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DRAFT FEASIBILITY STUDY

UPGRADING AND EXPANSION OF THE WASTEWATER STABILIZATION POND SYSTEM AT AS-SAMRA

August 1992

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Ministry of Irrigation and Water
Water Authority of Jordan

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SECTION 9

ENVIRONMENTAL ASSESSMENT

The Environmental Assessment forms a section of the Feasibility Study Report and represents the final element of the environmental review process starting with a review of the environmental effects of the existing As-Samra WSP System from the AGTP to the KTR (Survey Report) and from developing the environmental ratings of alternatives (Conceptual Study Report). As part of the Feasibility Study Report, alternatives, the Approved Project, and various technical discussions of treatment and delivery facilities and discharge requirements are presented in other sections and are not repeated herein.

9.1 PURPOSE AND NEED

The environmental assessment (EA) process has a central purpose of providing an independent and full-disclosure evaluation of the effects of the proposed upgrading and expansion of the WSP System upon the human and natural environment.

The environmental studies for this project began in October, 1991 with the evaluation of the effects on the exising As-Samra system. Conceptual alternatives were evaluated and ranked for their environmental effects and these were integrated with an overall review of alternatives as part of the Conceptual Report. The Scoping Session was held in March, 1992. Environmental assessment of the recommended alternative and approved project began in February, 1992 and is incorporated within the Feasibility Study Report.

9.1.1 Evaluation of Existing Facilities

Evaluation of the existing WSP system highlighted those effects created by the existing system facilities and those that should be addressed by upgrading and expanding existing facilities. This initial element of the EA process defined the existing and most probable future effects and information regarding the magnitude and trends of those effects.

9.1.2 Scoping Session and Statement

This element of the EA process provided a definition of what effects are considered as significant and insignificant (or much less significant). A wide array of interested and knowledgeable specialists and representatives contributed several concerns and issues and presented their estimation as to what is significant. These contributions to the consultants assured them that they would receive local advice

and direction as to the major concerns of the public who will be most affected by the construction and operation of the upgraded WSP facilities.

9.1.3 Conceptual Evaluations

Conceptual alternatives for upgrading and expanding the WSP system were developed to establish the ranking of environmental effects of the alternatives.

The recommended alternative included the best combination of environmental, engineering, and financial considerations. Some elements of the project were common to all alternatives and were not included in environmental review process or the integration with other aspects of the total project.

9.1.4 Feasibility Study Report

Once the Recommended Project was approved and more fully developed, purposes of the EA process shifted from a comparative evaluation to a more detailed evaluation of the approved project including the postions not originally considered as they were common to all alternatives. This evaluation focuses on the significant effects and development of suitable mitigation to reduce any adverse effects.

9.2 COMPARISONS OF PROPOSED PROJECT AND ALTERNATIVES

The proposed project evolved from reviews and comparisons presented in the Conceptual Study Report. During that phase of project development, primary focus was on differences between alternatives which all provided the same effluent quality from the same influent characteristics and alternative methods of delivering wastewater from the Amman and Zarqa areas to the As-Samra area as well as an area some 10 - 15 km further North from the existing site. Since the wastewaters and effluent were identical, the related sludge production was similar, although produced in somewhat different form. Detailed differences were not included in the comparisons nor were components which would be common to all alternatives.

9.2.1 Major Alternatives

Three general delivery and three treatment alternatives were reviewed: 1) pumped delivery, 2) gravity pipeline delivery, and 3) pumped and gravity pipeline combination; a) "natural" stabilization pond treatment, b) aerated lagoons, and c) conventional secondary treatment plant using the activated sludge process (similar to Ain Ghazal Treatment Plant).

Delivery Systems

The major delivery alternatives developed and reviewed, included: (1) pump conveyance from AGTP and from Zarqa, and (2) gravity flow from Ain Ghazal and pumped from Zarqa.

Pumped systems reduce the land areas and disturbances required for additional long sewer/siphons or force mains. Increased pumping into a single sewer/siphon system increases the risks from damage to and levels of damage from a single delivery system; no contingency is available and thus any maintenance must be conducted while the system is in operation. Gravity systems require dedicated

easements and large amounts of imported construction materials (pipe) although they minimize long-term energy use (Except for that required to inject Zarqa flows into the main sewer/siphon).

The recommended Project's delivery facilities of a separate parallel sewer/siphon (cross-connected at AGTP and Zarqa) causes adverse effects related to land resources, archaeological and short-term biotic impacts, construction resource use in the areas of Ain Ghazal, Rusiefa, Zarqa, Sukhna, and Hashimiyeh. Long-term use of the gravity flow system reduces the very high cost of energy use and reduces the risks and magnitude of sewage spills to surface water and the dependent irrigation systems.

Treatment Systems

Three general types of treatment methods for expansion were developed: (1) "natural" wastewater stabilization ponds (similar to the existing system), (2) conversion of the existing waste stabilization pond system to a mechanical aerated lagoon system, and (3) installation of a conventional secondary treatment plant along with using the remaining ponds. All three alternative treatment systems achieve the same effluent discharge value. As in the delivery alternatives, the more "natural", non-mechanical systems require much larger land areas than the existing WSP site while the conventional facilities requires minimal land areas but long-term energy and resource use. Conversion of some ponds to mechanically aerated lagoons requires little additional land and only moderate energy use. Similarly, aeration provides moderate risk factors from possible failure of mechanical systems, because of the greater assimilative capacity of the waste stabilization pond system.

Disposal of Effluent and Solids

As indicated above, all delivery and treatment alternatives discharge identical effluent to Wadi Dhuleil. De-nitrification is impractical and not required to meet basic requirements for agricultural use and the downstream effects from the discharge of effluent are virtually indistinguishable (especially below Sukhna and in King Talal Reservoir). One improvement for the Wadi Dhuleil channel is a series of cascades with a few small ponds to capture algae.

All treatment alternatives discharge settleable and suspended solids into the anaerobic ponds or primary clarifiers (activated sludge alternative). Treatment produces sludge which must be periodically, or continuously, removed and disposed of at disposal sites. For all practical conditions, the sludges are sufficiently similar that no significantly different process can be used for one and not the others and the eventual disposal will be burial or land-filling.

9.2.2 Comparative Summary

In summary, the recommended Project can be evaluated as follows:

Parallel Gravity Delivery of Sewage

1. Provides contingency in case the existing delivery system is out of service.
2. Reduces the risk of equipment failure (pumps) and discharge of untreated sewage to surface waters.
3. Reduces long term energy requirements.
4. Increases the possibility of archaeologic site disturbances.

