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Assessment of Small Wastewater Treatment Systems in Tunisia

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Assessment of Small Wastewater Treatment Systems in Tunisia

PRIDE Technical Report #6

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August 1992

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PREFACE

This assessment of appropriate wastewater treatment technologies for small Tunisian towns was funded by the U.S. Agency for International Development (AID) through the Project in Development and the Environment (PRIDE). PRIDE is a centrally funded project that provides technical assistance in environmental and natural resource management to AID's Near East (NE) Bureau, missions, and host-country institutions. AID commissioned this assessment in response to a request from the Government of Tunisia through its Ministry of Environment and National Physical Planning (MOE). It is emphasized that the purpose of this assignment is solely to provide technical assistance; in no way does this report make any determination or commitment of funds from AID or any donor for any program or project costs discussed herein.

PRIDE is being implemented by a consortium led by Chemonics International and including RCG/Hagler, Bailly, Inc.; Science Applications International Corporation (SAIC); Capital Systems Group, Inc.; Industrial Economics, Inc.; Enviroomics, Inc.; Resource Management International, Inc.; and Lincoln University.

Dr. Ahmad H. Gaber, a chemical and biomedical engineering specialist, served as the team leader for this assignment. Dr. Gaber is a professor of engineering at Cairo University and deputy chief of party for Chemonics' AID-funded Local Development II/Provincial (LDII/P) project in Egypt. Bonneau H. Dickson, Jr., a sanitary engineer with over 30 years of experience in wastewater engineering in the United States, Africa, Asia, and the Near East, participated in this assignment with Dr. Gaber and is the principal author of the report. Julie Bourns, the PRIDE project administrator, also participated in this assignment, providing French interpretation and research assistance services.

The PRIDE team traveled to Tunisia to begin the three-week assignment on April 18, 1992. They presented their findings and a draft report to the MOE and USAID/Tunisia representatives on May 7, 1992. Throughout the assignment, the team closely collaborated with the ONAS staff. The team appreciates the continuous and active support and participation of ONAS, which contributed significantly to the effectiveness of the study. The team also expresses its appreciation to James A. Graham, USAID/Tunisia mission director; Fathi Kraiem of RHUDO/NENA; and Hafid Lakhdhar of USAID/Tunisia for their support and contributions to the team's efforts.

The PRIDE team also emphasizes that the cost estimates for the technologies recommended in this report are illustrative only; precise cost estimates need to be developed for each wastewater treatment plant that is to be constructed in order to accurately reflect the unique physical conditions of the soil and water at each site.

LIST OF ACRONYMS

AL	Aerated Lagoon
BOD	Biochemical Oxygen Demand
DOR	Dorsch (Germany)
DT	Tunisian Dinar (Dinar tunisienne)
EA	Extended Aeration
GOT	Government of Tunisia
ICN	Ing. Conseil Neerlandais
NT	Normes Tunisiennes
mg/l	Milligrams per liter
MOE	Ministry of the Environment and National Physical Planning
OD	Oxidation Ditch
O&M	Operation and Maintenance
ONAS	Office National de l'Assainissement
PRIDE	Project in Development and the Environment
SC	Scandiaconsult (Sweden)
SONEDE	Societé National pour l'Exploitation des Eaux
SPDT	Small Projects Design Team

EXECUTIVE SUMMARY

The PRIDE team conducted this study in Tunisia from April 20 through May 7, 1992, with the close collaboration of the ONAS staff. The main responsibility of the PRIDE team was to advise ONAS on the most appropriate wastewater treatment technologies for use in small towns.

At present, 25 wastewater treatment plants are in operation in Tunisia and another 20 are under construction. These plants appear to be well designed, constructed, and operated. Foreign consultants designed all these plants, and most of them use the relatively complicated activated sludge process. Because the plants serve large populations and/or are located in intensely developed areas, the activated sludge process appears to be an appropriate technology.

In the near future, small towns with populations of 2,000 to 10,000 will need wastewater treatment facilities. SONEDE's goal is to provide piped water to every house in these towns. Because of the densities allowed in town planning in Tunisia, waterborne sewerage systems will be required if every house has a piped water supply (onsite systems are not feasible). Many small towns have already constructed sewer systems which discharge untreated sewage into nearby dry stream beds (*wadis* or *oueds*) or into coastal lagoons.

Appropriate Wastewater Treatment Technologies

Small Tunisian towns face serious water pollution problems that will necessitate substantial wastewater treatment expenditures in the future. As ONAS prepares a comprehensive wastewater treatment plant construction program for small towns, technologies will be selected that offer cost-effective service over the life of each capital investment.

