The Study on Water Resources Management in the Hashemite Kingdom of Jordan

FINAL REPORT VOLUME IV
SUPPORTING REPORT
FOR
PART-A "WATER RESOURCES MANAGEMENT MASTER PLAN"

Chapter 3 Wastewater Effluent

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Supporting Report for "Chapter 3 Wastewater Effluent"

ANNEX to 3.2.3

German Regulation on the Utilization of Sludge in Agriculture

REGULATION FOR THE UTILIZATION OF SLUDGE IN AGRICULTURE
(Klaerschlammverordnung Sept. 1983, GERMANY)

(Summary)

Preliminary Remarks

Sewage sludge is suitable to be used as fertilizer and soil conditioner due to its content of organic matter and nutrients. The correct application method is a precondition for the use. With respect to aspects of waste disposal and ecology, the sludge should be used as much as possible in agriculture.

§ 1 Field of Application

This regulation has to be followed by those who operate wastewater treatment plants with more than 5,000 P.E., and apply the sludge to soil used for agriculture, forestry, and horticulture.

§ 2 Definition

§ 3 Precondition for Application

The sludge has to be analysed with respect to the following parameters once in 6 month:

Pb, Cd, Cr, Cu, Ni, Hg, Zn,
N, P_20_5, K_20, CaO, MgO

The soil has to be analysed before with respect to the pH-value and the following heavy metals:

Pb, Cd, Cr, Cu, Ni, Hg, Zn,

§ 4 Application Restriction and Prohibitions

The application of raw sludge is prohibited.

The application of sludge to areas with vegetable and fruit cultivation is prohibited.

The application of sludge on meadows and for fodder cultivation is prohibited.

The application of sludge is prohibited in case the soil analysis exceeds one of the following parameters:

Element	mg/kg
Pb	100
Cd	3
Cr	100
Cu	100
Ni	50
Hg	2
Zn	300

The application of sludge requires a special permission in case the sludge analysis exceeds one of the following parameters:

Element	mg/kg
Pb	1,200
Cd	20
Cr	1,200
Cu	1,200
Ni	200
Hg	25
Zn	3,000

§ 5 Application Quantity

To be applied as 5 tons once every three years per hectare.

§ 6 Compulsory Evidence

The operator of the treatment plant has to fill a special delivery note and hand it over to the farmer. A copy has to remain in the operator's file for at least 5 years.

§ 7 Breach of law

According to § 18 of the Waste Disposals Law by the following

- who applies the sludge without performing the analysis according to § 3,
- who applies the sludge in contradiction to § 4, and
- who applies more sludge than mentioned in § 5 or does not properly fill and file the delivery note § 6.

ANNEX to 3.3.1

Alternative Treatment Technologies

Annex to 3.3.1 Alternative Treatment Technologies

Contents

ALTERNATIVE TREATMENT TECHNOLOGIES

The following chapter presents a series of tables, figures and charts, which can be used for the preliminary selection of wastewater treatment systems particularly in countries as Jordan.

It has to be mentioned that the mechanical and biological processes of wastewater treatment as presented in Sections 6.3 and 6.4 do certainly not reflect the variety of all possible processes, but they are most frequently or could be potentially applied in Jordan:

- Primary treatment
- Activated sludge (medium load)
- Extended aeration
- Trickling filter (high load)
- Stabilization pond system
- Constructed wetland

Similar thing can be said for the tertiary treatment processes as mentioned in Section 6.5. Due to the proposed reuse of treated effluent of treatment plants for irrigation, a certain advanced treatment has to be provided. Three systems of tertiary/advanced treatment are discussed:

- maturation ponds
- sand filtration
- membrane filtration

1. General criteria for alternative treatment technologies

Generally, there is a big variety of alternative process and technologies, which could be potentially applied for treatment of municipal sewage. However, due to local conditions, restrictions and requirements the number of alternatives may be reduced. In most of the cases the following criteria are considered as decisive analyzing the different processes and technologies:

- enough possibilities for future extension with respect of demographic development
- high viability allowing flexible and simple operation and maintenance
- high treatment efficiency
- high stability and reliability of process
- possible adaptation and extension of treatment to fulfill changed requirements with respect to treated effluent (e.g. receiving water, reuse of effluent)
- comprehensive fulfillment of existing regulations, requirements of hygiene and security
- good cost efficiency with respect to investment, operation and maintenance

Different treatment processes of wastewater may be compared considering potential reduction of pollutional load, such as BOD_5, suspended matter, nutrients for plants (e.g. P and N) and bacteria. Table 1-1 shows generally expected treatment performance for some widely used process. Nevertheless, treatment efficiency is only one criterion in selecting an appropriate treatment process.

Table 1-1: Reduction of pollutional loads for various treatment processes

Treatment process	Reduction in %			
	BOD_5	Suspended matter	Helminth eggs	Bacteria
Primary treatment	25 - 35	55 - 65	10 - 99	0 -50
Extended aeration	85 - 95	85 - 95	10 - 99	90 - 99
Activated sludge (medium load)	85 - 95	85 - 95	10 - 99	10 - 99
Trickling filter (high load)	80 - 90	70 - 90	10 - 99	10 - 99
Stabilization pond system	95 - 98	95 - 98	99 - 99,9	99,9-99,99
Constructed wetland	85 - 95	85 - 95	99 - 99,9	99,9-99,99

2. Mechanical treatment

The purpose of preliminary treatment (screening and degritting) is to remove large objects as well as grit, in order to prevent damage to subsequent treatment and process equipment. Objects normally removed by this treatment step can be extremely harmful to pumps and can increase downtime due to pipe clogging and clarifier scraper mechanism failures (see e.g. EPA Manual).

2.1 Screening

There are two types of bar screens (or racks). The most commonly used and oldest technology, consists of hand-cleaned bar racks. These are generally used in smaller treatment plants. The second type of bar screen is mechanically cleaned and is commonly used in larger facilities.

Screens are commonly designed respecting

spacing of bars:	12 mm
bar size:	10 mm
maximum flow velocity:	1.0 m/s

2.2 Degritting

Grit is most commonly removed in chambers, which are capable of settling out high density solid materials, such as sand, gravel and cinders. There are two types of grit chambers: (1) horizontal flow and (2) aerated. In both types the settleables are collected at the bottom of the unit. The horizontal units are designed to maintain a relatively constant velocity by use of proportional weirs or flumes in order to prevent settling of organic solids, while simultaneously obtaining relatively complete removal of inorganic particles (grit).

The aerated type produces spiral action whereby the heavier particles remain at the bottom of the tank, while organic particles are maintained in suspension by rising air bubbles. One main advantage of aerated units is that the amount of air can be regulated to control the grit/organic solid separation, and less offensive odors are generated. The aeration process also facilitates cleaning of the grit. The grit removed from horizontal flow unit usually needs additional cleaning steps prior to disposal.

Basic design parameters for grit chambers are

detention time (for Q_{max}):	3 – 10 min
hydraulic surface loading:	0.5 - 1.5 m/h

2.3 Primary treatment (primary clarifier)

Primary clarifiers are constructed in circular and rectangular shape. The following description considers a rectangular type.

Primary clarification involves a relatively long period of quiescence in basin (depth of 3 to 4.5 m) where most of the settleable solids in a pretreated wastewater fall out of suspension by gravity. The solids are mechanically transported along the bottom of the tank by a scraper mechanism and pumped as a sludge underflow.

The maximum length of rectangular tanks has been approximately 80 m, where widths of greater than 6 m are required; multiple bays with individual cleaning equipment may be employed, thus permitting tank widths up to 25 m or more. Influent channels and effluent channels should be located at opposite ends of the tank.

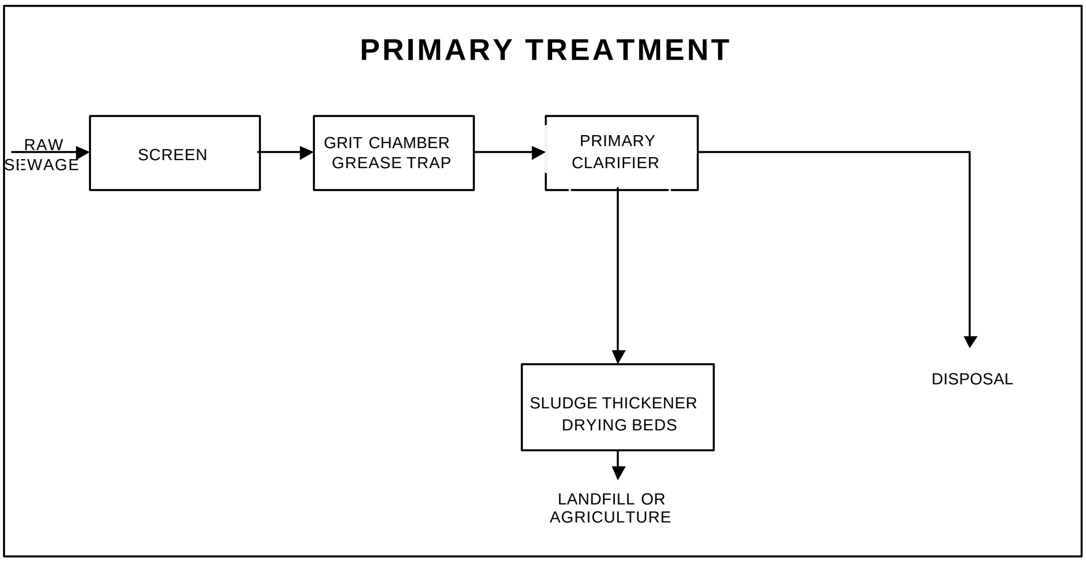
Sludge removal equipment usually consists of a pair of endless conveyor chains. Attached to the chains at about 3 m intervals are crosspieces of flights, extending the full width of the tank or bay. Linear conveyor speeds of 0.6 to 1.2 m/min are common. The settled solids are scraped to sludge hoppers in small tanks and to transverse troughs in large tanks. The troughs, in turn, are equipped with cross collectors, usually of the same type as the longitudinal collectors, which convey solids to one or more sludge hoppers. Screw conveyors have been used for the cross collectors.

Scum is usually collected at the effluent end of rectangular tanks by the flights returning at the liquid surface. The scum is moved by the flights to a point where it is trapped by baffles removal or it can also be moved along the surface by water sprays. The scum is then scraped manually up an inclined apron, or it can be removed hydraulically or mechanically, and for this process a number of means have been developed (rotating slotted pipe, transverse rotating helical wiper, chain and flight collectors, scum rakes). Figure 2-1 shows a schema of primary treatment including screen, grit chamber and primary clarifier.

Primary clarifiers are commonly designed for

detention time:	2.5 – 4 h
hydraulic surface loading:	0.5 - 1.5 m/h

Figure 2-1: Schema of primary treatment



3. Secondary treatment (biological)

For details see e.g. EPA Manual.

3.1 Activated sludge process

Activated sludge is a continuous flow, biological treatment process characterized by a suspension of aerobic microorganisms, maintained in a relatively homogeneous state by the mixing and turbulence induced by aeration. The microorganisms are used to oxidize soluble and colloidal organics to CO_2 and H_2O in the presence of molecular oxygen. The process is generally preceded by primary sedimentation (primary clarifier). The mixture of organisms and wastewater formed in the aeration basins, called mixed liquor, is transferred to gravity clarifiers for liquid solid separation.