Aerated Lagoon System at the As-Samra Site

1. Eliminates the need for site expansion and additional piping.
2. Uses available trained labor but requires a moderate increase in O&M costs and efforts.
3. Requires long-term electric power use.
4. The upset risk for treatment and effluent quality is considered minimal.
5. Archaeological impacts are significantly minimized.

9.2.3 Recommended Project

The four major components of the recommended project as they relate to the environmental effects are discussed below :

Ain Ghazal Preliminary Treatment Plant Site

The existing headworks (standby) and the new delivery facilities must be improved and expanded to eliminate discharge of raw sewage to Wadi Ain Ghazal and thence to Wadi Zarqa. Removal of debris and grit will protect the existing and new delivery facilities from erosion and settlement of solids. Rehabilitation of the existing odor control facilities will protect maintenance personnel and reduce release of odorous gases to the atmosphere.

Ain Ghazal - As-Samra Delivery Sewer/Siphon and Corridor

The existing delivery facilities must be expanded to eliminate the possibility of discharge of wastewater. Existing and new facilities should make maximum use of gravity systems in order to conserve energy for long-distance transmission and to reduce the potential for equipment malfunctions leading to the release of wastewater. Construction of new facilities must provide for recovery and preservation of antiquities along the transportation corridor. Construction of new facilities must be integrated with existing land uses in order to minimize construction and long-term impacts to the environment.

Zarqa Pump Station and Site

The existing pump station requires expansion to assure complete control of wastewater that would otherwise be discharged directly to Wadi Zarqa. Construction and future operations must be conducted with regard to increasingly urbanized surroundings and the need to protect farming and wildlife areas near the pump station and to be "good neighbors" with the nearby residents.

As-Samra Wastewater Stabilization Ponds and Effluent Disposal

Wastewater treatment at As-Samra must be upgraded and expanded to improve the effluent quality being discharged from the ponds. In order to provide continuing effluent quality, the upgraded system must provide for almost tripling the treatment capacity. Treatment should minimize loss of water while protecting the local and downstream environmental resources. Similarly, disposal of sludge should minimize adverse effects upon the biotic resources of the area. Future development should support other environmental programs of the Government of Jordan, e.g., "Greening of Jordan".

Improvements of the effluent channel should reduce nuisance and odor complaints and reduce channel infiltration losses of water to the local groundwater tables.

9.3 AFFECTED ENVIRONMENT

Existing and proposed Project facilities occur in six areas each with distinguishable combinations of environmental and human conditions. Secondary uses of effluent occur in two of these areas and along the remainder of the downstream Seil Zarqa channel, KTR, and Jordan Valley irrigation areas.

9.3.1 Ain Ghazal

The Ain Ghazal site (AGTP) is an area enclosed by the concrete channel of Wadi Ain Ghazal and the Amman-Zarqa Highway, the major intersection of Hashemite/King Abdullah, National 30, and National 70 roads, the Hijaz Railway and the rocky cliffs below the Hamza area of Ain Ghazal district, and the Amman Municipal Slaughter House. The site includes the original Ain Ghazal Treatment Plant, the headworks and septage facilities in the westerly portion, and the relatively undeveloped easterly portion. The entire site contains many trees and is relatively secluded from the general urban residential areas on the ridges and industrial areas to the southwest, except for the existing digesters which protrude some 20 meters above existing grade.

9.3.2 Ruseifa

Northeast of the Ain Ghazal site (downstream along Wadi Ain Ghazal), urban development ceases for about 5 km; the existing pipeline (and the future route) pass along the irrigated floodplain of Wadi Ain Ghazal. At 4 k, downstream of the inlet to the sewer/siphon, the Wadi Ain Ghazal joins the westerly flowing Wadi Zarbi and from here the wadi is referred to as Wadi Zarqa. Irrigated floodplains continue to the Yeast Plant (north, left bank) adjacent to the older, abandoned phosphate mining areas. North of Ain Ghazal, the pipeline generally parallels the Hijaz Railway and in some locations is directly adjacent to its right-of-way. From the beginning of the Wadi Zarqa, the existing pipeline route continues through the developed areas of Ruseifa and Zarqa. The pipeline passes under local streets and along the main road between Ruseifa and Zarqa. At numerous points, industrial and commercial development are close to the pipeline. Once the route reaches the

Zarqa Pump Station site, structural uses are generally restricted to areas above the floodplain.

9.3.3 Zarqa Pump Station - Sukhna

This section extends northward from the Zarqa Pump Station (20,400 m from Ain Ghazal) along the irrigated and cultivated valley floor of Wadi Zarqa (approximately 400 m wide) for about 8 km to the existing Emergency Pond, northwest of Sukhna (near the confluence of Wadis Zarqa and Dhuleil and the new Sukhna-Qunaiyeh road bridge). Some residential and commercial chicken farm structures exist on higher terraces along the road and on the floodplain. Residential areas of Sukhna extend westward down to the road and to a limited extent on the right bank of the floodplain.

9.3.4 Sukhna - Sallih

Between the Sukhna Road bridge, the existing pipeline route turns eastward and passes along the southern (left) bank of the narrow Wadi Dhuleil valley with high basalt bluffs. Some irrigation supports narrow fields on the lower valley floor of the north bank. In the Sukhna, Wadi Said, and Abu Sallih (village) areas, some surface water from the wadi channel is also lifted more than 50 m to the plateau and high terraces north of Sukhna, in the Wadi Said valley, and at Abu Sallih. Above the Sukhna Bridge, a second bridge connects Sukhna with the smaller village of Abu Sallih. A paper processing plant lies on the south side of the bridge and river, while several chicken farms lie at the base and on top of the north end of Jebel Bakiya (a high basalt plateau between Wadis Dhuleil and Said).

Abu Sallih includes cultivated farms and olive groves which extend up the Wadi Abu Sallih for several kilometers. A second road on the east of the village connects with Hashimiyeh (via National Road 11). This narrow valley begins to expand along the north (right) bank of Wadi Dhuleil from a point around 1 km east of the Sukhna-Abu Sallih Bridge.

