.1 through 6.6. It will serve an estimated 60 percent of the planning area population in 1984. On a strictly basic human needs basis, Shnellar Camp should be served. The decision for service must be made by the government, pending resolution of the refugee situation. It has not been included in the recommended project.

The recommended trunk sewer system will include:

- 22.3 km of trunk sewer ranging in size from 300 mm to 1100 mm
- 3.0 km of 500 mm force main
- The 117[illegible] m^3/hr East Side Pumping Station

The recommended collection sewer system will include:

- o 202.8 km of collection and subtrunk sewer ranging in size from 200 mm to 600 mm
- o The 68m^3/hr Subarea XVI pumping station
- o About 26,000 houses connections

The estimated costs are:

Trunk Sewer System	JD	2,383,000
Collection Sewer System		8,000,000
Terminal Manholes		1,949,000
Water Mains		974,000
TOTAL (without Subarea XX)	JD	13,306,000

The details of these estimates are shown in Tables 6.11 and 6.12.

6.7.5 Phase II Trunk and Collection Sewer Project

The recommended Phase I trunk and collection sewer project is designed to provide service to currently developed areas only. In general, only existing streets on which more than one-half of the developable lots have presently been built upon will be sewered during the Phase I project. Prior to 1984, the anticipated date of completion of Phase I construction, it is expected that a certain amount of new development will occur in the planning area and some streets which were only sparsely built-up when the 1979 aerial photographs were taken might be so heavily developed as to justify the installation of sewers immediately. If this does occur, and provided that funds are available, the construction of additional sewers during the Phase I construction project might be accomplished by the issuance of change orders.

Between 1984 and 2000, a significant amount of new development is projected to occur. The task of extending sewer service to newly developed areas may be accomplished through an ongoing sewerage project wherein a certain amount of new construction is undertaken each year, or larger projects, undertaken at 5 or 10 year intervals, may be designed to serve all areas which have become densely developed since the last major project was completed. The method employed will depend to a large extent upon whether funding is available on a yearly basis. This cannot be predicted with any certainty. For the purposes of estimating the

cost of the Phase II project, it has been assumed that the sewer extensions will be undertaken yearly as necessary and as the availability of funds permits.

Between 1984 and 1990 it is projected that the population of the planning area will increase by approximately 59,500 people. A significant amount of this growth is expected to occur in areas which are currently partially developed but do not have sufficient population density to justify the construction of sewers during the Phase I project. As the population increases, these areas will approach saturation densities and the installation of sewers will serve a portion of the present population as well as a percentage of the new population. The sewer service population is expected to increase by approximately 55,850 people between 1984 and 1990, a figure just slightly lower than the estimated total population increase for the entire planning area.

Approximately 10 percent of the increase in sewer service population is expected to occur as a result of new homes being built on vacant lots along streets in which sewers are to be installed during the Phase I construction and through the construction of extra dwelling units by the addition of second or third stories on houses which receive sewer services during Phase I. The remaining 90 percent, or slightly more than 50,000 people, will receive through Phase II construction.

Although it is not possible to predict with any real certainty the locations in which new families will build homes between 1984 and 2000, an attempt has been made to estimate the increase in service population in the planning area. An estimate has also been made of the number of people which will be served by the sewers constructed under the recommended Phase I project and the number that will require new sewer construction. The water main costs have not been included since they are in Chapter 5. The results of these estimates are as follows:

Description	1984-1990	1990-2000
Total Increase in service Population	55,850	147,200
Number Served by Phase I Sewers	5,600	16,200
Number served by New Sewers	50,250	131,000
Length of Pipe Sewers - km	66	205
Number of House Connections	7,975	20,300
1980 Construction Cost Including Terminal Manhole ($JD \times 10^3$)	3,291	7,353

The detail of these estimates are presented in Table 6.13 and 6.14.

During the 1984-90 period, it is anticipated that sewer service will not be required in Subareas IX and XV, areas which were not recommended for service in the Phase 1 project.

Between the years 1990 and 2000, the population of the entire planning areas is expected to grow by an additional 165,300 people, while the population which could be served by sewers is projected to increase by 147,200 people. During this time period, it expected that sewers will be extended to Mushirfiya in Subarea XX and to Subareas V, XI and XIV, the East [illegible] Pumping Station serving Subareas III and IV in Zarqa and the Army will require expansion and a second parallel force main. These costs are included in the 1990-2000 facilities construction cost estimate.

The 1984 to 1990 and 1990 to 2000 facilities are not shown on Plates 6.1 through 6.6 because their location is dependent upon the growth pattern.

6.8 Foreign and Local Costs

The construction costs have been divided into foreign and local costs. These are summarized as follows:

	Foreign ($JD \times 10^3$)	Local ($JD \times 10^3$)	Total ($JD \times 10^3$)
Phase I			
Trunk	625	1,758	2,383
Collection	2,003	5,997	8,000
Terminal Manholes	494	1,455	1,949
Water Mains	589	385	974
TOTAL	3,711	9,595	13,306

1984-1990	Foreign (JDx10³)	Local (JDx10³)	Total (JDx10³)
Collection	673	2,020	2,693
Terminal Manholes	152	446	598
TOTAL	825	2,466	3,291

	Foreign (JDx10³)	Local (JDx10³)	Total (JDx10³)
Phase II			
Trunk Expansion	71	179	250
Collection	1,395	4,185	5,580
Terminal Manholes	386	1,137	1,523
TOTAL	1,852	5,501	7,353

The details of the breakdown are shown on Tables 6.15, 6.16 and 6.17. For the JD 75 cost of the terminal manhole and sewer line on property, the cost is JD 19 foreign and JD 56 local.

References

1. Metcaff & Eddy, Inc., Wastewater Engineering, Treatment/Disposal/Reuse, Second Edition, 1979, p. 19

2. Metcaff & Eddy, Inc., ibid, p. 26

7.0 SEWAGE TREATMENT SYSTEM

7.1 Estimated Domestic Sewage Characteristics

A direct determination of the characteristics of domestic sewage generated in the Zarqa-Ruseifa area is not possible due to the absence of an existing sewerage system. However, an indirect means of estimating sewage characteristics is possible when considering that domestic sewage from this area should be essentially the same as that generated in the Amman area. Sufficient data are available to characterize the raw sewage entering the nearby Ain Ghazal Sewage Treatment Works located north of and providing service to the City of Amman and its immediate surrounding areas. A review of this data will not only reveal the character of the domestic waste anticipated from the Zarqa-Ruseifa area but also provide the basis for establishing total loadings of key waste parameters including biochemical oxygen demand (BOD_5) and suspended solids (SS).

Analyses of raw sewage generated in the Amman area are presented in the 1978 report on the Immediate Improvements and Expansion of Sludge Facilities for the Ain Ghazal Sewage Treatment Works, prepared by Binnie & Partners and Jouzy & Partners. Results prove conclusively that incoming waste, the bulk of which is from domestic sources, has a relatively high strength as compared to generally accepted values of comparable American and European sewage. Average BOD_5 and SS concentrations are estimated in the report at 890 mg/l and 830 mg/l, respectively. Furthermore, the results justify use of an average per capita pollutant load contribution for the Amman area of 55 grams per day (g/day) for both BOD_5 and SS. These estimates are in agreement with the 1976 report prepared by the consulting firm of Vattenbyggnadsbyran (VBB) which adopted values of 60 g/day for populations within the City of Amman and 30 g/day for populations in the outlying areas of Hussein and Wahdat. Consistent with these estimates, 60 g/day is selected as a representative per capita pollutant load contribution for the Zarqa-Ruseifa area.

7.2 Summary of Industrial Effluent Treatment Report

During the period from February 1980 through May 1980 Malcolm Pirnie, Inc. made an industrial waste survey of the Zarqa-Ruseifa area.

The findings and conclusions are contained in the Industrial Effluents Treatment Report.

All known industries in the Zarqa-Ruseifa area were canvassed and 43 of these industries were investigated in detail. Of the 43, 13 required pretreatment of their wastes before they would be acceptable for treatment at the Zarqa-Ruseifa municipal treatment plant and five were classified as being suitable for treatment at their source for discharge directly to the Zarqa River.

In estimating the BOD_5, suspended solids and flow tributary to the proposed facilities the characteristics of all tributary industries were categorized, quantified after pretreatment and added to the projected domestic wastewater load.

In analyzing the industrial wastewater load special care was taken to assure the load was treatable and that the resultant sludges would not poison the soil if the sludges were to be used as soil conditioners. To provide for industrial growth in the service area the available unoccupied land zoned for industrial use was assigned a unit flow, BOD_5 and suspended solids loading equal to the use of the presently occupied industrially zoned land.

7.3 Estimated Total Sewage Characteristics

The total raw sewage entering the new Zarqa-Ruseifa treatment system will consist of a blend of the above domestic and industrial components (see Chapter 6 for wastewater flow projections). The flow and pollutant loadings of the combined sewage are as follows:

	1990	2000	2020
Total Flow (m^3/day)	24,200	41,200	81,100
BOD_5			
kg/day	24,100	37,000	57,400
mg/l	996	898	600
SS			
kg/day	19,200	30,900	50,600
mg/l	797	750	624

These pollutant loadings characterize the combined sewage as a waste having an unusually high strength similar to that received at the Ain Ghazal Treatment Works. The main contributing factors for this

high strength include: the relatively low areawide per capita water consumption and the discharge of significant quantities of industrial wastes.

One additional parameter that must be given due consideration to fully characterize the raw sewage is the ammonia concentration expressed as nitrogen (ammonia-nitrogen). Ammonia is a toxic substance to some marine life and exerts an oxygen demand when most of the carbonaceous BOD (BOD_5) is oxidized. Previous studies by Binnie & Partners and Jouzy & Partners on the raw sewage entering the Ain Ghazal Treatment Works indicate average influent ammonia-nitrogen concentrations are 123 mg/l. A similar high strength concentration is expected in the wastes generated in the Zarqa-Ruseifa area.

7.4 Development of the Degree of Treatment Required

The planning and development of a centralized sewage treatment system consisting of one or more treatment plants for the Zarqa-Ruseifa area will eliminate the potential health hazard posed by the continued use of individual on-site sewage disposal systems. However, the abandonment of these local cesspools will not eliminate disease and groundwater pollution as it will merely shift the responsibility for environmental and public health protection to the new centralized treatment system. The degree of treatment provided at the new treatment plant or plants must, therefore, be fully adequate to protect the health and welfare of the area including protection of groundwater which is presently the prime source of potable water.

Although the National Water Master Plan proposes certain specific standards for effluent discharges to watercourses, there are at the present time no water quality standards promulgated or otherwise documented by the pertinent ministries within the Kingdom. It is, therefore, recommended that the degree of treatment proposed for the new treatment plant or plants be based on an analysis of site-specific criteria. Accordingly, the degree of treatment will be dependent upon both ultimate site selection and the proposed method of plant effluent disposal.

The discharge of treatment plant effluent to watercourses is the traditional disposal method for treated sewage and will be considered as a viable method for ultimate disposal of treated sewage at the new treatment plant. However, consideration also will be given to land

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application as an alternative to stream discharge as it would offer two distinct advantages. Land application of plant effluent would have the potential of increasing cultivated land area in the immediate region through irrigation and, additionally, would serve as a prime source of groundwater recharge. The latter of the two advantages is possibly the most significant since annual water demand in the planning area during recent years, drawn entirely from groundwater supplies, has been exceeding the natural recharge capability of the area. Land application would certainly alleviate although it may not entirely eliminate this condition. All the available treatment solutions and plant locations will have the same sludge disposal problem. This will be addressed in later sections of the study since the disposal of sludge does not directly affect the effluent quality.

Several potential sites are identified and investigated below with emphasis on evaluating site-specific conditions to determine the most advantageous and cost-effective treatment plant location or locations and scheme for disposal of treated sewage.

7.4.1 Site Selection

Three potentially suitable sites have been selected and are identified as the East Wadi site and the Upper and Lower Zarqa sites. The sites are generally located north of the City of Zarqa as shown on Figure 6.2.

Two sewage treatment system schemes are considered due to the natural topography of the Zarqa-Ruseifa service area. The first scheme involves construction of one sewage treatment plant at the most advantageous of the above three sites. The second scheme involves construction of two sewage treatment plants. One plant would be located at either the Upper or Lower Zarqa sites and would treat wastes collected from Ruseifa and those areas in the City of Zarqa west of the ridge separating the Zarqa River and the Wadi Saida. The other plant would be located at the East Wadi site and would treat wastes collected from those areas in the City of Zarqa east of the ridge. The dual plant alternative would have the benefit of minimizing collection system pumping requirements. Gravity conveyance of sewage to the plant would be possible for areas east of the ridge. However, hydraulic conditions are such that plant influent pumping would be required to permit gravity flow through the facility. The other treatment plant on the Zarqa

River also would permit gravity conveyance to the plant with influent pumping if the Upper Zarqa River site is used. No pumping would be required if the Lower Zarqa River site is selected. Under the single treatment plant scheme, more costly pumping facilities would be required to convey sewage across the dividing ridge.

A cost-effectiveness analysis is presented in Table 7.1 comparing single versus dual plant schemes. The tables referenced in Chapter 6 summarizing the conveyance and treatment costs of these schemes reveal that the lower conveyance system cost realized by the dual treatment plant scheme is overcome by the significant cost savings realized by constructing one larger but equally efficient treatment system under the single treatment plant scheme. It is, therefore, recommended that sewage from the Zarqa-Ruseifa area be treated at one treatment plant.

In analyzing each site the question of expandability must be addressed. Malcolm Pirnie, Inc.'s assignment for the preparation of this report is to plan initial facilities for the year 1990 conditions and plan for needs up to year 2000. Chapters 2 and 6 indicate that by the year 2020 the project area will be nearly saturated and the sewage flows will be nearly twice those of the year 2000.

A detailed description of each site and the determination of the site best suited as the location of the new treatment plant is presented below.

East Wadi - This 34-hectare site is located northeast of the City of Zarqa along a branch of the Wadi Saida and adjacent to an existing Army Ordnance Depot. In the absence of available topographical records, field observations were conducted and revealed the site to be gently sloping in nature in a westerly direction towards the Wadi. Furthermore, observations revealed the area is presently under cultivation and appears to have been used in the past for military training purposes.

Based strictly on a construction point of view, this site has the most to offer when compared to the other sites. The gentle sloping terrain would avoid the construction difficulties associated with steeper sloping lands and the total land area would certainly permit consideration of most treatment and disposal schemes in addition to allowing for facilities expansion to meet projected saturation demands. However, both environmental and adjacent land use conditions severely impact on the suitability of this site.

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The Wadi Saida is an intermittent watercourse that travels in a northerly direction from the site joining the Wadi edh Dhuleil approximately 2 kms upstream of the confluence with the Zarqa River. The intermittent flow nature of this Wadi as well as its highly porous rock strewn bed is quite similar to the conditions evident for the watercourse available to other sites being considered. However, penetration into the upper aquifer with possible ultimate intrusion of treated sewage into the lower water supply aquifer would be a distinct possibility. As a result, discharge of plant effluent to the Wadi Saida would require costly facilities for providing complete nitrification/ denitrification capability to avoid increasing the already high levels of nitrates in area groundwater supplies.

As an alternative to watercourse discharge, land application is considered with the previously mentioned benefits of providing additional cultivated lands and a source of direct groundwater recharge. Although the degree of treatment required at the treatment plant would still require combined primary and secondary treatment, the above nitrification/denitrification capability would be eliminated. A controlled irrigation program using treated sewage for only select crops is generally considered a cost-effective method of providing advanced treatment as the ability of soil and crops to absorb nutrients serves as an integral part of the overall treatment process. Nitrate levels can be effectively minimized to acceptable levels by reducing ammonia-nitrogen concentrations in plant effluent to within 10-15 percent of raw sewage values. Using a 2.54 cm per week application rate, land requirements are estimated at approximately 7 km^2 in 1990, 11.5 km^2 in 2000 and 23 km^2 in year 2020. These are reasonable estimates based on documented land application practices but do not reflect actual soil conditions at the East Wadi site. A detailed soil survey of this area would be necessary to determine optimum loading conditions. Unfortunately, the only area adjacent to the site that has terrain suitable for an irrigation program appears to be presently dedicated to military use. According to information received from the National Planning Council, military land receives top priority and would most likely not be made available for land treatment purposes.

It is concluded that the East Wadi site is not a viable location for the new treatment plant based on the economics of watercourse

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discharge and the presumed unavailability of acceptable adjacent land for irrigation.

Upper Zarqa River - This 13.7-hectare site is located northwest of the City of Zarqa along the Zarqa River and was originally selected in the 1975 report on Wastewater Disposal and Stormwater Drainage for the City of Zarqa prepared by Scan Plan Coordinator and Jouzy & Partners. Available site plans characterize this site as a steeply sloping side-hill site with slopes exceeding 15 percent. The land slopes from the east to the Zarqa River. As a result of this condition, construction on this site would require a tremendous amount of earthwork.

The suitability of this site for construction of the new treatment plant is significantly influenced by site size. Additionally, only watercourse discharge will be considered due to the unavailability of suitable adjacent land for land treatment purposes.

This section of the Zarqa River is similar to the Wadi Saida at the East Wadi site in that it is intermittent in nature having a highly porous rock strewn bed. The river travels in a northerly direction from the site approximately 7 kms to the community of Sukhnah. At Sukhnah, surfacing of the aquaclude separating the upper and lower aquifers allows springs under artesian pressure from the lower aquifer to provide continuous flow to the river. Furthermore, the presence of the aquaclude in the area extending from the site to Sukhnah precludes the possibility of groundwater pollution by nitrates discharged from the new treatment plant since peretration of the lower supply aquifer would not be expected. Nitrification/denitrification capability, therefore, is not considered necessary for a treatment plant at this site.

The impact of site size is substantial. It is estimated that the available site area would not be capable of accommodating any of the alternative treatment and disposal schemes considered in this section, assuming that the more cost-effective but land-intensive sludge drying beds are to be utilized in lieu of mechanical dewatering equipment. A detailed cost-effectiveness analysis presented in Table 7.2 substantiates the overwhelming cost benefit provided by sludge drying beds. However, the only way this site could be utilized is to construct a compact common wall activated sludge plant with mechanical sludge

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dewatering. Figure 7.1 shows a plot plan based on this premise. Table 7.3 presents the construction cost estimate for such a plan.

It is concluded that the Upper Zarqa River site is not suitable for the location of the new treatment plant due to limited site area necessitating excessive construction costs. It should be noted that the underlying reason for the site being considered unsuitable now but suitable under the original 1975 facilities planning report by Scan Plan Coordinator and Jouzy & Partners is the design flow and pollutant loading basis. The previous report included only sewage generated by the City of Zarqa whereas present considerations include both domestic and industrial contributions from the area of Ruseifa.

Lower Zarqa River - This 28.5-hectare site is located northwest of the City of Zarqa approximately 2 kms downstream of the Upper Zarqa River site along the Zarqa River. In the absence of available topographical records, field observations and preliminary surveys were conducted and revealed the site to be less steep than the upstream site and of better agricultural quality.

Since the potential for groundwater pollution is the same as the upstream site, the degree of treatment necessary would not include costly nitrification/denitrification. Furthermore, since suitable adjacent land is unavailable for land treatment purposes, watercourse discharge would be the recommended effluent disposal method. The determining factor of site suitability is, therefore, available site area.

It is estimated that sufficient site area is available to construct the new treatment plant utilizing any of the alternative treatment and disposal schemes considered in this section assuming use of the more cost-effective sludge drying beds. Furthermore, this site would lend itself for expansion to meet projected year 2020 saturation conditions.

Although construction would require considerable earthwork, benefits of minimizing the degree of treatment by eliminating nitrification/denitrification and the ability to evaluate several treatment schemes makes this site very favorable. It is, therefore, concluded that the Lower Zarqa River site is recommended for the location of the new treatment plant.

7.4.2 Existing Stream Conditions

The selection of the Lower Zarqa River site as the location of the new treatment plant and the planned use of the Zarqa River for watercourse discharge of treated sewage requires a review of stream conditions to determine the proper degree of treatment. Specifically, hydraulic, hydrologic and water quality conditions for areas both upstream and downstream of the site will be reviewed.

At the community of Sukhnah, located approximately 5 kms downstream of the selected site, springs from the lower aquifer feed the river and from this point on the river normally has a base flow due to the Sukhnah springs plus other groundwater additions. Upstream of Sukhnah and extending to the City of Amman, the river flow is affected by pronounced annual dry weather and wet weather periods. This seasonal influence is characteristic of watercourses in the Zarqa-Amman area.

Dry weather conditions occurring eight to nine months of the year result in a zero flow condition in the river upstream of Sukhna. The severity of this dry weather condition is evidenced by the fact that the treated sewage discharged at the upstream City of Amman's Ain Ghazal Treatment Works does not reach the City of Zarqa located approximately 20 kms downstream. The discharge is completely utilized by a combination of agricultural irrigation, upper aquifer recharge through river bed seepage and evaporation. Furthermore, any flow contribution during dry as well as wet weather periods from the existing springs in the vicinity of the City of Zarqa is not anticipated as actual spring flows have been decreasing year by year as the pumping of groundwater has increased. Presently, their contribution to the base flow of the river is insignificant to nonexistent.

The National Water Master Plan predicts stream flows in the vicinity of the City of Zarqa, on an annual basis, of 0.056 to 0.06 million $m^3/yr/km^2$ for a wet year, 0.04 to 0.044 million $m^3/yr/km^2$ for the average year and 0.028 to 0.034 million $m^3/yr/km^2$ for a dry year. For the 578 km^2 drainage area upstream of the selected site the annual river flows would be as follows:

Wet Year	-	650 km^2 x 0.058	=	37.70 Mm^3/yr
Average Year	-	650 km^2 x 0.042	=	27.30 Mm^3/yr
Dry Year	-	650 km^2 x 0.031	=	20.15 Mm^3/yr

The above figures are the total annual projected flows; however, all of these flows occurs on a three to four-month period. The average flows over a four-month period would be as follows:

Wet Year	-	37.70 Mm^3/yr	x	1/4	=	9.43 Mm^3/mo
Average Year	-	27.30 Mm^3/yr	x	1/4	=	6.83 Mm^3/mo
Dry Year	-	20.15 Mm^3/yr	x	1/4	=	5.04 Mm^3/mo

The average daily flow during the wet season would be:

Wet Year	-	9.43 Mm^3/mo	x	1/30	=	314,300 m^3/day
Average Year	-	6.83 Mm^3/mo	x	1/30	=	227,700 m^3/day
Dry Year	-	5.04 Mm^3/mo	x	1/30	=	168,000 m^3/day

The rainfall pattern in the Zarqa-Amman area is such that the flows in the Zarqa River will be very irregular and during the wet season the flows in the river may be considerably less than the average daily wet weather flow.

The water quality of the Zarqa River is affected by the following:

- Effluent from Ain Ghazal Treatment Works
- Effluent from industries discharging to the river between Amman and Zarqa
- Water runoff
- Use of fertilizers and pesticides on agricultural lands

Although there is no available quality data for the Zarqa River in the vicinity of Amman or the City of Zarqa, to permit a direct assessment of the impact of the above items, water sampling was performed further downstream in connection with the planning of the King Talal Dam in 1976 and 1977.

The King Talal Dam is located on the Zarqa River approximately 40 kms below the City of Zarqa. Sampling of the waters of the Zarqa River at the Jarash Road Bridge, a point approximately 6 km above the dam, taken in 1976 revealed the following:

Ca	98 mg/l	HCO_3	268 mg/l
Mg	41 mg/l	SO_4	192 mg/l
Na	145 mg/l	NO_3	6 mg/l

K	16 mg/l	Total Cations	300 mg/l
SO_2	15 mg/l	Total Anions	731 mg/l
Cl	238 mg/l	TDS	1031 mg/l
CO_3	11 mg/l	pH	7.9

There is no indication on the source of this data (Stanley Consultants, Feasibility Studies, Subactivity, Amman Water and Sewerage, AID/otr-c-1628 dated May 19, 1978) as to whether or not the sampling was done in the wet or dry season. In addition, no organic sampling was performed.

Since water quality of the river in the vicinity of the selected site will range from that of the effluent from the Ain Ghazal Treatment Works plus industrial wastewater contributions to a more dilute condition during the wet season, sampling results of the Ain Ghazal effluent from the Amman STP from April 10, 1976, through August 31, 1976, (five samples, type unknown) are presented as follows:

EC	1530.00	to	1880.00	mmhos/cam
TDS	998.00	to	1230.00	mg/l
pH	7.32	to	7.95	-
SO_2	25.00	to	53.00	mg/l
CA	2.84	to	3.97	mg/l
Mg	1.63	to	3.26	mg/l
K	0.97	to	1.36	mg/l
Cl	6.16	to	7.02	mg/l
CO_3		0		mg/l
HCO_3	1.58	to	9.63	mg/l
SO_4	1.54	to	2.10	mg/l
NO_3	28.7	to	208.2	mg/l
NO_2	0.08	to	4.3	mg/l
NH_4	3.74	to	28.6	mg/l

Once again no biochemical data was reported. A comparison of the data taken from samples at the Jarash Road Bridge and the Ain Ghazal effluent presented below show generally reduced downstream concentrations.

	Jarash Bridge	Ain Ghazal Effluent
CA	98 mg/l	113.6 to 158.8 mg/l
Mg	41 mg/l	89.7 to 179.3 mg/l
K	16 mg/l	37.8 to 53.0 mg/l
Cl	238 mg/l	218.7 to 249.2 mg/l
CO_3	11 mg/l	0 mg/l
HCO_3	268 mg/l	96.4 to 587.4 mg/l
SO_4	192 mg/l	147.8 to 201.6 mg/l
NO_3	6 mg/l	28.7 to 208.2 mg/l
TDS	1031 mg/l	998.0 to 1203.0 mg/l
pH	7.9	7.32 to 7.95

The discharge of the treated wastewaters from the Ain Ghazal Treatment Works appear to affect the waters in the Zarqa River in two areas, the hardness of the waters and the nitrate levels will be increased. From a public health standpoint the increase in nitrates is the most pertinent.

7.4.3 Future Stream Use

The Zarqa River begins in the area of Amman and ends at the Jordan River, with the King Talal Dam located upstream of the confluence with the Jordan River. Along this route are several major developed areas including Ruseifa, Zarqa and Sukhnah. With the exception of the area between Amman and Ruseifa, which utilizes river water for irrigation of agricultural lands, these developed areas presently do not use the watercourse as a source of potable water. Although the discharge of properly disinfected treated sewage at the selected site would not preclude the downstream use of river water for irrigation, future downstream use as a potable water source would be limited due to the high nitrate concentrations from the waste discharge. A relatively high degree of treatment would, therefore, be required for river water drawn at these developed areas for use as potable water.