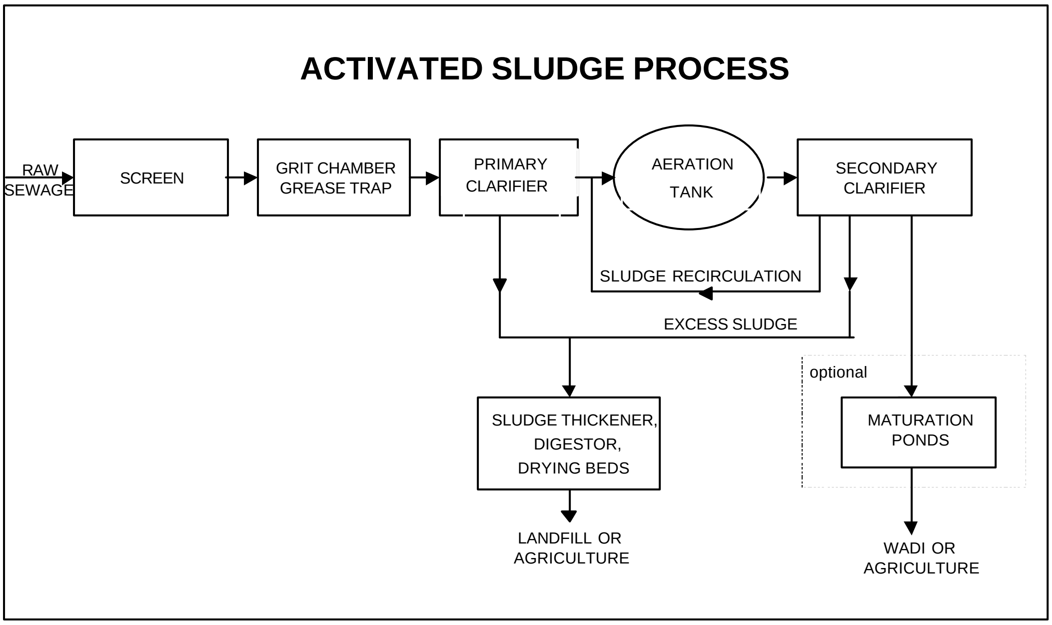
The major portion of the microorganisms settling out in the clarifiers is recycled to the aeration basins to be mixed with incoming wastewater, while the excess, which constitutes the waste sludge, is sent to the sludge handling facilities. The rate and concentration of activated sludge returned to the aeration basins determines the mixed liquor suspended solids (MLSS) level developed and maintained in the basins. During the oxidation process, a certain amount of the organic material is synthesized into new cells, some of which then undergoes auto-oxidation (self-oxidation or endogenous respiration) in the aeration basins, the remainder forming net growth or excess sludge.

Activated sludge systems are classified as high rate, conventional or extended aeration (low rate, see Section 3.2) based on the organic loading. In the conventional activated sludge plant, the wastewater is commonly aerated for a period of four to eight hours (based on average daily flow). Either surface or submerged aeration systems can be employed to transfer oxygen from air to wastewater.

Activated sludge systems (medium loading) are designed for
mass loading: 0.15 kg BOD_5/kg suspended matter
Mechanical aeration methods include the submerged turbine with compressed air sparkers (agitator/sparker system) and the surface-type mechanical entrainment aerators. The surface-type aerators entrain atmospheric air by producing a region of intense turbulence at the surface around their periphery. They are designed to pump large quantities of liquid, thus dispersing the entrained air and agitating and mixing the basin contents. The agitator/sparker system consists of a radial-flow turbine located below the mid-depth of the basin, with compressed air supplied to the turbine through a sparker. Volatile compounds are driven off to a certain extent in the aeration process. Metals will also be partially removed, with accumulation in the sludge.

Figure 3-1 presents a schema of treatment by activated sludge process.

Figure 3-1: Schema of treatment by activated sludge process



3.2 Extended aeration

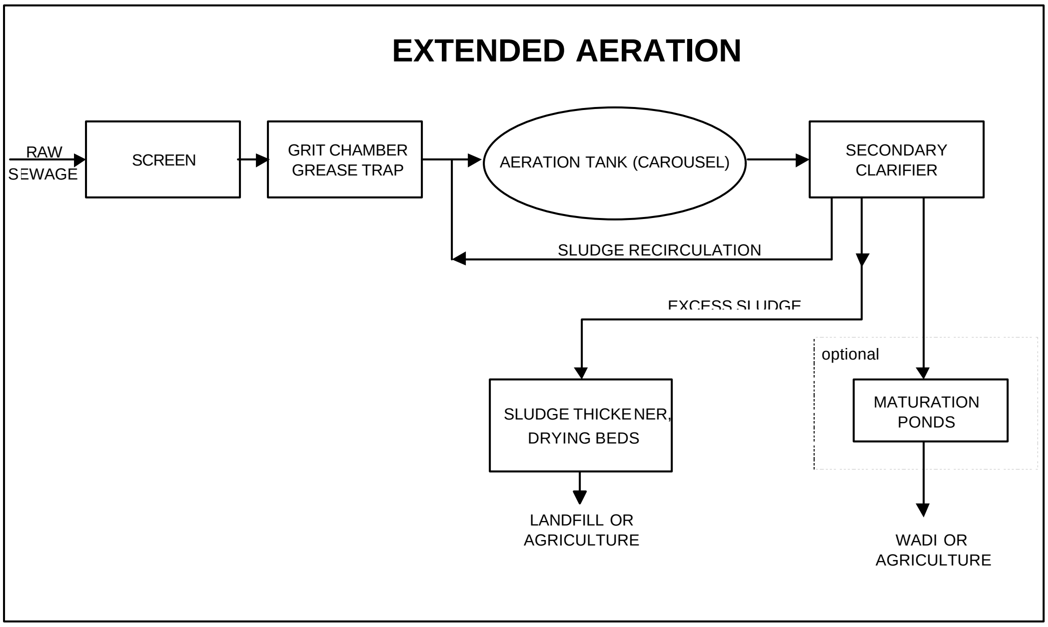
Extended aeration is the "low rate" modification of the activated sludge process. The detention time in the aeration basins is about 24 hours. Primary clarification is rarely used. The extended aeration system operates in the endogenous respiration phase of the bacterial growth cycle, because of the low BOD_5 loading. The organisms are starved and forced to undergo partial auto-oxidation. Volatile compounds are driven off to a certain extent in the aeration process. Metals will also be partially removed, with accumulation in the sludge.

In the complete mix version of the extended aeration process, all portions of the aeration basin are essentially homogeneous, resulting in a uniform oxygen demand throughout the aeration tank. This condition can be accomplished fairly simply in asymmetrical (square or circular) basin with a single mechanical aerator by diffused aeration. The raw wastewater and return sludge enter at a point (e.g. under a mechanical aerator) where they are quickly dispersed throughout the basin. In rectangular basin with mechanical aerators or diffused air, the incoming waste and return sludge are distributed along one side of the basin and the mixed liquor is withdrawn from the opposite side. Figure 3-2 shows a schema of treatment by extended aeration.

Generally, extended aeration system is designed for

mass loading:	0.06 kg BOD_5/kg suspended matter
volumetric loading:	0.15 - 0.3 kg $BOD_5/m^3/d$

Figure 3-2: Schema of treatment by extended aeration



3.3 Trickling filter process

The process consists of a fixed bed of rock media over which wastewater is applied for aerobic biological treatment. Biological slimes form on the media, which assimilate and oxidize substances in the wastewater. The bed is dosed by a distributor system and the treated wastewater is collected by an underdrain system. Primary treatment is normally required to optimize trickling filter performance and post-treatment is often necessary to meet secondary standards or water quality limitations.

The rotary distributor has become the standard because of its reliability and ease of maintenance. It consists of two or more arms that are mounted on a pivot in the center of the filter. Nozzles distribute the wastewater as the arms rotate, due to the dynamic action of the incoming primary effluent. Continuous re-circulation of filter effluent is used to maintain a constant hydraulic loading to the distributor arms.

Underdrains are manufactured from specially designed vitrified-clay blocks that support the filter medial and pass the treated wastewater to a collection sump for transfer to the final clarifier.

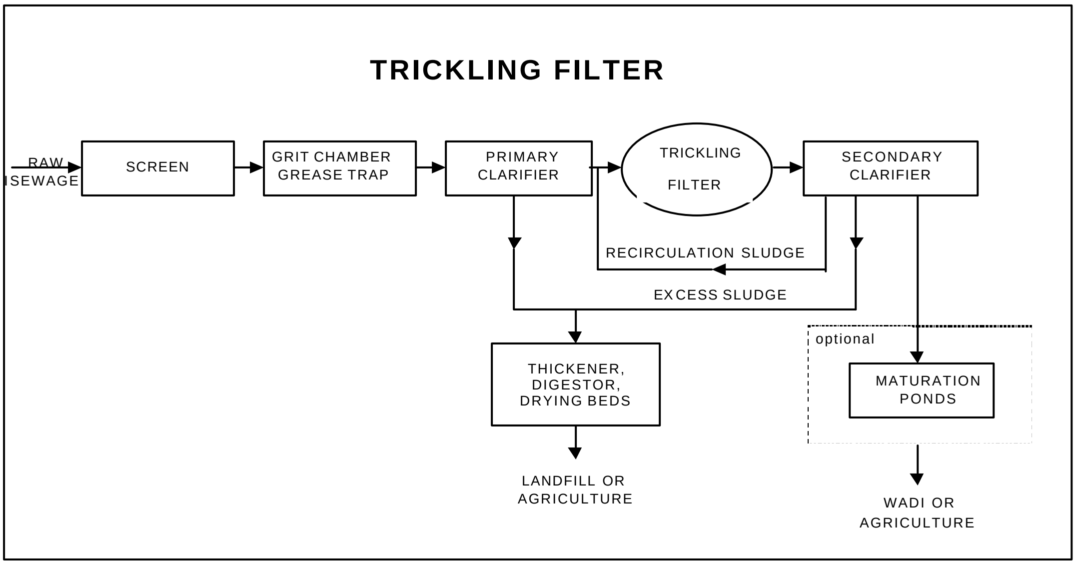
The filter media consists of 25 – 125 mm stone. The rate trickling filter media bed generally is circular in plan, with a depth of 1 to 2 m. Containment structures are normally made of reinforced concrete and installed in the ground to support the weight of the media.

A population of microorganisms attached to the filter media degrades the organic material present in the wastewater. As the microorganisms grow, the thickness of the slime layer increase. As the slime layer increases in thickness, the absorbed organic matter is metabolized before it can reach the microorganisms near the media face. As a result, the microorganisms near the media face enter into an endogenous phase of growth. In this phase, the microorganisms lose their ability to cling to the medial surface. The liquid then washes the slime off the media, and a new slime layer will start to grow. This phenomenon of losing the slime layer is called sloughing and is primarily a function of the organic and hydraulic loadings on the filter. Filter effluent re-circulation is vital with high rate trickling filters to promote the flushing action necessary for effective sloughing control, without which media clogging and anaerobic conditions could develop due to the high organic loading rates employed. Figure 3-3 shows a schematic presentation of a trickling filter process.

Generally, trickling filters are designed for

volumetric mass loading:	0.4 – 0.6 kg $BOD_5/m^3/d$
hydraulic surface loading:	0.5 - 0.3 $m^3/m^2/h$

Figure 3-3: Schema of treatment by trickling filter



3.4 Secondary clarifier

The design of secondary clarifiers is similar to primary clarifiers (see section 2.3) except that the large volume of flocculants solids in the mixed liquor must be considered during the design of activated-sludge clarifiers and in sizing of sludge pumps. Further, the mixed liquor, on entering the tank, has a tendency to flow as a density current interfering with the separation of the solids and the thickening of the sludge. To cope successfully with these characteristics, factors that must be considered in the design of there tanks include: (1) type of tank to be used, (2) surface loading rate, (3) solids loading rate, (4) flow-through velocities, (5) weir placement and loading rates and (6) scum removal.