9.3.5 Hashimiyeh

The Hashimiyeh area lies west of As-Samra (5-6 km) and receives direct effects from the existing WSP. Effluent irrigation supply from the Wadi Dhuleil channel supports the entire agricultural development along the widened wadi valley upstream of Abu Sallih. The main developed commercial and residential area lies midway through the section and at the main road (Highway 20) and extends eastward up onto the basalt plateau and toward the WSP. The Jordanian Petroleum Refinery and Al Hussein Thermal Power Station lie 1 to 2 km south of Hashimiyeh. Within the area, a few small commercial-industrial enterprises include a pre-fabricated concrete plant, a dairy (with several feedlots), and several chicken farms. Two steel fabricating plants exist along the main road to Mafraq and the secondary road to Abu Sallih. Less than ten farm residences lie along the floodplain and lower terraces.

9.3.6 Seil Zarqa - KTR

Downstream of the confluence of Wadis Dhuleil and Zarqa, the Seil Zarqa passes through a relatively narrow lower valley between terraces (30 - 80 m above the valley floor). which continue upward on either side to divides. Several villages (e..g, Dauqara) lie on the terraces and higher slopes, and Jerash is located about 4 km north of the Jerash Bridge, 35 km downstream of the WSP. Only the major Amman-Jerash and Zarqa-Jerash roads bridge the Seil Zarqa above King Talal Reservoir. Irrigated farmland is limited to within 50 - 150 m of the channel, although some olive orchards on the lower hill slopes may receive pumped water from the channel.

The Wadi Jerash (35 km downstream of WSP) receives discharge of treated wastewater from the Jerash Wastewater Treatment Plant and discharges to the Seil Zarqa. Seil Zarqa enters the KTR pool area about 45 km downstream of the WSP; the pool extends for another 2 km in a narrow deep, flooded valley before discharging from the King Talal Dam into the Jordan Valley area (about 15 km below the dam).

9.4 ENVIRONMENTAL EFFECTS OF THE RECOMMENDED PROJECT

Assessment of environmental effects involves the evaulation of the important activities during construction and operations. The assessment assumes that the Project will be implemented as designed in accordance with the drawings and specifications and that contract provisions will be complied with. It also assumes that the constructed facilities will be operated in accordance with recommended procedures and generally accepted operating practices and will be provided with adequate financial resources for normal operations and maintenance.

9.4.1 Impact Designation and Relationships

Impacts can be grouped into the general categories given below:

Direct - occurs within the corridor and at each site of work and includes:

- Surface water flow and quality
- Local groundwater quality and levels
- Pond and channel evaporation and seepage
- Disruption and disturbance of land uses
- Biota changes and loss of antiquities

Indirect - occurs beyond the aligment corridor route and actual sites of work and includes:

- Construction noise, air pollution, traffic congestion, and temporary disturbance of the environment
- Land use and air quality

- Pollution of the groundwater
- Evaporation

Secondary - side effects of the project which include:

- Odors from the Wadi Dhuleil and Seil Zarqa
- Levels and quality of the rural water supply
- Evaporation and non-point discharges of pollutants

Virtually all environmental effects can be avoided with sufficient economic resources (e.g., trenchless versus trenched construction for delivery systems). Some effects, such as those on commonly available resources may not be sufficiently significant (loss of limestone or basalt materials). Many other effects (once created) may not be reversible e.g., loss of unique archaeological antiquities and rare/endangered species.

The effects are summarized below as they are discussed in subsequent sections:

Significant Effects

- Surface water quality
- Construction
- Operations (Short Term)
- Groundwater quality
- Air quality
- Antiquities
- Biology
- Use of resources
- Land use
- Community Economy
- Health/Safety Risk

Less Significant Effects

- Ground resources and geotechnical
- Operations (Long Term)

As indicated above, most, if not all, effects of the Project are included as significant. During the Scoping Session and development of the proposed alternatives, the direct and indirect effects of facilities covering a route of 40 km and land areas of more than 300 ha and producing one of the most important products in the Kingdom - water - were reviewed. All are important to virtually all sectors of the natural environment and human community of the area. Criteria for importance reflect the following: (1) the significance of the affected sector (health, water, antiquities, and biota all being significant) (2) the reversibility of effects (significant

if irreversible), (3) the type of project activities (construction, operations), (4) the duration of effects, and (5) the levels of directness (direct effects being more significant).

9.4.2 Mitigation of Consequences

The following discussions of Project activities presume that no mitigation has been separately developed and approved (funded) for implementation either for upgrading of the existing facilities nor for expansion of the As-Samra WSP system.

Specific mitigation measures may be considered and included in the detailed design of the facilities; the mitigation measures included in Section 9.5 herein may be included in the detailed Project design.

9.4.3 Significant Effects

Significant effects have been summarized above and are developed in more detail in the sections below. The consequences deal entirely with the adverse effects of the Project activities on the natural environment and human communities and resources in the Project area and those areas affecting by construction and operations but are beyond the geographical limits of sites and routes. Many effects are indirect and secondary and are beyond the specific jurisdiction and authority of the WAJ but they result from the Project and would not occur without the Project. The alternative facilities have been reviewed in the Conceptual Study Report and summarized in the Section 9.3 herein.

Surface Water Flows and Quality

Environmental effects on surface water extend beyond the limits of the pipeline route and sites of the work and are considered to include irrigation use of the effluent from As-Samra WSP which flows to the King Talal Reservoir.

Desludging of existing anaerobic ponds, excavation (deepening) of existing ponds and construction of new inlets and outlets within the WSP will require a partial loss in treatment efficiency during the period of construction. This will result in the discharge of less-well treated effluent.

Levels of ammonia, sulfides, organic matter, and fecal bacteria are expected to increase during construction since the present chlorination system can not meet the demands of the present flows.

The expansion will treat sewage to eliminate these adverse effects. Construction sequencing of work will reduce these effects to insignificant levels and effluent will be treated to a level to maintain and support downstream users and beneficial uses of stream flows below As-Samra. Effluent and stream water quality will be improved over that at present and especially over that before the As-Samra WSP System was implemented in 1985/86.

Effluent Irrigation

Increased volume and improved quality of effluent will further encourage irrigation along Wadi Dhuleil and Seil Zarqa. Without proper irrigation and agricultural management, various indirect or secondary effects will arise including:

The Project area is seldom exposed to earthquakes but damages have occurred to structures in Amman (e.g., 1927 earthquake). Major seismic epicenters are generally located to the west of Amman in the Jordan Valley and further west to the Mediterranean coast. Structures will be designed in accordance with the required dynamic loading for above and below ground structures. No additional adverse effect is anticipated for the proposed Project or resulting from construction, operations, or presence of the Project facilities.

Operation Disturbances

Operation of the proposed Project and the existing WSP system facilities will be relatively isolated and secluded from general urban and public access. Odor controls, lighting, and screening of the Ain Ghazal and Zarqa sites will reduce disturbance below existing levels. Some traffic improvements for turning and parking will be provided for Zarqa, especially for trucks hauling debris and grit.