The downstream King Talal Dam was originally planned to provide irrigation water, but at a later date it was also considered as a potential source of potable water. But after the reservoir was partially filled, an examination of the quality of the water indicated that its use for potable water was very questionable. For the purposes of this report, the future use of the waters from the King Talal reservoir are assumed to be dedicated solely for irrigation purposes.

7.4.4 Degree of Treatment

The intended future use of downstream waters and the natural ability of the river to assimilate pollutant loads will establish the discharge requirements and, therefore, the degree of treatment required at the new treatment plant. Recognizing the future intended use of downstream waters strictly for irrigation purposes, the main objective of treatment will be to produce a disinfected effluent low in suspended solids to minimize river bed sludge buildup and low in BOD_5 to maintain aerobic river conditions.

Although present planning dedicates the reservoir at the downstream King Talal Dam as a source of water for irrigation, a possible future reassessment of the areawide water supply needs may result in consideration of the reservoir as a potable water source. However, utilizing the reservoir as a potable water source would require either nitrogen removal when treating the water for potable use or reduction of the nitrogen added to the river from discharges at both the new treatment plant and the upstream Ain Ghazal Treatment Works. Costly nitrification/denitrification facilities can be included at these upstream sewage treatment plants to minimize the discharge of nitrogen, but a more practical solution may be to utilize the nutrient uptake capability of the reservoir's aquatic environment to reduce nitrogen levels prior to water treatment. The process requirements at any new water treatment plant treating reservoir water would, therefore, be minimized. Based on this reduced treatment requirement and the general uncertainty concerning the future potable water use of the reservoir, nitrification/denitrification facilities are not recommended for the new treatment plant.

Disinfecting treated sewage prior to watercourse discharge is an accepted practice aimed at protecting public health by minimizing the potential for spread of waterborne disease. Since downstream river

water is used for irrigation and possibly other public uses, disinfection of plant effluent is essential.

Chlorine is the most commonly used disinfecting agent based on its effectiveness and economics of use. When chlorine is applied to treated sewage it rapidly breaks down into hypochlorous acid (HOCl) and hypochlorite ion (OCl). Each of these components are highly effective germicides. However, in the presence of sewage having high ammonia-nitrogen concentrations, as is the case with the Zarqa-Ruseifa sewage, the predominant germicidal agent is monochloramine. Monochloramine is formed from the reaction of ammonia-nitrogen and HOCl and is generally considered to be a weaker germicide as compared to HOCl or OCl. As shown on Figure 7.2, effective destruction of pathogenic disease causing organisms by means of monochloramines requires maintenance of a 2.0 mg/l chlorine residual in the plant effluent following 30 minutes detention. A chlorine dosage of 6 to 12 mg/l would be required to maintain this residual. As a comparison, typical American and European treatment plants receiving sewage with substantially less ammonia-nitrogen concentrations require chlorine dosages of 4 to 6 mg/l to maintain chlorine residuals of 1 mg/l following 15 minutes detention.

Although viral inactivation in addition to destruction of pathogenic bacteria is highly desirable, treatment plants rarely achieve complete virus removal since the cost associated with maintaining a 0.5 mg/l free chlorine residual following 15 minutes detention as recommended by the World Health Organization is prohibitive. Obtaining a free chlorine residual requires breakpoint chlorination or greater chlorine dosages resulting in essentially the complete utilization of ammonia-nitrogen and monochloramine.

With the relatively high raw sewage suspended solids concentrations, a high removal rate will be necessary to reach a plant effluent concentration that is generally considered acceptable to minimize river bed sludge buildup. Based on experience with treatment facilities having similar high level influent suspended solids concentrations it is anticipated that an effluent concentration of 30 mg/l can be effectively achieved by conventional primary and secondary sedimentation. However, a secondary settling aid such as polymer may be necessary to achieve the required removal rate.

The actual degree of biological treatment necessary to maintain aerobic conditions in the river will depend entirely on the ability of the river to assimilate pollutant loads along its entire length but in particular along its most critical sections. Specifically, an analysis is required to estimate the amount of oxygen utilized in the river during the assimilation of pollutant loads (deoxygenation) versus the natural ability of the river to increase dissolved oxygen levels (reoxygenation) to meet this demand.

The most critical downstream section of river is the 5 km section extending from the selected treatment plant site to the community of Sukhna. This section of river would have the potential of receiving the most concentrated pollutant loading since in addition to receiving the discharge from the new treatment plant, wet season flows may include the entire discharge from the upstream Ain Ghazal Treatment Works since irrigation, river bed seepage and evaporation of the Ain Ghazal flow would be minimal. Furthermore, the relatively moderate stream slope in this section nearly doubles downstream of Sukhna. Thus, the velocity and natural turbulence of the river in this section is at its lowest level thereby minimizing its ability to increase dissolved oxygen levels.

In the absence of adequate water quality and flow data which would permit use of conventional models for analysis of the rivers ability to assimilate oxygen-depleting wastes, an alternative method is utilized. The alternative method, as presented in the 1976 Water Pollution Control Federation Journal by E. C. Tsivoglou and L. A. Neal is based on the theory that the reaeration rate coefficient is directly proportional to the slope of free-flowing inland streams. Results obtained by tracer studies in more than 400 km of 24 streams verifies this theory to within acceptable limits of accuracy.

Assuming a 95 percent BOD_5 reduction as the reliable upper limit of performance offered by available treatment technologies, the alternative slope method for river analysis indicates that the combination of the proposed discharge and the Ain Ghazal effluent will most likely cause a serious depletion of dissolved oxygen in the river between the selected site and Sukhna. Dissolved oxygen levels may drop below 1 mg/l. To overcome this deficiency, excess dissolved oxygen must be introduced to the effluent at the new treatment plant through post-aeration facilities.

To minimize the possibility of the waters in the Zarqa River being devoid of dissolved oxygen and becoming septic, the treatment plant effluent should have an average 5-day BOD concentration of 50 mg/l and a minimum of 6 mg/l of dissolved oxygen. To prevent bottom deposits of sludge from exerting additional oxygen demand on the waters of the river during the warmer periods of the year, the plant effluent should also have an average suspended solids content of 50 mg/l.

7.5 Alternative Treatment and Disposal Systems

The treatment and disposal system proposed for the new treatment plant must be capable of meeting the water quality objectives established for the Zarqa River in Section 7.4 and, furthermore, must provide for sound sludge management. The basic treatment processes and operations required to meet these goals include the following:

- Preliminary Treatment
- Primary Treatment
- Secondary Treatment
- Final Sedimentation
- Disinfection/Post Aeration
- Solids Handling

A state-of-the-art review of available technologies for use in these processes and operations is presented below to provide a means of identifying viable alternative treatment and disposal systems. The applicability of the available technologies to the proposed treatment facilities is discussed where alternative processes are to be considered. This is especially true in the case of secondary treatment facilities.

7.5.1 Available Treatment Technologies

7.5.1.1 Preliminary Treatment

The major function of preliminary treatment is to separate coarse material from the wastewater, assuring efficient use and protection of subsequent treatment processes and equipment. Processes and equipment commonly used for pretreatment include screening, grit removal, odor control, and preaeration. In addition, influent pumping facilities may be required to provide sufficient hydraulic head to permit gravity flow through the treatment plant.

Screening

Large solids such as pieces of wood, roots, rags, and other debris found in combined sewer systems and to a lesser degree in separate

sewers may be removed either by screening, or by a combination of comminution and screening. A comminutor is a mechanically-cleaned screen which incorporates a cutting mechanism to shred the large solids which pass through the bar screens without removing them from the wastewater. A potential problem with this type of screening device is dulling of the comminutor blades, resulting in inefficient performance. However, this problem can be minimized with proper maintenance procedures.

Another method of screening is the use of bar screens. These screens consist of parallel steel bars placed at an angle in the influent channel. Solids which are collected on the bars may be removed either by automatic or manual rakes for further processing, such as for size reduction and dewatering.

Odor Control

Odor control typically is accomplished by chemical treatment of the plant influent waste stream. This chemical treatment usually is accomplished ahead of the screens and is intended to reduce odors caused by sulfide production in pipes, pumping stations, and wet wells. The odor-controlling chemicals, usually chlorine, ozone, hydrogen peroxide, or chlorine dioxide, are injected directly into the waste stream.

An alternative to chemical treatment to control odor involves either using aerated grit chambers or spraying odor-masking chemicals around the plant facilities.

Since the chemicals used for odor control also are typically used for disinfection, alternatives for odor control by chemical treatment are discussed in a subsequent section of this chapter concerning disinfection.

7.5.1.2 Primary Treatment

Primary treatment involves the removal of readily settleable suspended solids, mostly organic, plus grit, from the raw wastewater by gravity settling. When used to remove settleable suspended solids ahead of the chemical or biological processes utilized for colloidal and dissolved organic removal, this process is referred to as primary sedimentation. This simple process results in significant reductions in oxygen-demanding materials and suspended solids, thus reducing loadings to subsequent plant processes. Efficiently operated primary tanks can remove practically all settleable solids, 50 to 65 percent of

the suspended solids, and 25 to 40 percent of the biochemical oxygen demand (BOD).

The major purpose of primary sedimentation tanks is to provide a quiescent condition to allow the solids in the wastewater to settle out. The settled solids then are collected from the bottom of the tank and conveyed by scrapers to a trough or sump for removal as primary sludge.

A secondary purpose of primary sedimentation tanks is to collect the solids floating on the water surface. These nonsettleable suspended solids, called scum, usually are collected with dipping skimmers at the effluent end of rectangular tanks or with scum boxes near the effluent weir in circular tanks. The scum can be handled separately or together with the primary sludge prior to disposal.

The design of primary sedimentation tanks is based on several factors, including solids loading, detention time, surface settling rate, and overflow rate. Primary sedimentation tanks usually are rectangular or circular tanks approximately 3.1m deep. The surface loading rate and detention period are about 32,600 liters per day per square meter and 2 hours, respectively. Primary tanks will be required for this project.

7.5.1.3 Secondary Treatment

The major purpose of secondary treatment is to remove the BOD, which escapes primary treatment.

Secondary treatment technologies may be categorized as follows:

- Biological
- Physical-Chemical
- Land-Intensive

Various biological and physical-chemical secondary treatment techniques are described below. Land-intensive (land treatment-lagoons) techniques are not described since this process is not feasible at the selected Lower Zarqa site.

Activated Sludge Treatment with Air

The conventional activated sludge system is a biological treatment process in which raw or settled wastewater is mixed with an active biomass in an aeration tank. The biomass utilizes the carbonaceous oxygen-demanding materials in the wastewater as an energy source and converts this material to carbon dioxide, water, and additional biological solids.

In the activated sludge process, wastewater flows continuously into an aeration tank where air is added to mix the active biomass with the wastewater and to supply the oxygen needed for the microbes to break down the organic constituents. Air is introduced either by injecting it into diffusors near the bottom of the aeration tank or by mechanical mixers located at the surface of the aeration tank.

The activated sludge process is very flexible and has been adapted to a variety of wastewater treatment applications. The process is capable of producing a high quality effluent with typical removal efficiencies of between 85 and 95 percent of the influent BOD_5 and suspended solids.

One disadvantage of the activated sludge process is that it requires careful operational control. Also, energy requirements may be relatively high.

Trickling Filters

The trickling filter is a device for bringing settled wastewater into contact with a surface of biological growths. These growths function in the same manner as activated sludge, that is, in the presence of air, organic matter is stabilized to cell matter, carbon dioxide, and water. In operation, the wastewater is distributed over the active biological surface which is built-up on a medium of an inert material such as rock or slag, or on synthetic media. The individual pieces of material are sized to permit free flow of liquid downward and free flow of air upward to maintain aerobic conditions in the filter bed.

Trickling filters are classified by hydraulic or organic loading as standard-rate (low-rate) or high-rate. Standard-rate trickling filters require considerable land areas because of their characteristically low surface loadings. Recirculation of the effluent in a high-rate filter allows the application of higher surface loadings.

The use of rock trickling filters can result in plugging of the void spaces in the rock filter under high organic loadings. Also, the volume of the void spaces, which is limited in a rock filter, restricts the circulation of air in the filter and, thus, the amount of oxygen available for the microorganisms. To overcome these limitations, other materials, such as modules of corrugated plastic sheets, redwood slats and plastic rings, have been used in place of rocks. These media offer

larger surface areas for biological growths and, thus, permit higher surface loadings.

The major advantage of the trickling filter process is its basic simplicity. Operational control of the process is rather simple, resulting in ease of plant maintenance. In addition, energy requirements for the process are relatively low.

The major disadvantage of the trickling filter process is the effect of air temperature on the process performance because of the large, fixed surface area of the microorganisms exposed to the air within the filter. Treatment efficiency decreases in the winter and improves during the summer. The lowest wastewater temperature has to be considered in sizing the treatment units. Filter flies may also prevail although to a lesser extent with plastic filter media than with rock filters.

Rotating Biological Contactors

This process is sometimes referred to as a biodisc. Biodiscs, similar to biofilters, combine features of both the activated sludge and trickling filter processes.

3.7 Meter (12 feet) diameter plastic media are mounted on a horizontal shaft and rotated slowly while partially immersed in wastewater. Biological growth develops on the surface of the media, providing the microorganisms needed for treatment. Rotation of the discs alternately brings the biomass in contact with wastewater for removal of pollutants and exposes it to the air for absorption of oxygen. Aerobic biological growth utilizes soluble biological oxygen-demanding materials as an energy source and converts the material to carbon dioxide, water, and additional biological cells. The shearing action, created as the biomass is rotated through the wastewater, strips excess biological growth from the media. This sheared biomass is kept in suspension by the mixing action of the rotating media, until the flow of treated wastewater carries the solids out of the process into a clarifier for separation and disposal.

Major advantages of this process include simple and stable operation, relatively high degree of treatment, ease of solids separation and disposal, and relatively low operating, maintenance, and construction costs. A major disadvantage of biodiscs is the need for cover to

protect the biological growth against low air temperatures, since treatment efficiency is affected adversely by temperatures of 10 C, or less.

Rotating biological contactors will not be considered for this project since they are land-intensive and their use would negate the possibility of utilizing open sludge drying beds.

Physical-Chemical Treatment

The use of physical-chemical treatment systems has been studied intensively in recent years. Because of the relatively new techniques involved, much less data are available concerning physical-chemical treatment processes than concerning most biological treatment processes.

Physical-chemical treatment systems which achieve secondary treatment levels similar to those achieved by biological systems consist of primary settling (with or without chemical addition), chemical coagulation and sedimentation, effluent filtration, and carbon adsorption. Chemical flocculation of suspended and colloidal solids (using lime, alum, or polymers) can achieve suspended solids removals equivalent to secondary treatment. Oxygen-demanding materials can be removed by filtration using a wide variety of filtration media, including sand, anthracite coal, and diatomaceous earth followed by carbon adsorbers. In addition, microstraining, a form of mechanical filtration, can be utilized.

Capital costs for physical-chemical treatment systems are similar to those for biological treatment systems. Physical-chemical processes offer several advantages over biological treatment processes. Physical-chemical processes may remove certain nonbiodegradable organic materials which cannot be removed by biological processes. In addition, physical-chemical processes are more adaptable to shock loadings, consisting of either hydraulic loadings or loadings from toxic materials.

A major disadvantage of physical-chemical systems is the high operating cost because of the expense involved in the purchase and handling of chemicals required for the process. In addition, sludges from physical-chemical plants generally pose a greater disposal problem than biological sludges because of their chemical contents, resulting in higher costs for sludge processing and disposal.

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One of the drawbacks to the physical-chemical process for secondary treatment includes the lack of removal of such major wastewater constituents as ammonia, and such trace chemicals as cyanide and chromium. Another question concerning physical-chemical plants involves the resource expenditure and wisdom of dosing wastewater with such large quantities of chemicals, when similar treatment levels can be accomplished by allowing the oxygen demand to be accomplished naturally or biologically.

Because of the cost of importing the chemicals required plus the higher degree of technical effort to make a physical-chemical plant operate this alternative technology will not be considered.

7.5.1.4 Final Sedimentation

The objective of this process is to concentrate and remove solids from the wastewater prior to disinfection and final effluent disposal. Sedimentation takes place in rectangular or circular mechanically-cleaned concrete tanks. The functions of these tanks are to maintain the wastewater qualities produced by the preceding unit processes and to remove and return sludge to the system. The sedimentation units often include equipment to remove any remaining oil, grease, or scum that floats on the water surface.

This process is very similar to primary sedimentation. The tanks may be designed for natural or chemically-assisted settling. Differences between primary and secondary tanks are their location in the plant flow pattern, their settled sludge density, settling rates, solids loading, and scum volume.

Factors influencing sedimentation include particle size and type, suspended solids concentrations, tank configuration, and flow distribution. All chemical or biological secondary treatment processes are followed by final sedimentation. Final clarification will be required for this project.

7.5.1.5 Disinfection/Post Aeration

The final step in the treatment process generally is disinfection of the wastewater effluent prior to discharge to the receiving waters. However, the degree of treatment required for the new treatment plant also includes the addition of dissolved oxygen to maintain aerobic stream conditions. Post aeration typically is combined with the final disinfection step and includes either aerating plant effluent by a diffused air system, mechanical aeration system or by a cascade system.

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Disinfection is the killing of pathogenic (disease-causing) bacteria found in wastewaters. Various chemical and physical methods of disinfection presently are available. Chemical methods include disinfection with chlorine, ozone, and hypochlorite. The most promising physical method is the use of ultraviolet light. Other chemical and physical methods are available but their use has not been as widespread as the above methods. The most common and least expensive method of disinfection is chlorination.

7.5.1.6 Solids Handling Facilities

Solids which are removed by various wastewater treatment operations include grit, screenings, sludge, and scum from primary and secondary treatment process operations. The treatment and disposal of these materials is a major ancillary operation of a wastewater treatment facility. There are numerous methods of handling wastewater solids, many of which achieve similar objectives. Some, however, are more efficient or better suited to a specific set of conditions than others. Criteria which may determine these conditions include the type of solids, the condition of the solids, the size of the treatment facility, the local geographic conditions, and public opinion and attitudes.

Sludge handling consists of two majors steps: 1) treatment; and 2) reduction and ultimate disposal. The overall objective of sludge treatment is to condition the sludge for further major reduction processes and/or ultimate disposal. Although a large number of alternative combinations of equipment and processes are used for treating sludges, the basic alternatives are fairly limited.

The following sections provide information on the various sludge treatment and reduction and disposal alternatives.

Sludge Thickening

Thickening increases the solids concentration of the sludge by partial removal of the liquid portion. It is used to concentrate and reduce the volume of primary and waste-activated sludge, making subsequent operations more economical. Solids concentrations of five to six percent can generally be obtained from mixtures of primary and waste activated sludges.

Thickening methods which are most commonly used include:

- Gravity Thickening
- Flotation Thickening

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Gravity Thickening - Gravity thickening is an economical method of substantially reducing raw sludge volume prior to further processing or disposal. The dilute material is continuously fed to the surface of the tank at the center of the thickening tank. Mechanical scraper arms gently stir the sludge to dislodge gas bubbles and to keep the sludge moving toward the bottom center of the tank. Solids settle into a sludge blanket at the bottom of the tank while the supernatant liquor passes over an effluent weir around its circumference. This liquid is then returned to the head of the treatment plant. Thickened sludge is pumped from the bottom of the tank to the next sludge processing operation.

Flotation Thickening - Flotation thickeners are generally used on waste activated sludges. Because of their fluffy nature, these sludges can be thickened to a maximum of three to four percent with gravity thickeners, while flotation thickeners are capable of concentrating these sludges to a range of four to six percent.

Flotation thickeners consist of an aeration system and a flotation unit or tank. Effluent from the flotation unit is aerated in a retention tank and then fed into the flotation unit at the bottom with the sludge to be thickened. The fine air bubbles combine with sludge particles, forming a sludge blanket at the top of the unit. The air bubbles force the surface of the blanket above the water level, inducing drainage of water from the sludge particles. The clarified effluent is discharged under a baffle, while the thickened sludge is removed by a skimming mechanism at the top of the unit.

Some advantages of flotation thickeners over gravity thickeners include: a higher solids content, lower capital costs, and maintenance of the sludge in an aerobic condition. Because of the aeration system, however, higher operating costs are incurred.

The need for sludge thickeners depends to a large degree on the type of secondary treatment being utilized. Activated sludge definitely requires thickening. Trickling filter solids do not normally require thickening; they can be combined with the solids in the primary tanks and the combined sludge will concentrate to equal to that of activated sludge from a gravity thickener or a flotation thickener.

Sludge Stabilization

The primary functions of stabilization are to make the sludge less putrescible and odorous, and to reduce the pathogen content. Several

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of the available stabilization processes also result in the removal of much of the water content and a substantial decrease in the quantity of sludge solids.

The major sludge stabilization processes which are being used in wastewater treatment are anaerobic and aerobic digestion. Lime treatment and chlorine oxidation are alternative sludge stabilization processes, but their use has been limited, due to high operating costs. The selection of a specific method of stabilization depends upon the final disposal procedure. If the sludge is to be dewatered and incinerated or composted, frequently no stabilization procedure is employed.

Other means of sludge stabilization include radiation, ozonation, ultraviolet light, ultrasonics, thermo-radiation, addition of carbolic acid, coal tar distillage, formalin, and sunlight. These may be used to stabilize very small quantities of sludge and will not be considered in this study.

Anaerobic Digestion - Anaerobic digestion is a biological stabilization process which utilizes anaerobic bacteria to decompose the organic constituents to methane, carbon dioxide, and an inert humus-like substance. Volatile solids are reduced 30 to 40 percent, making them amenable to further processing, such as dewatering or drying. The digested sludge, when properly disinfected, is suitable for disposal as a soil conditioner for agricultural purposes or, after dewatering, for disposal in a sanitary landfill.

Anaerobic digestion processes may be standard-rate and high-rate processes. Each utilizes a two-stage digester system. The first-stage tank provides mixing, to ensure a homogeneous material, and heating, to maintain optimum temperature conditions. Most of the methane gas, a by-product, is produced in the first-stage tank and this may be used for heating and for operating mechanical equipment (see Appendix 7.1). The sludge then is transferred to an unheated second-stage tank where the digestion process is completed, accompanied by a separation of solids and liquid. The supernatant liquor from the second-stage tank is conveyed to the head of the treatment plant, while the sludge is transferred for further processing for drying and disposal.

The high-rate process is characterized by a higher solids loading rate and a lesser detention time in the first-stage tank.

Aerobic Digestion

Aerobic digestion accomplishes the same end results as anaerobic digestion, that is, reduction in volatile solids and stabilization of the sludge. The reduction of the volatile solids is done in the presence of oxygen and the end products are carbon dioxide and water; no methane is formed. The maintenance of an oxygen rich atmosphere for the organisms in the sludge requires a large input of energy in the form of electricity to drive the devices that transfer the oxygen from the air to the solution. The process is energy intensive but simple to operate.

Both types of digestion will be investigated.

Sludge Dewatering

Sludge dewatering operations are used to reduce the moisture content of sludge so that it can be handled and processed as a semi-solid rather than as a liquid. Methods commonly used for dewatering sludge include:

- Spreading on Drying Beds
- Vacuum Filtration
- Centrifugation
- Pressure Filtration
- Belt Filtration

Drying Beds - A very common dewatering method is drying of the sludge on open or covered sand beds. Sludge is spread on sand beds in 8-inch to 12-inch layers and allowed to dry. Solids concentrations of up to 40 percent may be obtained after 10 to 15 days. The sludge is disposed of in a landfill, or used as a fertilizer.

The use of drying beds is affected by many factors, including climatic conditions, sludge characteristics, media and pipe clogging, land values, and proximity to residential areas. Climatic conditions may limit the use of drying beds to the warmer months of the year, unless beds are covered with greenhouse-type enclosures. The use of drying beds is generally limited to well-digested sludges. This feature eliminates the nuisances and health hazards due to odors and flies associated with drying of raw sludge. As long as land is available and the cost of the labor to clean the beds is available, the use of uncovered drying beds is usually the most cost-effective alternative.

Vacuum Filtration - Vacuum filtration is a mechanical dewatering method which can be used to reduce the water content of raw or digested sludges. It is a continuous operation that is generally accomplished

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with cylindrical drum filters. As the suspended drum rotates through a vat of sludge, the material is drawn to the filter medium covering the drum by an internal vacuum. The dewatered sludge then is removed from the drum for disposal. Conditioning with chemicals, usually lime and ferric chloride, or organic polyelectrolytes, is necessary, prior to vacuum filtration.

Proper selection of filter medium, adequate thickening of the feed sludge, and sludge conditioning are important factors in the design of vacuum filtration processes. However, vacuum filtration only can dewater sludge to about 15-25 percent solids. Solids contents of 20 percent are the most common. This process is chemical and energy intensive.

Centrifugation - The centrifugation process generally is employed for solid-liquid separation processes in industry. It also is applicable to municipal wastewater sludges and has been used for many years with varying degrees of success.

The machines used in wastewater treatment plants are of the solid bowl, conveyor-type with electric motor drive. Sludge is fed into the rotating bowl at a constant flow rate, where it separates into a cake containing the solids and a dilute stream called the centrate. The sludge cake can be disposed of, while the centrate is returned to the head of the treatment plant.

Depending on the type of sludge, solids concentrations ranging from 15 to 25 percent can be achieved with centrifugation. Solids contents of 15-20 percent are the most common.

Centrifuge operation normally requires chemical conditioning which typically is accomplished by polymer addition. Also, construction for centrifuge operation requires special firm foundations and soundproofing because of the resulting vibration and noise.

The major difficulty encountered with centrifuge operation is the disposal of the centrate which is relatively high in suspended solids. The recirculation of these solids could hinder the treatment process and reduce the final effluent quality.

Area requirements and capital costs usually are lower for centrifuges than for vacuum filters. However, the reverse is true for operating costs.

Pressure Filtration - Use of this process to dewater municipal sludge was limited prior to 1950, because of deficiencies associated with the filter media, mechanical features, capacity, and discharge. With significant improvements in filter media and automation, pressure filters have become a very attractive sludge dewatering device. The recent increase in energy costs has made pressure filtration highly competitive when compared with other dewatering methods.

Pressure filters consist of a number of filter plates draped with filter media which are supported and contained in a frame or skeleton. The skeleton is equipped with a hydraulic or electromechanical closing device which, during operation of the filter, will hold the plates together with sufficient force to resist the total force created during dewatering. This force also makes the joints between filter plates leak-proof during operation. The sludge is pumped into the filter with the filtrate passing through the media, while the solids are trapped to form a cake. Sludge feed is terminated when a predetermined pressure is reached and the flow of filtrate is low. At the end of each filtration cycle, the filter is depressurized and the closing device released.

Mechanical plate-shifting devices are used to move one filter plate after another through a working space and, in so doing, discharge the filter cake by gravity to a truck or incinerator for ultimate disposal. When all filter plates have been shifted, the closing device is reversed, and a new cycle is begun.