Flow through rectangular tanks enters at one end, passes a baffle arrangement and traverses the length of the tank to effluent weirs. The maximum length of rectangular tanks has been approximately 90 m with depths of 3.5 to 4.5 m. Where widths of greater than 6 m are required, multiple bays with individual cleaning equipment may be employed, thus permitting tank widths up to 25 m or more.

Sludge removal equipment usually consists of a pair of endless conveyor chains. Attached to the chains at 4 m intervals are crosspieces or flights, 15 to 20 cm deep, extending the full width of the tank or bay. Linear conveyor speeds of 5 to 10 cm/min are common. The settled solids are scraped to sludge hoppers in small tanks and to transverse troughs in large tanks. The troughs, in turn, are equipped with cross collectors, usually of the same type as the longitudinal collectors, which convey solids to one or more sludge hoppers. Screw conveyors have also been used for the cross collectors. Tanks may also be cleaned by a bridge-type mechanism, which travels up and down the tank on rails supported on the sidewalls. Scraper blades are suspended from the bridge and are lifted clear of the sludge on the return travel. For very long tanks, it is desirable to use two sets of chains and flights in tandem with a central hopper to receive the sludge. Tanks in which mechanisms that move the sludge toward the effluent end in the same direction as the density current have shown superior performance in some instances.

Scum is usually collected at the effluent end of rectangular tanks by the flights returning at the liquid surface. The scum is moved by the flights to a point where it is trapped by baffles before removal, or it can also be moved along the surface by water sprays. The scum is then scraped manually up an inclined apron, or it can be removed hydraulically or mechanically, and for this process a number of means have been developed (rotating transverse rotating helical wiper, chain and flight collectors, scum rakes).

Generally, secondary clarifiers are designed for

hydraulic surface loading:	1.7 – 2.7 m/h
depth:	3.5 – 4.5 m

3.5 Stabilization pond system

Treatment by a stabilization pond system is commonly applied in countries of moderate climates for small and medium size towns. The series of stabilization pond system comprise, generally, anaerobic ponds, facultative ponds (artificially aerated or not) and maturation ponds. A screen upstream of the pond system removes large objects.

Anaerobic, facultative and maturation ponds are often used in series. Each stage in a series may be broken down into two or more ponds operated in parallel. Anaerobic ponds are frequently used ahead of facultative ponds in order to reduce the land area required. Facultative ponds followed by one or more maturation ponds are used, where a high-grade effluent is necessary, especially with regard to pathogenic organisms. This is the case when effluent is reused for agricultural purposes and for aquaculture. Figure 3-4 shows a schema of a stabilization pond system.

A. Anaerobic ponds

When anaerobic ponds are compared with other conventional treatment plants, they take the place of the following units (see WHO: "Wastewater stabilization ponds", Tech. Publ. No. 10, 1987):

- Primary settling tanks
- Sludge thickeners
- Anaerobic sludge digesters
- Gas popes and burners
- Sludge drying facilities
- Pumps, motors and equipment involved in primary treatment
- Sometimes, screens and grit chambers

During slow passage of the wastewater through the pond and after some time has elapsed, the following changes will have taken place:

1. Most of the suspended solids will have settled to the bottom of the pond.
2. Some removal of pathogenic agents will have been achieved.
3. Floating material, including oil, grease, plastics and other items, will have been carried to the surface, where they will build up in a scum layer. Scum baffles or similar devices will subsequently prevent this scum from leaving the pond with the effluent.
4. Part of the suspended solids, including worm eggs, parasites and bacteria, settle to the bottom of the pond. Here they undergo anaerobic decomposition, concentration and part mineralization. Anaerobic bacteria break down the organic material. Through the metabolism (respiration and growth) of these bacteria, part of the organic matter is converted into mineral matter. During this phase, gases are generated, primarily CO_2, CH_4 and H_2S. These gases are dispersed into the atmosphere through the liquid surface. A portion of the sludge resulting from the settling of solids will be transformed into gas. This reaction, together with sludge thickening, accounts for the very slow build-up of solids in an anaerobic pond. As a result, the accumulated sludge may be estimated at only 40 liters per person per year.

The liquid effluent from the anaerobic pond is nearly always transferred to a facultative pond. This effluent will have low levels of suspended and settleable solids and worm eggs. In terms of BOD_5, the effluent will often have a 40 – 60 % reduction in concentration from that in the raw influent to the primary, anaerobic pond, depending on temperature and retention time.

B. Facultative ponds

A facultative pond is built with a smaller depth and with a large surface area than an anaerobic pond of the same volume. The designer attempts to maintain an aerobic upper layer "floating" upon an anaerobic lower one. The aerobic condition in the upper layer is produced by dissolved oxygen. This is primarily generated as a result of photosynthesis caused by the incidence of solar radiation upon the algal population of the pond.

Aerobic and facultative bacteria in the upper and middle layer metabolize the dissolved, colloidal and suspended organic matter, consuming dissolved oxygen and producing CO_2. This is transformed into algal cell material (organic carbon). Facultative bacteria also consume combined oxygen from nitrates and sulphates when free oxygen is exhausted.

During the passage of wastewater through a facultative pond, the following changes may be observed:

1. Most of the remaining suspended solids settle to the bottom of the pond, where they develop a layer that works like an anaerobic sludge digester. This is the anaerobic zone of a facultative pond. If the pond is a primary one, worm eggs, parasites and some bacteria will be reduced as in an anaerobic pond.
2. Above the anaerobic sludge layer, an intermediate zone exists in which dissolved oxygen is present some of the time, fed from the upper layer. The intermediate zone is greenish in color due to the presence of algae.
3. The upper layer is a natural culture medium for algae and operates as an aeration system, producing oxygen for the aerobic and intermediate zones. The oxygen concentration varies with depth and the time of day. At night, there is no oxygen production. But some surface diffusion of atmospheric oxygen occurs.
4. The algae in the upper layer coexist with bacteria in synergistic relationship.
5. During the stabilization process, much of the biodegradable organic matter is transformed, mainly into living organic matter – in the form of algae, bacteria, protozoa, etc. (Living or dead algae generate a biochemical oxygen demand and for this reason a few authors consider facultative ponds to be poor treatment devices, since one type of organic material is simply converted into another. However it should be noted that algal biochemical oxygen demand in the effluent is not necessarily detrimental to the environment or for the reuse of treated effluents for agricultural irrigation).
6. The effluent of a facultative stabilization pond taken from the surface layer is strongly green-colored because of the presence of algae. It also contains other living organisms, such as micro crustaceans, bacteria and rotifers, and it has a high content of dissolved oxygen. However, there are practically no suspended solids that will settle.

Bacteria consume oxygen in respiration and multiplication and, at the same time, they break down organic matter present in the wastewater. As a by-product of their metabolism, they release into the liquid mass carbon dioxide as well as nitrates, sulphates, phosphates and other mineral salts. Algae in turn use these by-products when they absorb light to synthesize their own cellular material, releasing oxygen. Aerobic bacteria, continuing the cycle, then consume some of this oxygen. Part of the oxygen generated by algae during photosynthesis remains dissolved in the liquid mass, often giving rise to oversaturated conditions in the upper layer, while a part is dissipated to the atmosphere.

A facultative pond used as a secondary pond (i.e. following an anaerobic pond) in climates where the average "coldest month' air and water temperatures do not go below around 10^{o} C and 15^{o} C, respectively, should have a minimum retention time of 5 days for typical domestic wastes. The upper limit is determined by design parameters and the area of land available, and can extend to tens of days. When facultative ponds are used as primary ponds at the temperatures quoted above, the retention times will be tens of days.

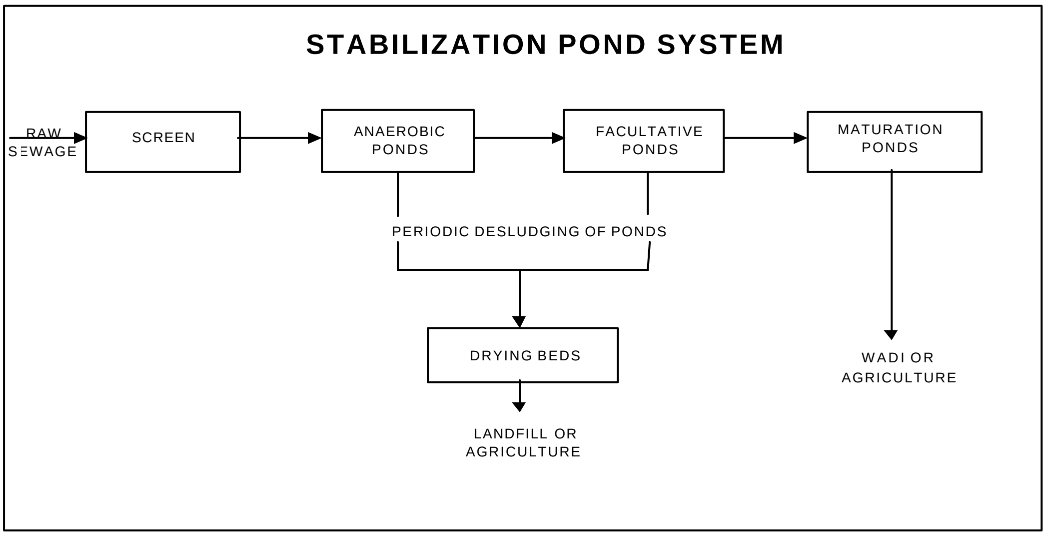
C. Maturation ponds

Maturation ponds are used mainly for reduction of pathogenic organisms. Besides removing a very high percentage of fecal bacteria, viruses, protozoa and other pathogens, maturation ponds may also remove some algae and some nutrients. Occasionally, however, algal blooms do occur in maturation ponds.

The bactericidal effect of maturation ponds is due to several natural factors, including sedimentation, lack of food and nutrients, solar ultra-violet radiation, high temperatures, high pH-value, predators, the toxins and antibiotics excreted by some organisms, as well as natural die-off. These ponds should only be used to upgrade the effluent from facultative pond, from another maturation pond (or from another type of wastewater treatment plant). They should not receive raw wastewater nor anaerobic-pond effluents. Although they are not designed specifically for upgrading poor effluents from other ponds, they achieve this objective to a certain, though limited, extent, having the effect of "polishing" the effluents from preceding stages of treatment.

Maturation ponds are normally designed for a retention time from 3 to 10 days per pond when two or more are in series (a minimum of 5 days when only one is used), while typical depths range between 1.0 and 1.5 meters.

Figure 3-4: Schema of stabilization pond system



3.6 Constructed wetlands

Wastewater treatment by constructed wetlands is a relatively new technology in sewage treatment, which has been developing over the last two decades. The process is based on the ability of certain types of aquatic and marginal plant to host aerobic bacteria on the root rhizome systems as well as on the ability of certain plants to remove pathogenic bacteria through the mechanism of complex chemicals exuded through the root systems. Reed plants (e.g. *phragmites*) have a great potential for biological treatment related to its extensive root and rhizome system, which transfers valuable amount of oxygen to the root zone. Some fodder plants show similar advantageous abilities. In relation to medium and big size towns, the technology of constructed wetlands may be an alternative option for the smaller treatment plants in rural areas of Jordan.

Screening (generally without grit removal) has to be provided as preliminary treatment of raw wastewater. An Imhoff tank or better an aerobic pond (see section 3.5.A) may carry out primary treatment. Figure 3-5 shows an arrangement of treatment by constructed wetland.