Operation at As-Samra will generate some increase in activities and noise levels from aerators and trucks. All activities will be at least 1000 m from any residential or significant public access areas. Traffic to the site will increase slightly but not significantly. Most vehicular movement will be limited to the expanded site and generally involve movement between the anaerobic pond area and the sludge drying and/or burial areas. Truck deliveries of chemicals or debris and grit from Ain Ghazal, Zarqa, and Hashimiyeh will be primarily responsible for traffic to the site.

Operational Air Quality and Meteorology

Operations of the upgraded and expanded ponds are expected to require: (1) continuous odor control at the AGTP and WSP headworks, (2) periodic (5 to 10 years) desludging of the anaerobic ponds, (3) aeration of wastewater during treatment, and (4) increas- ed and improved chlorination. These activities may contribute to some periodic releases, and/or infrequent accidental releases, of malodorous gases which may detrimentally affect local nearby residents.

Mechnanical aeration will require a significantly greater use of power which will increase the base load for generation at the power station at Zarqa. Since the station uses oil with a moderate to high level of sulfur (> 2%) and has relatively short stack, some local degradation of air quality nearby can be expected in this industrial area of Zarqa and in the residential areas of Hashimiyeh and Sukhna.

9.5 MITIGATION, MONITORING, AND CONTROLS

Mitigation measures are specific elements to be implemented in a project that go beyond normal construction and operations requirements in reducing or minimizing adverse effects of other project activities (e.g., archaeological monitoring and recovery during trenching excavations). As such they will be included in the Project Tender Documents and Operations and Maintenance Manuals. These measures will be indicated in the following discussion.

Monitoring and controls are generally proposed to assure that (1) levels of anticipated effects are not exceeded without further mitigation, (2) implemented mitigation measures are in fact fully implemented and provide adequate mitigation

- Increased fertilizer and pesticide use for agriculture and the subsiquent return to surface water channels.
- Maintenance and increase of rural population growth, agricultural intensification, and livestock rearing along Wadi Dhuleil and Seil Zarqa which in turn generates a greater demand for water supplies and thus more wastewater.

Groundwater Quality

The effluent of As-Samra can enter the local groundwater through minor seepage from the ponds, infiltration from the wadi channels , and through soil infiltration from irrigation.

Based upon available information and field surveys, the following environmental effects from effluent can be reasonably assumed:

- As-Samra ponds infiltrate minor amounts of effluent into the local groundwater tables
- Effluent in the Wadi Dhuleil channel infiltrates into the local groundwater tables
- Irrigation with effluent concentrates constituents in the soil
- Rural development has increased infiltration of pollutants into the local groundwater and also results in overpumping of groundwater thus reducing the groundwater ability to assimilate and dilute pollutants

Local groundwater quality in the area was seriously degraded in the 1970's, reaching 3000 mg/l TDS. The WSP Effluent contains much lower values of TDS and thus can be considered to reduce (dilute) the groundwater TDS. Minor seepage from the ponds can be expected, based on the performance of the existing ponds. Groundwater quality, however, is being equally, or more affected by the rapid expansion of abstraction, improperly operated wells, and surface developments, which contribute seepage from irrigation, feedlots, solid waste disposal and cesspools.

Chemical constituents in groundwater arise from those of water infiltrating into the groundwater and those acquired during the process of infiltration. The major groundwater constituents of concern are those which will interfere with common rural uses for irrigation supplies including bacteria, sulfides, ammonia, iron, salt, boron and heavy metals.

Virtually all well water quality data from WAJ and other sources demonstrate increasing levels of contamination in the groundwater since the early 1970's, especially for salts (total dissolved solids, sodium, and chlorides in particular). Where recorded, water levels in the aquifers have decreased even before and after operations of Ain Ghazal and As-Samra treatment facilities. Available data are insufficient for any statistical analyses to ascertain the relative contributions of effluents from either Ain Ghazal Treatment Plant (1970 - 1985) for groundwater along Wadi Zarqa, or As-Samra WSP (1985 - 1991) for groundwater along Wadi Dhuleil).

WAJ influent/effluent records suggest that wastewater from the WSP is seeping into the underlying soil and alluvium. Records indicate that on average over the last six years; seepage rates were about 2400 cu m/d.

The generally rocky bottom of the Wadi As-Samra, Wadi Dhuleil, and Seil Zarqa would typically allow surface water in the channel to infiltrate the underlying valley alluvium. No adequate data is available to document locations and quantities of infiltration and exfiltration of groundwater along the wadi channels.

Effluent infiltration from the wadi channels represents a highly variable contribution, although its quality will greatly improve due to improved effluent quality once the project has been implemented. Further contributions of improved effluent should gradually dilute other contributions and may provide some improvement to the alluvial groundwater wells adjacent to the channel.

Most farmers of the floodplain and terraces near the Wadi Dhuleil and Seil Zarqa draw effluent from the channel throughout most years and especially during the normal summer irrigation period. Cultivation generally uses either small plot or row flood irrigation and some drip irrigation. Some cultivation still uses pumped well irrigation or mixes well water with effluent drawn from the channel. Effluent irrigation of previous dryland farming has increased surface infiltration of water not directly used by plants or lost as evaporation. If no infiltration occurs, salts would rapidly increase in the root zone and kill poorly irrigated crops. Flood irrigation using earthen ditches also has a very low efficiency, i.e. water infiltrated compared to water used by the plants.

Existing and anticipated irrigation practices along Wadi Dhuleil and Seil Zarqa may improve after further degradation causes significant impacts on the cash value return from irrigation. Irrigation effects using effluent from the expansion will not differ significantly from those at present. Chronic salt leaching will persist much as is the case now. Groundwater tables are generally small and isolated and the effects of chronic and accelerated salt leaching from the soil may render some smaller tables virtually unuseable.

Irrigated farming along the Wadi Dhuleil and Seil Zarqa depends on effluent during the summer. Increased crop production and the economic benefits of the crops have supported agricultural intensification, increased rural population growth, and general improvement of rural economics and standards of living. These "improvements" have increased demands on existing groundwater sources.

Rural development in the Zarqa and Hashimiyeh areas have greatly accelerated due to increased roadway access, piped potable water supplies, and general economic improvement generated from increased cash return from irrigated crops. Dairy livestock, chicken and egg farms, increasing populations, and improving rural lifestyles all generate greater demands for water from local groundwater sources for irrigation and upon the piped water system supply for human consumption.