The capacity of a pressure filter is determined by the number of chambers and the volume of each chamber. The chambers are formed by the filter plates such that there is one less chamber than there are plates.

Compared with other sludge dewatering methods, pressure filters have higher cake solids concentrations (between 30 and 40 percent by weight), higher filtrate clarity, higher solids capture, and lower chemical consumption. The disadvantages associated with pressure filtration include batch operation and filter cloth life limitations. Due to high fuel costs and recent improvements in the degree of automation, filter media, and unit capacities, pressure filters may well be the most efficient sludge dewatering devices.

Belt Filtration - The belt filter press is another device capable of dewatering sludge. This device operates on the principle that bending a sludge cake contained between two filter belts around a roll introduces shear and compressive forces in the cake allowing water to work its way to the surface and out of the cake, thereby reducing the cake moisture content.

The belt filter press has three processing zones along the length of the unit. These include the initial draining zone, which is analogous to the action of a drying bed; the press zone, which involves application of pressure; and a shear zone in which shear is applied to the partially dewatered cake. A significant feature of the belt filter press is that it employs a coarse-mesh, relatively open-weave, metal-medium or synthetic fabric.

The belt filter press is capable of producing a drier cake than that produced by vacuum filters. Also, it consumes less energy than a vacuum filter. The major disadvantage with this device is the problem of belt wear, breakage, and limited number of operational installations.

Screenings, Grit and Skimmings

The amount of screenings, grit and skimmings collected at a waste treatment plant usually is small. But their sanitary disposal is very important because they are the most objectionable materials. Most often these wastes are grinded, concentrated and landfilled.

7.5.1.7 Conclusions from State-of-the-Art Review

The above findings indicate that there are many alternatives available for wastewater treatment and for handling of the sludges produced. Accordingly, the final selection of a wastewater treatment and disposal system for the new treatment plant must be based on consideration of the following key factors:

Nature of the Raw Wastes

Industrial wastes may have significant effects on the capacity and performance of a particular treatment process. Industrial pretreatment requirements should minimize these effects, but the process should be flexible enough to accommodate variations in pretreatment efficiency.

Effluent Requirements

The process must be capable of achieving treatment levels compatible with the water quality objectives established for the Zarqa River.

Process Reliability

The selected process should be capable of providing a maximum degree of reliability.

Sludge Production

The ability to handle sludges produced by the selected process in a cost-effective and environmentally sound manner must be considered.

Resource Consumption

The selected process should require a minimum expenditure of resources, such as power and chemicals.

Space Requirements

Treatment processes proposed for any plant must be compatible with space available.

Costs

The selected process must be cost-effective over the projected life of the treatment facility.

Each of these factors will be considered in developing and evaluating wastewater and sludge treatment and sludge disposal alternatives for the new facility. (See Appendix 5.2 for cost estimating background.)

7.5.2 Selected Alternative Treatment Systems

The alternative treatment and disposal systems considered most applicable, and yet cost-effective, are shown schematically on Figures 7.3, 7.4 and 7.5. The selected alternatives utilize a combination of the above technologies but basically differ by the proposed method of secondary treatment. Specifically, the following secondary processes are evaluated:

- Activated Sludge (Air)
- Trickling Filter (Stone Media)
- Trickling Filter (Plastic Media)

7.5.2.1 (Alternative 1) Activated Sludge with Anaerobic Digestion and Power Generation

Based on the analysis presented in Appendix 7.1 anaerobic digestion of the excess sludges will be utilized along with use of the gas produced to generate power.

Because of the availability of low price labor and land, sludge dewatering for alternatives will be by use of open drying beds. The beds will be uncovered and sized to store sludge during the wet season.

The plot plan of the Lower Zarqa site presented on Figure 7.6 shows the new treatment plant utilizing the activated sludge process. The key design elements used in layout of this facility are as follows:

Aeration Tanks	-	0.5 Kg BOD_5/Kg MLVSS/day 3600 MLSS
Final Clarifiers	-	23,020 liters/m^2/day
Flotation Thickeners	-	9.77 Kg/m^2/hr

MLSS = Mixed Liquor Suspended Solids Concentration
MLVSS = Mixed Liquor Volatile Suspended Solids Concentration

Table 7.4 presents a cost-effectiveness analysis for this alternative as well as for the other alternatives. Table 7.5 presents a detailed estimate of construction costs for each alternative including both local and U.S. shares. For purposes of analysis, the costs presented in these tables reflect the construction and annual operation and maintenance (O&M) requirements of year 2000 facilities while using present 1980 prices. A summary of the costs for the activated sludge alternative are as follows:

Capital Cost	JD 10,907,000
O&M	
Energy	36,000
Chemical	70,000
Maintenance	86,000
Labor	82,000
	JD 274,000

The present worth of this alternative based on a 20-year period of analysis and a 10 percent interest rate is as follows:

Capital Cost - Salvage Value	JD 9,893,000
Present Worth of O&M	2,332,000
Total Present Worth	JD 12,225,000

7.5.2.2 (Alternative 2) Trickling Filter (Stone Media) with Anaerobic Digestion and Power Generation

The plot plan presented on Figure 7.8 shows the new treatment plant utilizing the stone media trickling filter process. The key design elements used in layout of this facility are as follows:

Trickling Filters	-	0.63 Kg/m^3/day 4:1 Recirculation Ratio
Final Clarifiers	-	25,098 liters/m^2/day

A summary of the costs for the stone trickling filter alternative (see Table 7.4) are as follows:

Capital Cost	JD 13,215,000
O&M	
Energy	16,000
Chemical	64,000
Maintenance	74,000
Labor	75,000
	JD 229,000

The present worth of this alternative based on a 20-year period of analysis and a 10 percent discount rate is as follows:

Capital Cost - Salvage Value	JD 11,857,000
Present Worth of O&M	1,949,000
Total Present Worth	JD 13,806,000

7.5.2.3 (Alternative 3) Trickling Filter (Plastic Media) with Anaerobic Digestion and Power Generation

The plot plan presented on Figure 7.9 shows the new treatment plant utilizing the plastic media trickling filter process. The key design elements used in laying out this facility are as follows:

Trickling Filters	-	1.89 $Kg/m^3/day$ 3:1 Recirculation Ratio
Final Clarifiers	-	23,020 $liters/m^2/day$

A summary of the costs for the plastic trickling filter alternative (see Table 7.4) are as follows:

Capital Cost	JD 10,734,000
O&M	
Energy	14,000
Chemical	64,000
Maintenance	74,000
Labor	75,000
	JD 227,000

The present worth of this alternative based on a 20-year period of analysis and a 10 percent discount rate is as follows:

Capital Cost - Salvage Value	JD 9,796,000
Present Worth of O&M	1,932,000
Total Present Worth	JD 11,728,000

7.5.2.4 (Alternative 4) Trickling Filter with Plastic Media and Aerobic Digestion

This alternative is similar to Alternative 3 except that aerobic digestion is substituted for anaerobic digestion and electric power will have to be purchased off site instead of generated on site. The plot plan presented on Figure 7.8A shows the new treatment plant utilizing the plastic media trickling filter process plus aerobic digestion. The key design elements used in laying out this facility are as follows:

Trickling Filters	-	1.89 g/m^3/day 3:1 Recirculation Ratio
Final Clarifiers	-	23 920 liters/m^2/day
Aerobic Digesters	-	20 days detention

A summary of the costs of this alternative (see Table 7.4) are as follows:

Capital Cost	JD 9,290,000
O&M	
Energy	343,000
Chemical	64,000
Maintenance	74,000
Labor	75,000
	JD 556,000

The present worth of this alternative based on a 20-year period of analysis and a 10 percent discount rate is as follows:

Capital Cost - Salvage Value	JD 8,540,000
Present Worth of O&M	4,732,000
Total Present Worth	JD 13,272,000

7.5.2.5 Analysis of Alternatives

Process Reliability

Each alternative is capable of providing a high degree of process reliability in addition to the necessary flexibility to accommodate variations in industrial pretreatment efficiency. However, the stone and plastic trickling filter processes with high recirculation rates are inherently more adaptable to shock loads than the activated sludge process.

Space Requirements

Available site area is sufficient for any of the alternatives considered but the actual area requirements vary. The stone trickling filter process requires significantly more land as compared to the requirements of both the plastic trickling filter and the activated sludge process which require essentially the same area.

O&M

On-site power generation utilizing methane gas from plant digesters is feasible to meet 100 percent of plant energy needs for all alternatives and will serve to effectively reduce overall plant O&M costs by minimizing power costs. Power costs will be limited to those costs associated with on-site generation facilities. A brief summary on the cost-effectiveness of on-site power generation is included in the Appendix 7.1.

Although power costs are minimized, the cost of generating power under the activated sludge alternative is twice that required under the trickling filter alternatives. This in addition to higher labor and chemical costs results in a significantly greater O&M cost for the activated sludge alternative as compared to the trickling filter alternatives. The O&M requirements for the stone and plastic trickling filter alternatives are essentially the same.

In the case of alternative 4 no electric power will be generated on the site with the exception of possible emergency power. This alternative also has a higher power demand than Alternative 3 since aerobic digesters have been substituted for anaerobic digesters. Due to the need for off-site purchased power and a higher power demand the cost of energy is significantly greater than Alternative 3, Other O&M costs remain essentially the same.

Expandability

Available site area is such that any of the alternative treatment processes may be expanded in capacity to meet year 2000 requirements. However, the site area is insufficient for expansion to meet the saturation conditions of year 2020. The proposed sludge drying bed operation must be either abandoned for more costly mechanical dewatering equipment or greater land area acquired to allow plant expansion to meet saturation conditions.

Possible future expansion of overall plant treatment capability to meet nitrification/denitrification requirements could be readily accomplished by the addition of essentially the same process equipment under each alternative.

Cost of Engineering

The four alternatives have different engineering costs since they have different complexities. In general, the more expensive a project is

to construct, the more engineering cost is required. In Chapter 9, the engineering cost is estimated as a percentage of the construction cost. Thus, the different engineering costs are generally reflected in the total project cost estimates. The recurring operation and maintenance costs are usually higher when the engineering and construction cost is lower.

A good example of this is a comparison of Alternatives 3 and 4. Analysis of all alternatives presented both from a monetary and qualitative viewpoint indicate that Alternative 3 is the best-suited solution. However, Alternative 3 will have a higher engineering cost than Alternative 4 because the facilities are more complex.

Alternative 4 has an energy cost estimate for the year 2000 projected conditions of JD 343,000 per year as compared with JD 14,000 per year for Alternative 3. At the year 2000 design conditions, the increased cost is equal to JD 329,000 per year. Depending on the rate of making service connections to the sewer system, the increased engineering costs to design Alternative 3 instead of 4 would be repaid in the first several years of operation. Once dual fuel engine generators are installed, it is still less expensive to use purchased fuel than to purchase electric power. With the past history of escalating energy cost the payout period could be substantially less.

7.5.2.6 Recommended Treatment and Disposal System

The above qualitative analysis reveals that the alternatives offer similar advantages in most key areas. The exception is in the area of operation and maintenance where greater labor, power and chemical requirements are associated with the activated sludge process as compared to the trickling filter alternatives and the anaerobic digestion with gas utilization as compared to aerobic digestion with off-site energy purchase. However, since the impact of these O&M requirements are directly reflected in the annual O&M costs the basis for selecting the most practicable treatment and disposal system will be a combined analysis of the total present worth of the alternatives and energy requirements.

Based on the total present worth in JD 1,000, the alternatives are ranked as follows:

	Present Worth	Annual Energy Cost
Alt. 3 - Trick. Filt. (Plastic) W/Anaerobic Digestion	JD 11,728	JD 14
Alt. 4 - Trick. Filt. (Plastic) W/Aerobic Digestion	JD 13,272	343
Alt. 1 - Act. Sludge W/Anaerobic Digestion	JD 12,225	36
Alt. 2 - Trick. Filt. (Stone) W/Anaerobic Digestion	JD 13,806	16

The recommended treatment and disposal system based on least cost is, therefore, the treatment system utilizing the plastic trickling filter secondary treatment process with anaerobic digestion and power generation. A partial site plan of the main treatment process area plus a detailed plant process plan of the main treatment process area plus a detailed plant process flow diagram, solids balance, hydraulic profile and longitudinal profiles through process units are presented on Figures 7.9 through 7.15, respectively. Unit design criteria are presented in Table 7.6.

7.5.2.7 Description of Selected Plan

Raw sewage would enter the recommended treatment facility from an interceptor traveling along the existing roadway connecting the City of Zarqa and Sukhnah. The sewage would be immediately screened to remove wood, roots, rags and other debris. Screened sewage flow would be monitored and then degritted in aerated grit chambers to minimize plant odors as well as to remove grit that can produce an undesirable grit buildup in downstream process units, particularly sludge digesters. Collected screenings and grit would be landfilled. Screened and degritted sewage would flow to a splitter box where chlorine could be applied as required for additional odor control. The main purpose of the splitter box, however, would be to equalize the flow to the primary clarifiers where settleable suspended solids are removed. Surface scum and skimmings from these clarifiers would be collected, ground, concentrated and landfilled. Primary clarifier effluent would then flow to a distribution chamber serving to equalize flow to the trickling filters where the majority of BOD reduction occurs. Designed for 83 percent removal at 40 C. Trickling filter effluent would then enter a wet

well/distribution chamber. A portion of the flow entering this chamber would be returned to the trickling filter to meet process performance requirements while the remaining flow would be distributed equally to the final clarifiers. Effluent from the final clarifiers would be monitored and then conveyed to chlorine contact/post aeration tanks for disinfection and maintenance of proper dissolved oxygen levels prior to discharge into the Zarqa River. Disinfected/aerated effluent would be used for in-plant nonpotable purposes.

Sludge drawn from the final clarifiers would be pumped into the primary clarifiers where it would be collected along with primary sludge and pumped to the primary and secondary digesters for stabilization. Digester gas would be used in conjunction with generators to meet all plant power needs. Digested sludge would be pumped to open air sludge drying beds. The drying beds and digesters will be sized to store sludge during wet months. Digester supernatant and drying bed filtrate would be returned via pumping to the primary clarifiers for processing.

The digestion facilities and sludge drying beds for the first stage of construction will be sized to meet the year 1990 loading conditions. Until the plant influent load is equal to the year 1990 design load the plant facilities will be capable of handling septage in varying amounts depending on the connected load at the time. Some additional facilities may be required to screen and equalize the septage.

7.6 Cost Estimate of Recommended Treatment and Disposal System

7.6.1 Basis of Cost Estimates

All cost analyses presented in this chapter follow the rules and regulations set up by the U.S. Environmental Protection Agency for performing cost-effectiveness analyses. The various components of a cost-effectiveness analysis are described as follows:

7.6.1.1 Economic Evaluation Criteria

The present worth analysis has been used for the economic evaluation based on the following criteria:

- Amortization Period - 20 years
- Planning Period for this analysis - 1980 to 2000
- Discount Rate - 10 percent
- Economic Life

  Major structures - 50 years
  Equipment - 20 years (average)

- Salvage Value - by straightline depreciation

7.6.1.2 Construction Costs

Construction costs consisting of costs on equipment and civil work have been estimated based on preliminary sizing of the treatment units, quotations from U.S. equipment manufacturers and current unit prices for construction materials in Jordan. Estimated construction costs reflect June 1980 cost levels (see Appendix 5.2).

Equipment costs have included costs from U.S. manufacturers, freight costs with insurance and handling charges to Jordan, unloading and transportation costs to the job site, cost for installation and a 20 percent overhead and profit for the general contractor.

Costs for civil work include the construction costs on site formation, building structures, tanks, pipelines and associated site work. Current unit prices from the Jordanian construction industry are used with an added on 20 percent overhead and profit for the general contractor.

7.6.1.3 Other Costs

- A total of 44 percent of the subtotal of construction costs has been allowed for construction contingencies, administration, legal, and engineering costs (see Chapter 9).
- Land acquisition costs for the treatment facilities is assumed to be JD 3 per square meter.

7.6.1.4 Capital Costs

- Total capital costs equal to the sum of total construction costs and total other costs.
- Salvage value equal to the present worth of the remaining capital costs, except for land, after depreciation is applied over the planning period. Land is assumed to be a salvage value at the end of the planning period equal to its prevailing market value at the beginning of the planning period.
- Net capital cost equal to total capital cost less salvage value.

7.6.1.2 Annual Operation and Maintenance Costs

Operation and maintenance costs for the various alternatives include all annual expenditures for labor, power and fuel, chemicals, routine replacement of equipment and equipment parts, miscellaneous supplies for the treatment plant, hauling costs of sludge cake for disposal and costs associated with administration and overhead. These costs have been estimated for each alternative based on preliminary determinations of manpower requirements, energy and chemical consumption and requirements for other materials. The following unit prices have been utilized in developing estimates of annual operation and maintenance costs:

Labor - Average JD 160 per month per man, including 20 percent fringe benefit

Power - 6.5 fils per kilowatt-hour, assuming on-site generation from digested gas (see Appendix 7.1). Purchased electric energy 30 fils per KWH include demand charges, etc.

Fuel - JD 30 per metric ton

Chemical -
Chlorine - 329 fils per kilogram
Ferric Chloride - JD 2.6 per kilogram

Hauling -
JD 1 per cubic meter

Administration and Overhead - Include salaries and fringe benefits of management personnel

7.6.2 Project Staging and estimated Costs

Malcolm Pirnie, Inc.'s assignment for the preparation of this report is to plan for the immediate construction of initial facilities to meet the year 1990 conditions while planning for future needs up to year 2000. The two-stage construction program necessary to meet these planning requirements involves the immediate first-stage construction of facilities capable of providing treatment capacity through year 1990. Second-stage construction would be required at year 1990 involving an expansion of the initial facilities to meet year 2000 conditions.

The estimated capital and annual operation and maintenance costs associated with these construction stages are presented in Table 7.7

The total costs are based on present 1980 prices and are summarized as follows:

	Capital	O&M
Phase 1	JD 7,677,000	JD 151,000
Phase 2	JD 3,057,000	JD 240,000

The construction cost has been divided into foreign and local costs as follows:

	Foreign JD x 10^3	Local JD x 10^3	Total JD x 10^3
Phase 1	2,548	2,350	4,898
Phase 2	1,104	1,019	2,123
Total	3,652	3,369	7,021

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8.0 STORMWATER DRAINAGE SYSTEM

8.1 Introduction

The objectives of the stormwater drainage system have been planned in a manner consistent with the overall goals of the study. The primary objective of the stormwater drainage system is to avoid, to the maximum feasible extent, flooding conditions which represent a threat to human life and health and which may cause property damage. At the same time temporary ponding and flow of stormwater along streets and footpaths will be acceptable if flow depths and velocities do not become excessive. This approach to design is warranted both by the basic project objectives and the relatively infrequent and low amounts of rainfall characteristic of the planning area.

The success of any stormwater drainage system depends upon:
a) the regulation and control of new development in a manner consistent with the criteria and standards contained in the Town Plan, and
b) continuing and effective maintenance of the system. New site development must take place in a manner consistent with the criteria and standards contained in the Town Plan so that new areas will be safe from flooding and present development will not be adversely affected by changes taking place.

In the first part of this Chapter, the basic principles governing drainage design are elaborated upon and the design criteria is established. In the second part of the Chapter, the existing situation is thoroughly examined taking into consideration the physiographic aspects. The third part of the Chapter deals with the proposed stormwater drainage systems. The systems are discussed and the appropriate solutions consistent with the conditions are outlined. The last part of the Chapter deals with cost estimates and economic considerations.

8.2 Design Criteria

8.2.1 Hydrological Considerations

Inspection of Appendix 8.1, Isohyetal Map of Jordan, shows that the planning area falls on the western fringes of the inland desert, and therefore, its climate may be characterized as arid to semi-arid. Rainfall data obtained from the Natural Resources Authority (NRA), indicates that the mean annual rainfall in the Planning Area based on a forty

year-record is 130 millimeters. The maximum annual total on record is 280 millimeters and the maximum daily rainfall is 60 millimeters.

The quantity of runoff in this project will be determined by the Rational Method:

$$Q = 0.00278\ CiA$$

where Q is the maximum discharge in cubic meters per second,

C is the runoff coefficient,

i is the rainfall intensity in millimeters per hour for a duration equal to the time of concentration of the watershed, and

A is the area of the watershed in hectares.

The rainfall intensity will be derived from the NRA curves which have been reproduced in Appendix 8.2. These curves are based on a 30 year record. From our experience of using NRA data on a number of projects, we have found their data reliable.

The runoff coefficient for use in the Rational Method may be selected from Appendix 8.3.

The time of concentration, tc, will be computed from the Kirpich Formula.

$$tc = 0.0192\ \frac{L^{1.155}}{H^{0.385}}$$

where, tc is in minutes,

L is the horizontally projected length of watershed in meters, and

H is the difference is elevation between the location and farthest point on the watershed in meters.

The factors that led to the use of the Rational Method on this project are: a) all the watershed areas in the planning area are ungaged, and therefore, determination of runoff has to be done by methods based on rainfall data; b) the easy-to-use features of the Rational Method, and the fact that, of all the empirical flood formulae, it has the advantage that its physical meaning is reasonably clear, and c) our experience with the use of the Rational Method on similar projects in the areas has given satisfactory results.

8.2.2 Hydraulic Considerations

Depending on physiographic, hydraulic and planning conditions, stormwater runoff may be discharged either aboveground through natural or artificial channels, or underground through pipe conduits or box

culverts. However, irrespective of the method of disposal, the hydraulic sections and the stipulated slopes should be selected so that safe and efficient operation is guaranteed.

The hydraulic section of pipes, culverts and channels that are long, and where uniform flow conditions exist, will be computed by the Manning's Equation,

$$Q = \frac{1.0}{n} AR^{2/3} S_0^{1/2}$$

where Q is the discharge in cubic meters per second,

n is the roughness coefficient,

A is the cross-sectional area in square meters,

R is the hydraulic radius in meters, and

S_0 is the longitudinal slope

In the design of culverts where the control is at the inlet, the hydraulic section will be determined by the application of the nomographs appearing in Appendices 8.4 and 8.5.

The capacity of gutters will be determined by the Manning's Equation in the following form as developed by Izzard:

$$Q = \frac{2.66\ Z\ S_0^{1/2} d^{8/3}}{n}$$

where, Q is the discharge in cubic meters per second,

n is the roughness coefficient,

Z is the reciprocal of the cross slope,

S_0 is the longitudinal slope, and

d is the depth at curb.

For an efficient grate inlet operation, all rectangular bars should be parallel with the flow and the openings should cover at least 50 percent of the width of the grate. The required clear length of the bar (L_b) can be computed by formula given below (recommended by U.S. Department of Transportation).

$$L_b = 0.92\ (d - d_b)^{1/2}$$

where L_b length of clear opening of grate in meters,

V mean approach velocity in the gutter in meter per second,

d depth of flow at the curb in meters, and

d_b depth of bar in meters.

A summary of the hydraulic design criteria applied in this project is outlined below:

- o Pipe materials: Reinforced concrete pipe
- o Manning's roughness coefficient n: 0.015
- o Minimum diameter of pipe: 30 centimeters
- o Depth of flow in culverts at design discharge: 0.8 of the diameter in pipes culverts and 0.8 of the height in box culverts.
- o Maximum manhole spacing: 80 meters
- o Inlet spacing: depending on flow velocities and depth of flow at the curb.

8.2.3 Drainage Design Considerations

Our local inquiries and considerations on this subject have yielded the following conclusions:

- o Public inconvenience during and after rainfall: The inconvenience of infrequent flooding is acceptable provided streets are passable shortly after the end of rainfall. What is not acceptable by the inhabitants is the ponding of water in inefficiently drained areas for hours after the end of the storm.
- o Hazards to public safety: In areas where houses are built in close proximity to the wadis carrying discharges above their capacity, the danger of children being swept away by the flowing water exists.
- o Risks of property damage: The risk of significant financial loss through flood damage exists in streets that do not have outlets to wadis, or where the outlets have been blocked by poor planning and haphazard construction.

In the light of the above conclusions, we recommend that the design of the stormwater drainage system be in accordance with the following guidelines:

- o Streets with short over-land travel distances: No drainage facilities will be provided on streets draining in the direction of a wadi and where the overland travel distance is short, unless the depth of surface flow and flow velocity are such as to be a safety hazard or a source of property damage to adjacent properties.
- o Streets with long and winding over-land travel distances: Drainage facilities will be provided on such streets, and discharge points made at the proper location.
- o Depressions and streets without outlets to wadis: Drainage facilities will be installed here and appropriate outlet points provided.

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- Streets running adjacent to or coinciding with a wadi course: Water will be intercepted at the upstream end of the wadi and drainage facilities provided in the street to convey the water to the proper outlet.
- Wadis running through built-up areas: If the stream channel of the wadi is deep and well defined and the cross-section is deemed sufficient to accommodate the flood discharges, no drainage works will be provided. However, should the stream channel be considered inadequate, provisions will be made to intercept and divert the flood waters.
- Wadis intersecting main roads: Culverts will be provided at all these crossings and appropriate discharge channels provided.

The stormwater drainage system will consist of the following components:

- Primary Drainage Network: This will consist of culverts, main lines, and possibly open channels which will convey stormwater runoff to Zarqa River or stream channels of wadis tributary to Zarqa River.
- Secondary Drainage Network: This will consist of smaller pipes and possibly open channels which will convey stormwater runoff to the primary drainage system.

It should be noted that streets and footpaths are an important part of the stormwater conveyance system. As finances permit and consistent with other social objectives and amenities, the streets and roads should be paved and provided with curbs and gutters to improve their stormwater conveyance capabilities. In streets where underground drainage facilities have been provided, gutter inlets should be installed. The spacing of the inlets depends on the depth of surface flow and flow velocity in the gutter. Typical desirable street and footpath cross-sections appear in Appendices 8.6 and 8.7.

Typical stormwater drainage inlets to be used in this project appear in Appendices 8.8 through 8.11. Note that none of the inlets has been provided with a catch basin as the utility of including a catch basin is open to question.

8.2.4 Service Criteria

The range of design discharge frequencies used in engineering projects is as follows:

- For storm sewers in residential areas, 2 to 15 years, with 5 years most commonly reported.
- For storm sewers in commercial and high value districts, 10 to 50 years, depending on economic justification.

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- For large culverts and flood protection works, 50 years or more.

Based on our experience with similar projects in the region, we have adopted the following frequencies:

- Primary drainage network-major culverts, 50 years.
- Primary drainage network-pipelines and minor culverts, 10 years.
- Secondary drainage network, 5 years.
- Open channels and ditches, 5 years.

Depths of flow and flow velocities which pose a threat to human safety or cause property damage should be avoided. A recommended criterion is that the velocity in the deepest part of the gutter be limited to 3 meters per second.