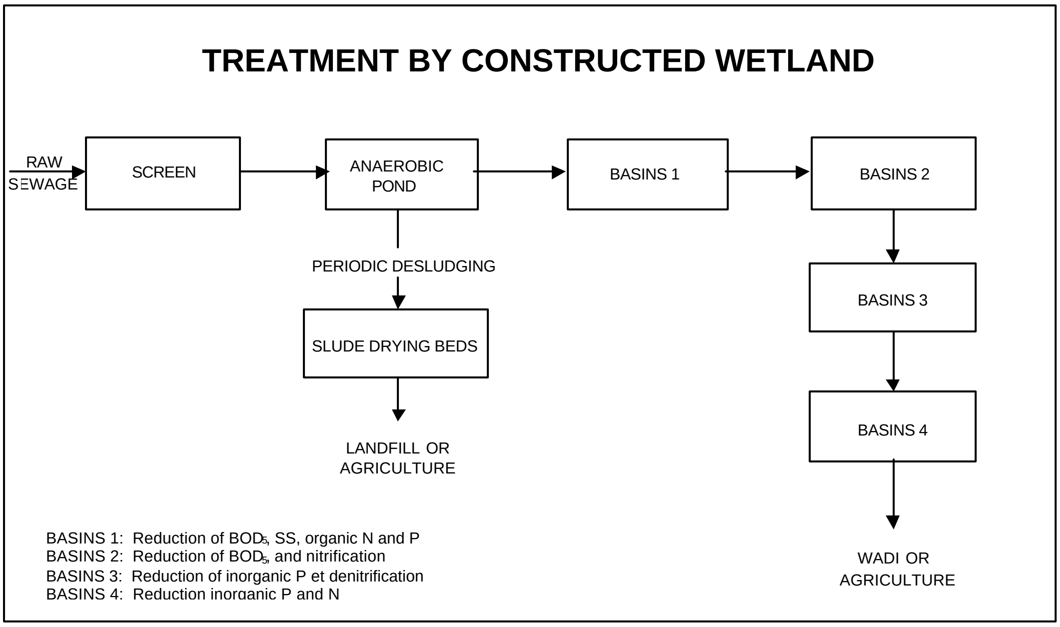
Secondary treatment is achieved through a series of primary and secondary reed beds, which are operated in parallel. In principle the systems require the formation of beds ranging form 0.5 to 1.0 meter in depth with an impermeable lining. The lining can be an impermeable cohesive natural clay, a plastic or rubber membrane depending on local availability and cost. The bed is formed from a layer of media about 0.5 m in depth. Trials have been conducted using various media types: cohesive soils as well as a range of granular media and gravels.

The flow configuration through the media can be either horizontal of vertical. In the latter it is necessary to have a layer of fine sand over the top of the media in order to distribute the flow. The systems have been used for complete treatment of sewage, for the secondary treatment of settled sewage and for tertiary treatment or polishing of effluents.

In general terms the trials with horizontal flow system require a much larger surface area than with vertical flow systems. For purposes of secondary and tertiary treatment, horizontal flow systems require 3 – 8 m^2 per person. There are many examples of horizontal flow, soil-based systems, which suffer from clogging and over surface flow. Such occurrences will decrease process performance, and provide potential breeding sites for mosquitoes.

Vertical flow systems, when compared to horizontal flow schemes, can increase the biological treatment performance, but decrease the area requirements to 1 – 2 m^2 per person. The most effective performance with vertical flow beds occurs when beds in parallel are used in rotation allowing a period of a few days for the solids collected on the surface during operation to mineralize.

Figure 3-5: Schema of treatment by constructed wetland



4. Tertiary treatment (advanced)

4.1 Maturation (polishing) ponds

Maturation (polishing) ponds are used often as tertiary treatment step, when effluent is reused for agricultural purposes and for aquaculture. For this target in several existing treatment plants in Jordan maturation ponds were constructed. For details of process description it is referred to section 3.5.C.

4.2 Sand filtration

Although sand filtration is one of the principal unit operations used in the treatment of potable water, the filtration of effluents from wastewater treatment processes is a relatively recent practice. Filtration is now used for achieving supplementary removal of suspended solids (including particulate BOD_5) from wastewater effluents of biological processes. Generally two types of sand filtration are practiced i.e. slow sand filtration and rapid sand filtration.

A. Slow sand filtration

Slow sand filters are very efficient in the removal of fecal coliforms or nematode worm eggs and like maturation ponds reduce the BOD_5 and suspended solids concentrations in the treated effluent: Normally, the filtered effluent quality is better than that produced by maturation ponds.

A minimum of two sand filters has to be provided, operating alternately. The efficiency of a slow sand filter is not only based on its filtering capacity, but also on biological and physico-chemical phenomena: On the upper layer of the filter complex processes can be observed such as local flocculation, sedimentation and adsorption as well as biological decomposition of organic components. The overall filtration velocity is usually limited to between 2 and 4 meters per day. When the operating filters begin to clog and the surface water level begins to rise, the second filter is brought on-line. The clogged filter is then allowed to drain and to dry, after which the cake (upper level) on the surface of the sand is manually removed: The sand is raked and re-leveled and the filter is returned in operation. The removed sand (of the upper layer) has to be washed and can be reused.

The Typsa Study of 1998 proposes slow sand filtration for several planned treatment plants in North of Jordan.

B. Rapid sand filtration

A complete filtration operation comprises two phases: filtration and cleaning (backwash). During filtration phase wastewater passes the filter bed composed of sand and, thereby, particulate matter is removed. The end of the filter run is reached, when the suspended solids in the effluent start to increase (break through) beyond an acceptable level or when a limiting headloss occurs across the filter bed. Once either of these conditions has been reached, the filtration phase is terminated and the filter must be cleaned (backwashed) to remove the material retained within the granular filter bed. Reversing the flow through the filter usually does this. A sufficient flow of wash water is applied until the granular filter medium is fluidized (expanded). The material that has accumulated within the bed is then washed away. Air is often used in conjunction with water to enhance the cleaning of the filter bed. The wash water containing the suspended solids that are removed from the filter is returned to the biological treatment process.

DAR proposed 1998 in its study rapid sand filtration as advanced treatment for the planned Wadi Shallala Treatment Plant.

4.3 Membrane filtration

New developments in water and wastewater treatment focused (amongst others) on the application of membrane separation technology including reverse osmoses, ultra filtration and micro-filtration. Especially micro-filtration may be of particular interest in the advanced treatment of sewage to be reused for irrigation.

In this context one type of the variety of different systems shall be presented - a disc filter based on micro-filtration. Wastewater enters a filter tank by gravity or pump where its energy is dissipated by a baffle. Flow will pass through the cloth membrane and the filtrate will be collected in a center tube where it is directed, by gravity, to final discharge over an overflow weir. Solids will attach to the outside of the cloth media and form a mat. As these solids collect on the media, filtering resistance through the cloth increases causing the water level in the tank to rise. The differential between the tank water level and the effluent channel water level is monitored by a pressure differential or probe system. When the differential reaches a preset level, backwash is automatically initiated by relaying a signal to a PLC, which in turn sends a "start" signal to both the drive and the backwash (vacuum) pump.

Under the normal operation, the disks remain stationary and submerged. During backwash, the disks will remain submerged and rotate at 1 rpm. Suction heads, connected to the suction side of the submersible vacuum pump, are located on both sides of each disk. As the disk rotates between the suction heads, the vacuum pump will draw filtered water, collected inside the center tube, back through the cloth media and remove both the entrapped solids particles and the backwash water and discharge them to a preclarification point in the wastewater treatment system.

A single vacuum pump is provided for each pair of disks at a time for one full revolution. When cleaning of the first pair of disks is complete, the vacuum pump for these disks will shut off and the backwash process will initiate on the next pair of disks. This will continue until all disks have been backwashed at which time the drive will shut off and the disks go back to stationary mode.

Over time, some fine particulate matter may become entrapped within the media and not be effectively removed by the backwash function. This will cause the headloss through the cloth to be greater than that of a "clean" cloth even after backwash. When the backwash pressure reaches a predetermined level, a high-pressure spray wash is necessary carried out by a special device of spraying nozzles.

Such an automatic backwash filter system is proposed as advanced wastewater treatment for the North Jordan Valley Project.

5. Eco-technologies („Shimanto Method")

During the "Seminar on the Sustainability of Water Resources Management and Development" of September 4th 2000 organized by the Ministry of Water and Irrigation in cooperation with Japan International Cooperation Agency (JICA) Prof. Dr. M. Murakami introduced the so called "Shimanto Method" for producing clean water for reuse: "The application of new eco-technology of treating the organic materials is based on the following three objective challenges: 1) low capital cost, 2) simple and non-expensive operation and maintenance and 3) low energy requirement. The Shimanto Method removes the organic materials as well as nitrogen and phosphate by using the bio-filters from conventional solid waste disposals such as plastic fragments, withered (mushroom) tree, activated carbons and calcium carbonate conglomerates, of which the effluent with BOD of less than 1 – 3 mg/l is being used to supply water for no drinking purpose such as toilet flushing, garden irrigation and groundwater recharge …". Prof. Dr. M. Murakami recommended to the Study Team to investigate whether this method could be applied for wastewater treatment in Jordan.

Since 1994 the Shimanto treatment method is used in Japan in particular to treat polluted river water. Meanwhile some 15 plants are in operation having a capacity between 50 and 2,400 m³/d. Some of the facilities are pilot plants. According to information got of some of the existing plants the BOD_5 at the influent is in the range of 15 up to 80 mg/l. The BOD_5 at the effluent of these plants was measured to be lower than 5 mg/l. It is reported that investment cost for plants based on the "Shimanto Method" are 3 – 6 times lower than for conventional treatment plants for capacities between 50 and 3,000 m³/d.

With respect to the pollutional load of organic matter the average BOD_5-concentration of the raw sewage of the existing Jordanian treatment plants is between 500 and 1,200 mg/l (up to 1,500 mg/l). In comparison to this, practical experiences with the "Shimanto Method" were gained for much lower concentrations only (according to available information). Therefore, we do not see a possible application of the described "Shimanto Method" for the treatment of municipal wastewater in Jordan.

However, a potential field of application could be specific locally limited cases, where in scarcity of water a demand for irrigation water does not exist. In this case pretreated wastewater together with further treatment probably by the Shimanto Method allowing the reuse of treated wastewater for no drinking purpose such as toilet flushing could be supported.

6. Criteria of process application

6.1 Mechanical and biological treatment processes

The most important criteria for the selection of treatment process are:

- land requirement
- efficiency
- reliability
- sustainability
- simplicity
- Effluent quality or the end use
- environmental impacts
- sludge disposal
- construction cost
- operation cost

These criteria may be subdivided in aspects considering the technical process itself, the implementation, operation and maintenance as well as others.

Summary sheets for each of the processes described in sections 3 and 4 are attached at the end of this Annex. These include conditions of application, performance, advantages and disadvantages summarized.

6.2 Tertiary treatment processes

As far as the presented tertiary treatment systems are concerned only for the maturation ponds are comprehensive experiences are available in countries like Jordan. Therefore, it is difficult to assess and compare the presented systems.

However, some advantages and disadvantages of the maturation ponds in comparison to the sand filtration and micro-filtration may be summarized:

Criteria	Maturation ponds	Sand filtration/ micro-filtration
Land requirement	high	low
Applicability for high quantity of sewage	bad	good
Efficiency of process	medium	high
Losses due to evaporation	high	low, (medium for slow sand filters)
Losses due to backwash	none	some (none for slow sand filters
Staff requirement (number)	low	?
Staff requirement (qualification)	low	high
Simplicity of process	low	sophisticated
Process safety	high	low
Breeding of mosquito	high	low (medium for slow sand filters)
Imported material	none	considerable portion (none for slow sand filters)
Power requirements	none	high (none for slow sand filters)
Investment cost	low	high
Cost for operation and maintenance	low	high

As shown by the table, the maturation ponds have considerable advantages in comparison to sand filtration and micro-filtration. Therefore, it is recommended as a general rule to apply these systems in future also. However, there could be particular local condition, where one of the other two systems may be applied.