This same rural population also generate increased non-point sources of wastewater and runoff from feedlots, solid waste disposal sites and septic tanks and cess pools.

Air Quality

The residents of Hashimiyeh and others in the vicinity have endured odor and other sewage-related nuisance problems over the last few years. Odor generation must considered as a significant adverse effect, no matter how short-term or infrequent.

Maintenance of the anaerobic ponds will require desludging of the existing anaerobic ponds from time to time. Sludge will require dewatering and drying on large sites (Dabba Plains represent the only existing available lands). Various methods of dewatering in-place using the existing ponds or in special drying beds will expose the sludge to air and generate odor releases of entrapped sulfide and other gases. Past experience has demonstrated that odorous gases from the As-Samra area affect the residents of Hashimiyeh and future desludging will also significantly affect the same residents. However, procedures and chemicals can be use to mitigate and reduce the release of odorous gases.

Archaeological Resources

Archaeological resources include both the antiquities or artifacts themselves and, equally important, the context and arrangement of their preservation. Both elements are unique and losses are irretrievable once disturbed or removed. Although the direct effects of construction may be short-term for the resources themselves, losses to archeology and studies of culture and perhaps tourism will occur if antiquities are disturbed during construction which must be deemed as significant effects.

Most citizens accept the significance of direct destruction of antiquities, but continued expansion of irrigated agriculture and conversion of floodplain and terrace areas for cultivation, rural structures, and livestock facilities further expands and generates the long-term secondary effects of the covering, disturbing and loss of antiquities. If no irrigation water was available, land conversion would be much reduced in these areas.

Archaeological resources are known along most of the valley floors and many higher terraces and plateau areas in the Ain Ghazal to Khirbet As-Samra area. Direct effects of construction for the sewer/siphon, headworks at Ain Ghazal, expansion of the Zarqa Pump Station, the new anaerobic ponds, and any sludge disposal facilities nearby will have a high potential for encountering and destroying significant archaeological resources.

Indirect excavations for construction equipment access, pipe bedding and materials, and local concrete aggregates may further expand the adverse effects of construction on archaeological resources. Because of the importance of proper bedding materials for the pipeline, off-site excavations for these materials could generally occur along the Wadis Zarqa and Dhuleil, where archaeological resources are known or anticipated.

Continuation of existing and future irrigation supply will generate secondary detrimental effects as more irrigation and intensive farming and livestock rearing occurs along Wadi Dhuleil and Seil Zarqa in areas where archaeological resources have the highest probabilities of occurring.

Increasing agricultural activities and rural intensification will cause excavations and land surface disturbance which may generate secondary losses of significant archaeological remains and information along Wadi Dhuleil and Seil Zarqa. These secondary effects are probably of greater significance than the more limited but intense direct impacts of pipeline and pond excavations. The availability of irrigation water is supporting agricultural excavations, trenching, grading, and leveling in the Sukhna area, while the new Sukhna-Qunaiya road along the north (right) bank of Seil Zarqa (west from Sukhna) has been excavated across numerous terraces with improved access to irrigated fields and olive groves. Such secondary activity may have destroyed or disturbed antiquities.

Biotic Resources

Biotic resources of the Project sites and areas differ markedly and have been both improved and degraded by earlier construction and operation of the existing facilities. In a similar manner, the Project activities will generate a complex mixture of benefits and detriments for the "natural biota" of the areas.

The Ain Ghazal Treatment Plant site contains many introduced trees, shrubs, and grasses and generally provides a moderate to high value biotic habitat especially for birds and other wildlife in an otherwise biotically-barren urban landscape. Project activities at the site are limited generally to the headworks area which is generally disturbed and recently planted with young trees. Demolition of above-ground structures in the central and eastern parts of the site would generate considerable disturbance which would be most significant during the fall-spring bird migrations and over-wintering. Some existing trees will be removed which will require replacement.

Land use conversion of "undeveloped and cleared" areas of the Ain Ghazal area to industrial purposes would result in indirect or secondary adverse effects and would reduce the avialable "safe-havens" for the remaining birds and other wildlife.

Direct, short-term effects of pipeline construction on biota are well recognized but generally very localized and short-term. In general, the existing and anticipated Project route will pass through already highly disturbed irrigation and urban areas between Ain Ghazal and Zarqa Pump Station where the existing biota has little or no value. Beyond the Zarqa Pump Station, irrigation and over-grazing have left only small areas of "natural" riparian vegetation and associated wildlife. These areas represent low-value biota. These areas can and may be avoided or replanted and represent only minor short-term effects.

Expansion of the Zarqa Pump Station and associated pipeline-related construction will destroy a few trees and shrubs around the existing facility. The existing facility has provided a "safe-haven" for birds in the relatively barren urban and desert area. Although irrigated fields provide some useful habitats especially

during winter migrations, more protection is provided by the fenced enclosure of the pump station. As at Ain Ghazal, the biotic value of the site and future impacts have been created by the existing facility and its operation. Future construction will eventually provide the same habitat and protection but with a loss for several years. Because of the temporary nature of construction, any effect the resident and migratory wildlife and "natural areas", any losses of trees and shrubs and disturbance by workers, equipment, and activities must be considered as minor.

As with the other Project sites, the existing site at As-Samra has proved a relatively safe and undisturbed refuge for many thousands of birds during the fall-spring migrations. Because of the greatly improved biotic value and the greater importance assigned to it by the continued and expanding losses in the surrounding areas, any future adverse effects from the Project activities assume even greater significance.

Construction of the parallel sewer/siphon, headworks, three additional anaerobic ponds, and other related facilities will have direct and significant adverse effects on the biotic resources of the As-Samra site. Construction disturbance and direct removal of vegetation will affect resident and migratory wildlife for at least two years.

A new sphere of potentially adverse effects will arise regarding sludge disposal. Sludge disposal will require conversion of nearby land to drying or landfill areas.

Improved and increasing amounts of effluent will become available for riparian irrigation and indirectly lead to increased conversion of existing disturbed and overgrazed areas and riparian vegetation. Increased rural development will also increase the disturbance to resident and migratory birds and other wildlife. Increased rural populations will promote increased grazing pressures on remaining upland and vegetated habitats. As such, these increasing disturbance pressures represent indirect and secondary effects upon the few existing significant biotic resources.