Maintenance of the open channels, pipelines, culverts and drainage inlets should be carried out periodically. Removal of rubbish, debris and silt from culverts and drainage inlets should be done as necessary. Repair of storm damage should be carried out immediately.

Site development control is an important aspect of stormwater control planning. Building encroachment of minor and major waterways should be avoided. Site development over a stream channel or a wadi should be prevented unless an adequate culvert to convey the storm runoff is provided.

8.2.5 Design Methodology

The watersheds within the planning area have been assigned reference numbers and appear on Plates 8.1 through 8.6.

The design of the major culverts for the primary drainage networks, in general, accommodate the storm runoff of areas greater than 250 hectares and are designed for a 50 year frequency storm runoff. The design discharges of watersheds greater than 250 hectares in area appear in Appendix 8.12.

The design of the pipelines and minor culverts for the primary drainage networks are for a 10 year frequency storm runoff. It should be noted that in most instances the element of the network under consideration is serving only a subarea of a watershed. Therefore, to facilitate computations, Appendix 8.13 was prepared and gives runoff values for areas of different [illegible] for a given time of concentration. The design discharge is obtained by multiplying the runoff value by the area served.

The elements of the secondary drainage network on designed for a 5 year frequency storm runoff. The runoff values are also given in Appendix 8.13.

8.3 Existing Situation

8.3.1 Description

All watersheds in the planning area drain into Zarqa River except for a small densely populated area in the northeastern part of the city which drains into a dry wadi bed, known as Wadi Saida. Wadi Saida, in turn, drains into Zarqa River at a point downstream of the planning area. The watersheds within the planning area have been assigned reference numbers and appear on Plates 8.1 through 8.6.

The catchment area of Zarqa River up to the northern boundary of the city is 650 square kilometers. The major tributaries of Zarqa River in the planning area are: Wadi Qattar (W.S.1), Wadi Ishsha (W.S.16) and Wadi Hajar (W.S.24).

There are no streamflow gaging stations on Zarqa River in the Planning area or in the immediate vicinity. In this report, the discharge was estimated by the Rational Method and by the Slope Area Method. In the Rational Method approach, using a flood frequency of 100 years and a runoff coefficient of 0.2, the discharge was estimated at 720 cubic meters per second. The slope area method, based on the high water marks left by the floods of November 28-29, 1979, gave a discharge of 515 cubic meters per second. For purposes of comparison, and as a check on the validity of the discharge value obtained above, the discharge was plotted on the graph appearing in Appendix 8.14. The comparison is acceptable.

During the storm of November 28-29, 1979, Zarqa River overflowed its banks and, as a result, several houses built on its flood plain were damaged. The Ruseifa-Zarqa and the Zarqa - Sukhnah roads were closed to traffic because of the high water. The Civil Defense reported that it had to evacuate over 60 families stranded by the high waters.

An approximate profile of Zarqa River derived from contours appears in Appendix 8.15. Appendix 8.16 includes six cross-sections of Zarqa River taken along its route in the planning area. The estimated high water levels of the November 28-29, 1979 flood have been drawn on the sections. The extent of the flooding is apparent from inspection of these sections.

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In the Town Plan of the Zarqa-Ruseifa area, the flood plain of Zarqa River has been designated as an agricultural zone. This limits building development to 25 percent of the total area. This can be looked upon as an advantage in an area subject to flooding. However, being an agricultural zone sets restrictions on the amount of flood protection works that can be installed.

8.3.2 Existing System

At present, there is no stormwater drainage system in the planning area. Inspection of the streets, roads and footpaths showed that stormwater is allowed to run in them down to the wadis. Many of these wadis are not large enough to handle the discharge and flooding occurs as a result of this. Another problem with this type of drainage is that streets that do not have an outlet to a wadi are flooded for hours after the storm is over.

In many locations, the buildings have been erected over the stream channels of the wadis and the blocked natural water courses replaced by culverts running under the buildings.

Most of these culverts are inadequate in size and are blocked during heavy rainfalls causing severe ponding at their upstream ends.

In many locations, typical of footpaths, the houses have been built so close to the stream channels that the outer walls of the houses serve as sidewalls to the channel. This result in serious scour problems to the foundations and potential hazard to public safety. This indicates that, even if an elaborate stormwater drainage system is not installed in the planning area, solutions must be found to deal with these situation.

There are bridges and culverts in the planning area that discharge to the waters of Zarqa River and tributaries of Zarqa River. These bridges and culverts have been assigned reference numbers and appear on Plates 8.1 through 8.6 and consist of the following:

i) Highway bridges B.1, B.2, B.3, B.4, B 7, B.8 and B.9.

ii) Railroad bridges B.5 and B.6.

iii) Road Culverts C.1 through C.30.

8.3.3 Determination of Useable Portions of the System

In determining which portions and elements of the system are useable, consideration is given to: structural soundness, hydraulic capacity, blockage from debris and siltation and channel degradation downstream of the structure.

The characteristics and condition of the structures are outlined in Appendices 8.17 and 8.18.

As seen from inspection of these tables, most of the structures are useable. However, repair work and maintenance is required on several of these structures before they can operate efficiently.

8.4 Proposed Drainage System

8.4.1 General

The proposed drainage system has been designed to collect, convey and dispose of stormwater runoff from inhabited areas in as fast and efficient a way as possible and in accordance with the design criteria and design considerations previously presented. Gravity flow has been maintained throughout the system.

The planning area has been divided into a number of watersheds following the natural topography, as shown in Plates 8.1 through 8.16, and a system of primary and secondary drainage networks was designed to cope with the storm runoff from each watershed. Wherever convenient, or possible, more than one watershed were combined in one outflow conduit in order to minimize the number of discharge points into the waterways, and consequently, reduce the overall cost of the project. The secondary networks, or laterals, collect and convey the runoff from streets to the primary networks, or interceptors, which, in turn, convey the waters to its discharge points in the waterways.

In conformity with the design considerations presented in Section 8.2.3, overland flow of water has been allowed in footpaths and streets wherever the natural conditions do not warrant its interception or where the physical conditions present the use of underground conduits.

All conduits forming the drainage system are either reinforced concrete pipe, reinforced concrete channels, or reinforced concrete box culverts. All conduits shall be installed at depths that do not result in excessive excavation costs, nor at the same time cause interference with other utilities whether existing or proposed.

8.4.2 Primary Networks

The primary networks are the main interceptors that receive flows from the secondary networks and convey it to the discharge points. The primary networks are designed to carry the 10 years storms and accomodate,

in most areas, the storm runoff of large areas. Consequently, the flows reaching these conduits are large and, subsequently, they have large cross-sectional areas. These conduits have, therefore, been designed as reinforced concrete box culverts instead of circular pipes in order to provide the required cross-sectional areas.

The locations of these culverts, being mostly at the edges or lower reaches of watersheds do not warrant the extensive use of inlet points into them except in possibly rare cases.

All primary culverts shall be provided with appropriate wing walls at their lower end and transitional sections shall be provided wherever the channel cross section changes in size. At all changes in direction, adequately long bends will be provided to prevent the creation of diagonal waves if and when supercritical flow occurs.

8.4.3 Secondary Network

All secondary networks are of reinforced concrete pipe ranging in size from a minimum of 300 mm diameter to a maximum of 1000 mm. They have been designed to cope with runoff resulting from a 5 year storm.

Secondary networks have, wherever possible, been extended to reach all low and land-locked points in streets where water tends to pond. Inlet structures shall be installed at all such low points as well as on long streets with flat gradients and on street intersections. No inlet points are envisioned on steep streets as the fast flowing water tends to jump the inlets.

Storm runoff often carry with it eroded soil and windblown silts, accumulated debris, vegetation and decaying animal wastes. To safeguard stormwater systems against clogging by such objects, sand traps or sumps are usually installed at each of the inlet points. However such sumps require constant maintenance and cleaning to continue in performing their functions. Such maintenance may overtax the capabilities of municipalities. Therefore, and, taking advantage of the self-cleaning velocities that can be generated throughout the systems, sand traps were not used. Occasional flushing of certain reaches of the system where exceptionaly heavy debris may have found its way should be sufficient to maintain the system problems free.

8.4.4 System Description

The extent of the watershed and systems proposed are shown on Figure 8.1. Details are on Plates 8.1 to 8.6.

- Watershed W.S. 31

  This large watershed is served by a system of existing culverts and channels identified on the Plates as C.14, C.15, C.16, C.17 and C.18. The area is mostly undeveloped but is planned for future development. The existing main culverts are adequate to carry the runoff from this area. No secondary networks are proposed at the present for this area as the design of such network must necessarily await the determination of final street gradients.

  Primary line II is installed in the upper reaches of the watershed and conveys the storm runoff to existing culvert C.14.

- Watershed W.S. 30

  This watershed comprises an area of approximately 15 hectares and is situated at the northeastern tip of the presently developed area. Primary line I is proposed to be constructed on the main road to carry the flow from this watershed into the wadi situated to the east. The proposed discharge point is in the vicinity of existing culvert C.1E.

  A secondary line I-1 collects the runoff from the streets of the watershed and conveys it to primary line I.

- Watershed W.S. 29

  This watershed comprises a large section of Zarqa and has a total area of almost 170 hectares of completely developed and inhabited land. The area slopes to the east towards a dry wadi. Running alongside this wadi and at the eastern end of the watershed is the Matraq Road which delinates the limit of residential development.

  An extensive system of secondary network is proposed to serve the area. The network conveys the water to a primary interceptor line III proposed to be constructed in the road parallel to the Army Base. This culvert collects runoff as it proceeds in a notherly direction until it reaches the end of the watershed where it discharge its flow into a dry wadi tributary to Wadi Zarqa.

- Watershed W.S. 43

  This watershed, having an area of approximately 60 hectares is located at the extreme north end of the planning area and is mostly undeveloped except at its southern tip. The importance of this watershed is that it contributes storm runoff in the direction of the Zarqa Road which necessitates its interception. A small secondary network is proposed within the developed area of the watershed to intercept the flow from the higher grounds and convey it to the primary line IV.

- Watershed W.S. 42
  With a total area of approximately 72 hectares, this watershed is, like W.S. 43 which borders it, undeveloped except at its southwestern tip. Similar to W.S. 43, this watershed has also been provided with a small secondary network which collects the runoff and conveys it to primary line IV.

- Watershed W.S. 38 and 39
  This watershed, with an area of approximately 86 hectares, borders on the western side of watershed W.S. 29 where a natural ridge separates the two watersheds. Like watershed W.S. 29, this watershed is mostly developed except at it northwestern end. The proposed system designed to serve this watershed comprises two secondary lines IV-3 and IV-4. Both these secondary lines discharge their flow into primary line IV. Primary line IV runs along Sukhnah Road and discharges into Zarqa River at Wadi Quseib confluence.

- Watershed W.S. 37
  Situtated south of watershed W.S. 38, this is a densely developed land comprising a total area of approximately 32 hectares. The shed is proposed to be served by two secondary networks that discharge into primary line V which conveys the water into the Zarqa River in the vicinity of existing bridge B.9.

- Watershed W.S. 33
  This is a relatively small area of approximately 21 hectares situated at the southern end of W.S. 37 and bordering on the river. A brief system of secondary network serves the area and conveys its runoff to the primary line VI.

- Watershed W.S. 28
  Another relatively small watershed of approximately 27 hectares and situated at the southern end of W.S. 29 and east of W.S. 33. The area is served by a relatively extensive secondary network which terminates at primary line VI.

  Primary line VI intercepts the flow from W.S. 28 and runs in a north westerly direction until it meets with the secondary system of W.S. 33 where it changes direction and discharges into the Zarqa River.

- Watersheds West of Zarqa River
  Areas of Zarqa west of the Zarqa River are sparsely populated and do not warrant the construction of a drainage system especially due to the fact that overland flows in the developed area are relatively short and close to the discharge points at Zarqa River.

- Ruseifa-Area south of Zarqa River
  This is the largest of the Ruseifa areas and is bounded on the north by the Zarqa River whereas phosphate mines crop to the south of it. The Amman-Zarqa Road runs parallel to the Zarqa River at the northern end of the development. A natural ridge, parallel to the Zarqa River divides the area into two narrow elongated sections of almost equal areas. Water falling on the southern section drains towards the phosphate mines and flows eastwards through an existing culvert C.3, and finally reaches the wadi. The northern section drains in a northerly direction in the direction of the Amman-Zarqa Road.

  The width of either of the above sections is within the allowable limits of overland flows, and as such, no drainage works would ordinarily be proposed. However, in order to protect the Amman-Zarqa Road from flooding, primary line VII is proposed to intercept water from lateral streets and convey it to Zarqa River in the vicinity of existing bridge B.2.

- Ruseifa-Area north of Zarqa River-Jebel Al Shamali
  This area falls within two watersheds, W.S.11 and part of W.S. 12. The part within Watershed W.S. 11 has a natural waterway at its high northern end that intercepts the water flowing from the upper reaches of the watershed before it enters the built-up area and conveys it to the Zarqa River. The built-up area drains directly and efficiently into the wadi through a number of streets. The street gradients are such that no water accumulation points exist and the total runoff from the individual streets and its fast discharge into the Zarqa River do not warrant the construction of any drainage works.

  The part within watershed W.S. 12 is very narrow and drains into a natural waterway that runs in a south-easterly direction at the foot of the development and into the Zarqa River. Here again, the short length of over-land flows do not warrant the construction of any drainage works.

- Ruseifa-Awjan Al Janubi area
  This area falls within part of W.S.12, W.S.17 and W.S.18. The part in W.S. 17 is very small and narrow and drains into a natural waterway that runs along side of it and discharges into the Zarqa River through the existing culvert C.5.

  The part that is within watershed W.S.12, unlike the first is large in area and has an elongated narrow shape. A number of small waterways run through it creating what, in effect, may be called sub-watersheds that are small in

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area and consequently their contribution is small. At no point does a large water concentration occur that warrants its collection and conveyance through a piped system. Street side ditches should be sufficient for the purpose.

- Watersheds in the Musheirteh area
  This area consists mainly of the Schneller Refugee Camp which falls outside the area limits of the project. Scattered housing developments exist to the north and to the east of the refugee camp but these are too small to be considered for a drainage system.

- Other Watersheds
  Other watersheds that have not been discussed above, but are indicated on the plates, exit throughout the project area and are a testimony to the rugged and hilly terrain. These watersheds are not inhabited and no drainage works are therefore considered.

8.4.5 Staged Construction

Like in most projects, stormwater drainage systems are normally phased over a period of years and are programmed in such a way that their construction is compatible with the need for the system and with the availability of public funds. With at least one of the above factors being unknown, that is, the availability of public funds, it is only possible to point out to the order of priorities that need be followed.

The Agreement requires that all the primary networks be in Phase I. In arriving at priorities within Phase I, primary networks that serve large inhabited areas or protect major roads from flooding should come first. Based on this, the order of priorities in Phase I should be as follows:

- First priority-Primary lines I, II and III.
- Second priority-Primary line VII.
- Third priority-Primary lines IV, V and VI.

Secondary networks are recommended for construction after completion of the primary networks. Therefore, the secondary networks will be in Phase II.

The order of priorities within Phase II should be as follows:

- First priority-Secondary lines I-1, II-1, III-1 through III-5.
- Second priority-Secondary lines III-6 through III-15
- Third priority-Secondary lines IV-1 through IV-4, V-1 and V-2, VI-1 through VI-6 and VII-1.

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8.5 Cost Estimates

8.5.1 This section presents the estimated construction cost of the recommended stormwater improvements. The costs include the pipes, culverts, manholes, inlets, and other appurtenances required for proper operation of the system.

8.5.2 Phase I Cost Estimate

The Phase I project is the primary network. The lengths and construction cost of the Phase I project are summarized as follows:

Zarqa			
Lines I to VI	- 10.3 km	JD	889,000
Ruseifa			
Line VII	- 2.4 km		141,000
Total Phase I		JD	1,030,000

These costs have been divided between foreign and local costs and are shown below in thousand JD:

	Foreign	Local	Total
Phase I			
Zarqa	249	640	889
Ruseifa	39	102	141
Total	288	742	1,030

The details of the total lengths are shown in Appendicies 8.19 and 8.20.

8.5.3 Phase II Cost Estimate

The Phase II project is the secondary network. The lengths and construction cost of the Phase II project are summarized as follows:

Zarqa			
Lines I to VI	- 25.9 km	JD	1,147,000
Ruseifa			
Line VII	- 0.4 km		19,000
Total Phase II		JD	1,166,000

These costs have been divided between foreign and local costs and are shown below in thousands JD:

	Foreign	Local	Total
Phase II			
Zarqa	323	824	1,147
Ruseifa	5	14	19
Total	328	838	1,166

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The details of the total lengths and cost estimates are shown in Appendicies 8.21 and 8.22.

8.6 Justification of Proposed Stormwater Drainage System

Attempting to justify public expenditures on stormwater drainage works from a purely cost-benefit point of view is, at best, a questionable endeavour. Too many variables and intangibles are encountered that are difficult or even impossible to assess. However, in undertaking such an attempt the following three factors are normally considered:

- Public Safety
- Property Damage
- Public Inconvenience

No monetary value can be put on public safety and well being, and no public funds should be spared where the safety of the public may be reasonably impaired. However, public safety is not considered as a major issue in this particular project since the amounts of rainfall that are experienced in the area are not expected to cause hazardous conditions. It is known that during the storm of November 28-29, 1979 some street flooding occured and there were a few incidents where residents had to be rescued after being surrounded by rising waters. However, all these incidents occured within or near the Zarqa River, and during what was considered to be a 100 year storm. It is not usual practice to consider such freak storms when designing stormwater drainage works. Attempting to provide protective works against such storms would entail wadi bed improvements, construction of dikes and bridges and expropriation of nearby farm lands, all resulting in prohibitively high costs and providing only questionable results. Funds are better spent in developing higher grounds for home construction and encouraging the public to move to new areas that are better protected.

Property damage caused by flooding is normally assessed through claims made on insurance companies that handle such services. In the planning area, no such insurances exist from which proper estimates of damages can be made. Reports of property damages were made after the November 1979 flood. But, here again, most of these damages occured to properties on the banks of the Zarqa River. Few other damages occured elsewhere. To our knowledge, no assessments of these damages were made.

Even where it is possible to estimate property damages, no accurate assessment can be made to public inconvenience. The work and productive time lost due to traffic holdups, roads and streets being impassable, and disruption of power and communication services can amount to substantial sums in any given area over a short period of time. For example, assume 50% of the current population (276,000) lose one day's productive work (10 JD), every two years. The cost is about JD 700,000 per year. On the basis of the total cost calculations presented in Chapter 9, this would finance about 4.5 million JD construction cost. This is about twice the cost of the proposed program. Prevention of these losses to the public and to the government by itself justifies the capital expenditures for the proposed stormwater drainage system. There is also a public health benefit if water is not permitted to remain ponded for a long time. Ponded water usually becomes polluted and children play in it. It can also become a breeding ground for mosquitos.

Based on these considerations, we have set the design criteria that govern the extent of services to be provided and the allowable overland flows that may be tolerated. And, with the same reasoning as above, we have recommended a more intensive system for certain parts of the area when population density may be higher or where commercial activity more intense than for other parts where population density is not so high or where future growth can be expected to move in new directions.

9.0 PRELIMINARY RATE STUDY

9.1 Purpose

The purpose of the preliminary rate study is to establish the proposed rate structure required to finance the recommended water distribution, sewerage, and stormwater projects. The questions of ability to pay, economic benefits, sensitivity analysis, and pricing strategy are discussed in Chapter 10.

9.2 Total Project Costs

The construction cost of the recommended projects has been estimated in prior chapters. Before a preliminary rate structure can be determined, additional project costs such as engineering, land, and contingencies must be determined.

The construction cost is the estimated price, without any contingency factor, that will be paid to the contractor. The estimated cost has been based upon preliminary sizing of the treatment units, preliminary water main and sewer routes, and preliminary soil analysis. It is customary and prudent to add a minimum 10 percent contingency factor to preliminary construction estimates. The construction cost plus 10 percent contingency cost is the "construction plus contingency" cost.

Current (June 1980) costs have been used to estimate the construction cost. It is anticipated that the tenders will be received starting mid-1981. An inflation allowance for one year should be added to the construction plus contingency to allow for the anticipated inflation up through the mid-point of construction. This report will utilize 14 percent.

Engineering costs include preparation of detailed design and tender documents, prequalification and pre-contract services, detailed soils investigation and foundation engineering, contract administration, construction inspection, shop drawing review, house connection design, test witnessing, preparation of record drawings, preparation of operation and maintenance manuals and start-up assistance. This is estimated at 10 percent of the construction plus contingency cost.

A management services cost which includes the internal costs of the planning and implementing governmental agencies must be added. These functions include review and award of contracts, review of estimates and field change orders, progress meetings, processing of contractor's

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payments, periodic inspection of the work, financial planning, and financial institution appraisal. Also included are legal costs such as review of tender documents, bid award and contractor's claims. The cost of training local personnel in the efficient operation of the proposed facilities is included in the management services cost. This is estimated at 7 percent of the construction plus contingency cost.

The total percentage increase to the base construction cost, before any land and financing factor is applied, is 144 percent. This overall factor is exclusive of land cost and interest during construction. The land cost must be added on an individual project basis. Discussion with government representatives indicates that funds borrowed from the central government would be loaned to the local municipalities at 6 percent. It is also assumed that the average construction contract will take 2.5 years and the cash utilization will be on a straight-line basis. Interest will be paid only at the funds are borrowed.

Assuming the first principal repayment on borrowed money is delayed one year for start-up, then the total project cost must be increased due to the interest on the one full year plus the interest on 50 percent of the full cost for 2.5 years of construction assuming a straight-line cash utilization over the 2.5 year period. With a 6 percent interest rate, this is equivalent 15.0 percent of the total funds borrowed.

In summary, the total project cost (TPC) based on the raw construction cost (CC) is calculated as follows:

$$(CC \times 1.44 + LAND) \times 1.15 = TPC$$

This is the amount of the loan that must be repaid, assuming no subsidies.

9.3 Implementation and Operation Procedures

9.3.1 Water Implementation and Operation

Before determining the preliminary rates, it is necessary to determine how the project will be implemented and operated. There are two separate questions: 1) implementation, and 2) operation.

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For the water systems, there are three reasonable alternatives:

1) Implementation and operation by each municipality

2) Implementation by a joint agency and operation by each municipality.

3) Implementation and operation by a joint agency.

The major advantage of Alternative 1 is that it would require no reorganization of staff and facilities for implementation. There would be some minor operational duplication. For example, a combined agency would have a single director whereas each municipality now has its own director. Likewise, each municipality would have its own meter repair shop and spare part stockpile as compared to a combined effort. The major disadvantages are considerable duplication during implementation and limited technical capability during operation because of limited funds and limited availability of technically qualified staff.

Alternative 2 would prevent duplication during implementation but would still have the operational disadvantages of Alternative 1. It would have the advantage that the operational staffs would not have to be reorganized.

We believe that Alternative 3 combines the advantages and minimizes the disadvantages of each alternative. Hence,it is recommended that a joint (Zarqa & Ruseifa) agency implement and operate the water systems of both municipalities. For the purpose of the preliminary rate analysis, the two existing water departments will be combined.

9.3.2 Sewerage Implementation and Operation

Unlike the water system, there is no existing sewerage system base upon which to build. This is an advantage because the most efficient and equitable system can be established. The sewerage system is also unlike the water system since a substantial amount of joint facilities must be constructed.

The most likely implementation and operation alternatives are as follows:

1. Joint Agency responsible for sewage collection, conveyance, and treatment throughout the planning area.

2. Joint Agency responsible for sewage conveyance and treatment throughout the planning area. Collection responsibility would remain as a municipal function.

3. Zarqa assume responsibility for implementation of the sewage treatment and trunk system. Collection responsibility would remain a municipal function.

Under Alternative 1, a joint agency could be formed to implement and operate sewage service throughout the planning area. The joint agency would build the plant, trunk system, and all collection systems. This would be the most efficient form of implementation since it would eliminate duplication of effort. It would also standardize rates in the planning area and furnish the same service to all inhabitants. Each Municipality would be represented on the joint agency. A possible problem with this type of arrangement is that Zarqa, since larger, could tend to dominate the Agency if the representation were proportional to population. In this case, Zarqa would be in a position to dictate policy to Ruseifa. A possible solution to this problem would be to have equal representation appointed by each of the municipalities and a representative from an area outside of the municipalities appointed by governate or central government.

Alternative 2 is similar to Alternative 1 except the responsibility for the sewage collection system would remain with the municipalities. This would have the advantage of allowing each municipality to have direct control over policy and procedures. It would have the disadvantage of duplication of effort and, probably different policies and procedures, and cost within each municipality.

Alternative 3 would have the advantages of Alternative 1 but would prevent Ruseifa from having any control over the treatment and trunk policy and costs.

We believe that Alternative 1 is the best method to implement and operate the sewerage system. Therefore, the cost analysis for sewage service will be based upon a joint agency totally responsible for all sewage activities.

9.3.3 Joint Implementation and Operation

Since the recommended implementation and operation procedure for both water and sewerage is a joint agency, the next logical alternative to consider is a combined water and sewerage agency. The precedent has been set in Jordan with the establishment of the Amman Water and Sewerage Agency (AWSA).

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AWSA is presently composed of the following sections:

- Board
- General Manager
- Administrative Department
- Technical Department
- Water Department
- Sewerage Department
- Finance Department
- Transportation Department

The Board, General Manager, and Administrative Department are responsible for overall policy and its implementation. The Technical Department is responsible for design and construction. The day-to-day operation of the facilities is done by the Water Department and Sewerage Departments. The Finance Department handles the billing for all services. The Transportation Department provides all required vehicles. The present staff totals about 950.

An agency similar to AWSA is a logical alternative for the entire water-sewerage problem in the planning area. The next level of organizational structure would be a regional or national agency to handle the water-sewerage problem on a wider scale. Such an organization could control all the water resources of the country or a drainage basin. The government is currently considering assigning this responsibility to the Water Supply Corporation. The resolution of this question on a nationwide basis is beyond the scope of this report.

For report purposes, the preliminary rate analysis will be done with a joint water agency and a joint sewerage agency.

9.4 Existing Charges and Policies - Water

9.4.1 Zarqa

Under the authority of the National Municipal Ordinance, the Municipal Council issues the necessary administrative regulations and has responsibility for the water use. The Zarqa water department is a semi-independent section of the Municipality. It maintains a separate budget.

The existing water rate schedule is set by the National Government and is the same for the entire Kingdom except for the City of Amman.

The current rates became effective January 1, 1979. The prior increase was in 1968. The current rate schedule on a bi-monthly basis is as follows:

0 - 10 m^3 @	80 fils/m^3
- 30 m^3 @	120 fils/m^3
[illegible] m^3 @	220 fils/m^3
More than [illegible] ^{3} @	300 fils/m^3

The minimum bi-monthly b[illegible] 480 fils which is the equivalent of 6 m^3.