SUMMARY SHEET – Preliminary treatment including primary clarification (Level of treatment: primary treatment)

DESCRIPTION		The process consists of an elimination of large objects by a screen and a grit chamber as well as suspended organic matter by a primary clarifier. The clarifier is constructed of reinforced concrete and is equipped with automatic scrappers. The settled sludge has to be removed from the bottom of the clarifier, dried and stabilized by a drying bed (or better by an aerobic or anaerobic digester).
APPLICATION		As preliminary treatment and upstream of biological treatment steps. In general: for plants of more than 500 population equivalents
PERFORMANCE		Degree of elimination: 25-35 % of BOD_5 et 55-65 % of SS.
AVANTAGES		
Technical	+	low land requirements
Implementation		
Operation/maint.		
Others	+	appropriate for the treatment of high sewage quantities, where land cost is high
	+	extension possible for secondary/biological treatment
DISADVANTAGES		
Technical	-	effluent contains still high concentrations of BOD_5
	-	low elimination of bacteria and other pathogen germs
Implementation	-	necessity of imported electromechanical equipment
Operation/maint.	-	necessity of qualified staff for routine operation/maintenance
Others	-	no possibilities for reuse of the effluent
	-	sufficient as intermediate treatment process together with an deep sea outfall

SUMMARY SHEET – Activated sludge treatment
(Level of treatment: secondary treatment)

DESCRIPTION		The process consists of an artificial intensification of the phenomenon of natural self-purification by microorganisms (mechanical aeration and intensive recycling of activated sludge). The bacteria float in the sewage in form of flocs. The detention time of the sewage in the activated sludge tank is 4 to 8 h and the one of sludge 5 to 10 h. An activated sludge tank and a secondary clarifier follow a primary clarifier. The sludge has to be dried and stabilized in a drying bed (or better in an aerobic or anaerobic digester). The clarifier tanks are constructed in reinforced concrete and they are equipped by automatic sludge scrappers at the bottom.
APPLICATION		In general: for plants of more than 5,000 population equivalents
PERFORMANCE		Degree of elimination: 85-95 % of BOD_5 et 85-95 % of SS
AVANTAGES		
Technical	+	good reduction of BOD_5 and SS
	+	low land requirements
Implementation		
Operation/maint.		
Others	+	appropriate for the treatment of high quantities of sewage, where the cost of land is high
	+	possible extension for nutrient removal and/or for advanced treatment (tertiary)
DISADVANTAGES		
Technical	-	low elimination of bacteria and other pathogen germs without disinfection
Implementation	-	necessity of imported electromechanical equipment
	-	necessity of sophisticated constructions
Operation/maint.	-	necessity of qualified staff for the maintenance of equipment
	-	operation of complex treatment processes
	-	high consumption of electrical energy
	-	necessity of imported spare parts
Others	-	reuse of treated effluents requires additional treatment

SUMMARY SHEET – Extended sludge treatment
(Level of treatment: secondary treatment)

DESCRIPTION		The process consists of an artificial intensification of the phenomenon of natural self-purification by microorganisms (mechanical aeration and intensive recycling of activated sludge). The bacteria float in the sewage in form of flocs. Sewage is aerated e.g. in a continuous (looped) channel in form of a carousel, which creates a recirculation flow of sewage. Cylindrical steel brushes with a horizontal axis provoke a flow velocity of 0.3 – 0.4 m/s in the channel and a good aeration at the same time. The process requires only one (secondary) clarifier downstream of the aeration tank. The eliminated sludge has to be recycled by 95 % to the aeration tank. This results in detention times of the sewage of 1 to 3 days and of the sludge of 20 to 30 days. The highly mineralized sludge has to be dried in a drying bed. The clarifier tank is constructed in reinforced concrete and it is equipped by automatic sludge scrappers at the bottom.
APPLICATION		In general: for plants of 5,000 to 50,000 population equivalents
PERFORMANCE		Degree of elimination: 85-95 % of BOD_5 et 85-95 % of SS
AVANTAGES		
Technical	+	good reduction of BOD_5 and SS
	+	low land requirements
Implementation		
Operation/maint.	+	production of low quantities of sludge (highly mineralized)
Others		
DISADVANTAGES		
Technical	-	low elimination of bacteria and other pathogen germs without disinfection
Implementation	-	necessity of imported electromechanical equipment
	-	necessity of sophisticated constructions
Operation/maint.	-	necessity of qualified staff for the maintenance of equipment
	-	operation of complex treatment processes
	-	high consumption of electrical energy
	-	necessity of imported spare parts
Others	-	reuse of treated effluents requires additional treatment

SUMMARY SHEET – Treatment by trickling filter
(Level of treatment: secondary treatment)

DESCRIPTION	The process consists of an artificial intensification of the phenomenon of natural self-purification by microorganisms. The sewage flows over fixed bed (e.g. stones). Biological slimes form on the fixed bed, which assimilate and oxidize organic substances in the wastewater. By the creation of optimum conditions for the microorganisms, the number of microorganisms is increased significantly in comparison to natural conditions. This leads to an intensified decomposition of organic matter. The trickling filter and a secondary clarifier follow a primary clarifier. The sludge has to be dried and stabilized in a drying bed (or better in an aerobic or anaerobic digester). The clarifier tanks are constructed in reinforced concrete and they are equipped by automatic sludge scrappers at the bottom.	
APPLICATION	In general: for plants of 5,000 to 200,000 population equivalents	
PERFORMANCE	Degree of elimination: 80-90 % of BOD_5 et 70-90 % of SS	
AVANTAGES		
Technical	+	good reduction of BOD_5 and SS
	+	low land requirements
Implementation		
Operation/maint.		
Others	+	appropriate for the treatment of high quantities of sewage, where the cost of land is high
	+	possible extension for nutrient removal and/or for advanced treatment (tertiary)
DISADVANTAGES		
Technical	-	low elimination of bacteria and other pathogen germs without disinfection
Implementation	-	necessity of imported electromechanical equipment
	-	necessity of sophisticated constructions
Operation/maint.	-	necessity of qualified staff for the maintenance of equipment
	-	operation of complex treatment processes
	-	high consumption of electrical energy
	-	necessity of imported spare parts
Others	-	reuse of treated effluents requires additional treatment

SUMMARY SHEET – Treatment by stabilization pond system
(Level of treatment: tertiary treatment)

DESCRIPTION		Treatment by stabilization pond system consists of anaerobic, facultative and maturation ponds used in series. Anaerobic ponds have a depth of 3 to 5 m and pre-treat the sewage of high organic load and, therefore, the surface of the subsequent ponds may be reduced. Facultative ponds are 1.2 - 2 m deep. They have an upper aerobic layer and a lower anaerobic layer, while a facultative layer is between both. Maturation ponds are quite shallow (1 – 1.2 m) and function in an aerobic milieu. These ponds serve to reduce in particular the bacteria and to improve the microbiological quality of the sewage (tertiary treatment). The detention time in all the ponds is in average 20 days (anaerobic: 3 - 5 days; facultative: 10 - 20 days; maturation: 5 -10 days).
APPLICATION		In general: for plants of 2,000 to 100,000 population equivalents
PERFORMANCE		Degree of elimination (ponds in series): Anaerobic ponds: 50 - 70 % of BOD_5 et almost 100 % of SS Facultative ponds: 60 - 90 % of BOD_5 et almost 100 % of SS Maturation ponds: 60 - 80 % of BOD_5
AVANTAGES		
Technical	+	good reduction of BOD_5, bacteria and worm eggs, i.e. it is possible that the effluents fulfill the requirements of WHO standards concerning the reuse of the treated sewage for agricultural irrigation
	+	good absorption of choc loadings (hydraulics and pollutants)
Implementation	+	low qualified staff required for construction
	+	natural ponds may be used
Operation/maint.	+	low qualified staff for maintenance required
	+	no electromechanical equipment required
	+	no electrical energy required
	+	desludging of anaerobic ponds every 3 – 5 years and of facultative ponds every 10 – 20 years
Others	+	effluents are appropriate for reuse in agricultural irrigation
DISADVANTAGES		
Technical	-	high land requirements (0.3 – 0.4 ha/1,000 inh.)
	-	SS loading of effluent may be high due to algae growths
Implementation		
Operation/maint.		
Others	-	Snails and mosquitoes may develop at the slopes of the dikes, if they are not properly maintained
	-	eventual odor problems (caused by anaerobic ponds)
	-	high losses by evaporation (if reuse for irrigation is proposed)

SUMMARY SHEET – Treatment by constructed wetland
(Level of treatment: tertiary treatment)

DESCRIPTION		The process is based on the ability of certain types of aquatic and marginal plant to host aerobic bacteria on the root rhizome systems as well as on the ability of these plants to remove pathogenic bacteria through the mechanism of complex chemicals exuded through the root systems. Reed (e.g. phragmites) or some fodder plants have a great potential for biological treatment related to its extensive root and rhizome system, which transfers valuable amount of oxygen to the root zone. Screening (generally without grit removal) has to be provided as preliminary treatment of raw wastewater. An Imhoff tank or an anaerobic pond may carry out primary treatment.
APPLICATION		In general: for plants of 500 to 5,000 population equivalents
PERFORMANCE		Degree of elimination: 85-95 % of BOD_5 et 85-95 % of SS
AVANTAGES		
Technical	+	high efficiency
	+	good elimination of bacteria and worm eggs
	+	flexible process and good absorption of choc loadings (hydraulics and pollutants)
Implementation	+	low qualified staff required for construction
	+	natural ponds may be used
Operation/maint.	+	low qualified staff for maintenance required
	+	no electromechanical equipment required
	+	no electrical energy required
Others	+	effluents are appropriate for reuse in agricultural irrigation and aquaculture
	+	harvested biomass may be used as energy source, compost or fodder
	+	appropriate for decentralized solutions
DISADVANTAGES		
Technical	-	high land requirements (10 - 20 ha/1,000 inhab.)
	-	pre-treatment required (screen, aerobic pond) to eliminate of gross objects and settleable matter
Implementation		
Operation/maint.	-	production of high quantities of biomass, which requires a particular management
Others	-	some ponds may offer favorable habitats for snails and mosquitoes
	-	high losses by evaporation (if reuse for irrigation is proposed)

ANNEX to 3.4.1

Description of Proposed Measures for Wastewater Collection, Treatment and Disposal

Annex to 3.4.1 Description Of Proposed Measures For Wastewater Collection, Treatment And Disposal

Contents

1. ABU NUSEIR TREATMENT PLANT

Abu Nuseir Treatment Plant serves the Abu Nuseir Housing Area only (for details of the existing system refer to Section 1 of Annex 3.1). Figure 1.1 shows the existing sewerage system of Abu Nuseir Sewerage System.

The plant was put in operation in 1988 to a capacity of 4,000 m^3/d. Presently only one third of its capacity is used.

The wastewater treatment is based on an activated sludge process preceded by a rotating biological cylinders (RBC) "roughing" system. At the moment only one of the two aeration carrousels is operating. The other train and the two RBC units have not yet been put into service. The plant is currently producing an effluent of reasonable quality. Low contents of fecal coliforms are certainly due to the continuous chlorination of the effluent. The mechanical sludge dewatering system is out of service. The waste sludge is digested, thickened and tankered to Ain Ghazal.