Community Disturbance by Construction

The communities of Ruseifa, western Zarqa, Sukhna, and Hashimiyeh will be subject to construction disturbance and disruption of community life, residences, and transportation. Truck traffic will use existing congested streets and roads for moving materials and equipment to and from the sites of work. Truck traffic will disrupt normal traffic, and generate considerable dust, exhaust fumes and noise, especially in the congested areas of Ruseifa and Zarqa.

Construction of the sewer/siphon through the south-westerly portions of Zarqa and eastern end of Ruseifa will interfere directly with road use and generate considerable local disturbance. Because of the limited road capacities between Zarqa and Amman, increased congestion on one road will indirectly divert and further congest the remaining roads. All traffic will have to travel through the central commercial and residential area of Zarqa in order to reach the route. Since this route also lies along the main road from Zarqa to Jerash (and Syria) increased

congestion during construction will generate, significant temporary disturbance effects for these areas.

Construction Use of Resources

Construction of a major infrastructure and supply of equipment for the WSP will cause a large increase in the demand for construction materials and generate considerable employment, income, and local revenue. In general this will benefit many people in the Amman - Zarqa area, but unfortunately the construction employment will be of relatively short duration.

Rapid increases in demand for unskilled and semi-skilled labor will increase wage rates. Short-term increases in wages and commercial economic activities will stimulate local economic development. Such increases may not be sustained after construction is completed and the rapid declines following construction are detrimental, but expected.

Operational Use of Resources

Wastewater production is related to the conservation and reuse of the wastewater arriving at As-Samra WSP and discharged to the Wadi Dhuleil-Seil Zarqa. Water use and wastewater generation in Amman and Zarqa will increase, and as the standards of living increase, residents will undoubtably increase their use of water using appliances.

The proposed Project has been developed to maintain as much as possible the existing water surface areas and thereby the total evaporation. Aeration may increase the water evaporation somewhat but evaporation should remain less than 20 percent of the average throughput of the WSP. At present, very few surface coverings or chemical evaporation inhibitors can be practically used for reducing evaporation from large surface water bodies and have not been included in the proposed Project.

Additional water losses will occur along the Wadi Dhuleil and Seil Zarqa above King Talal Reservoir due to continuation and expansion of agriculture. These losses cannot be avoided without total disruption of existing irrigation which has been developed over the past six years. Existing and continuing future uses of effluent for irrigation and other local farming activities will contribute to the reduction of the channel flow for downstream irrigation uses.

Conservation of the water from the As-Samra system requires programs to reduce industrial discharges without pretreatment streams and the management of irrigation and eventually the leaching and discharge of irrigation drainage water to the Wadi Dhuleil and Seil Zarqa.

Proposed delivery and possible sludge disposal systems will increase the total amount of land dedicated for infrastructure support. Because of the remote location of treatment and sludge facilities, little significant effect will arise from conversion of existing open areas for infrastructure uses. The Ain Ghazal site and the first half of the pipeline route lie in desireable and developing lands and

dedication of the land to infrastructure support will constrain future land use along the route.

Land acquisition and use for infrastructure will remove usable land areas from future availability and increase values of remaining lands in the general area. Land use in the immediate vicinity of the existing and proposed sewer/siphons must be controlled in order to avoid damage to the sewer/siphon. Land use between the pipeline and the wadis will be of particular importance because of potential erosional effects due to construction. Imposition of land use controls in the vicinity of the sewer/siphons will limit existing owners' use and therefore the future land use value of their properties. Some properties between the sewer/siphons and natural land, use constraints (wadi banks and steep slopes) will further reduce land available for agricultural uses. The sewer/siphon routes through Ruseifa, Zarqa, Sukhna, and Hashimiyeh will be most affected by these infrastructural land dedication and use restrictions.

The Project will use gravity to deliver over 200,000 cu m/d (avg. daily flow) of wastewater in the year 2005 through a 39-km pipeline without pumping from Amman. Because of the location of Zarqa, more than 50,000 cu m/d must be pumped into the pipeline which then flows by gravity siphon to As-Samra. The Project treatment plant at the As-Samra WSP however, will use considerable (at least in the winter) amounts of electricity for the aeration of wastewater.

The existing delivery system and hydraulic flow through the WSP make use of about 100 m of elevation and do not use any direct energy. By such use, the energy required to deliver well or surface water to Amman and Zarqa are conserved. Conventional treatment alternatives would require large amounts of electric power generated from the power station at Zarqa and commensurate use of imported oil. These power uses are balanced against the use of agricultural lands and evaporative losses from a wastewater stabilization system.

Discharge of the effluent from WSP will increase the power generation through the turbine at King Talal Dam.

Indirect energy consumption off the project site is also represented by the imported aerators and other equipment which requires manufacturing and transport to the site.

Other energy resources may be represented by chemical disinfection, and the nutrient and soil conditioning value of treatment by-products.

Use of greater volumes of liquid chlorine for chlorination creates adverse resource conservation effects because of the large amount of energy requirements for its generation and delivery to the site. Solar-biotic "natural" disinfection however, to treat the same volume would expand the size of maturation ponds and lead to evaporation of large amounts of water.

For the local Jordanian resource base, importation of liquid chlorine and reduced water losses may be a suitable alternative to surface water importation.

The current WSP effluent contains about 50 mg/l of ammonia and oxidation to nitrates along with organic removal or denitrification will diminish the nutrient value of the effluent and increase requirements of fertilizer use for downstream irrigation.

Increased use of resources generates related adverse effects in other environmental sectors: air pollution from oil-fuelled power generation in Zarqa-Hashimiyeh basin, increased traffic and air pollution for delivery of chlorine and fertilizers, and health risk from discharges of poorly disinfected effluent if chlorine is not used.

Economies, Lands, and Development

The Jordanian industries concentrate on light construction materials, foods/beverages, and other light industries focusing on domestic and light commercial products. Medium to heavy industries are few and generally are not capable of producing equipment required for safe and sustained operations of the WSP System. A parallel sewer/siphon would require importation of about 39 km of large diameter steel pipe and accessory fittings which cannot be manufactured locally. The aeration treatment alternative would require imported mechanical aerators, supporting switch gear, and other electro-mechanical equipment and controls and contribute to dependency on foreign equipment, spares, and technical assistance and reduces or inhibits development in the medium industries. Some development in mechanical related industries may occur, because of the continuing preventive maintenance which will be conducted in Jordan.

The presence and operation of the existing facilities at Ain Ghazal, Zarqa Pump Station, and WSP have reduced the adjacent land values and the possibility for intensive land uses in these areas. Improved service at the facilities may reduce the adverse effects but continued presence will probably continue the depression of surrounding land values in conjunction with the more significant effects of dedicated land uses and land use restrictions.