All water services are metered. Free water is only provided to religious and government buildings.

The various additional miscellaneous fees are shown in Appendix 5.1.

9.4.2 Ruseifa Water

The Ruseifa water rates and miscellaneous fees are the same as Zarqa since they are set by the National Government. All water is metered and free service is provided to the same class of customers as in Zarqa.

9.5 Annual Cost of Phase I Project-Water

9.5.1 Capital

The total estimated construction cost of the Phase I project for Zarqa is JD 2,230,000. This amount includes JD 1,000,000 to finance extension and replacement between 1981 and 1990. These annual improvements will be financed on a yearly basis from annually generated revenues so they will not be included in the anticipated Phase I loan. This is normal water utility practice since the date and location of these improvements are dictated by development patterns. These extensions are generally small size lines and construction is usually done by the utilities' own forces. This results in a lower cost since contractors profit and the financing cost is eliminated.

The net amount of funds to be borrowed for the raw construction costs for Zarqa is JD 1,230,000.

The total construction cost of the proposed Phase I project for Ruseifa is JD 1,050,000. This amount includes JD 100,000 to finance extensions and replacements between 1981 and 1990 and JD 150,000 for purchase and installation of meters. The extensions and replacements and meters will be financed on an annual basis and will not be included

in the anticipated Phase I loan. Thus, Ruseifa will require an annual allocation of JD 25,000.

The net amount of funds to be borrowed for the raw construction cost for Ruseifa is JD 830,000.

The total net amount of funds required for the raw construction cost of the Phase I water project is:

Zarqa		1,230,000
Ruseifa		830,000
	Total	2,060 000

The majority of water distribution improvements will be in public streets and right-of-way. Therefore, there will be only a minor amount of land costs.

The total borrowed amount will be:

(JD 2,060,000 x 1.44) x 1.15 = JD 3,411,000

Assuming 6 percent interest payable by the Agency and a 22 year repayment period, the additional annual debt service beginning in 1985 is JD 283,300. This is calculated using the 22 year 6 percent capital recovery factor which is 0.08305.

9.5.2 Operating

Table 9.1 shows the operating expenditures for the Zarqa Water Department. The 1977 to 1979 figures are the actual amounts from the Municipality's records. The 1980 amounts are the Zarqa budget. The 1981 to 1990 amounts have been estimated assuming the recommended project is implemented. The increase in salaries is required by the addition of staff for the proposed project plus ordinary expansion. We have added 2.5 staff members each year between 1981 and 1990. In 1981, we have added 2 additional staff members to bring the department up to desired strength and serve the meters for Ruseifa. The cost of pumping power and chlorine have been increased in proportion to the increased water use. Other expenditures have been increased slightly each year to allow for normal expansion and improvement. The estimate was first made assuming there would be no inflation and the amounts at various inflation rates were also calculated.

Table 9.2 shows the operating expenditures for the Ruseifa Water Department. Neither the 1977 actual costs or budget, 1979 actual costs nor 1980 budget figures were available. We have estimated the 1980 through 1990 operating expenses assuming the project was implemented. We have added 0.5 staff members in each year between 1981 and 1990 to handle the growth.

Thus for the joint agency, 3 staff members will be added each year.

The operating cost of the joint agency is obtained by the combination of Tables 9.1 and 9.2. The result is Table 9.3. It has been assumed that the creation of the joint agency would be effective January 1, 1981. Hence, only 1981 to 1990 are shown on Table 9.3.

9.6 Proposed Rates - Water

To develop a rate structure the proposed project costs must be added to the existing Zarqa Water Department and Ruseifa Water Department costs.

The financial statements for 1977 to 1980 for the Zarqa Water Department are shown on Table 9.4. 1980 is the budget and the 1977-1979 amounts are actual costs from the Municipality's records. The estimated 1980 revenue from water rates is shown to be considerably higher than 1979, apparently on the basis of the new well being completed. The planned capital improvements also appears high, apparently based on the new well.

Because of the problems with the new well which will delay its completion, we believe that both the revenues and capital improvements will be substantially lower than originally estimated. The apparent intent was to have a slightly positive cash position at the end of 1980. For the purpose of the 1981 to 1990 analysis, the December 31, 1980 balance will be assumed to be zero.

We were unable to obtain any depreciation records from Zarqa so depreciation was estimated on the available information. There are three types of assets:

1) Those existing prior to the Zarqa 1965 supply project.
2) The 1965 supply project, and
3) Those constructed after the 1965 project.

Based on an analysis done for the 1965 supply project, the annual depreciation for those facilities constructed prior to 1965 was estimated at JD 2,600. The analysis stated that straight-line depreciation was used to estimate this amount. In order to establish book value, we assumed that these assets would be fully depreciated in 1990.

The estimated total project cost of the 1965 project was about JD 404,000. Assuming straight-line depreciation and a 40 year life, the annual depreciation is JD 10,100.

It is also believed that annual capital improvements ranged between JD 20,000 and JD 50,000 from 1966 to 1979. For this report, we have used the actual capital improvements for 1977, 1978 and 1979 and estimated JD 67,600 for 1980. Between 1968 and 1976, we have assumed that the annual capital improvement amounts increased linearly between JD 20,000 in 1966 and JD 40,000 in 1976.

These three types of assets are collectively referred to as "existing" on Table 9.4.

Table 9.4 shows the Debt Service Coverage (DSC) for each year. This is calculated as follows:

$$DSC = \frac{\text{Net Operating Income}}{\text{Debt Service}}$$

This is a frequently used indicator when the analysis is on a cash basis.

Table 9.4 also shows the estimated value of the net fixed assets at the end of each year. This number is required in calculating the Rate of Return.

The Rate of Return (RR) is calculated as follows for public utilities:

$$RR = \frac{\text{Gross Revenue} - (\text{O\&M} + \text{Depreciation})}{\text{Rate Base}} \times 100$$

The "O&M" is the operating expenditures and the Rate Base is the average value of the net fixed assets in operation during the year. This is calculated by averaging the prior year end with the current year end balance.

The Ruseifa financial statements for the 1978 budget and actual costs and for the 1979 budget are shown in Table 9.5. These were the only records available from the Municipality.

We were unable to obtain any depreciation records from Ruseifa. The depreciation and net fixed assets shown in Table 9.5 are based on 40 year straight-line depreciation using estimated original costs.

Table 9.6 is the Pro Forma Income Statement for 1981 to 1990 for the recommended Zarqa-Ruseifa Joint Water Agency. This statement assumes current rates, no inflation, and reduced Zarqa sales.

The average revenue per m^3 of water sales for Zarqa was 120 fils in 1979. For Ruseifa, the 1979 average revenue per m^3 of water sales was 111 fils based on the 1979 budget water sales, excluding bad debts, and the 1978 actual use. This is reasonable since there is less water use per customer than in Zarqa. Since the demand projections have assumed an increase in water use so that the per capita use will be closer to Zarqa, we have used an average revenue of 115 fils per m^3 for Table 9.6.

The total water sales assume that unaccounted-for-water will be reduced linearly from 40 percent in 1980 to 30 percent in 1990. The jump in water sales in 1985 is due to sewer system start-up. This statement assumes that the JD 100,000 per year for Zarqa and JD 25,000 per year for Ruseifa is the total cost for the capital improvements. Some of this work will be done by the Municipality staff which will offset the project overhead costs. Since the budgets indicate a small cumulative cash position at the end of 1980, we have assumed the amount to be zero.

The assumptions for Table 9.6 are the idealized case based on continued increasing water sales and no inflation. We believe that this will not be the actual case but the estimates have been presented as the base condition.

The situation changes significantly when 7.5 percent inflation is added to the operating expenditures and capital improvements. Table 9.7 illustrates that a rate increase would be required about 1983 to keep positive cash flow. The effect of 5, 10, and 15 percent inflation is discussed in Chapter 10. The 7.5 has been used since it is the mid-point between 0 and 15 percent inflation.

The analysis presented in Table 9.7 shows that, on a cash basis, the existing water rates will be insufficient to generate sufficient revenues by 1983 and thereafter. Three major items will cause the necessity of the rate increase: (1) operating expenditures are rising

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faster than water sales because the assumed inflation is rising faster than the estimated growth, (2) the capital improvements, and (3) the additional debt service cost.

For this preliminary analysis, it is assumed that a proposed rate increase should meet these two criteria: (1) maintain a net positive cash flow between 1980 and 1990, and (2) maintain an average Rate of Return of about 8 percent during the 1985 to 1990 period. In an inflationary economy, the first criteria will usually control. It will also be assumed that the block structure will remain the same.

Since the cumulative cash position shows the first significant deficit in 1984, this year has been selected as the first year of the increase. We assumed that there would be one increase for the 1984 to 1990 period. Using 1987 as a test year, it was determined that a rate increase from an average rate of 120 fils/m^3 to 165 fils/m^3 would approximately meet the rate criteria in 1987.

This trial rate of 165 fils/m^3 was then checked for the 1984 to 1900 period. The result is shown in Table 9.8 and the rate of 165 fils/m^3 beginning in 1984 is a satisfactory rate. There is a positive cumulative cash flow. The average Rate of Return for 1985 to 1990 is 7.4 percent. This analysis assumes that another rate increase will be necessary in 1990.

If the existing rate of 120 fils/m^3 is escalated from 1979 to 1984 at 7.5 percent, the result is 172 fils/m^3. Therefore, the rate of 165 fils/m^3 is realistic.

Throughout the preliminary rate analysis, we have not considered the cost of the supplemental supply. There is no firm information available on the price that the government will charge the municipalities for imported water. This need for additional supplies is required both for Zarqa and for Ruseifa. The exact cost of making available additional supplies when needed cannot be calculated at this time. If the facilities are planned and constructed prior to a steady demand for the imported water, some additional "ready to serve" costs may be incurred. If the charges were based only on the water purchased, they would be allocated equally to all water sold. For example, if 20 percent of the water were purchased and all of it was sold, the unit rate would increase by 20 percent of the unit cost of the supplemental supply. This is examined in a sensitivity analysis in Chapter 10.

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9.7 Existing Charges and Policies - Sewerage

9.7.1 Zarqa Sewage

Zarqa owns and operates 8 scavenger trucks which clean out cesspools. The cost per cleanout is JD 2.5. In addition, about 32 privately-owned scavenger services operate in Zarqa. The average cost per cleanout by the private scavengers is JD 3.5 or more.

9.7.2 Ruseifa Sewage

Private scavengers provide the only cesspool cleaning service in Ruseifa. The average cost is JD 3.5 or more per cleanout.

9.8 Annual Cost of Proposed Project - Sewerage

The total project construction costs for Phase I and Phase II of the recommended project are as follows:

Phase I	1980 JD
Treatment Plant	4,898,000
Trunk Sewer System	2,383,000
Collection System	8,000,000
Terminal Manholes	1,949,000
Water Mains	974,000
Total Construction Cost	18,204,000
1984 - 1990 Growth	
Collection System	2,693,000
Terminal Manholes	598,000
Total Construction Cost	3,291,000

Using the same assumptions developed for the water project financing, the amount of funds to be borrowed is:

(JD 18,204,000 x 1.44 + 736,000) x 1.15 = 30,992,000

The land cost estimate is JD 736,000 and is shown in Table 9.9. It includes the land for the ultimate plant site.

The annual repayment with a 6 percent, 22 year loan is JD 2,574,000.

It is assumed that the Zarqa-Ruseifa Joint Sewerage Agency will begin testing on January 1, 1984. By July 1, 1984, the plant will be ready to accept flow and the collection system will be complete to the point that homeowner hook-ups can start. Debt service repayment is not scheduled to start until 1985 to allow a six months for hook-ups and revenue collection.

The estimated operation and maintenance cost of the recommended treatment plant is given in Chapter 7.

Only limited maintenance is usually required for large diameter trunk sewers. However, the trunk sewers should be inspected a least once a year at all manholes. Any build-up of solids, deterioration of structural concrete, loose or broken manhole covers and steps should be corrected. A trunk sewer maintenance crew would consist of a foreman and three laborers. The trunk sewer inspection and minor repair should require about four months per year. The remainder of the year, the crew could be assigned to collection system maintenance.

Maintenance of the extensive collection sewer system is a continuing task requiring specialized equipment and a trained staff. During the initial phase (1984-1990) three crews (1 foreman + 3 labors) should be sufficient. Each crew should be equipped with a light-duty trunk plus sewer cleaning equipment, a trash pump, safety equipment, and miscellaneous hand tools. A sewer jet or other trunk-mounted high pressure sewer cleaning equipment is desirable.

The recommended Phase I project has a large (East Side) and small (Subarea XVI) pumping station. The estimate includes 9 men to provide for continuous attendance at both these stations. A full time mechanic is also included for pumping station maintenance. Any specialized staff would probably be available from the treatment plant staff.

The Joint Sewerage Agency will also be required to have an administrative staff to handle the overall management of the system. A usual function of this staff is billing and, in some cases, meter reading. The sewerage charge is generally a percentage increase on the water bill. It has been assumed that this function would be provided free-of-charge by the water departments. The administration section must also contain a 2 man crew to monitor the industrial discharges.

The proposed staff of 89 persons for the Joint Agency, inclusive of treatment plant operation, is shown in Table 9.10.

The estimated average cost, in June 1980 dinars, for the 1984 to 1990 period is as follows:

Item	JD
Labor 50 x JD 2000/yr	100,000
Energy (pumping station)	27,000
Transportation	3,000
Equipment and Supplies	4,000
Miscellaneous	3,000
Specialized Equipment	3,000
	140,000

The proposed rates should also include an annual amount to pay for the 1984 to 1990 collection system which will be required as the population grows and the need for sewers expands. The total estimated construction cost in current prices is JD 3,291,000 as shown on Table 6-13 and explained in Chapter 6. Since the extensions will be built with local contractors we have added about 35 percent for other project costs. The total cost is JD 4,443,000 or about JD 635,000 per year. If the projects were financed on a long-term basis, using the water distribution assumptions, the annual cost would be JD 452,600. This method would result in a higher total cost over the project life since an annual payment would be required for 22 years. In an expanding utility, it is usual practice to collect a certain amount each year for the system growth. This is similar to financing the water capital improvements on an annual basis. Therefore, we have selected to use the annual cost on the capital improvement basis, JD 635,000.

The total average annual cost (1984 to 1990) of the Phase 1 sewerage project plus the 1984 to 1990 collection system expansion in 1980 costs is:

Capital (Annual payment)	
Phase 1	JD 2,574,000
Collection (1984-1990)	635,000
Operation & Maintenance	
Plant	136,000
Trunks/Collection	140,000
TOTAL	JD 3,485,000

9.9 Proposed Rates - Sewerage

It is proposed that the sewerage charges be recovered as a surcharge on the water bills. In addition, additional revenue will be obtained from those industries with private wells and the Army Base.

The average 1985 to 1990 water sales, corrected for sewered population served, is estimated at 5,550,000 m^3 per year.

The average industrial flow to the wastewater system between 1984 and 1990 is 6200 m^3/d (2,263,000 m^3/yr). This is mostly from industries which are large enough that a meter and sampling station will be required. The total BOD_5 associated with this flow is about 15 percent above the population equivalent for the flow. The suspended solids is considerely less. In actual practice, there should be surcharges for BOD_5, SS, and other constituents that increase the treatment cost above domestic flow. For the purpose of this estimates, we have assume that these surcharges can be neglected. Any amounts collected will be additional revenues.

The third source of flow to the system will be the Army Base which has an estimated population of 35,000. This will contribute 2310 m^3/d (843,000 m^3/yr). Assuming the Army Base constructs its own collection system, they should only be charged for the Trunk System and treatment plant costs. This is about 45 percent of the total annual cost. On a proportion basis, the Army Base should pay the full rate for 45 percent of its flow, 1040 m^3/d (380,000 $m^3/yr.$).

The average total billable flow between 1985 and 1990 is:

Dom. & Comm.	5,550,000 $m^3/yr.$
Industrial	2,263,000
Army Base	380,000
TOTAL	8,193,000 $m^3/yr.$

Dividing the total annual cost without inflation by the billable flow results in a cost per m^3 of 425 fils. This assumes no inflation. If we assume 7.5 percent inflation on the operation, maintenance, and collection system expansion, the annual cost is JD 4,085,000. This is 499 fils/m^3.

If the rate is calculated on the basis of repayment of only O&M, the no inflation rate is 34 fils/m^3 and the rate with 7.5 percent inflation is 56 fils/m^3.

Since there is a considerable range of unit costs that could be

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assigned to the sewerage project, there is also a substantial number of Pro Forma financial statements that could be created.

Analysis presented in Chapter 10 demonstrates that an average of JD 18.8 per year can be paid by a combination of the lowest and second lowest income groups sewerage service. With a water use of 7 m^3/mo for the these income groups, this allows a rate of 225 fils/m^3. This is in current costs but with 1985 water use. Assuming that the income of the two groups increases at 7.5 percent inflation, the amount that the groups could afford in 1987 would be about 375 fils/m^3.

Table 9.11 is a Pro Forma Income Statement for the 1984 to 1990 period assuming 7.5 percent inflation and a sewerage charge of 375 fils/m^3 beginning in 1984. The 1984 flow have been reduced by 50 percent since this is the start-up year.

This analysis shows that the rate of 375 fils/m^3 is sufficient to cover operation and maintenance and capital improvements plus about 59 percent of the debt service. From 1984 to 1990, about JD 920,000 will be required from other sources each year to balance the cash flow. These other sources could be property taxes, general revenue, central government subsidy, or a grant. Additional revenue could also be generated by a graduated rate scale similar to the water rates. However, the recommended rate has been kept at the minimum level because it is a "basic human needs" project.

The Urban Property tax is based upon the estimated rental value of the properties. It is 17 percent of the total rental value. The Ministry of Finance gets 10 percent and the Municipality 7 percent. The total 1979 base for Zarqa - Ruseifa was about JD 1,450,000. Assuming 7.5 percent inflation, this value would be JD 2,400,000 in 1987. If the deficit in the sewer program were financed solely from the Urban Property Tax, the rate would increase from 17 percent to 62 percent. It appears that a different source of funding will be required.

9.10 Annual Cost Phase I - Stormwater

The total construction cost of the Phase I stormwater project is JD 1,030,000. Using the same borrowing assumptions previously developed, the amount to be borrowed, assuming no land cost, is:

$$(JD\ 1{,}030{,}000 \times 1.44) \times 1.15 = 1{,}706{,}000$$

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The annual repayment is about JD 142,000 assuming a 6 percent, 22 year loan.

If the improvements were made on an equal annual basis over ten years, the other project costs are estimated at 35 percent of the construction cost. The annual payment excluding inflation would be JD 139,000. Escalated to the mid-point of the period at 7.5 percent, the annual cost would be JD 207,000.

The source of this revenue is usually general taxes similar to the Urban Property tax. Hence, a preliminary rate study does not apply.

10. ECONOMIC AND SENSITIVITY ANALYSIS

10.1 General

The purpose of Chapter 10 is to investigate the economic benefits of the proposed projects, determine the resident's ability to pay for the projects, and present a sensitivity analysis of the variables used in the preliminary rate study plus any other reasonable alternative considerations.

10.2 Economic Analysis

10.2.1 General Observation

Work on the 1981-85 Five Year Plan for Jordan is in the process of being organized. The economy will continue to depend indefinitely on the two major sources of external funds: (a) remittances from Jordanians employed abroad; and (b) foreign loans. Assuming that Saudi Arabia in particular, and other Gulf Coast States, continue to have substantial incomes from the sale of petroleum and petroleum products, there will continue to be a demand for skilled Jordanian labor abroad throughout the planning period.

The size of Jordan (2.3 million population) means that the internal market is relatively small. Consequently, for many products sufficient size of production units cannot be achieved to enable sufficient economics of scale to make production economically viable. Thus, relatively little development of import substitution industries may be likely.

Because adjacent countries are also in process of development, and because of the relatively high cost of labor in Jordan, there may also be little likelihood of developing industries to serve other Middle Eastern markets unless productively is increased. Major industrial development in Jordan will continue to be associated with exploitation of natural resources, such as phosphates and potash, and related outputs, such as fertilizers. Location will be determined by the locations of the resources.

Although essentially full employment exists, there is substantial underutilization and low productivity which is costly, particularly in the service and construction sectors of the economy. About 60 percent

of the labor force is employed in the service sector (non-manufacturing), a very high proportion for a developing economy. For at least two decades, the service sector has represented almost 65 percent of Gross National Product (GNP) as shown below. Although the service sector has remainded constant, there has been a shift from the agricultural sector to the industrial sector. It is because of this trend that growth of the Zarqa-Ruseifa area will continue, especially if adequate water and sewerage services are available.

RELATIVE SHARES OF JORDAN'S GNP, % BY SECTOR

Time Period	Agriculture	Industry	Services
1954 - 61	22	13	65
1962 - 66	21	16	63
1967 - 72	18	17	65
1973 - 75	12	24	64

The Cost of Living Index (CLI) has risen substantially in the last decade, with a large increase between 1978 and 1979, as shown by the data below:

Date	CLI	Percent Increase
1976	111.5	-
1977	127.7	14.5
1978	136.6	7.0
Jan. 1979	150.8	10.4
Dec. 1979	170.5	13.1

The overall increase during the period averaged about 13 percent per year. Because of costly low productivity, high proportion of labor force in the services sector, and large inflow of funds from external sources, the cost of living is likely to continue to increase. However, efforts are being made to reduce this inflation. Not all components would increase at the same rate, as indicated by past trends. Food is expected to account for an increasingly larger portion of household expenditures, at least for households with less than medium income.

There is no rent control on either residential or commercial space in a formal sense. However, rent is controlled since once an individual, a household, an enterpreneur occupies space at a given rent, that rent cannot be raised. Thus, only when the occupant moves out, can the rent be raised. The level of rent then becomes market rate or a negotiated rate related to the market rate.

Because of its location and because of its transport system, Jordan could become a stocking and distribution center for some significant portion of the Middle East. Some assembly activities could be associated with the stocking/distribution activity. The logical location for such an activity in Aqaba, which is already undergoing planned development, including upgrading of housing to accommodate families. The lack of a labor force and a much hotter climate in Aqaba may be a deterient to such a move.

Because of the power of the government to issue permits for water withdrawals and for use of land, industrial development can be directed toward planned locations, if so desired. An industrial area between Zarqa and the petroleum refinery has been designated by AURPG as a major area for future industrial development in Jordan. This area may also be the same as one of the free trade zones designated by the Central Government. The existing industrial area along the Zarqa River in Ruseifa has locational advantages in terms of access to transportation, access to labor force, and access to water. The area northeast of Zarqa is on a major road and is in one of the major directions of residential development.

10.2.2 Municipal Finance

Municipalities are directly under the Ministry of Municipal, Environmental and Rural Affairs and have relatively little autonomy. An understanding of municipal finances is essential for all aspects of the project relating to user charges and to the financing of any proposed projects.

Annual revenues of a municipality are obtained by two paths, which might be characterized as direct and indirect. Revenues obtained directly by a municipality i.e. paid directly to the municipality, consist of various business, vocational, and professional fees, and fines. Revenues obtained indirectly by the municipality include:

- fuel taxes collected by the Central Government and remitted to municipalities according to a formula;

- o taxes on property within the municipality collected by the Central Government, based on assessed values of rental income and tax rates established by the Central Government, and remitted to the municipalities; and

- o surpluses from municipal utility agencies, such as the Zarqa Water Department, which agencies have separate budgets and are intended to be self-supporting.

The revenues from the foregoing sources must cover the annual costs of the municipality, including that portion of the debt service on capital expenditures which is to be paid back by the municipality.

Extraordinary revenues or funds for capital investments, for example, for various infrastructure facilities, are obtained from:

- o loans from the Village and Municipal Loan Funds;

- o loans from foreign sources;

- o loans from local banks, and

- o transfers (contributions, grants) from the Central Government.

The loans from the Village and Municipal Loan Fund are at interest rates substantially below market rates of interest. Loans from foreign sources are generally also at interest rates less than market rates. Loans from both sources represent some degree of subsidy to the recipients of services, e.g. water and sewer services. Transfers from the Central Government represent political decisions with respect to subsidies to be provided to achieve social goals.

10.2.3 Zarqa-Ruseifa Economic Activity

The improvement of the water supply and distribution system plus the installation of sewers in the streets and treatment of the waste-waters collected by these sewers will result in some immediate and long-term economic gains by the Municipalities. Some of these gains, both short-and long-term, are as follows:

- o Increased productivity by the laboring force due to decrease of debilitating ailments due to waterborne diseases.

- o Increased value of the real property due to a dependable water supply and sewerage system.

- o Increased development of the available commercial and industrial land do to the availability of a dependable water system and a sewerage system that will adequately take care of their wastewaters.

- Increased population due to increase of commercial and industrial activities that require a local labor force.

- Increased real property tax base for generating additional revenues for the municipalities for use in financing of additional improvements.

From a monetary viewpoint, the only immediate financial gain to the municipalities is the increased value of the existing improved real property. This gain can only be realized if there is a reassessment of the property. The property owner will see it only at the time his property is sold. A 5 to 10 percent increase in real property values after public water and sewers are provided is not unreasonable.

The local government agencies and commercial and industrial enterprises will see an improvement in profit due to higher productivity from their present employees due to the decrease in debilitating diseases. No percent of improvement can be predicted but there definitely will be an increase.

The increase in commercial and industrial facilities will be a long-term situation. The construction of commercial and industrial facilities is dependent on the economic law of supply and demand. If Zarqa-Ruseifa were the sole market places for everything manufactured, then the growth of such establishments would be very slow. Accompanying the slow growth would be a slow growth in the population of the area since the source of making a living is dependent on the availability of jobs.

The advent of a good water and sewer system will present a prime situation for encouraging business to locate in the area and it is hoped that such business will have markets throughout Jordan, and even possibly some export potential. If this happens, then, Zarqa and Ruseifa will grow and the tax base and economic climate will also grow. The making of predictions as to the magnitude of such growth is beyond the scope of this report.

Zarqa and Ruseifa have grown to their present size because of the availability of a labor force principally made up a refugees from the Palestinian problem. The future growth on this area will be dependent on the available market for the products manufactured in the area. Without knowledge of the projected markets for the products presently being manufactured in Zarqa-Ruseifa, it is impossible to project any increase

in tax receipts resulting from increase property values and general economic activity in the cities. The AURPG has projected a continued growth of the Zarqa-Ruseifa area and this Report has used their projections.

As stated before, it would not be unusual to find that the resale value of real property in the cities have increased by 5 to 10 percent due to the advent of a good water and sewer system. This increase in property values can only result in a benefit to the cities as increased tax revenue if a reevaluation of the real property is made.

10.3 Internal Economic Rate of Return

10.3.1 General

There are a variety of benefits associated with the provision of convenient and safe water and sewerage systems. The more important benefits are improved health, water quality, and general living environment. The benefits partially include reduced medical costs, general improvement in individual well-being, increased productivity, lower employee and student absentee rates, increased property values, and improved living conditions. These benefits cannot be accurately quantified.