Figure 1.2 shows the existing and future treatment system. The projection of the wastewater production is shown in the following table (acc. to Consultant's Study Report). The plant will reach its final capacity

in 2020: 4,200 m^3/d (36,800 connected inhabitants)

Therefore, an extension is not required before 2020.

Presently, wastewater of the Abu Nuseir Treatment Plant is discharged in Wadi Bereen discharging via Wadi Zarqa finally into the King Talal Reservoir. Downstream of this reservoir water flows to the Jordan Valley for its ultimate reuse. In future it is proposed to reuse the effluent in agricultural areas located northeast of the treatment plant. Effluents could supply irrigation water for an area of about 80 ha in 2020 taking into account the demand for olive and forest trees (see following table). Irrigable land may be supplied by gravity. Proposed wastewater reuse areas are presented in the Figure 1.3.

Even if other water quality parameters of the effluent would allow unrestricted irrigation, due to the helminthes eggs content the effluent can be reused for restricted irrigation only.

Consultant's Study Report:

TYPSA, Symonds Travers Morgan and Universal Engineering Consulting: "Wastewater collection, treatment, disposal and/or reuse systems project for the catchment area of Yarmouk River and Jordan River. Interim Report", July 1998

Stanley Consultants: "Upgrading and expansion of the Baqa and Abu Nuseir wastewater treatment plants. Conceptual Report", January 1994

Stanley Consultants: "Upgrading and expansion of the Baqa and Abu Nuseir wastewater treatment plants. Feasibility Report", October 1994

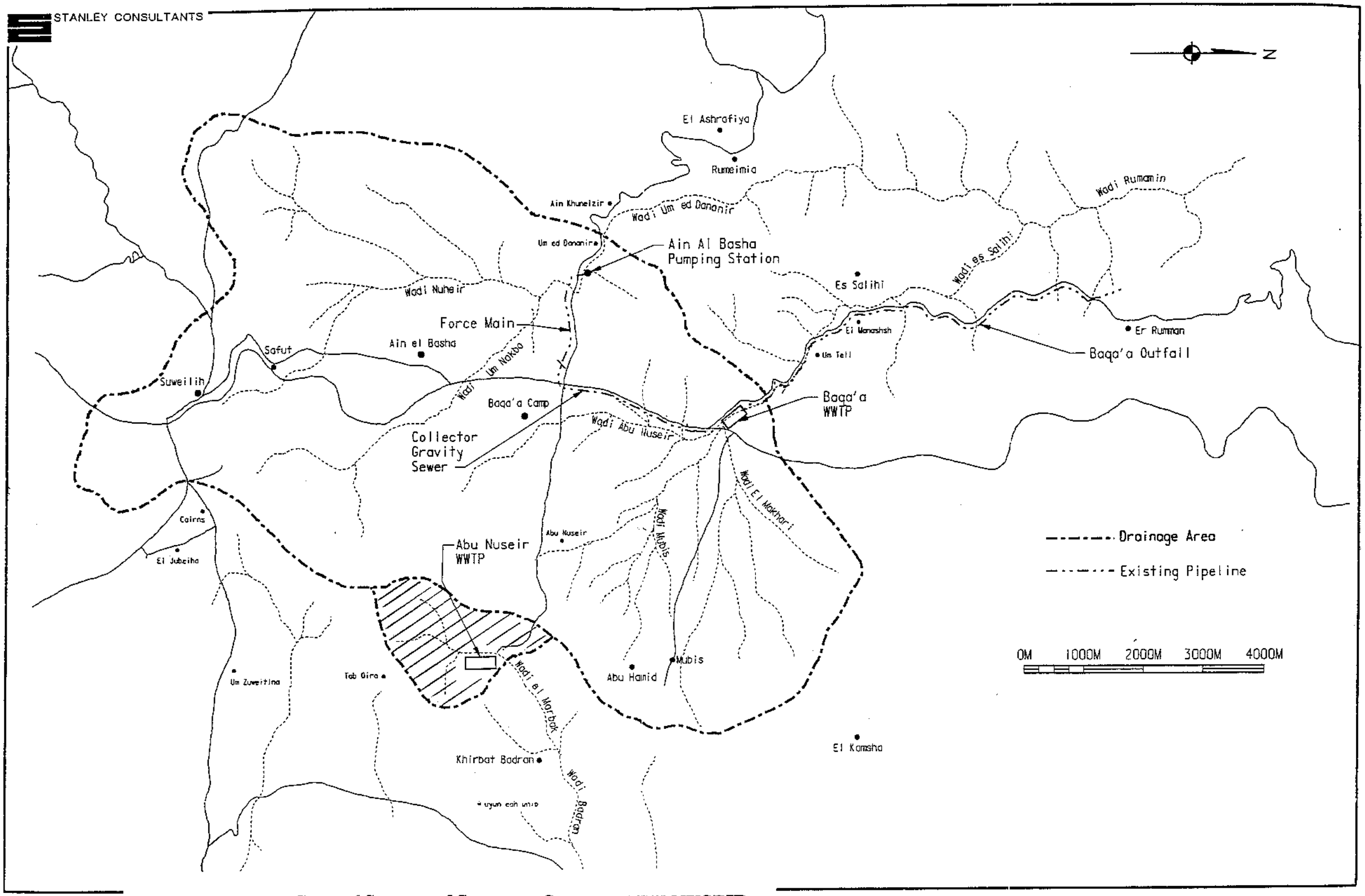


FIGURE 1.1: General Layout of Sewerage System - ABU NUSEIR

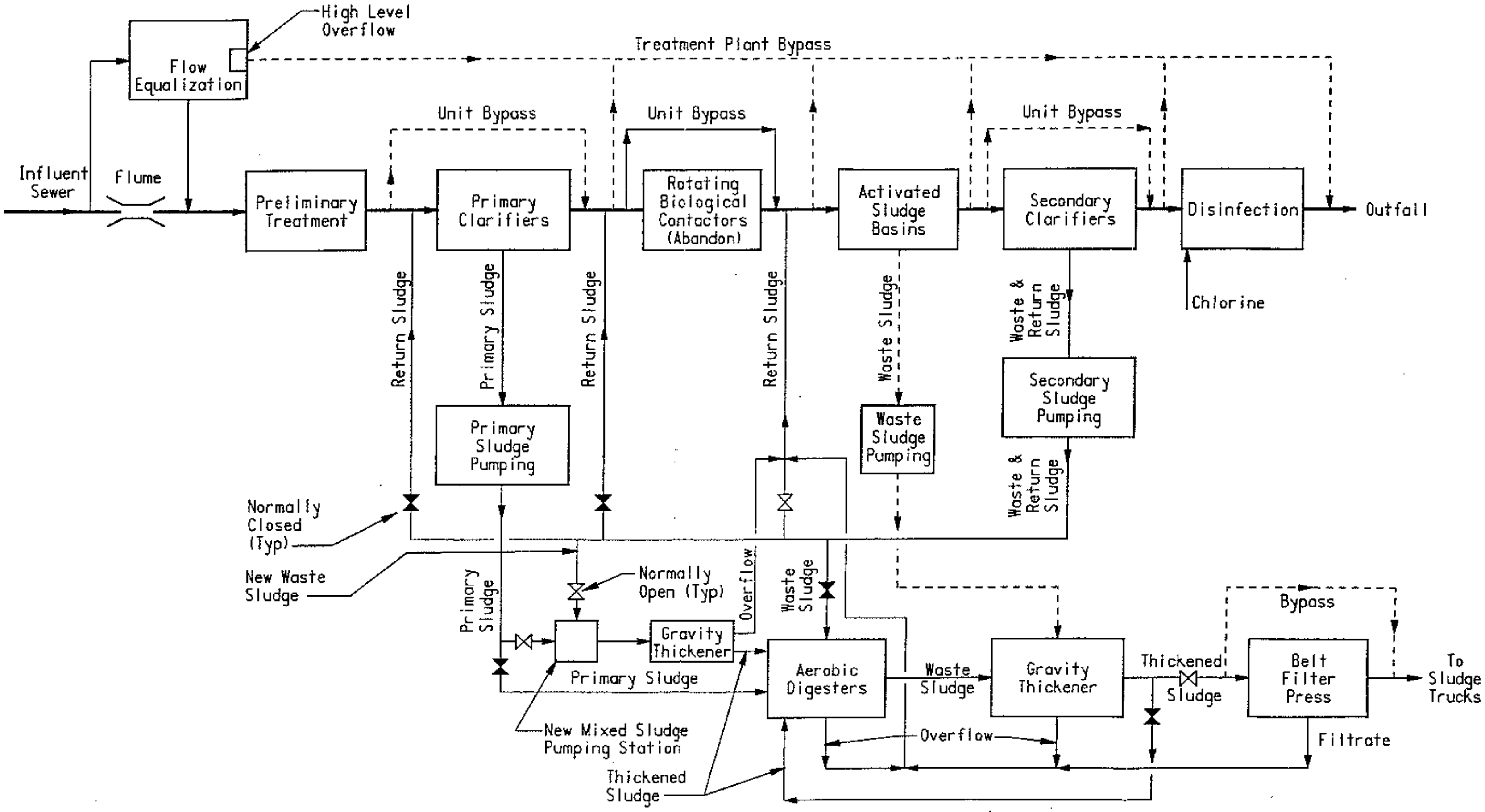


FIGURE 1.2: Layout of Existing and Future Wastewater Treatment Plant - ABU NUSEIR

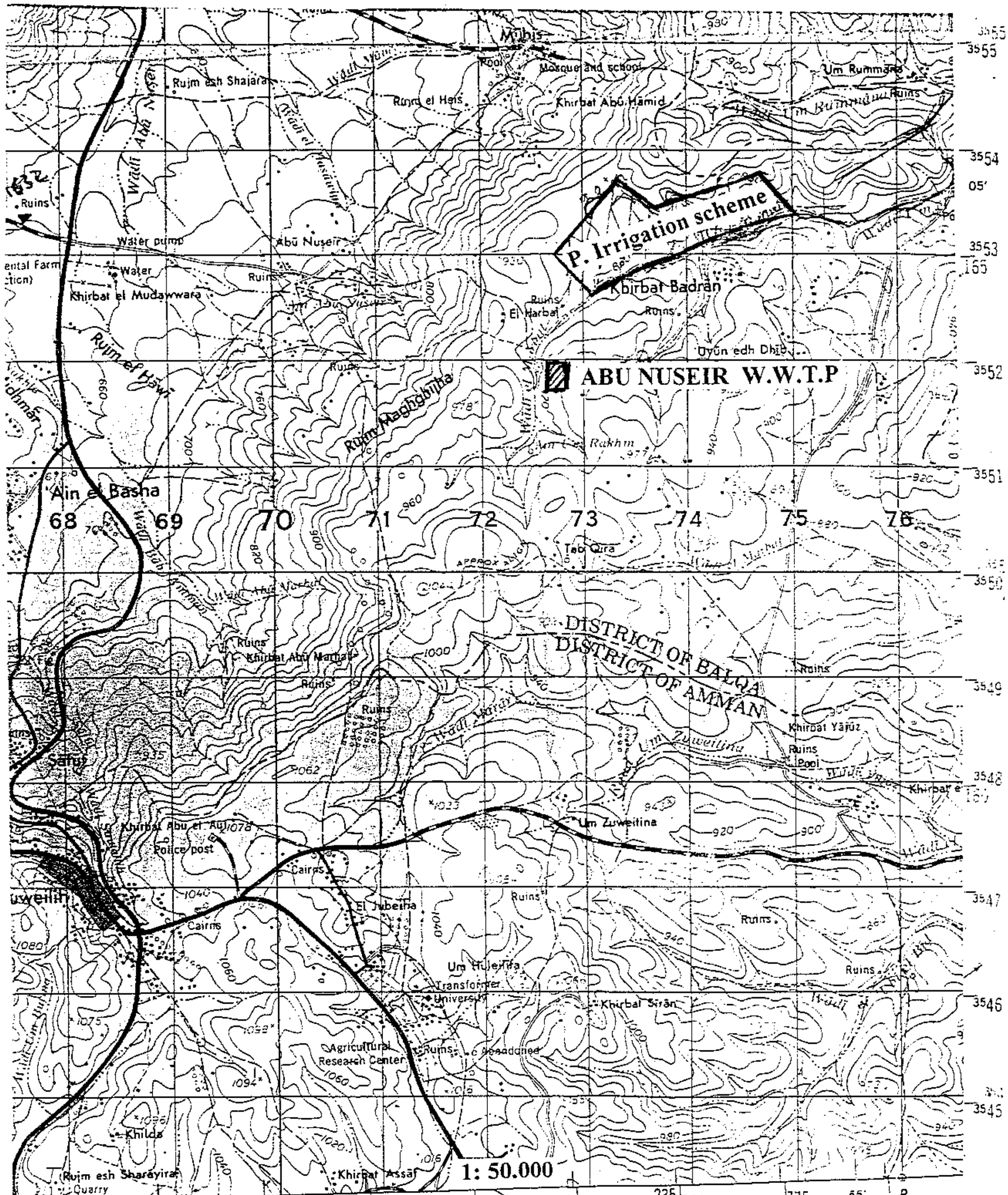


FIGURE 1.3: Potential Reuse Areas - ABU NUSEIR

PROJECTION OF WASTEWATER PRODUCTION OF TREATMENT PLANT: 1 ABU NUSEIR

SCENARIO 0 "Consultants' Study" (acc. to Consultant's Study Report, TYPSA)