Community Health, Safety Risks and Management

Improved treatment of the As-Samra effluent will produce beneficial health effects for rural populations using the effluent from the channel for irrigation. Improved effluent quality will allow untreated non-point sources to have less effect due to the dilution and improved assimilative capacity of the stream.

Persistent improved quality of effluent, stream flow, and irrigation water will cause many to presume the safety of the water and reduce avoidance and precautions which are more normal for the existing "identifiable" sewage effluent. Since the effluent's health-related quality is largely determined by mechanical treatment and disinfection, periodic upsets and malfunctions may be expected in all types of treatment plants and can expose downstream users to possible water-borne diseases for which they will be unprepared.

Catastrophic Risk and Management

Risk from major malfunctions will persist in any system with such long delivery pipelines, mechanical equipment, and chemical disinfection facilities, although upgrading and expansion will significantly reduce the risks compared to existing conditions. Provision of a second sewer/siphon will increase the potential risk from third-party damage, but its existence will improve maintenance capability for both and reduce the risk from facility and equipment failures. Dependency upon mechanical treatment systems and chemical disinfection will increase the risk and significance of malfunction, although the great redundancy of aerators and proper redundent design for chlorination should reduce any increase in risk to an insignifcant level.

The stabilization ponds provide some limited habitat for ducks and other floating birds and some diving birds which feed on debris discharged in the first anaerobic ponds. Many wading and shore birds make use of floating scum-layers and flotsum stranded along the pond edges, while insect-feeding birds feed over all ponds but especially over the scum-layers. Because of the relative isolation and low operating activities, all migratory birds can make use of and are protected in most areas of the As-Samra site.

Although initially enclosed by a security fence, the fence has been opened in many areas and local residents make use of the site for grazing and harvesting forage for livestock. A more immediate fence has been established to partially restrict direct access to the ponds but it has little exclusion value.

Planting of several thousand trees have greatly improved the original overgrazed habitats of the site. Secondary woodland habitats have been formed around the perimeter and especially the westerly area of the site. Such planting and general protection from hunting and severe overgrazing has greatly enhanced the biotic value of the As-Samra site.

9.4.4 Less Significant Issues

Several environmental conditions will arise during the long-term operation of the facilities which can be anticipated but do not cause significant detrimental effects.

Ground Resources and Geotechnical Constraints

The proposed Project will use relatively small amounts of cement, aggregate, and sands during construction. Larger use will be for bedding materials for the sewer/ siphon and various concrete structures for the inlets/outlets at the ponds, pumping station and headworks additions.

Land slippage and bank stability/erosion are a major concern for the routing of the second sewer/siphon in relationship to the relatively narrow topographic corridor and the presence and protection of the existing sewer/siphon. Additional measures will be taken to avoid interference and damages from land slippage to either the existing or Project sewer/siphons.

to achieve the anticipated overall reduction in significant effects, and (3) additional measures are implemented when either unknown effects are encountered or anticipated effects are exceeded.

9.5.1 Construction

Construction mitigation measures have been well developed for most projects and are generally accepted within the design, procurement and construction activities. These typical measures are summarized below and must be incorporated in specifications and tender documents in order to have any direct enforcement. Construction inspection must also be managed in order to assure enforcement of the controls provided in the construction tender documents.

Archaeological Resources

Mitigation for disturbance and loss of archaeological and historic resources (antiquities) has been applied in Jordan (even the King Talal Reservoir construction involved archaeological mitigation in the 1960s). Standard mitigation should include:

- Surface surveys of all excavation and grading areas prior to construction.
- Trial excavations on significant sites and areas located by surveys within access and earthwork areas.
- Complete archaeological recovery for significant areas which are to be excavated or graded.
- Sterile cover of remaining significant remains adjacent to but not within excavation areas
- Onsite monitoring of all equipment excavation and training of supervisory staff for monitoring of hand excavations, during construction.
- If significant sites are to be excavated, the trench or structural excavation should be manually excavated through the site prior to construction in the area
- Onsite conservation and preservation of remains for future transport and handling.
- If earthwork and archaeological resources are significant and extensive, early surface surveys and testing can delineate areas and allow for realignments or relocations in order to minimize construction time delays for salvage excavations of the resources

Construction Disturbance

Mitigation and compensation for construction disturbance generally involves improved management of activities, scheduling, and some direct equipment and other controls. These include:

Timing of Construction. -- Seasonal and night-time scheduling of work to allow maximum activity in those areas well separated from residences and public area. Reducing night-time activities in areas adjacent to or within 100 m of residences and

public areas. Seasonal effects can be reduced by timing construction in agricultural areas to periods after harvesting and before planting.

Equipment Restrictions -- Equipment should be muffled or enclosed or located in such positions so as to reduce or minimize noise, vibration, and exhaust from affecting nearby residences, institutions, and public areas. If muffling is not practical, then construction should only allow use of low-noise equipment within 200 m of residences.

Traffic Control -- When many deliveries are involved (i.e. imported pipe), traffic controls on routes, off-site holding areas, scheduling, and stacking of vehicles should be required to reduce disturbance to traffic and residents along the haul routes. Traffic direction may require flagmen and additional traffic officers at major impacted intersections. It may be desinable to develop and, require compliance with, specific routings and schedules in the Ruseifa, Zarqa, Sukhna, and Hashimiyeh areas and provide traffic control personnel at major intersections.

Dust, Rubble, Debris, and Sludge Control and Cleanup. -- Contracts should have standard conditions regarding maintaining of the construction sites in an clean, safe, and orderly condition, but they should also include direct specifications and bid items for watering of site and access routes; rubble/debris and sludge removal; covering of loads during transport to/from the sites; control of drainage and runoff; cleaning equipment before entry to ashalted public streets/roads; and remediation of runoff sediment, debris and mud which leaves the sites of work and cause a public or environmental nuisance.

Protection of Wadiş – Since major pipeline construction will be adjacent to or crossing existing wadis which may have high winter-time flows, provision must be included to eliminate sources of eroded soils and debris or transport to the wadi channels. Between November 15 and April 15, construction should require surface runoff controls for drainage and runoff.

Biotic Resources

Tree planting should commence as one of the first items of work and should concentrate at the Ain Ghazal site, Zarqa Pump Station, and around the headworks area. Within the As-Samra area, all fencing for the existing site, new fencing around the new facilities and new fencing for any sludge disposal area should also be established as a first item of work. All grazing, forage gathering, and soil tilling should cease on the existing As-Samra site. Such exclusion should continue for at least three and if possible, five years. Once grasses, herbs, and young shrubs have re-established themselves, limited grazing can be established on specific test plots, and limited tilling can be concentrated beneath the canopy areas of the olive trees.