One method of general economic analysis of proposed projects is to compare the annual incremental revenues and benefits against costs over the life of the project which has been taken as 40 years from start-up.

A commonly used method is the "discounted cash flow" method based on current relative prices and costs in a base year exclusive of escalation. The "cash flow" refers to the fact that the required data must be given as the amounts at the actual dates of receipt and disbursement. "Discounted" applies to the calculation of present worth.

Because there are so many non-quantifiable factors, this calculation is usually based upon the revenues and expenditures (costs) for water and sewerage projects.

The method also requires that true (non-subsidized) costs be used. Discussions with various governmental officials indicate that overall the petroleum products industry is subsidized for about 35 percent of its cost from customs and taxes. The various products are subsidized at different rates so that those used by the lower income groups receive the greatest subsidy.

The major petroleum product used in the water and wastewater industry is the fuel oil used to generate electricity. The fuel oil sells for JD 30 per tonne but costs JD 65 per tonne. The present electric rate schedule states that the rate may be increased 0.047 fils for each 100 fils increase in fuel oil prices. In the economic analysis, the estimated electric rates have been adjusted to the true cost of fuel oil.

10.3.2 Water Project

The proposed water project is an addition to existing systems. Thus, the internal economic rate of return must compare the incremental benefits against the incremental costs. This comparison is made in the year incurred. For example, the amount of funds spent for construction are considered as spent in the year paid to the contractor.

The incremental benefits are the increased revenues if the project is implemented. If the water and sewage projects are implemented, the water sales are expected to increase in accordance with the Chapter 5 projections. If there is no project, the sales would be expected to remain at current levels and the unaccounted-for-water at about 40 percent. The existing supply of 28,320 m^3/d would place an upper limit on use.

The incremental revenue is the difference at the current rate of 120 fils/m^3 (Ruseifa 115 fils/m^3) between the Chapter 5 projections and the lower projections up to the present well supply capacity.

The incremental expense can be estimated based on current operating costs. Since the first year in which costs are increased is 1980, this is the base year for the analysis. However, only small incremental operating costs will be incurred before 1984, the first year of scheduled project completion. The estimated non-inflated operating expenditure in 1984 is JD 460,200. We estimate that all operating costs over JD 455,000 per year are incremental costs due to the proposed Phase I project. For the estimates between 1984 and 1990, Table 9.3 was used. For 1990 to 2000, the incremental operating expenditures were increased at the average rate between 1985 and 1990. The 1984 expenditures were excluded from this average because of the large increase due the anticipated sewerage system start-up.

The capital costs were based upon estimated cash expenditures for construction. The Phase II expenditures assume completion of the facilities in 1990. The annual capital improvement costs are JD 100,000 each year until 2000 for Zarqa and JD 25,000 from 1981 until 1990 and JD 10,000 thereafter until 2000 for Ruseifa.

The details of the Internal Economic Rate of Return calculation for the water project are presented in Table 10.1. The rate is about 7.8 percent for the 1980-2024 period.

10.3.3 Sewerage Project

The quantifiable benefits of the sewerage project are the expected revenues at the proposed rate with no inflation of 225 fils/m^3. The sewage flows were calculated by the addition of: (1) water sales with the proposed water project corrected for population served, (2) industrial flow, and (3) the Army Base contribution.

The operating expenditures consist of the plant costs plus trunk and collection system costs. For 1984 to 1990, these costs are as explained in Chapter 9. For 1991 to 2000, the plant staff was immediately increased to the year 2000 expanded plant staff and the other plant costs were increased linearly between the 1990 and 2000 amount. The trunk and collection system O & M costs were annually increased at the average 1985 to 1990 annual increase rate.

The capital costs were based upon estimated cash expenditures for construction. The Phase II expenditures assume completion of the facilities by 1990. These facilities include the plant and pumping station expansion plus the trunk and collection system costs for those areas that had no Phase I project (V, IX, XI, XIV, XV, XX). The facilities to handle 1991 to 2000 growth were divided into equal annual expenditure of JD 682,000. This is the estimated current construction cost with 35 percent added for other project costs.

Table 10.3 shows the detailed calculation of the Internal Economic Rate of Return for 1980 to 2024. The rate is about 3.7 percent.

10.3.4 Combined Water and Sewerage Project

The Internal Economic Rate of Return for the combined water and sewerage project can be obtained by combination of the receipts and costs shown in Tables 10.1 and 10.2. This is done in Table 10.3 and the rate for the combined project is about 4.4 percent.

10.4 Ability of Residents to Pay for Water and Sewerage Service

10.4.1 Background

Ability to pay for municipal services can be defined as a household's capacity to absorb a new expenditure or an increase in an existing expenditure within the constraints of household income. Ability to pay is particularly critical for low-income families because most of the income is spent on necessities, consequently they have less discretion in the manner by which it is spent. After expenditures for rent, food, clothing and fuel have been made, there is usually little remaining for other items. Substantial absolute increases in the cost of one item cause hardship because there is so little elasticity in overall expenditure patterns. The problem with the ability-to-pay concept is that (1) it is difficult to make reliable estimates of a population's "necessary" expenses, and (2) even if a reliable estimate could be made, a value judgement is still required in determining how much of "excess" income could be, or should be spent in lieu of some other expenditure.

10.4.2 Present Cost of Water Service

Water rates in Zarqa and Ruseifa are characterized by a progressive block rate structure, with higher unit rates being charged as consumption increases. Metered water intake in the planning area is estimated to average about 45 l/c/d which, for a family of average household size seven, is about 19 m^3 during a two-month billing period. On the present rate schedule this amount would cost JD 1.880 every two months or about JD 11.3 annually. The results of the household survey indicate that low-income families consume less water than middle and upper-income families. With reference to the income distribution characteristics developed in Section 3.1.1, the following estimates of average consumption and annual costs have been made:

Income Group	Range of Annual Income (JD)	Average Metered Water Intake (m^3 per month)	Average Annual Water Expenditure (JD)	Expenditure as Percentage of Income
Lowest Fifth	0-1000	5.0	4.800	0.5% or more
Second Fifth	1001-1320	6.5	6.960	0.5 - 0.7%
Middle Fifth	1321-1620	8.9	10.560	0.7 - 0.8%
Fourth Fifth	1621-2460	12.2	14.880	0.6 - 0.9%
Upper Fifth	2461 or more	15.0	19.200	Less than 0.8%

In general, the estimated cost of water to most households is presently less than one percent of income and does not, therefore, represent a significant economic burden.

10.4.3 Present Cost of Wastewater Disposal

The present cost of wastewater disposal for planning area households consists of the initial construction cost for the cesspool and the cost of periodic pumpouts. The cost of a new cesspool is estimated to be about JD 250. It is fairly likely, however, that some homeowners avoid this expense by digging the cesspool themselves. After a few years of use, the permeability of the cesspool is usually greatly reduced, and the homeowner must construct a second cesspool. It is not uncommon for a household to have three or more cesspools.

The municipality of Zarqa charges the homeowner JD 2.500 per pumpout, while the private tankers (which are about four times as numerous), charge JD 3.500 or more, depending on the location of the house, topography, and other factors. Some respondents in the household survey reported pumpout charges as high as JD 6. The frequency with which a cesspool must be pumped varies according to a number of conditions: the amount of water used, the age of the cesspool, topographic and subsurface conditions, and the amount of rainfall. The household survey indicated that cesspools were pumped an average of four times per year, but the fact that there are only about 40 tankers in operation in an area with nearly 30,000 cesspools suggests that the actual number is probably closer to twice per year.

Because low-income families use less water than middle and upper-income families, it is likely that their average annual costs are somewhat less, although considerable variation in costs would be expected because of other factors. Estimates of annual disposal costs by income category are presented in Table 10.4. As was the case for water supply, pumpout expenditures are less than one percent of income. If, however, a new cesspool must be installed (say, every five years), the average annual cost could increase by JD 50 per year. In the lowest fifth income group, this amount would constitute 5 percent of annual income or more, which makes it seem rather likely that many homeowners would excavate the cesspool themselves in order to avoid the cost. In the upper fifth income group, the average annual cost would be less that 2.0 percent of income. For the middle three-fifths it is likely that some homeowners

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may excavate the cesspool themselves while other may hire a contractor. On average, expenditures for this purpose are estimated to not exceed 2.5 percent of income in all income categories.

Sewers would also eliminate the practice of throwing sullage into the streets and the nocturnal pumping of wastewater sumps into the streets, a source of emnity among neighbors and subject to municipal fines. In 1979, the total fines paid for these violations were about JD 10,000. These fines were probably more prevalent in the lower income group.

The various costs of water and wastewater disposal are summarized below:

		Sewage Disposal		
Income Group	Water Service %	Cesspool Installation* %	Cesspool Pumpout %	Total Percentage
Lowest Fifth	0.5 or more	5.0 or more	0.3 or more	5.8 or more
Second Fifth	0.5 - 0.7	3.8 - 5.0	0.4 - 0.5	4.7 - 6.2
Middle Fifth	0.7 - 0.8	3.1 - 3.8	0.4 - 0.5	4.2 - 5.1
Fourth Fifth	0.6 - 0.9	2.0 - 3.1	0.4 - 0.6	3.0 - 4.6
Upper Fifth	Less than 0.8	Less than 2.0	0.6 or less	3.4 or less

* At 50 JD/yr - Would be less if cesspool were dug by the homeowner himself.

Generally speaking, total expenditures could range from 3.4 to 6.1 percent of income, although actual expenditures are probably lower for those homeowners who dig their own cesspools.

10.4.4 Family Budgets

Although they are likely to be rather outdated, the following data give some indication of the relative importance of various expenditure categories for Zarqa households in 1967.[1] (A family budget survey by the Department of Statistics, now in progress, will not be completed until 1981).

Avg. 1967 Zarqa Household Budget

Food	35.28%
Rent	18.36%
Fuels and utilities	6.36%
House furnishings and operations	8.81%
Clothing and footw[illegible]	13.17%
Other goods and servi[illegible]	18.02%
Transportation	3.65%
Medical care	2.45%
Personal care	3.09%

Reading and education	3.62%
Recreation	1.08%
Smoking	5.13%

From 1967 to 1974, the cost of living rose most rapidly in the categories of food (102%) and clothing (10%). (1) Since 1975, the greatest increases have been in the categories of other goods and services (98.3%), clothing (88.3%) and housing (69.5%). (2)

For families in the lowest fifth income group, present water and sewage disposal costs (assuming self-installation of cesspool) average an estimated 0.8 percent or more of income. Because this represents a rather small fraction of income, even a substantial increase in water and sewer expenditures would require only a relatively minor reduction in the combined total of other expenditures. If, for example, sewer and water expenditures were to double, the expenditures for other items would be reduced by about one percent. The budget would, however, become increasingly sensitive to larger and larger increases. This raises the question of willingness to pay, that is, to what extent is the consumer willing to shift the allocation of his income to sanitary facilities from some other items. Respondents in the household survey stated that they would pay any amount to eliminate the cesspool problems. Realistically, however, the willingness to pay has limits which could not be adequately defined by means of the survey.

The suggested guidelines given below assume that households in all income groups would be able to absorb a small increase in expenditures for water and sewer above the present level.

Income Group	Income Range (JD)	Recommended Maximum Expenditure* as Percentage of Income	Recommended Maximum Total Average Annual Expenditure (JD)
Lowest Fifth	0-1000	2.0%	20
Second Fifth	1001-1320	2.5%	33
Middle Fifth	1321-1620	3.0%	49
Fourth Fifth	1621-2460	3.5	86
Upper Fifth	2461 or more	4.0	98

* Water and Sewerage Service

These suggested guidelines are less stringent than the frequently used guideline that a near-subsistence level family should not have to spend more that 5 percent of its income on water and sewerage services. (3)

10.4.5 Other Considerations

The means by which the water and sewerage projects may be financed can take several forms: water rates, sewer connection fees, a sewer surcharge based on metered water consumption, and a property tax levy.

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Government subsidies may supplement these sources of revenue. In addition, there would also be the private cost of modifications to household plumbing.

Each of these costs has different implications for affordability depending on who pays and the magnitude and frequency of payments. The water rates and sewer surcharges will generally be borne by the user whether he is owner or tenant (except, perhaps, for apartment buildings with a single meter). The property tax and the sewer connection fee are usually borne by the owner, even if he is not the occupant. These costs would ordinarily be passed on to tenants as part of the rent, but because of rent control policies, they will have to be borne by the landlord until such time as the dwelling becomes vacant and the rent can be re-established according to the prevailing market. This may be a strong disincentive for landlords to connect rental dwellings. The same would be true of plumbing modifications of rental units, such as the addition of flush toilets, etc.

The water and sewer charges are generally small payments at two-month intervals and are more amenable to the financial resources of low-income households. Property taxes may be somewhat larger amounts paid annually. The house connection cost and the cost of plumbing modifications are one-time costs of often substantial amounts of money. For this reason, they are often beyond the ability of low-income households who have little surplus income for savings and no access to consumer or home-improvement loans. The social survey of Janna'ah residents for the Jordan Urban Project reports the following responses to this question about willingness to pay for a house connection: (4)

0-1.999 JD	38%
2.000-4.999 JD	19%
5.000 JD or more	14%
Not willing	29%

A suggested mechanism for assisting low-income households in meeting these large one-time costs is to provide a financing plan at moderate interest rates for a period of three to five years. This could be done on an individual basis by permitting installment payments as was done in Amman. The social survey of Janna'ah residents (4) reported that 40 percent of households were willing to take out a loan for home improvements at monthly payments of JD 10 or less; another [illegible] percent were willing to make monthly payments up to JD 15.

10.4.6 Pricing Strategy

The above analysis demonstrates that the lowest and second lowest income group pay, on the average, about JD 26.5 per year for a combined water and sewer bill.

Based on the current average price of 120 fils/m^3 (115 fils/m^3 - Ruseifa) and 7.5 percent inflation, the average water price could increase to 172 fils/m^3 (165 fils/m^3 - Ruseifa) by 1984. It was demonstrated in Chapter 9 that the 165 fils/m^3 rate was sufficient to make the proposed water projects financially viable.

The annual current cost of water for the two lowest income groups would be 7.7 JD per year assuming 7 m^3/mo. This estimate allows for increased water use as described in Chapter 5 plus assumes the same block structure as is currently in force. This leaves JD 18.8 per year for sewage service. The sewage rates were set on the ability of the two lowest groups to pay JD 18.8 per year. These rates varied from 225 fils/m^3 in 1987 with no inflation to 375 fils/m^3 with 7.5 percent inflation and 600 fils/m^3 with 15 percent inflation.

Amman currently charges 30 fils/m^3 for sewage. It is reported that the actual cost is at least 100 fils/m^3. The difference is paid by some form of government subsidy. This rate could be compared with the 225 fils/m^3 rate (no inflation) proposed for Zarqa-Ruseifa. There is a wide variation.

It could be argued on an equity basis, that, the cost in Zarqa-Ruseifa should be no greater than Amman. However, the Amman system was started several years ago and its debt service payments for comparable facilities are lower because of inflation. Thus, on a cost-of-service basis, it could be argued that the Amman rates should be lower.

The entire question of subsidized rates is a political and social issue and can not be resolved in an engineering report. The proposed rates presented herein are based on estimated true cost, modified by ability to pay.

The proposed rates are based on the average rate per m^3. This is the total sales revenue divided by the total sales. The present water rate price schedule has an increasing cost as more water is used. While the actual cost of water service decreases per m^3, the use of an increasing rate schedule can be justified for two major reasons: 1) encourages conservation, and 2) it is a form of subsidy for the lower income groups.

For these reasons, plus the fact that it is already accepted policy, we anticipate that the "reverse" pricing policy will continue. The increase in price seems steep enough to promote conservation.

The sewerage rate has been set at the level that the two lowest income group can afforded to pay. Because this rate is already comparatively high, we have not recommended an increasing block structure similar to the water rates. If the government decides that the subsidy should be reduced, this is one method of increasing revenues.

The current minimum water bill is based on 3 m^3 per month. With the advent of a waterborne waste disposal system, more water will be required. One of the benefits of an improved water and sewerage system will be the health benefits and human amenities derived from more frequent washing and bathing. These will only occur to the greatest extent possible if there is no severe economic penalty. It is suggested that the minimum bill be increased but that there also should be a substantial increase in the water allowance. The exact amounts must be determined by a more detailed study. However, this pricing strategy will make the minimum amounts of water and sewerage service available to the lowest income groups.

10.5 Sensitivity Analysis

10.5.1 General

The purpose of the sensitivity analysis is to estimate the effect on the project costs and proposed rates caused by variation from the initial estimates. The following types of variables will be investigated:

- Inflation Rate
- Over-and underestimate of project costs
- Overestimate of water use
- Non-bonding of Annual Capital Improvements
- Effect of wholesale water costs
- Effect of nitrification/denitrification facilities.

10.5.2 Inflation Rate

Based on the Consumer Price Index, the overall rate of inflation in Jordan has averaged 13 percent for the past five years. Political leaders are attempting to reduce this rate but it is a matter of conjecture about the degree of success that will be achieved. The rates proposed in Chapter 9 are based on an average inflation rate of 7.5%

between 1981 and 1990. This assumes that there will be some success in reducing inflation.

For the sensitivity analysis, alternative Pro Forma Financial Statements were prepared for 0, 5, 10 and 15 percent inflation rates. For these statements, the operating expenditures and capital improvement costs were escalated at the appropriate inflation rate. For ease in comparison, all rates were increased in 1984. For the higher inflation rates, this resulted in a considerable swing from positive to negative cash flow between 1984 and 1990. In actual practice, these increases would probably be handled by more frequent rate increases of smaller size.

The financial characteristics with the alternative inflation rates are presented in Table 10.5 for the Joint Water Agency and Table 10.6 for the Joint Sewerage Agency.

As could be expected, the proposed rates climb substantially with increasing inflation. However, there is also a "benefit". The debt service is fixed at the time of financing and remains constant throughout the project. Under a high inflation rate, the ability to pay becomes greater. Since the debt service is a large portion of the annual costs, especially for the sewerage project, the cash flow and project viability increase as the inflation rate increases. This is because more revenue is generated by the increased ability to pay.

The required average rates (1984 increase) for a self-sufficient water project at the various inflation rates are:

Percent Inflation	Joint Water Agency
0	110 fils/m^3
5	145 fils/m^3
7.5	165 fils/m^3
10	190 fils/m^3
15	255 fils/m^3

These rates generally follow the overall inflation rate because the debt service payments are a relatively small portion of the total cost.

The rates for the proposed Zarqa-Ruseifa Joint Sewerage Agency are based on ability to pay rather than cost. These rates increase with inflation. With the sewerage agency, the debt service is a relatively large portion of the total cost. Thus, with increasing rates, there is a continual reduction of the annual subsidy as inflation increased. The proposed rates based on ability to pay and the annual subsidy for the Zarqa-Ruseifa Joint Sewerage Agency at the various inflation rates are:

Percent Inflation	Proposed Rate	Average Subsidy (1984 - 1990)
0	225 fils/m^3	JD 1,426,000
5	315 fils/m^3	1,128,000
7.5	375 fils/m^3	920,000
10	440 fils/m^3	850,000
15	600 fils/m^3	229,000

10.5.3 Over-or Underestimate of Project Cost

The multiplier for the other project costs derived in Chapter 9 contains some items which make our total project cost estimates conservative. These items are: 1) 10 percent construction contingency, and 2) 14 percent inflation.

Because there are several factors in the total project cost, we have selected to examine the effect of a 10 and 25 percent overrun in the total project cost. This increase would be applied to the Phase I project. Because there is also a possibility of not utilizing all of the contingency allowances, we will also examine a 10 and 25 percent decrease in Phase I costs.

For the sewerage project, there is a possibility of obtaining a direct grant. The amount of any grant is unknown but to cover this possibility an additional trial of a 50 percent total cost underage will be shown for the sewerage project.

Since we have examined the proposed rates at 7.5 percent inflation, the sensitivity analyses for the rate changes will also be performed at this inflation rate. Listed below are the rates with similar financial consequences as the proposal rate:

Item (fils/m^3)	Joint Water Agency	Joint Sewerage Agency
Current Proposed Rate	165	375
Rate with 10% Overage	170	405
Rate with 25% Overage	180	450
Rate with 10% Underage	160	345
Rate with 25% Underage	150	300
Rate with 50% Underage	-	225

For these range of project costs, the water rates are the more insensitive to a change in project cost. The increase or decrease in the rates is about one-third of the percent increase or decrease in the project cost.

The changes with the sewerage project are a slightly less than the percent increase or decrease.

Since the sewage rates were set on the ability to pay, a different way to view the sensitivity analysis would be to have the 375 fils/m^3 rate constant and determine the amount of subsidy which would be required to stabilize the rate. This additional amount is JD 257,000 per year if there is a 10 percent increase and JD 644,000 per year if there is a 25 percent increase. If there is a decrease, the decreased in subsidy would be these amounts.

10.5.4 Overestimate of Water Use

If the water demand and water sales have been overestimated, the rates will have to be increased to produce the same revenue. The most likely factors in overestimate of water use would be a population growth less than projected or a failure to reduce unaccounted-for-water.

Listed below are the rates with similar financial consequences as the proposed rates for a 10 percent and 25 percent overestimate of water and sewage sales:

Item (fils/m^3)	Joint Water Agency	Joint Sewerage Agency
Current Proposed Rate	165	375
Rate with 10% Less Sales	185	415
Rate with 25% Less Sales	225	500

The percent increases in the unit rates are about 1.2 times the percent overestimate in sales. Since both the water and sewage rate are dependent on the amount of water, the change in rates is addative. For example, if there was an overestimate of 10 percent, the total bill (water plus sewage) would be 600 fils/m^3 in lieu of the 540 fils/m^3 proposed, an increase of 11 percent.

10.5.5 Non-Bonding of Annual Capital Improvements

In Chapters 5, 6, and 9, it was explained that the normal system expansion and growth would be financed by annually internally generated funds. In this sensitivity analysis, the effect of this decision is examined.

For the sewerage project, the method of annual payment results in an annual cost of JD 635,000 per year, assuming no inflation. If the project were bonded using the same overhead costs and financing period, the annual payment for each years improvement would be JD 65,000. Under this method, the 1984 payment would be JD 65,000 and the 1990 payment would be JD 455,000. Over the life of the financing period, the total cost of the annually generated method would be JD 4,445,000 (7 x 635,000)

compared to JD 10,010,000 (7 x 65,000 x 22 yrs). However, the greater amount would be paid over 29 years rather than 7.

For the same subsidy, the rate could be reduced from 375 fils/m^3 to 325 fils/m^3 between 1984 and 1990. For the same rate, the average subsidy could be lower from JD 920,000 to JD 545,000 per year. However, after about 1990, the rates would have to be increased to generate the additional JD 455,000 per year in bond repayments. At 25 percent above the 1990 billable sewage flow, this would require an increase of 42 fils/m^3.

For the water project with no inflation and using the same methods as described above, the rate could be reduced from 165 fils/m^3 to 158 fils/m^3 between 1981 and 1990. However, after 1990, an additional 55 fils/m^3 would be required to pay the deferred debt.

10.5.6 Effect of Wholesale Water Costs

During the water rate analysis, the cost of supplemental water was not included because the cost is not available. The present cost of wholesale or bulk water is 65 fils/m^3.

We have assumed that by 1985 when the supplemental supply will be required, the rate will have increased to 100 fils/m^3. With this increase, the 1984 average rate adjustment would have to be to 190 fils/m^3 rather than the 165 fils/m^3 recommended.

10.5.7 Effect of Nitrification/Denitrification Facilities

If the King Talal Reservoir is used for a potable water supply, it may be required that nitrification/denitrification facilities be add to all upstream sewage treatment plants. For the recommended plant, this would increase the capital costs about 25 percent and the energy use about 40 percent. Since the gas available for on-site power generation will be sufficient to met the increased energy requirements, the increased energy requirements will have little effect on operating cost.

The effect on rates will be about the same as the analysis with 25% overage on project costs.

10.6 Project Prioritization

10.6.1 General

The economic analysis in Section 6.7.3 showed that the lowest overall cost on the basis of unit construction cost per person for the trunk and collection system was to build up to and including Subareas VII, XII

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& XIII. Based on human needs and capturing the Ruseifa industrial flow, it was recommended that the Phase I project be extended up to and including Subarea XVI. For this analysis, it was assumed that the sewage treatment plant unit costs would continually decrease as population was added.

This analysis assumed that there were sufficient funds for the initial construction.

10.6.2 Treatment Plant Considerations

The proposed treatment plant for the year 1990 has three similar treatment trains. The minimum size plant that should be constructed is a plant with two treatment trains. This will provide for a degree of treatment during normal maintenance and, in the event of operational difficulties, usually one of the two trains will operate.

On a flow basis, the two treatment train system will serve the basic project (Subareas I, II, III, IV) plus Subareas VII, VI and X. Depending upon the degree of industrial pretreatment achieved and the proportion of industrial and domestic flow, the plant may be somewhat biologically overloaded during the interim period. A lower degree of treatment may result. Then, on a flow basis, the third treatment train must be added. The unit construction cost per person served is:

Add	Plant Construction Cost Per Person Served (JD)
Minimum	33.68
VII	28.02
X	20.83
VI	20.09
VIII, XII & XIII*	21.86
XVII	20.71
XVI	19.30
XX	18.67

* Add Third Treatment Train based on flow.

Therefore, the unit construction costs decrease except for the slight increase when the third treatment train is added

In Chapter 6, the minimum project was the serving of Zarqa. This will have three problems: (1) a high unit cost, (2) exclusion of the industries in the Awajan Esh Sharqi area, and (3) under-utilization of the plant. However, it does require the least amount of initial funds.

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10.6.3 Reduced Project

On the basis of system and environmental consideration, we have selected the Chapter 6 "minimum" project (Zarqa only) and the project which fully utilized the two treatment plant trains for illustration of the reduced projects. The various capital cost items along with the recommended project are shown below:

Minimum (Zarqa Only)	
Plant	JD 3,836,500
Collection & Trunk	8,101,825
Construction Cost	11,938,325
Land	736,000
Total Project Cost*	20,616,300
Annual Payment	1,712,200
Annual Payment/Person	15.03

Fully Utilize Two Treatment Trains	
Plant	JD 3,836,500
Collection & Trunk	10,172,600
Construction Cost	14,009,100
Land	736,000
Total Project Cost*	24,045,500
Annual Payment	1,997,000
Annual Payment/Person	10.46

Recommended Project	
Plant	JD 4,898,000
Collection & Trunk	13,306,000
Construction Cost	18,204,000
Land	736,000
Total Project Cost*	30,992,000
Annual Payment	2,574,000
Annual Payment/Person	10.15

* See Chapter 9

Based on Table 6.10 the costs of any intermediate alternative can be derived. The 1980 present worth of the East Side Pumping Station operation at the 1984 rate between 1984 through 2000, JD 194,600, must be deducted

from the Table 6.10 collection and trunk sewer costs before the calculation.