Basic data:

Population in 1994: 18.879

	Unit	1994	2000	2005	2010	2015	2020
Growth rate (previous period)	%	-	3,24	3,24	3,24	3,24	3,24
Spec.water demand	l/c/d	130,00	120	143	143	143	143
Commercial demand	m³/d						
Small industrial demand	m³/d						
Pastoral demand	m³/d						
Coverage	%	65	65	75	85	85	85
Return factor	-	0,8	0,8	0,8	0,8	0,8	0,8
Losses/inflow	%	0	0	0	0	0	0
Specific pollutional load	$gBOD_5/c/d$	65	65	65	65	65	65

	Unit	1994	2000	2005	2010	2015	2020
Population	c	18.879	22.860	26.811	31.445	36.880	43.254
Connected (sewerage)	c	12.271	14.859	20.108	26.728	31.348	36.766
Not connected (sewerage)	c	6.608	8.001	6.703	4.717	5.532	6.488
Water demand							
Domestic demand	l/c/d	130	120	143	143	143	143
	m³/d	2.454	2.743	3.834	4.497	5.274	6.185
Commercial demand	m³/d						
Small industrial demand	m³/d						
Pastoral demand	m³/d						
Total	m³/d	2.454	2.743	3.834	4.497	5.274	6.185
Wastewater production							
Return flow (w.demand)	m³/d	1.276	1.426	2.300	3.058	3.586	4.206
Losses/inflow	m³/d	0	0	0	0	0	0
Total	m³/d	1.276	1.426	2.300	3.058	3.586	4.206
	m³/month	38.287	42.793	69.011	91.730	107.585	126.181
	m³/a	465.820	520.648	839.628	1.116.053	1.308.955	1.535.199
Pollutional load							
Poll. load (dom.demand)	$kgBOD_5/d$	798	966	1.307	1.737	2.038	2.390
Poll. load (com.demand)	$kgBOD_5/d$						
Poll. load (small ind.)	$kgBOD_5/d$						
Others	$kgBOD_5/d$						
Total load	$kgBOD_5/d$	798	966	1.307	1.737	2.038	2.390
Reuse of wastwater							
Inflow to the treatment plant	m³/a	465.820	520.648	839.628	1.116.053	1.308.955	1.535.199
Losses in treatment plant	%	5	5	5	5	5	5
(due to infiltr./evap.)	m³/a	23.291	26.032	41.981	55.803	65.448	76.760
Effluent of treatment plant	m³/a	442.529	494.616	797.647	1.060.250	1.243.507	1.458.439
Net water demand per ha	m³/d/ha		50	50	50	50	50
Irrigable reuse area	ha	0	27	44	58	68	80

Water demand for irrigation Olive and forest trees 50 m³/d/ha (during peak period)

2. AQABA (CENTRAL) TREATMENT PLANT

Two plants will serve in future Aqaba:

- Central Aqaba Treatment Plant (receiving wastewater from Aqaba Town)

and

- South Coast Aqaba Treatment Plant (receiving wastewater from Teeba – Tourist Residential Area, see Section 29)

The existing sewerage system of Aqaba Town will be extended and some of the main collectors reinforced (for details of the existing system refer to Section 2 of Annex 3.1). Wastewater collection will rely on 6 pumping stations located along the shoreline of Aqaba. Figure 2.1 presents the proposed sewerage system.

The new Treatment Plant Central Aqaba will be constructed adjacent to the existing Aqaba wastewater stabilization pond facility. Screens and 2 aerated grit chambers shall treat wastewater. Biological treatment shall be based on an activated sludge process (extended aeration) comprising activated sludge tanks and secondary settling tanks. Additional treatment shall be provided by maturation (polishing) ponds using the existing maturation and facultative ponds. Sludge generated at the facility will be dewatered by gravity drying beds. Figure 2.2 shows the proposed new treatment system.

The projection of the wastewater production is shown in the following table (acc. to Consultant's Study). The treatment plant will be implemented in two stages with the following design capacities

in 2010 (Phase 1): 24,000 m^3/d (165,000 connected inhabitants)
in 2025 (Phase 2): 48,000 m^3/d (345,000 connected inhabitants)

Montgomery/Watson Consulting Engineers have proposed in the Conceptual Wastewater Study of January 2000 the reuse of treated wastewater for irrigation of agricultural land, the Peace Gardens, the Royal Gardens and two Golf Courses. In addition, they proposed to consider the Fertilizer Complex (south of Aqaba) as a user for surplus production of reclaimed water (about 6.2 MCM/a) as the Fertilizer Complex's water demand (3.5 MCM/a of DISI water) is currently significant with respect to the total freshwater supply to Aqaba and is expected to increase in the future. However, this proposal was abandoned in the Feasibility Stage in May 2000 (with consent of WAJ) due to high cost of investment and of operation: The cost of building a reclaimed water pumping station and a 26 km long pipeline (DN 600, DI) to the Fertilizer Company from the north side is estimated to 7 mio. JD. Annual costs for capital recovery and electrical energy total about 900,000 JD.

According to the proposal made by Montgomery/Watson in the Feasibility Study all treated effluent of the treatment plant will be reused for agricultural irrigation. The effluents could supply irrigation water for an area of about 680 ha in 2020 taking into account the water demand for mixed crops (see following table) as proposed by the Consultant. Suitable land for irrigation exists in particular north and northeast of the plant. A pump station is required to pump the effluent by a pipeline (DN 400) to a reservoir. Proposed agricultural reuse areas are presented in Figure 2.3.

However, the decision concerning the reuse of treated effluent should be reviewed. It is recommended to reuse all treated effluent of the plant for agricultural crop irrigation, industrial reuse in the Fertilizer Complex and landscape irrigation within the city area. For the purpose of green spaces and parks irrigation a feeder pipeline from the reservoir to the town has to be constructed. The presently existing irrigation pipes have to be connected to this feeder line.

Total investment costs of Phase 1 (for future rehabilitation, expansion and development measures) based on preliminary design and 2000 prices (Study of Montgomery Watson) are:

Treatment plant	15.92 million JD
New gravity sewers	1.59 million JD
Improvements of pumping stations	1.00 million JD
Effluent reuse system (agricultural reuse only)	3.63 million JD
Total base costs	22.14 million JD
Physical contingencies	3.32 million JD
Total investment costs	25.46 million JD

According to the Montgomery Watson Study Report proposed measures will be implemented between 2001 and 2003 (Phase 1).

Consultant's Study Report:

Montgomery Watson/ATJ: "Technical and economic Feasibility Study and Final Design of the upgrading and expansion of the water and wastewater facilities at Aqaba. Conceptual Wastewater Study – Wastewater Sector. Final Report", January 2000

Montgomery Watson: "Technical and economic Feasibility Study and Final Design of the upgrading and expansion of the water and wastewater facilities at Aqaba. Feasibility Study – Wastewater. Volume I. Final Report", May 2000