Other biotic mitigation and compensatory measures are included below for longer term mitigation.

9.5.2 Mitigation for Long-Term Operations

Air Quality

Operations will cause some adverse effects due to maintenance of the anaerobic ponds (desludging). Odors from the operation can be overcome by recirculating aerobic water, performing work when the wind is away from nearby residential areas or by masking the odor.

Surface Water Quality

Longer-term water quality improvements must focus on improving the influent wastewater quality delivered to WSP. A major WAJ program must be undertaken to control sources of high strength salts and boron. These are essentially unaffected by the wastewater treatment process. Industries must pre-treat prior to discharge and have redundent features if a unit must be taken out of service for maintenance. In part, this is susbtantially an enforcement program, since regulatory compliance alone is not sufficient to reduce influent salts.

Wadi Dhuleil Improvements

Residents of Wadi Dhuleil have been adversely and significantly affected by the WSP. However, they have also received considerable economic benefit from improved and continuous irrigation supplies.

Initial review of alternative Wadi Dhuleil channel improvements indicated that costs were very high for relatively limited beneficial effects. The evaluated improvements, however, provided for a concrete channel. The following improvements would provide significant benefits to the local residents.

- Establish a defined channel routing, and
- Develop a low-flow channel alignment, and excavate and grade the alignment to contain low flows. Provide minimal surface controls of the channel such as gabions and riprap.
- Provide a piped water supply and sewer system to residents from Sukhna to Hashimiyeh who do not presently have those services.
- Provide improved irrigation management training services to irrigators along Wadi Dhuleil valley.

King Talal Reservoir- Surface Water Resources

The King Talal Reservoir is an irrigation and power generation storage reservoir, although attempts have been considered to use it for recreation and fisheries. These uses are totally inappropriate because of its location and configuration and consequently no mitigation is proposed related to any activities or uses.

Local Groundwater Quality and Volume

All water discharged from As-Samra is dedicated for irrigation purposes in the Jordan Valley. No formal diversion of water for local groundwater recharge has been anticipated. Improved effluent water quality from As-Samra WSP will have little beneficial effect upon the downstream groundwater tables.

Monitoring of WSP process flows and local groundwater levels will provide information regarding which ponds are seeping the most and some specific seepage controls could be initiated once the seepage has been localized.

Biotic Resources

The proposed Project will intensify activities and convert some "improved" and rehabilitated natural biotic areas for ponds and sludge disposal. These effects require both short- and longer-term mitigation. Generally, measures would involve the following:

- Restore existing fencing and exclude grazing and harvesting of vegetation for a minimium of three years and then control grazing according to a range management program suited to the seeding requirements demonstrated during the three-year exclusion period
- Acquire and protect large (500 ha) upland areas adjacent to WSP for future sludge disposal areas and allow the "natural" recovery of upland vegetation (grassland steppe) by preventing grazing.
- Provide a perennial source of water of approximately 1000 cu m/d for marshland development along the eastern portions of the Wadi As-Samra watershed.

The potential evaporation and bottom seepage represents about 4,000 cu m/d depending on the season. This water loss should be reduced although it cannot be eliminated. During desludging and pond restoration and upgrading and for any new ponds, bottom seepage must be reduced by placing a clay or other impervious lining.

Although desludging will occur during the construction period of the Project, desludging forms an integral part of the long-term operations of the WSP system. Sludge and effluent are the major products of wastewater stabilization, and sludge will be generated in large quantities. After proper handling and treatment, the sludge may be used for soil amendments such as an organic conditioner which is needed by most Jordanian soils. Because of the high costs for transport, the lack of nitrogen fertilizer value, and the tillage requirements, sludge may have to be distributed free to the farmers east of the WSP (Khirbet As-Samra Village area) and along Wadi Dhuleil/Seil Zarqa in order to recover any value for the land. However the sludge should be first tested to determine that no harmful effects will occur.

A short-term measure of the Project could demonstrate the "land-farming" of sludges within the WSP site or on adjacent areas (e.g., Dabba Plains to the east). If sufficient long-term interest and dedication were evidenced, a sludge conveyance pipeline and filling facility could be developed in the Khirbet As-Samra and Dabba Plains area. Such use would mitigate the adverse effects for resource conservation and other environmental sectors arising from landfill disposal of the sludge.

Fisheries -- Long-term improved treatment and effluent allows for some beneficial and mitigation through aquaculture with fisheries. Introduction of fish can provide some reduction of suspended solids when properly harvested.

Maintenance of a standing fish crop assures that water quality should be acceptable for general downstream uses.

Generally the fish could not be used for direct human consumption, but it could be processed for livestock (chicken and cattle) feed or even as fertilizer in the local area.

Risk Management and Emergency Response

An immediate and long-term consequence of the existing and proposed delivery system involves the risk of accidental release of untreated wastewater. Time risk must be reduced to the maximum extent possible.

A flow monitoring system capable of detecting leaks can be used to identify when a leak is occurring. Once a spill has been detected, a spill response plan, staff, and equipment must be available and set in motion immediately. An immediate measure would be to notify the affected residents and agencies and the actions required of them. Following control of the leak, a remedial action plan must be initiated for clean-up and to provide a longer-term evaluation of what caused the leak and how similar conditions can be controlled.

9.6 LIST OF PREPARERS

The following persons worked on/or reviewed the Environmental Assessment :

- Dr. C. Thomas Williams, an environmental specialist, who has over 20 years experience in the preparation of environmental impact reports, environmental assessments and other environmental reports to meet both CEQA and NEPA requirements both in the USA and overseas.
- Mr. Philip N. Storrs, Chief of Environmental Studies, with over 22 years experience in technical supervision and direction of multidisciplinary environmental studies.
- Mr. Richard R. Deussen, Project Manager, who has over 30 years experience in managing large study and design projects with environmental concerns both in the USA and overseas.
- Mr. Ali Mobadda Al-Labadi, Geologist and Hydrogeologist, with over 15 years experience in geology and hydrology with the Natural Resources Authority and a private consulting firms.
- Mr. Samir Maher, Agronomist, has over 15 years experience in crop management and irrigation methods.
- Ms. Elvira V. Gaddi, Senior Environmental Engineer, with 12 years experience in air quality and environmental report preparation.