The reduced project calculations show that for an increase of about JD 802,000 per year, a 50 percent increase in the annual cost of the minimum project, the recommended project can be implemented. The recommended project will serve about 123 percent more people than the minimum project.

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1. Department of Statistics, 1974 Statistical Yearbook

2. Department of Statistics, The Cost of Living Index, December 1979.

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11.0 HEALTH-RELATED AND ENVIRONMENTAL CONSEQUENCES OF ALTERNATIVES

11.1 Introduction

The purpose of this chapter is to compare the environmental impacts associated with the proposed action to the impacts of taking no action to upgrade the water distribution, sewerage and stormwater drainage facilities for the Zarqa Ruseifa Area. Further, where feasible alternatives exist the relative merits or disadvantages of each option are compared. In each case those impacts which were identified by the scoping process as potentially significant have been emphasized.

Although numerous alternative actions may be considered in a facilities planning study of this type, the initial screening process has eliminated a number of options. Many of the options which were eliminated are related to the scale of the project. With respect to water distribution the option of providing for individual house connections was compared to that of community taps. Since many, if not most, households already have individual connections, reliance on community taps would appear to be a step backward from both a public health and cultural standpoint. Similarly, the concept of small-scale wastewater disposal involving either upgraded septic tank-soil absorption systems or small community collection and disposal systems was eliminated, because of the density of units and unsuitable site soil conditions. The only feasible alternatives remaining which warrant further consideration are related to the centralized sewerage and wastewater treatment systems. These options include:

- o Sewerage and Treatment Plant Configurations
- o Industrial Treatment
- o Sludge Disposal

11.2 No Action

This section evaluates the projected environmental consequences if no action is taken to improve the water distribution systems and sewerage and stormwater drainage systems in Zarqa and Ruseifa. The assessment is organized in a manner which reflects the associated impacts on key natural and cultural resources.

11.2.1 No Action - Health Conditions

If no action is taken there will be no improvement in the facility-related conditions which may currently contribute to an unsatisfactory health situation in the Zarqa-Ruseifa area. Individual house connections constructed of unsuitable materials will continue to be a risk with respect to contamination. Cesspools will continue to be the principal form of wastewater disposal, resulting in contamination of ground-water resources and contamination of leaky, corroded water supply pipes when service is interrupted. Surface overflows from cesspools in combination with ponding of inadequately drained stormwater will continue to be an additional health risk if sewage and stormwater drainage facilities are not provided. Finally, stormwater drainage facilities would reduce erosion and structural damage, which are a risk to the safety of the residents of the area.

11.2.2 No Action - Geology and Soils

The major impact of no action on these resources is related to the erosion and sedimentation associated with stormwater runoff. Along the steeply sloping uplands bordering the Zarqa River there is evidence of erosion and undermining. Over time this will result in unstable slope conditions and possible property damage.

Further, the erosion of soil reduces the potential for agricultural usage and limits the feasibility of reforestation. The eroded soil results in turbidity and an influx of nutrients adversely affecting the water quality in the Zarqa River and King Talal Reservoir. Where sediment is deposited in culverts or critical river cross sections it may cause flooding.

An improved stormwater drainage system will reduce the magnitude of these impacts. However, there will be minor impacts, including fracturing of rock and short-term erosion, as a result of blasting and excavation for stormwater, water and sewerage facilities.

11.2.3 No Action - Climate and Air Quality

If no action is taken to alleviate existing problems with private cesspools, septic odors will continue to impair air quality in the densely developed areas of Zarqa and Ruseifa. Further, stormwater will continue to accumulate in certain areas, causing stagnant pools which may be an additional source of odors. Finally, if no action is taken to collect and treat wastewater there will be no opportunity to augment

the rainfall deficiencies associated with the local climate by applying treated effluent to raise crops and recharge the ground water.

11.2.4 No Action - Water Resources

Both the surface water and ground-water resources of the study area are significantly affected by the lack of adequate sewerage and stormwater drainage systems.

As noted in II.2.2, the provision of stormwater facilities may result in localized water quality improvements by reducing the erosion of soil particles and associated nutrients. These systems will also alleviate local ponding conditions in poorly drained areas, thereby increasing the runoff and augmenting stream flow. However, this in turn will reduce the local ground-water recharge to some degree.

Surface water and ground-water quality are impaired by current waste disposal practices. Overflowing septic tanks or cesspools contribute to the contamination of stormwater runoff. Further, inadequately treated industrial wastewaters are clearly of concern, especially with respect to the introduction of toxic chemicals such as heavy metals into the water resources of the area. Cesspools built into the porous or fractured bedrock and shallow soils contribute to the contamination of the upper aquifer as evidenced by high bacterial, nitrate and chloride levels in numerous wells.

However, it must be recognized that current wastewater disposal practices represent a substantial recharge of the upper ground-water aquifer, which will be eliminated if action is taken to collect and treat wastewater at a central facility. Offsetting this loss is the waste of water which is currently experienced as a result of the inadequate water distribution system, and overflowing roof storage tanks made necessary by a lack of reliable supply.

11.2.5 No Action - Ecosystems

Most of the study area is intensively committed to either urban development, mining, or agriculture, so that the natural terrestrial ecosystems have already been eliminated. However, stormwater controls will reduce local erosion and create more suitable conditions for greenbelt or agriculturally created habitat capable of supporting small mammals or birds. This will improve the quality of life for local residents in an aesthetic sense.

Of greater importance is the recognition of the potential impacts of existing wastewater disposal practices on aquatic resources. The discharge of inadequately treated industrial wastewater is of particular concern since it may result in conditions toxic to both aquatic and terrestrial life forms.

11.2.6 No Action - Archaeological Resources

Although the full extent of archaeological remains from previous occupations of the planning area is unknown, it is clear that such resources may be found throughout the area. The no-action alternative would not result in excavation or construction of previously undisturbed sites and thereby would not adversely affect archaeological resources.

11.2.7 No Action - The Man-made Environment

The erosion, undermining and flooding associated with a lack of adequate stormwater drainage facilities currently represents a threat to property, including buildings, roads, bridges, culverts and other structures. Construction of water, sewerage and stormwater facilities will require excavation and possibly blasting which, unless carefully controlled, may also result in property damage. No action would avoid the risk of damage to utilities, including electricity and water supply, which could occur during construction. In addition, no action would not result in the disruption of traffic and associated temporary inconvenience associated with construction of facilities. However, the long-term benefits of a structural solution clearly outweigh the relatively minor short-term construction impacts which are avoided by no action.

Of greater concern are the relative merits of controlling land use by providing an attractive infrastructure of water distribution, sewerage and stormwater drainage facilities. Currently, the lack of facilities provides little incentive for development to occur in conformance with the existing Master Plans for development. As a result agricultural lands are utilized for either residential or industrial growth. The no action plan would not improve this situation. In contrast, the provision of these amenities should make development in conformance to the Master Plan more attainable. Further, the provision of facilities should allow development at a higher density, thereby resulting in a greater preservation of land for other usage.

11.3 Sewerage and Treatment Plant Configurations

As noted in 6.5, three alternative treatment plant sites have been identified. In addition, three possible strategies for utilizing these sites were delineated involving either a single plant or two plants. Each of these options will require a different configuration of trunk sewers and pump stations. Further, the selection of a site may have a substantial influence on the method of effluent disposal.

The site initially selected for the Zarqa treatment plant (Upper Zarqa site) was eliminated for two major reasons. Firstly, the inclusion of Ruseifa plus the associated industries results in the need for an expanded facility which cannot be accommodated on that site. Secondly, this site is located in an area slated for near-term future development with which a treatment plant may be incompatible.

The remaining locations are the lower Zarqa site (Site A) and the East Wadi site (Site B). Each of these sites is described in 7.4. The relative merits and disadvantages of each site in conjunction with the single-plant versus two-plant configuration are presented below with respect to potential impacts on key natural and cultural resources. The options are:

- o Alternative 1, all treatment at Site A (Lower Zarqa)
- o Alternative 2, all treatment at Site B (East Wadi)
- o Alternative 3, treatment at both sites

11.3.1 Sewerage and Treatment - Health Conditions

There are no significant differences among the alternatives with respect to health conditions. There is the potential under Alternative 2, utilizing effluent for the raising of crops, for the public to be exposed to pathogenic organisms on crops. Careful consideration must be given to the type of crop and to processing methods in order to avoid this risk. It would appear to be most prudent to grow grass as pasturage or fodder to preclude this potential impact. The option of discharge to the Zarqa River from the lower Zarqa site (Site A) also has the risk of downstream use of effluent for irrigation and possible contamination of crops by pathogenic organisms.

11.3.2 Sewerage and Treatment - Geology and Soils

The soil conditions at both the Lower Zarqa site (A) and the East Wadi site (B) appear to be suitable for cultivation. In either case construction of a sewerage treatment plant would disturb and commit

soil resources. The proximity of Site A to the Zarqa River may result in better natural conditions for agricultural use than Site B. However, if land application were utilized to take advantage of the nutrients in the effluent at Site B, a more efficient utilization of otherwise arid soils would be realized.

The disturbance caused by utilizing two sites is greater than building on one site. However, the single-site concepts also require additional sewerage mains and/or pump stations which tend to equalize the degree of disturbance and associated erosion potential.

Bedrock at each site appears to be greater than six meters deep and significant impacts on geological resources are not anticipated. Possible blasting in some areas may alter the natural fracture pattern of the bedrock, altering localized ground-water flow patterns and possibly springs.

11.3.3 Sewerage and Treatment - Climate and Air Quality

Each of the proposed sites is relatively remote from existing development. Therefore, should odors or pathogenic aerosols be generated, they would not affect nearby residents. Generally the greater the number of treatment plants and pump stations, the greater the risk of odor generation. Alternative 2 utilizes a pump station in close proximity to the intensely developed portion of Zarqa, which increases the potential of local air quality impairment from odors.

The use of effluent to irrigate soils in the vicinity of Site B would have the positive impact of overcoming the rainfall limitations associated with local climatic conditions.

11.3.4 Sewerage and Treatment - Water Resources

The potential impact of these facilities on water resources is the area which warrants the greatest consideration. Each alternative results in the beneficial effect of improving the quality of the ground water by eliminating inadequate individual cesspools. However, there are potentially adverse effects associated with effluent discharges which may counterbalance these benefits.

A plant at Site A would occupy floodplain lands and may result in a constriction and some increase in flood levels upstream. Furthermore, direct discharge to the Zarqa River will increase nutrient loads in the King Talal Reservoir and may create toxic ammonia concentrations in the Zarqa River downstream of the discharge.

Selection of Site B would avoid floodplain encroachment. Furthermore, a discharge to the wadi will not affect surface water quality, since it is projected that the flow will be completely absorbed into the wadi bed. However, this may result in nitrate contamination of the upper aquifer. If land application were utilized at Site B, the crops would utilize the nitrates and ground-water recharge could be achieved without significant contamination.

II.3.4 Sewerage and Treatment - Ecosystems

The adverse impacts on the terrestrial ecosystem from any of the sewerage and treatment options are similar and minor since the sites are under cultivation. However, the potential impacts on aquatic organisms are significantly different. Treatment at Site A will result in an increased flow of nutrients to the King Talal Reservoir. Although eutrophication would probably occur as a result of background nutrients alone, this discharge may aggravate the situation. Furthermore, the discharge may produce levels of ammonia which would be toxic to aquatic organisms for a considerable distance downstream from the plant.

In contrast, treatment and effluent disposal at the East Wadi site would have no significant effect on aquatic ecosystems.

II.3.5 Sewerage and Treatment - Archaeological Resources

It is difficult to project the relative impacts of construction of each of the alternatives on these resources since the extent of archaeological remains is not clearly delineated. However, it appears more likely that sites may be encountered along large River than further to the east away from this natural corridor of occupation. For this reason it is possible that Alternative 2, which utilizes the East Wadi site, may have less overall potential impact on archaeological resources.

II.3.6 Sewerage and Treatment - The Man-Made Environment

The potential impacts of construction on property and utilities are essentially equal for each alternative. Similarly, there are no substantial differences in the degree of disruption of traffic and temporary inconveniences resulting from construction.

There may be differences in aesthetic conditions associated with the operation of facilities. Alternative 2 involves the use of two pump stations along the river near the Zarqa-Kuseifa Bridge which may result in undesirable odors. Alternative 3 requires the use of two

treatment plants, doubling the visual impact of these facilities and the potential for generating objectionable odors.

However, the most significant impact is with respect to land use. Alternatives 1 and 3 require use of the lower Zarqa River which is in the floodplain and is currently used intensively for agriculture. The East Wadi (Site B) is also cultivated, but does not appear to be used as intensively as Site A. If land application were used, approximately 25 km^2 of land, currently utilized by the army, would have to be committed to irrigation. In order to preserve the land in the Zarqa Valley there would have to be a change in priorities, allowing the use of the land for agriculture rather than military use.

11.4 Industrial Treatment

The Industrials Effluent Treatment Report which is summarized in 7.2 identified three alternative approaches:

- Joint industrial-municipal treatment with individual pretreatment where appropriate.
- Joint industrial-municipal treatment with a "centralized pretreatment facility."
- Individual industrial treatment with direct discharge to the Zarqa River or nearby wadi.

The impacts of each of these approaches is compared below with respect to key natural resource and cultural factors.

11.4.1 Industrial Treatment - Health Conditions

The complete reliance on numerous individual industrial treatment facilities will have the greatest risk of insufficient treatment and resultant exposure to hazardous materials in effluents, aerosols or sludges which have not been disposed of properly. This is aggravated by the proximity of some industrial areas to residential and crop-producing areas in Ruseifa and Zarqa. Joint industrial-municipal treatment with pretreatment, either centralized or individual, could, in the event of a process upset, result in contamination of sludges which might otherwise be suitable as a soil additive. If contaminated sludges were used to grow crops, hazardous materials such as cadmium or other heavy metals may enter the food chain. Similarly, concern is warranted for the use of effluent to irrigate crops at Site B, which be become contaminated as a result of the failure of pretreatment facilities.

11.4.2 Industrial Treatment - Geology and Soils

Much of the industry is located along the Zarqa River in Ruseifa, where it is surrounded by prime agricultural land. The provision of individual treatment or pretreatment facilities would result in an additional commitment of these soil resources. Construction of a centralized pretreatment facility would also involve agricultural land, but this may be done more efficiently than with multiple facilities.

Multiple industrial treatment or pretreatment facilities generating potentially hazardous sludges increase the risk of soil contamination resulting from improper disposal. Joint industrial-municipal treatment has the potential for resulting in contamination of municipal sludges which might otherwise be suitable as a conditioner to improve local soil conditions.

11.4.3 Industrial Treatment - Climate and Air Quality

Dispersed individual treatment or pretreatment facilities located in developed areas may result in greater exposure to odors or aerosols than with a more remote centralized facility. Contamination as a result of improperly functioning pretreatment facilities could preclude the use of effluent in a land application scheme to overcome local rainfall deficiencies.

11.4.4 Industrial Treatment - Water Resources

Each of the schemes would improve the existing situation by eliminating the discharge of inadequately treated industrial wastes to surface or ground water. However, generally the more facilities involved, the greater the potential for equipment failure or process upsets which may result in improper discharges. In this sense, complete reliance on totally independent treatment plants would have the greatest risk, while a centralized facility would have the least risk. However, the single centralized pretreatment facility would result in all industrial effluents entering the Zarqa River. Although concentrations of certain materials may be acceptable in the effluent, there may be a tendency for low levels to accumulate in the King Talal Reservoir and reach undesirable levels in the sediments.

Further, the reliance on a single pretreatment facility could result in a serious bypass of large volumes of improperly treated industrial waste, which is less likely with individual facilities.

Finally, the inclusion of industrial effluents could preclude the use of the treated wastewater for land application of crops which may enter the food chain.

11.4.5 Industrial Treatment - Ecosystems

The area occupied by many of the industries in the Ruseifa area is surrounded by agricultural lands. In other areas nearby vacant land might be reforested as greenbelts. Each of these land uses provides habitat for small birds, mammals and other wildlife, which break up the urban development pattern in a desirable way. The construction of numerous industrial treatment or pretreatment facilities would divert these lands from the creation of such habitat.

As noted in 11.4.4, multiple facilities increase the risk of a failure and the discharge of inadequately treated industrial waste which may harm aquatic life. In contrast, a single centralized facility decreases the risk of a failure. However, if a problem occurs the volume of the improperly treated discharge would be greater.

Finally, it will be more difficult to control the disposal of sludges generated from numerous individual industrial facilities. This may result in an increased risk of exposure of terrestrial wildlife to hazardous materials.

11.4.6 Industrial Treatment - Archaeological Resources

The limited information available describing previous occupations of the Zarqa-Ruseifa area indicates that the greatest potential for encountering archaeological resources is along the river corridor. Therefore, the multiple facility alternative has a greater potential for encountering such resources than the centralized facility.

11.4.7 Industrial Treatment - The Man-made Environment

Since many of the existing industries are located in the developed river corridor, the individual treatment alternative has a greater potential for impacting the man-made environment than a single centralized pretreatment facility at a more remote location at either the lower Zarqa site or the East Wadi site.

11.5 Sludge Conditioning and Disposal

As a result of initial screening, several sludge handling options have been selected for final evaluation. In each case the sludge would be digested in order to stabilize the material, thereby avoiding odors

and reducing the potential exposure to pathogenic organisms. Dewatering may be accomplished by drying beds or mechanical dewatering equipment. Ultimate disposal may involve landfilling or the use of the material as a soil conditioner. The beneficial and adverse impacts of each of these are compared below.

11.5.1 Sludge - Health Conditions

Digestion should result in a stabilized material relatively free of pathogens. Similarly, pretreatment of industrial wastes should preclude the introduction of hazardous materials which may affect the suitability of the sludge as a soil conditioner. Therefore there are no significant advantages or disadvantages associated with health conditions which would result in the selection of a particular dewatering or disposal option.

11.5.2 Sludge - Geology and Soils

The use of drying beds requires more land and associated soil resources than mechanical dewatering. However, because drying beds are more efficient, the resultant product has a higher solids content, and lower volume. Therefore sludge from drying beds requires less land for ultimate disposal. With respect to ultimate disposal, the use of the sludge as a soil conditioner is favored over landfilling, as it may improve soil characteristics in areas slated for reforestation or reclamation of mined lands.

11.5.3 Sludge - Climate and Air Quality

Digested sludge is not generally considered to have an objectionable odor. Therefore, there are no differences in sludge handling and disposal alternatives in this respect which would favor the selection of a particular alternative.

11.5.4 Sludge - Water Resources

In each case, the water from the dewatering process would be returned to the treatment plant for processing prior to disposal. However, since it is anticipated that mechanically dewatered sludge will have a higher water content than sludge from drying beds, there may be more potential for contamination of water resources as a result of runoff or percolation of the excess water containing high nutrient levels.

11.5.5 Sludge - Ecosystems

The use of sludge as a soil conditioner is considered a positive benefit which, if used to reclaim land or augment agricultural soils, may enhance wildlife habitat. In contrast, landfilling requires the disturbance and commitment of lands which might otherwise provide such habitat.

11.5.6 Sludge - Archaeological Resources

The use of drying beds requires more land at the treatment plant site, and therefore may result in a greater potential for disturbing archaeological resources if they are present on the site.

11.5.7 Sludge - The Man-Made Environment

The use of sludge as a soil conditioner should improve the quality of the soil and increase the value of the land. This may enhance the reclamation of mined lands and allow reforestation or expanded agricultural usage.

The use of sludge dewatering beds requires more land at the treatment plant site but requires less land for ultimate disposal, since the sludge contains less water and is reduced in volume.

Finally, sludge drying beds use solar energy and avoid the use of the other energy resources required by mechanical dewatering. These other energy resources may then be used for other purposes to enhance the man-made environment.

11.6 Impacts of Proposed Action and Mitigating Measures

The proposed action involves the provision of improvements to the water distribution, sewerage and stormwater drainage systems in Zarqa and Ruseifa. A detailed description of the recommended project is provided in Chapter 12. This section will identify the environmental impacts associated with the proposed action. Mitigating measures which may be employed to reduce the magnitude or duration of adverse impacts are also identified.

11.6.1 Proposed Action - Health Conditions

11.6.1.1 Water Distribution

The proposed improvements will not result in any adverse health-related impacts. In contrast, the project will replace expedient home connections installed using inferior materials and with inadequate construction management. These inadequate facilities are subject to

contamination resulting from inflow of polluted ground water when service is interrupted. Furthermore, provision of a more reliable water supply would be a factor in encouraging improved sanitation practices. A more reliable water supply system may eventually obviate the need for roof storage tanks, which are another potential source of contamination.

11.6.1.2 Sewerage

The proposed project will provide major beneficial impacts by eliminating the cesspools which represent a serious health risk. Overflowing cesspools result in pools which are a source of direct contact or indirect (vector) contact with disease-producing organisms. Furthermore, the cesspools contaminate ground water which is used as a water source. During interruptions in service, polluted ground water may enter the potable water distribution system through poor joints or holes caused by corrosion.

There are some potentially adverse effects related to the provision of centralized wastewater treatment facilities. Primarily, there is the potential that effluent from the plant, which would be discharged to the Zarqa River, may be withdrawn downstream and used to irrigate crops raised for human consumption, resulting in transmission of disease. Furthermore, the inclusion of pretreated industrial wastes may result in contamination of sludges. If used a soil conditioner, heavy metals may enter the food chain in harmful levels. These potential impacts may be avoided by careful monitoring of the plant effluent and sludges and provision for control over the use of these materials on lands intended for edible crops.

11.6.1.3 Stormwater Drainage

The health-related effects associated with providing improved stormwater damage are all positive. The proposed action will reduce ponding, a potential source of disease, and reduce the safety-related effects of flooding and erosion.

11.6.2 Proposed Action - Geology and Soils

11.6.2.1 Water Distribution

Construction of the water facilities will require possible blasting and excavation. Blasting may cause additional fracturing of rock, affecting local ground-water levels or springs. Excavation will disturb the soil surface, causing conditions conducive to erosion by

both wind and stormwater. These impacts may be mitigated by careful consideration of the size and placement of blasting charges in close proximity to active wells or springs. Furthermore, the prompt restoration of excavated areas and stabilization with rip-rap, pavement, vegetative cover or netting will reduce the potential for soil erosion.

11.6.2.2 Sewerage

The proposed action recommends the use of the lower Zarqa River site (Site A), which would result in the commitment of land and soils which are currently used for agriculture. This is balanced to some degree by the processing of sludge to produce a soil conditioner which may be used to improve soil conditions at other locations. This soil conditioner may aid in the reclamation of mined lands in Ruseifa or expanded use of other soils for agriculture. Construction of sewer lines will have construction impacts, as noted above, for the water distribution system.

11.6.2.3 Stormwater

Adverse construction impacts and applicable mitigating measures are similar to those described above for water distribution and sewerage systems. The beneficial effects include: reduction of soil erosion which results in sedimentation of culverts or stream channels; and reduction of undermining of banks which may result in property damage.

11.6.3 Proposed Action - Climate and Air Quality

11.6.3.1 Water Distribution

Construction will disturb soils, exposing them to a higher potential for wind entrainment, and may cause local short-term increase in dust, which is already a problem. Mitigation of this was described previously. However, over the long term an improved water distribution system will provide better service to wash away the dust from the mines, which is a problem especially to the residents of Ruseifa.

11.6.3.2 Sewerage

Potential adverse construction impacts on air quality and mitigating measures are similar to those for water pipelines. A major benefit to air quality will be to eliminate the pervasive septic odors associated with failing cesspools or frequent pumping in densely populated urban areas. Although the sewerage treatment plant may be a source of odors, this potential impact is mitigated by the relatively remote location of the plant site. If necessary, odor control measures such as the use of oxidizing agents or deodorants may be employed.

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11.6.3.3 Stormwater

The adverse impacts associated with the proposed stormwater drainage system are generally short-term and similar to those noted previously for water distribution and sewerage pipelines. Mitigating measures are also similar.

11.6.4 Proposed Action - Water Resources

11.6.4.1 Water Distribution

The proposed improvements to the existing distribution system should decrease the losses from leaky pipes, and may eventually reduce the need for roof storage tanks which overflow and result in additional losses. However, it is probable that a more reliable supply and increased pressure may induce greater water use, which may offset the reduction of losses to some degree.

11.6.4.2 Sewerage

The provision of sewerage and centralized treatment facilities will eliminate the serious contamination of the upper ground-water aquifer which currently results from cesspools. The overflow of cesspools which contaminate stormwater would also be eliminated. These rather broad beneficial effects are in contrast to several adverse impacts. The elimination of cesspools will reduce the recharge to the upper aquifer resulting from the introduction of wastewater. Furthermore, sewering would eliminate the constraint on water use resulting from limited cesspool capacity and may result in incrased water use. In addition, the discharge of effluent may result in toxic ammonia levels in the Zarqa River downstream of the treatment plant and exacerbate the eutrophication problems caused by excessive nutrients in the King Talal Reservoir. Finally, although industrial waste materials in the effluent should not exceed acceptable levels in the river, there may be an accumulation of contaminants, such as heavy metals, in the sediments of the reservoir.

11.6.4.3 Stormwater

Ponding of runoff in low, poorly drained areas would be reduced by providing better drainage facilities. However, this would also eliminate a source of local recharge to the upper ground-water aquifer. The proposed facilities would also reduce erosion and sedimentation which has a local impact on the quality of surface waters such as the Zarqa River. Finally, the runoff of stormwater would be accelerated,

augmenting the flow of surface waters and the Zarqa River following storm events.

11.6.5 Proposed Action - Ecosystems

11.6.5.1 Water Distribution

The proposed improvements to the water distribution system will have no impacts of significance on the local ecosystems.

11.6.5.2 Sewerage

The provision of sewerage and treatment facilities may have substantial impact on aquatic ecosystems, especially the Zarqa River and King Talal Reservoir. The discharge from the lower Zarqa site will extend the dry weather flow in the Zarqa River upstream from Sukhnah for a greater portion of the year. Theoretically, this may result in expanded aquatic habitat. However, the quality of this flow augmentation will be impaired by high ammonia levels, which may be toxic to aquatic organisms. Furthermore, the discharge will contain levels of nutrients, which may result in a worsening of the algal problems and depletion of oxygen in the King Talal Reservoir. In addition, although industrial pretreatment should assure that levels of heavy metals or other hazardous materials are kept within acceptable levels in the effluent, these substances may accumulate in the sediments. Accumulated materials may be taken up by benthic invertebrates and enter the aquatic food chain.