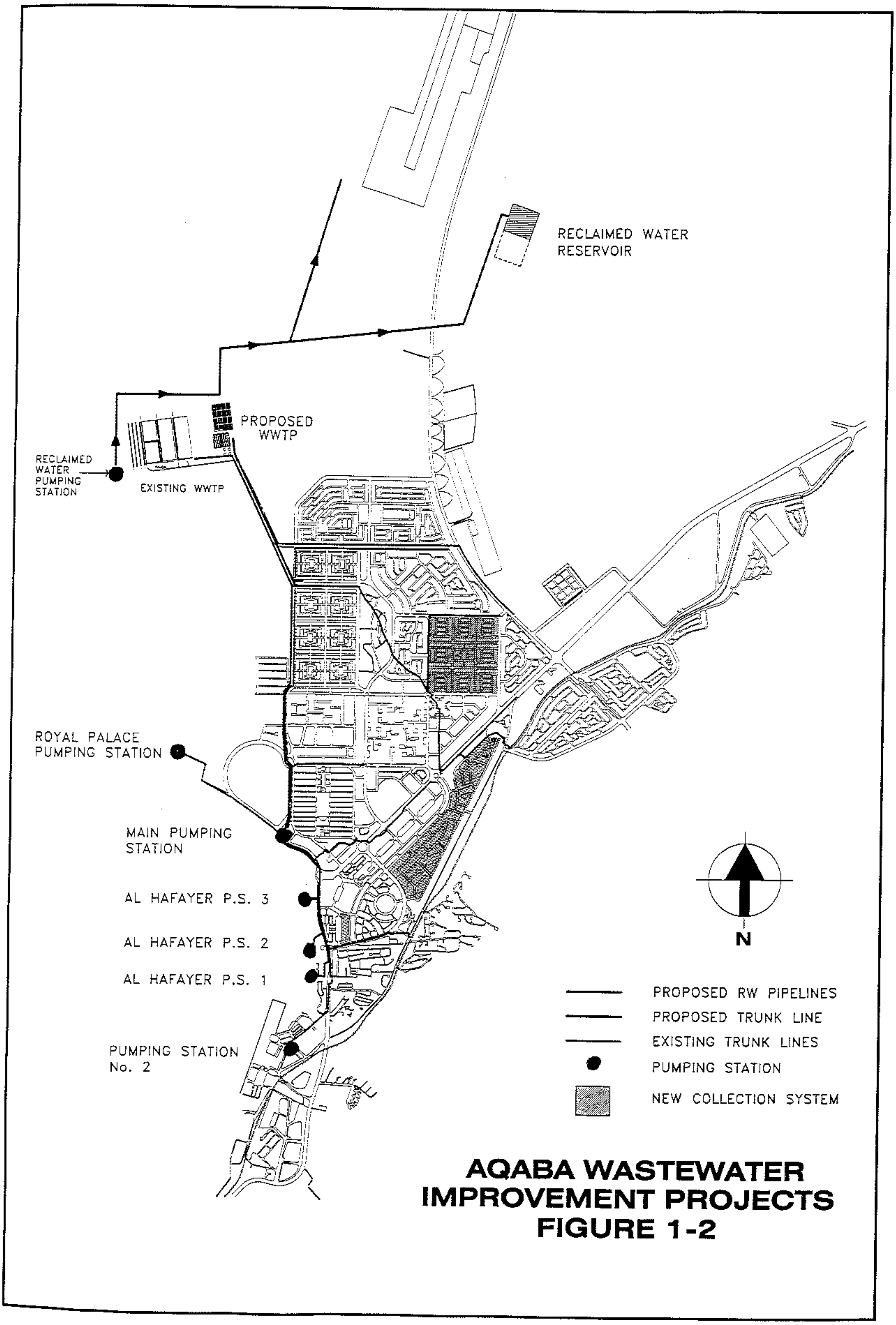


FIGURE 2.1: General Layout of Proposed Sewerage System - AQABA

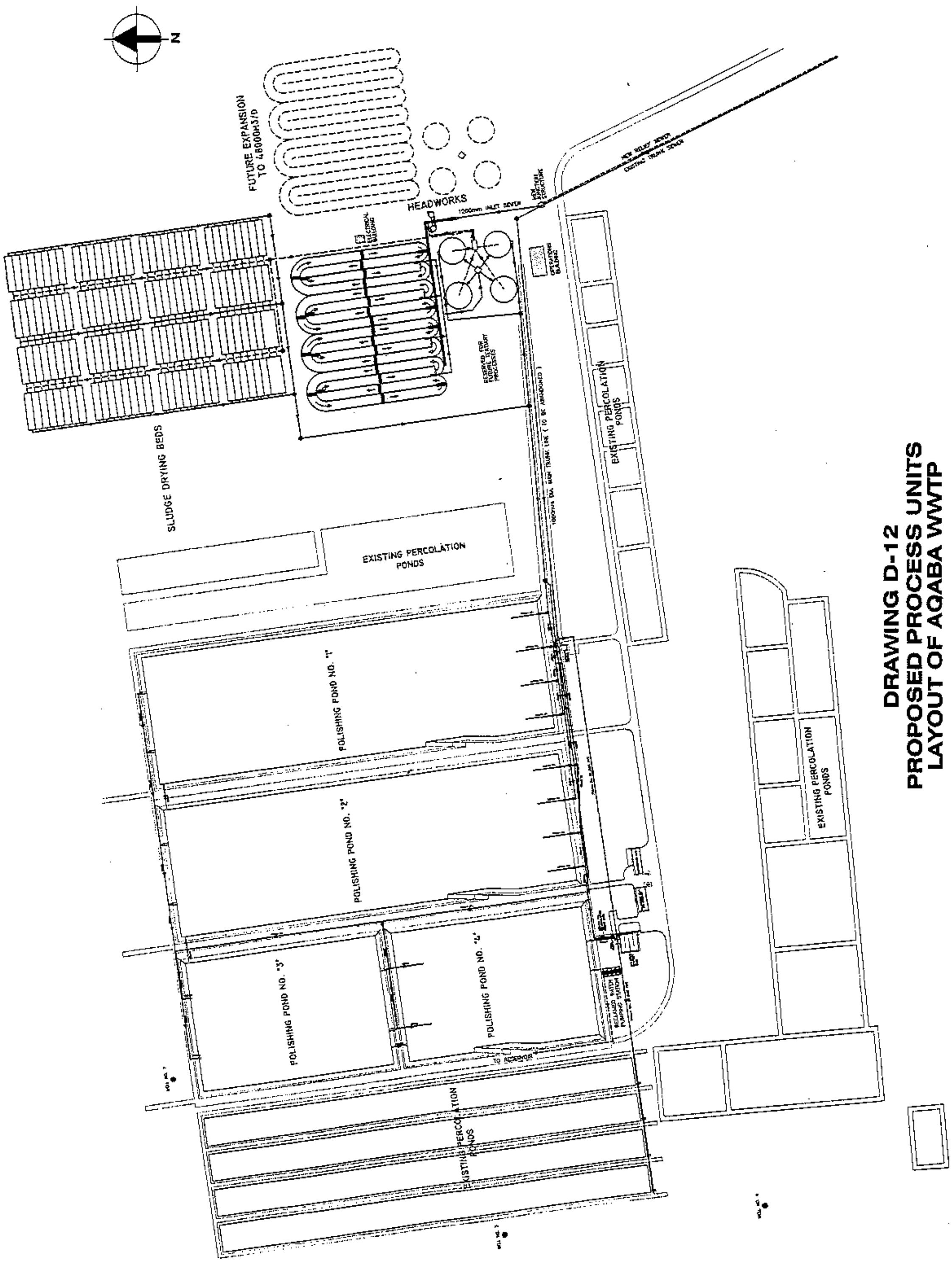


FIGURE 2.2: Layout of Proposed Wastewater Treatment Plant - AQABA

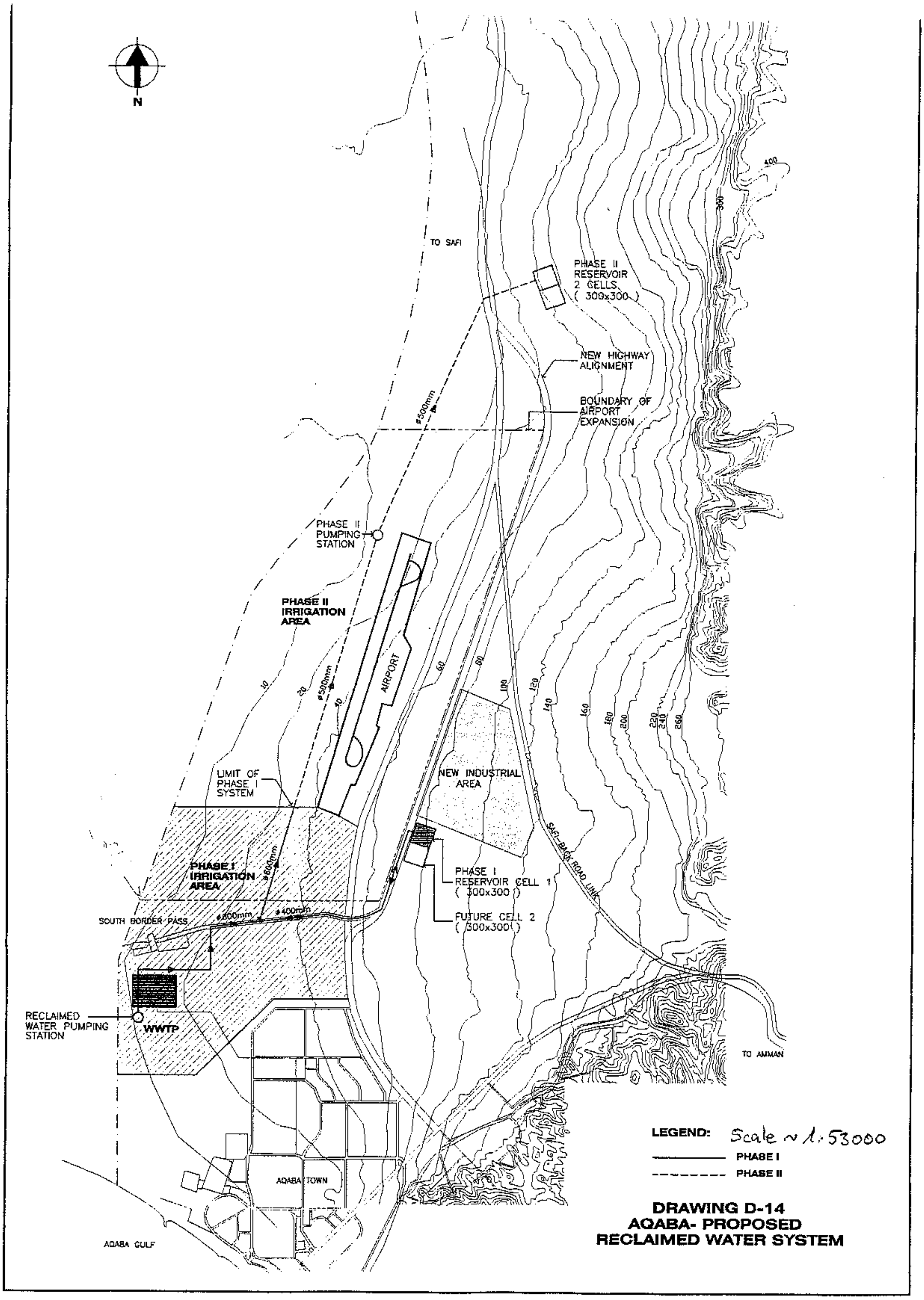


FIGURE 2.3: Potential Reuse Areas - AQABA

PROJECTION OF WASTEWATER PRODUCTION OF TREATMENT PLANT: 2 AQABA

SCENARIO 0 "Consultants' Study"

Basic data:

Population in 1994 — 64.020

	Unit	1994	2000	2005	2010	2015	2020
Growth rate (previous period)	%	-	3,64	7,82	7,44	7,32	5,05
Spec.water demand	l/c/d	120	145	148	148	148	148
Commercial demand	m^3/d						
Small industrial demand	m^3/d						
Pastoral demand	m^3/d						
Coverage	%	70	78	100	100	100	100
Return factor	-	0,9	0,9	0,9	0,9	0,9	0,9
Losses/inflow	%	0	0	0	0	0	0
Specific pollutional load	$gBOD_5/c/d$	65	65	65	65	65	65

	Unit	1994	2000	2005	2010	2015	2020
Population	c	64.020	79.338	115.605	165.503	235.619	301.433
Connected (sewerage)	c	44.814	61.883	115.605	165.503	235.619	301.433
Not connected (sewerage)	c	19.206	17.454	0	0	0	0
Water demand							
Domestic demand	l/c/d	120	145	148	148	148	148
	m^3/d	7.682	11.504	17.110	24.494	34.872	44.612
Commercial demand	m^3/d						
Small industrial demand	m^3/d						
Pastoral demand	m^3/d						
Tourist demand	m^3/d	538	743	1.387	1.986	2.827	3.617
Total	m^3/d	8.220	12.247	18.497	26.481	37.699	48.229
Wastewater production							
Return flow (w.demand)	m^3/d	5.179	8.597	16.647	23.832	33.929	43.406
Losses/inflow	m^3/d	0	0	0	0	0	0
Total	m^3/d	5.179	8.597	16.647	23.832	33.929	43.406
	$m^3/month$	155.361	257.913	499.414	714.974	1.017.873	1.302.189
	m^3/a	1.890.228	3.137.941	6.076.200	8.698.855	12.384.127	15.843.302
Pollutional load							
Poll. load (dom.demand)	$kgBOD_5/d$	2.913	4.022	7.514	10.758	15.315	19.593
Poll. load (com.demand)	$kgBOD_5/d$						
Poll. load (small ind.)	$kgBOD_5/d$						
Others	$kgBOD_5/d$						
Total load	$kgBOD_5/d$	2.913	4.022	7.514	10.758	15.315	19.593
Reuse of wastwater							
Inflow to the treatment plant	m^3/a	1.890.228	3.137.941	6.076.200	8.698.855	12.384.127	15.843.302
Losses in treatment plant	%	25	25	10	10	10	10
(due to infiltr./evap.)	m^3/a	472.557	784.485	607.620	869.885	1.238.413	1.584.330
Effluent of treatment plant	m^3/a	1.417.671	2.353.456	5.468.580	7.828.969	11.145.715	14.258.972
Net water demand per ha	$m^3/d/ha$		58	58	58	58	58
Irrigable reuse area	ha	0	111	258	370	526	674

Water demand for irrigation — 58 $m^3/d/ha$ (during peak period)

Consultant's proposal: Mixed crop pattern