The processing of sludge into a soil conditioner may have several beneficial aspects. The use of soil conditioner to aid in reclaiming mined lands or augment marginal soils for use in reforestation or agriculture may create desirable habitat for some forms of wildlife. However, the construction of the industrial pretreatment facilities and municipal sewage treatment facilities will require the commitment of land in existing agricultural areas which may currently serve as habitat for small birds, mammals and other wildlife commonly found in the urban fringe.

11.5.6.3 Stormwater

Construction of stormwater drainage facilities should not result in significant impacts to either terrestrial or aquatic ecosystems.

11.6.6 Proposed Action - Archaeological Resources

11.6.6.1 Water Distribution

The proposed improvements in the water system will involve excavation throughout the urbanized area of Zarqa and Ruseifa. Although generally the pipelines are placed in existing roads or footpaths, avoiding previously undisturbed areas, it is possible that cultural artifacts may be encountered, especially along the Zarqa River.

Although the extent and locations of archaeological resources in the area are not well documented, precautions may be taken to minimize the potential impacts of construction. During the detailed design a field walkover survey of proposed routes could be made in search of surficial evidence of previous occupations. The impacts of urbanization and agricultural activities may have already obliterated such evidence, however. Should surficial evidence be encountered, test pits may be employed to determine the extent of the artifacts. The Department of Antiquities should be notified before construction excavation begins, so that an inspection may be made by a specialist, in compliance with the Antiquities Law of Jordan. Because the financial resources of the Department are limited, it may be desirable to include funds in the project budget for a resident inspector specializing in antiquities. If a significant archaeological site is encountered, the Department may judge that a salvage operation is appropriate, which may result in short project delays. In other cases it may be more appropriate to relocate the proposed routing.

11.6.6.2 Sewerage

The proposed sewerage system is more extensive than the water distribution project and involves substantial construction of trunk sewers and the treatment plant in the Zarqa River corridor. The extent and location of these activities greatly increase the potential of encountering cultural artifacts. If remains are found the mitigating measures noted above should be employed.

11.6.6.3 Stormwater

The proposed drainage improvements are less extensive than either the proposed water distribution or sewerage networks. However, some construction is proposed in the river corridor. If artifacts are encountered, appropriate mitigation should be undertaken to reduce damage and loss of these resources.

11.6.7 Proposed Action - The Man-made Environment

11.6.7.1 Water Distribution

The construction of the water distribution system may require blasting, which represents a potential threat to the foundation of older mud brick buildings or other property. Blasting and excavation also are a potential threat to existing water lines and buried electric lines, where present. Excavation in streets and footpaths will disrupt traffic patterns and cause inconvenience to residents of the area. Furthermore, excavation will generate dust, noise and, if cesspool drainage is encountered, odors. All of these impacts are short-term in nature. The potential impacts to private property are best avoided by appropriate choice of construction techniques when in close proximity to sensitive structures. Existing utilities should be surveyed and marked on maps and in the field to alert the construction crews of their location. Excavations should be covered at night and the length of trench opened at a given time minimized to reduce traffic disruption, inconvenience and safety hazards. All work in streets should be preceded by appropriate signs, barricades and signals to reduce the potential for construction-related accidents.

11.6.7.2 Sewerage

The construction of severage pipelines involves short-term impacts similar to those for water lines. Similar mitigating measures are recommended.

In addition, the pump station on the east side of Zarqa, industrial pretreatment facilities and the municipal treatment plant site involve the commitment of extensive land resources. In particular, the municipal treatment plant site is located in a prime agricultural area along the Zarqa River. The availability of sewers is not expected to result in a faster rate of growth than would otherwise occur. Elimination of cesspools will, however, remove the constraint that now prevents higher density development. Although higher densities could ultimately result in greater conservation of land resources, conscientious enforcement of the land use regulations will be necessary to prevent illegal expansion in excess of planned densities.

11.6.7.3 Stormwater

The construction of stormwater facilities would have short-term impacts similar to those for the water distribution and sewerage system.

It is anticipated that these effects will be counterbalanced by a reduced property risk resulting from greater control of flooding, erosion and undermining in localized areas.

QUALIFICATIONS OF PREPARERS
ENVIRONMENTAL ASSESSMENT

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Mr. Shelstad was responsible for the compilation and evaluation of supporting information for the socio-economic and health studies and assisted in the development of information for the environmental assessment while in Jordan. He prepared appropriate portions of the environmental assessment report.

He has a BS in Architecture from North Dakota University and an MS in Environmental Design from Yale University. He is a member of the American Institute of Certified Planners and a registered professional planner in the State of New Jersey.

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John C. Henningson - Environmental Specialist

Mr. Henningson assisted in the compilation of information and evaluated site conditions in Jordan for the environmental assesment. He was responsible for coordinating the preparation of the report by participating staff.

He has a BS in Biology from Syracuse University and an MS in Environmental Engineering from Rensselaer Polytechnic Institute. He is the Manager of Environmental Sciences and Planning for Malcolm Pirnie, Inc. where he has coordinated the environmental evaluation for over 75 projects including numerous facilities planning efforts.

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Robert J. Bolton - Resource Management Specialist

Mr. Bolton assisted in preparing portions of the environmental assessment particularly the description of the affected environment.

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Gary J. Jellick - Agronomist/Soil Scientist

Mr. Jellick assisted in the evaluation of the feasibility of applying effluent to the land to raise crops and the use of process sludge as a soil conditioner. He also prepared the portions of the environmental assessment dealing with geology, soils and groundwater.

Mr. Jellick has a BS in Agronomy from Pennsylvania State University. He has considerable expertise with respect to identifying the chemical and physical properties of soil and evaluating their suitability for waste disposal. He has assisted in the preparation of appropriate portions of environmental reports for several wastewater and solid waste disposal studies.

12.0 RECOMMENDED PROJECT

12.1 Description and Phasing of Recommended Project

12.1.1 General

The projects as developed and described in this Feasibility Study are for the following phases:

Phase I - Provide adequate service for the 1990 population

Phase II - Provide adequate service for the 2000 population

Since some elements of the recommended project are difficult and uneconomical to parallel, these are planned for the year 2020 population which has been assumed to be close to the saturation population. These items are the trunk and collection sewer system and the water distribution network. The recommended water distribution and sewerage systems projects also provide for annual improvements to keep pace with the anticipated growth as it occurs.

12.1.2 Recommended Water Distribution Project

The major thrust of the recommended water distribution project is:

- Additional Supply
- Reinforce Existing Systems
- Expansion to New Areas
- Reduction of Unaccounted-for-water
- Reduction of Roof Tanks

It is anticipated that the future supplemental supply will come from the Azrak pipeline which is being constructed on the east side of the planning area. Also the East Ghor/Amman pipeline which can be connected to the Azrak pipeline if pumping from Azrak is discontinued. Discussions with the Amman Water and Sewer Authority and Jordan Valley Authority indicate that water is anticipated from Azrak in 1981 and from the East Ghor/Amman project by 1982. The supplemental supply for both Zarqa and Ruseifa is recommended to come from a common 24-inch pipeline connected to the Azrak-East Ghor/Amman transmission main near Awajan Esh Sharqi.

In the existing Zarqa and Ruseifa distribution systems, there are several incomplete distribution network loops. There are also several areas where there is poor flow distribution between the existing mains. Correction of these deficiencies is included in the recommended project. See Figure 5.11.

To serve the footpaths in the poorer sections of the planning area, the municipalities have constructed the mains in the streets but the homeowners have been required to construct the service connections to their homes. As a result, the footpaths contain several 13 and 25 mm connections. These will be removed during sewer construction in the footpaths and will be replaced with 50 mm pipes. The cost is included in the sewer project but their replacement is a water distribution improvement.

The developing areas are principally south and west of the existing population centers. Distribution loops are planned to serve these areas. In general, the first part of the loops are recommended in Phase I with closure in Phase II.

The unaccounted-for-water is currently about 40 percent. It is recommended that measures be instituted to reduce this to 20 percent, a more acceptable level. The measures would include a leak survey, replacement of the existing leaky pipes, and improved metering. It is recommended that Ruseifa gradually acquire ownership of the water meters and add a meter repair and test facility.

The roof tanks are a health hazard since they provide a means of water supply contamination. Ideally, these tanks should be eliminated. However, this does not appear practical because of the present fear of water shortage similar to Amman and the required changes in the arrangement of internal plumbing to by-pass the existing flow-through tanks. Given that it is impractical to eliminate the roof tanks, it is recommended that the municipalities increase their efforts to have the tanks kept clean and covered.

The recommended facilities are summarized as follows:

Zarqa

Phase I - 81 km of mains ranging in diameter from 50 to 600 mm

Phase II - 73 km of mains ranging in diameter from 50 to 400 mm

Ruseifa

Phase I - 40 km of mains ranging in diameter from 50 to 600 mm

Phase II - 15 km of mains ranging in diameter from 50 to 150 mm

1-700m^3 reservoir.

12.1.3 Recommended Sewerage System

The recommended sewerage system consists of a proposed treatment plant plus the trunk and collection system to convey the flow to it. The recommended system also includes the pretreatment requirements which are described in the Industrial Effluents Treatment Report.

Based on evaluation of alternative sites, it is recommended that a 24,200 m^3/d (Phase I) treatment plant be constructed on a 28.5 hectare site located adjacent to the Zarqa River northwest of the city. The proposed plant will utilize a plastic-media trickling filter system to achieve the required high degree of treatment. The plant will be designed with moduler units for time-phased expansion. Sludge disposal will be by anaerobic digestion, drying beds, and land disposal. The methane gas obtained from the digestion process will be used to power internal combustion engines which, in turn, will generate sufficient electrical power to operate the plant.

The recommended trunk system includes a sewer system alongside the Zarqa River from the proposed plant site to Ruseifa. Subtrunk and collection systems drain to these trunks. About one-third of Zarqa drains away from the Zarqa River eastward toward the Wadi Saida. This flow will be conveyed to a proposed pumping station site north of the Zarqa municipality wells and pumped over the ridge to the Zarqa River basin. (See Figure 6.3).

The recommended collection system consist of the sewers in the main streets and footpaths and a house lateral from the street or footpath sewer to the property line. At the end of the house lateral, it is recommended that, in many cases, a terminal manhole be constructed to facilitate connection of the household plumbing.

The recommended facilities are summarized as follows:

Phase I

- o 24,200 m^3/d treatment plant
- o 1175 m^3/hr pumping station
- o 22 km of trunk sewer ranging in diameter from 300 to 1,100 mm
- o 3 km of 500 mm diameter force main
- o 203 km of collection and subtrunk sewer ranging in diameter from 200 to 600 mm
- o 68m^3/hr Subarea XVI pumping station
- o 26,000 house connections

1984-1990

- o 66 km of collection sewer ranging in diameter from 200 to 300 mm
- o 7,970 house connections

Phase II

- o Expand treatment plant to 41,200 m^3/d
- o 205 km of collection and subtrunk sewers ranging in diameter from 200 to 300 mm
- o 20,300 house connection

12.1.4 Recommended Stormwater System

The recommended stormwater drainage system has been designed to collect, convey, and dispose of stormwater runoff from critical inhabited areas in as fast and efficient a way as possible. Gravity flow has been maintained throughout the system. (See Figure 8.1).

The Phase I facilities are the main interceptors that receive flow from the various watersheds and convey it to the discharge points. They serve large inhabited areas or protect major roads from flooding. These facilities are called the "primary network".

The secondary facilities drain the internal streets and low and landlocked points where the water tends to pond.

The recommended project is summarized as follows:

Phase I

- 13 km of 3000 to 1000 mm diameter pipelines and larger box culverts

Phase II

- 26 km of 300 to 1000 mm diameter pipelines.

12.2 Cost of Recommended Project

The construction cost of the recommended projects has been estimated on the basis of June 1980 costs. These are summarized as follows:

Phase I	Construction Cost (JD)
Water	3,310,000
Sewerage	18,204,000
Stormwater	1,030,000
	22,544,000
1984-1990	
Sewerage	3,291,000
Phase II	
Water	2,050,000
Sewerage	9,476,000
Stormwater	1,166,000
	12,692.000
TOTAL - ALL PHASES	JD 38,527,000

All of these projects require certain other costs which must be added to the construction cost to obtain total project costs.

It is anticipated that these projects will have three categories of overhead costs:

1. Major projects which will be designed by international consulting engineers, built by large contractors, and financed by long-term borrowing - These will have the following other project costs:
   - o 10% Construction Contingency
   - o 14% Inflation
   - o 10% Engineering
   - o 7% Management Services and Staff Training
   - o 15% Interest during Construction
   - o Land

2. Smaller sewer collection projects which will be designed by local consulting engineers, built by local contractors, and financed with annually generated revenue - For these, the other project costs are estimated at 35 percent of the construction cost.

3. Water extension projects which will be designed by the water department staff, built by the staff, and financed with annually generated revenue - For these, the construction cost is assumed to included the overhead cost since the work to be done by the water department staff will offset some overhead cost.

The total project cost for the recommended major projects is summarized as follows:

	Construction Cost (JDx1000)	Other Project Cost (JDx1000)	Total Project Cost (JDx1000)
Phase I			
Water	2,060	1,351	3,411
Sewerage	18,204	12,788	30,992
Stormwater	1,030	676	1,706
	21,294	14,815	36,109
Phase II			
Water	950	623	1,573
Sewerage	4,428	2,905	7,333
Stormwater	1,166	765	1,931
	6,544	4,293	10,837

The total project cost for the smaller sewer collection projects is summarized as follows:

	Construction Cost (JDx1000)	Other Project Cost (JDx1000)	Total Project Cost (JDx1000)
1984-1990	3,291	1,152	4,443
1991-2000	5,048	1,772	6,820

ANNUAL COST

1984-1990	JD 4,443,000/7 = JD 635,000
1991-2000	JD 6,820,000/10 = JD 682,000

The total project cost for the water extension projects and Ruseifa metering, assumed to be the construction cost, is summarized as follows:

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Phase I (1981-1990)

Zarqa	-	JD 1,000,000
Ruseifa	-	250,000
		JD 1,250,000

Annual Cost JD 125,000

Phase II (1991-2000)

Zarqa	-	JD 1,000,000
Ruseifa	-	100,000
		JD 1,100,000

Annual Cost JD 110,000

The total project costs for all recommended projects, inculding the 1984-1990 sewerage growth project in Phase I, by Phase are:

	Total Project Cost (JD)
Phase I	
Water	4,661,000
Sewerage	35,435,000
Stormwater	1,706,000
	41,802,000
Phase II	
Water	2,673,000
Sewerage	14,153,000
Stormwater	1,931,000
	18,757,000

TOTAL Phase I and Phase II JD 60,559,000

The total project costs for all recommended projects, assuming the 1984-1990 sewerage project is in Phase I, by type of project are:

	Total Project Cost (JD)
Water	
Phase I	4,661,000
Phase II	2,673,000
	7,334,000
Sewerage	
Phase I	35,435,000
Phase II	14,153,000
	49,588,000

Stormwater		
Phase I	1,706,000	
Phase II	1,931,000	
	3,637,000	
TOTAL ALL Projects		JD 60,559,000

12.3 Preliminary Rate Analysis

12.3.1 General

The purpose of the preliminary rate analysis was to establish a proposed rate structure for the recommended projects.

The analysis was done with a 7.5 percent rate of inflation. A sensitivity analysis was performed for higher and lower inflation rates, higher and lower capital cost estimates, and overestimates of water use.

12.3.2 Water Rates

The current average water rate for Zarqa is 120 fils/m^3 and for Ruseifa, adjusted for similarity to Zarqa, is 115 fils/m^3.

The rate analysis was based on establishment of a rate structure that would: (1) maintain a net positive cash flow between 1980 and 1990, and (2) maintain an average Rate of Return of about 8 percent during the 1985 to 1990 period.

With these assumptions, a rate increase effective January 1, 1984 to 165 fils/m^3 for both Zarqa and Ruseifa appears to be sufficient to make the water projects self-sufficient. This increase is about equal to the assumed 7.5 percent rate of inflation.

12.3.3 Sewerage Rates

It is proposed that the sewerage charges be recovered as a surcharge on the water bills. The sewerage system has very large initial capital cost and is of such a magnitude that, if it were to be self-financing, it would put an excessive strain on the middle to lower income families. Therefore, part of it's capital construction cost will have to be subsidized by the government or other agencies.

The "ability to pay" analysis indicated that the lowest and second lowest income groups could pay 225 fils/m^3 based on current costs. This escalates to 375 fils/m^3 by 1984 which is the proposed rate. The 375 fils/m^3 will cover the estimated operation and maintenance cost plus about 59 percent of the debt service. An average annual subsidy of about JD 920,000 will be required to balance the cash flow.

12.3.4 Stormwater Costs

Storm system costs are financed from general revenues so a rate study was not required.

The annual debt service of the Phase I project is JD 142,000.

12.4 Institutional Arrangements

Chapter 9 presents a detailed analysis of the alternatives available for administrating and managing the proposed facilities. The conclusions reached in Chapter 9 are as follows:

- A joint (Zarqa-Ruseifa) agency should be used to implement and operate the water facilities.
- A joint (Zarqa-Ruseifa) agency should be used to implement and operate the sewerage facilities.
- Consideration should be given to combining the water and sewerage agencies into one agency responsible for both.

12.5 Implementation Schedule

The implementation schedule for a project similar to the one being proposed for the Zarqa-Ruseifa area is usually governed by the item that has the longest required lead time. In situations similar to this project, the construction of the sewage treatment facilities usually sets the critical path of the implementation schedule. The financing and construction of additional water distribution extensions and improvements will not be completely beneficial if the sewerage system is not ready to receive the increased sewage that will be generated. Similarly, the financing and construction of the sewerage system will not be completely beneficial if the treatment facilities are not ready to treat and satisfactorily dispose of the sewage being conveyed to it.

The scheduling of the completion of the different elements of the project should be such that the elements are completed in the following order if possible:

- First the sewage treatment plant. It should be completed one to two months before the first sewage is conveyed to the plant.

- Second-the construction of the sewage trunk and collection system should start at the treatment plant and proceed progressively away from the plant. Sections of the system can be completed before the treatment plant is ready to receive sewage but it would not usually be economically justifiable to finance and build a large section of the system before the house sewers can be connected and the collection of service charges commenced.

- Third-the water system construction should follow closely behind the sewerage system. Some of the reinforcing of the existing distribution system can start immediately but no extension should be commenced unless the sewers will be ready to accept the newly generated sewage.

- Fourth-the stormwater drainage system can be started and completed at any time. Where elements are to be constructed in streets where either sewers or water mains are also to be installed, the construction of the elements showed be planned so the disturbance to the neighborhood is kept to a minimum.

Figure 12.1 shows a tentative planning and construction schedule for all the elements of the proposed first phase of the project. For all elements of the work, except the sewage treatment facilities, it is anticipated that multiple construction contracts will be prepared. The purpose of preparing multiple contracts for the water distribution, sewerage and drainage work is two-fold.

- The disturbance of the streets and footpaths of the communities will be controlled and kept to a minimum.

- All qualified local contractors will be able to tender on the works rather than being limited to a few large contractors. The disadvantage of doing this is that it spreads the construction out over a longer period and requires the borrowing of funds sooner than would otherwise be required.

The scheduling of water distribution and sewer construction contracts for work in the same streets should be controlled and, in some cases, combined so that the disturbance to the residents of the area will be minimized.

12.6 Training Program

12.6. General

The proposed Zarqa-Ruseifa Joint Sewerage Agency will be charged with implementation and operation of the second largest sewage collection, conveyance, and treatment system in the Kingdom. This is a major undertaking and cannot be successfully accomplished without trained personnel. As shown in Table 9.10, the estimated staff for the Joint Sewerage Agency is 89 persons. All will need some training.

Since there are few treatment plants or collection systems in the Kingdom, the Agency will have to train its own staff. Some help may be available from the proposed Jordan National Water and Wastewater Training Center.

Training should start in advance of placing the system in operation. Ideally, the Chief Engineer and Plant Superintendent would be hired near the beginning of the construction period and can become throughly familiar with the facilities as they are constructed.

Without a known source of trained wastewater operators and maintenance personnel, the start-up, operation, maintenance and training of personnel will be an extremely difficult undertaking unless, during the first 6 months to 1 year, a skeleton staff of trained people are continuously available. With only one wastewater treatment facility of similar character in the country, the availability of trained personnel may be very low.

A proven way of overcoming this problem is to retain the design engineer's services to provide a skeleton staff to operate and maintain the facilities while at the same time training the local staff. For the first 3 to 4 months, the operation and maintenance of the facilities will be principally by the skeleton staff. The day time operation will be nearly exclusively theirs and they will have to be "on-call" during the remainder of the time.

The personnel selected by the design engineer to participate in this operation should be highly skilled in their specialties and should be able to speak Arabic if possible. The personnel should cover the following areas:

- Operations
- Mechanical maintenance
- Electrical maintenance
- Instrumentation maintenance
- Laboratory operations
- Preventative maintenance

In the cases of operations and mechanical maintenance personnel, there should be two people for each specialty. The cadre of trained operators and maintenance personnel who will do the teaching and training should be on the site 3 months before the end of construction. The lead operators should also be on the site at the same time. The maintenance personnel should be on the site by the time the testing period is commenced. (See Figure 12.1).

To meet objectives of the training program, new employees should be trained in the operation and maintenance of all types of wastewater facilities. The program should include formal classroom training, practical on-site training, and the development of an on-going program for the training and development of future employees. The formal training should provide a blend of classroom lectures, laboratory instruction, and workshops. The practical training should consist of on-site instruction and specific assignments at existing facilities to guarantee "hands-on" experience. Material utilized in the training program should be developed in a manner such that it could be readily employed as the basis for an on-going training and development program.

A system of personnel classification by skills and experience should be developed to define specific job requirements. Upon successful completion of the training program, certificates should be awarded to each individual. The certificates should be specific to each job category and training course to develop a system which will encourage personnel development and advancement.

An important addition to the training program should be public education or relations. This public education should be used to help prevent the recurrence of many of the existing problems in other collection and conveyance systems. The dumping of garbage, debris, and related solid wastes into the sewer system has caused problems in many sewerage system elsewhere. A general public information and education program

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could lead to the reduction of solid waste dumping in the sewer system. It is anticipated that such a program could be effectively implemented during the course of this project.

12.6.2 Program Development

The development of the training program should include determination of course content and structure, preparation of all necessary materials, and establishment of a reference library.

The course content should be planned to cover all aspects of wastewater operation and maintenance. It should be structured for both formal classroom and on-site work. The formal classroom portion of the training program should include instruction in the following areas: orientation; basic science; mathematics; and operation and maintenance of wastewater collection, conveyance, treatment, and disposal facilities. The instruction should be provided by a combination of lectures, laboratories, and workshops as appropriate for trainee classifications. An example of a general topic outline which could serve as the basis for the formal classroom training is presented in Appendix 12.1.

The Appendix 12.1 outline is quite complete and lists the majority of the topics that must be taught. However, all personnel should not be given all topics. The supervisory personnel and lead operators should be familiar with all the material in the outline but only selected topics should be given to laborers, drivers, and clerks. Some specialized training not listed in the outline will be required for personnel such as the industrial waste technicians and electrical maintenance personnel.

The practical or on-site training should emphasize "hands-on" experience at all types of wastewater management facilities. Special work assignments could be developed to coincide with classroom instruction.

Materials to be provided for completion of the training program could include printed matter, audio-visual aids, dual language manuals, and references. Printed matter to be used in the training program should consist of course outlines, lesson plans, lecture notes, and illustrations. This material should be provided to supplement both classroom and on-site training as necessary.

An important part of the training program should be the development of audio-visual aids in both English and Arabic. Video tapes and/or photographic slides of lectures, laboratory procedures, and operation and maintenance techniques should be prepared. Development of these aids

will provide trainees with the opportunity to review subject material at their convenience. In addition, these audio-visual aids would serve as the basis for establishment of an on-going training program. Wherever possible, currently available audio-visual aids should be utilized to expedite the work. Updating of these available aids and development of site-specific films and slides should be performed as required.

Complete training and operations and maintenance manuals should be prepared in both English and Arabic. These manuals should be prepared in a style and format which would be readily used as on-the-job guides by Agency personnel. Step-by-step operation and maintenance procedures should be provided for all systems and pieces of equipment. Graphical presentations in the form of drawings, sketches, enlarged details, and photographs should be used to the greatest extent possible. Tabular and diagramatic presentations should also be emphasized, in addition to functional design of facilities.

A preliminary outline for the dual language training is presented in Appendix 12.2.

12.6.3 Trainee Selection

Based upon our experience with similar programs, it is not anticipated that a 100 percent trainee holding rate will be maintained throughout the duration of the Training Phase. A careful analysis should be made of local factors which would affect the holding rate. These factors would include availability and attractiveness of alternate employment opportunities and past employment histories for certain job classification. Based upon these factors, the number of trainees initially enrolled should be larger than needed. The program dictates that a careful determination be made of the type and number of individuals for initial training. If a larger than expected number of personnel complete the training program, there should be ample opportunity for employment at the other treatment plants planned for the Kingdom.

Educational prerequisites and job experience vary with the position. The Chief Engineer must have a college degree in sanitary, civil, or chemical engineering. The Executive Director should have a College degree in one of these fields or another appropriate discipline. Ideally, both should have prior experience at similar positions.

In order to present the range of educational prerequisites and job experience for Agency personnel, occupation description of the following positions are in Appendix Supplemental Material 12.3:

- Superintendent
- Lead Operator
- Operator
- Chemist
- Laboratory Technician
- Maintenance Supervisor
- Driver/Laborer

12.6.4 Classroom Work

Classroom work should include lectures, laboratory instruction, and workshops. Engineers and operational personnel experienced in training programs should be utilized to ensure effective transfer of information. Special emphasis should be placed upon the development of interesting and informative lectures to hold the attention of trainees.

To maximize the number of employees participating in the training program, a detailed schedule should be developed for rotating trainees through classroom work and on-site guidance. This schedule will also ensure coordination of the classroom work with the on-site guidance in a comprehensive training program. This portion of the program could occur during the start-up operations.

12.6.5 Overseas Training

Selected key personnel in management, engineering, and laboratory operations should receive training overseas, if possible. It is suggested that the personnel to receive this training are the executive director, chief engineer, superintendent, and chemist. The overseas training will involve inspections of large municipal wastewater facilities, training in operation, meetings with personnel filling similar positions in such facilities, and laboratory instruction. The timing of this training should be scheduled so that the personnel are back in Jordan before the facilities testing period is started. An overseas stay of 3 to 6 months is suggested.

12.6.4 Future Training and Development

To ensure the successful operation of existing and future wastewater facilities, a on-going training and development program should be initiated. The materials developed for the initial training program could serve as the basis for this on-going project. For example, audio-visual aids and dual language manuals would provide an excellent resource for continued instructors in the training programs. All instruction materials should be developed in a manner that would allow their periodic revision to maintain the latest technology.