Although activated sludge systems were appropriate for the larger facilities built in the past, less complicated and less costly wastewater treatment facilities will be needed in the small towns. The most appropriate wastewater treatment technologies for the small towns are stabilization pond systems where land is available and aerated lagoons where land is more restricted.

Very approximate capital costs and operation and maintenance (O&M) costs for these technologies and for activated sludge systems are presented in Table V-6, which is repeated below. The costs of wastewater treatment facilities are very site-specific and the numbers in Table V-6 are only approximate.

Table V-6. Suggested Per Capita Costs for Use in Preliminary Planning (US$/capita per year)

	Stabilization Ponds	Aerated Lagoons	Activated Sludge
Capital Costs	50	75	125
Operation and Maintenance Cost	1.00	2.00	4.00

Institutions

ONAS, which has been assigned responsibility for wastewater treatment systems in Tunisia, appears to be capable of designing and building wastewater treatment plants with appropriate technologies, if the ONAS staff can become familiar with these technologies and modify their design philosophy to think on a small scale.

It is recommended that ONAS establish a Small Projects Design Team (SPDT) to supervise the design and construction of wastewater treatment facilities for small towns.

A pilot program is recommended to provide practical training to the SPDT. The objectives of the recommended pilot program are 1) to develop within ONAS the capability to plan and oversee the design of wastewater facilities for small towns, and 2) to demonstrate this capability by actually constructing several treatment facilities in small towns. The pilot program includes the following components:

Familiarization Phase. SPDT becomes acquainted with the recommended appropriate technologies.

- Dissemination of technical literature.
- Site visits to existing stabilization pond and aerated lagoon facilities in Egypt, Jordan, and the United States.

Design Phase. SPDT learns by doing, guided by an experienced foreign engineer.

- Case studies.
- Practical familiarization with design, construction, and operation of a wastewater treatment facility.
- Supervised designs by each ONAS engineer in the SPDT, and construction of these plants.

With the relatively limited technical assistance provided by the pilot program, all future designs of stabilization ponds and aerated lagoons could be done in-country without the assistance of foreign consultants.

It is envisioned that ONAS will only do the preliminary designs and oversee construction of the wastewater treatment facilities. Private Tunisian consulting firms will do the detailed designs and Tunisian contractors will do the construction.

No Tunisian institution appears to have responsibility for operating and maintaining wastewater treatment facilities in small towns. ONAS, the municipalities, or SONEDE could fulfill this function. SONEDE appears to be in the best position to operate and maintain the wastewater treatment facilities because it will already have operation and maintenance staff in the small towns where facilities are built.

Implementation

Implementation of the pilot program is discussed in Section VI of this report. The program is estimated to cost approximately $US119,000 for technical assistance spread over a nine-month period, including an evaluation at the end of two years. In addition, it would be highly desirable to have available approximately $US4 million toward the end of the initial nine-month period so that the supervised designs which the ONAS SPDT prepares can go into construction without long delays.

After ONAS gains experience with the round of projects included in the pilot program, it can undertake additional projects as financing permits.

It is strongly recommended that the pilot program and the first few rounds of projects include only projects using stabilization ponds and aerated lagoons. As experience is gained with these appropriate technologies, they will be preferred over more complicated technologies.

Legislation

The discharge criteria in the existing Tunisian legislation may be slightly stricter than required. However, treatment to the secondary level is necessary to avoid nuisance conditions and will more or less meet the requirements of the existing legislation. The recommended stabilization pond and aerated lagoon technologies provide secondary treatment. For these reasons, there is no pressing need to modify the existing legislation at this time.

SECTION I
INTRODUCTION AND BACKGROUND

A. Scope of Work and Purpose of Assignment

This assignment responds to a request from the Tunisian Ministry of the Environment and National Physical Planning (MOE) for technical assistance in assessing appropriate wastewater treatment technologies for use in small towns. The scope of this assignment is thus narrowly focused on technology and does not involve an evaluation of the sanitation sector or program design. In broader assignments, many policy and strategic issues such as legislation, institutions, human resources, and public acceptance must be addressed. In Tunisia, these issues have for the most part already been resolved. The scope of work, which is presented in Annex A, was designed to assure that the broader policy and strategic issues were considered, but this assignment focused on technical engineering issues. As a result, the report aims to reach an audience that is technically knowledgeable about wastewater treatment. The problem that was addressed can be stated as follows:

> In 1974, the Government of Tunisia (GOT) formed ONAS as the primary technical agency to deal with wastewater issues in the country. ONAS has evolved into a large, technically competent organization.
>
> The first priority of the wastewater effort was to provide wastewater facilities in the large cities and in areas especially important to tourism, which is crucial to the national economy. This effort has largely been accomplished by the construction of 25 foreign-designed, relatively sophisticated, wastewater treatment facilities.
>
> The current emphasis is on providing wastewater treatment facilities in secondary cities. Twenty wastewater treatment plants are under construction, again relying primarily on relatively sophisticated foreign technology.
>
> In the near future, the Government wishes to provide wastewater treatment facilities to many more small towns with populations ranging from 2,000 to 10,000.
>
> The PRIDE project team was asked to evaluate whether there are simpler, less costly, more appropriate wastewater treatment technologies than those used to date which should be considered for small towns in Tunisia.

B. Approach and Methodology

Because ONAS has been assigned responsibility for wastewater treatment in Tunisia, the PRIDE project team's interaction with the Tunisian Government was mostly with this organization. Interacting with ONAS was a key part of the fieldwork, both because ONAS is

the best source of information on wastewater treatment in Tunisia and because it will undoubtedly be the organization that is called upon to carry out the recommendations of this report.

In the discussions with ONAS, the broadest possible range of wastewater technologies and topics was explored, even though it was known that many were probably not appropriate for small towns, to assure that potentially viable technologies were not overlooked and to assess the receptivity of ONAS to alternative approaches. Although many were explored, this report focuses only on those deemed most appropriate for use in the small towns of Tunisia.

Throughout the work, the ONAS staff was found to be technically competent, interested, energetic, and extremely cooperative. The constructive assistance which all levels of the ONAS staff rendered to the PRIDE project team is gratefully acknowledged.

C. Sources of Information

The PRIDE team relied on three types of sources to gather information on the nature and extent of wastewater treatment problems and related issues. These included a review of available literature concerning wastewater treatment and water resources management published by GOT agencies, multilateral donors, and private consulting firms; visits to wastewater treatment plants and sewered and unsewered towns in Tunisia; and discussions with GOT officials in Tunis and in a number of governorates and municipalities. A list of persons contacted and sites visited is presented in Annex B.

Extensive information about the wastewater situation in small towns in Tunisia is being made available in a World Bank funded study (SOTINFOR/SERAH, 1992) which is being published. A summary of the SOTINFOR/SERAH work is presented in Annex C.

D. Characteristics of Small Towns

The SOTINFOR/SERAH study considers Tunisian towns with a population at or greater than 2,000 (using 1990 figures) and which need wastewater treatment services; the study covers 199 such towns. Of these, the 119 towns with populations between 2,000 and 10,000 are the target of the PRIDE team assignment. About half of these towns do not have sewer systems and thus do not yet need wastewater treatment facilities. None of them have wastewater treatment facilities, (i.e., all small towns with sewer systems are discharging untreated wastewater).

All Tunisian towns are required to prepare and abide by municipal plans, which results in quite uniform town layouts throughout the country. The high densities of Tunisian towns necessitate waterborne sewer systems if piped water is to be supplied to each house (i.e., the densities are too high for on-site disposal systems to be effective). In addition, the streets in these planned towns are wide enough to allow conventional gravity sewers to be constructed with relative ease.

One other feature noted in the towns visited was the cultural preference for hillside sites. In many cases only hillside locations were available but sometimes the hillsides were apparently chosen to avoid encroaching on valuable agricultural areas in the flat land. A practical effect of this propensity for hills is that the towns have ample slope so the sewers do not have to be deep. Conventional gravity sewers are relatively inexpensive to construct.

E. Environmental Legislation

Two GOT standards (*Normes Tunisiennes*) concerning protection of the environment relate to wastewater treatment in Tunisia. NT 106.002 regulates the discharge of effluents into public waterways, and NT 106.03 regulates the utilization of treated wastewater for irrigation. The standards require that target levels for BOD, suspended solids, and specified chemical and organic matter be attained before wastewater is discharged into the ocean, stream beds, or public sewers. The standards also set target levels for BOD and suspended solids for wastewater to be reused for agricultural purposes. A summary of the most important requirements of these two laws is presented in Annex D.

The discharge criteria included in the Tunisian legislation closely match those used in the United States. These criteria may be stricter than necessary for conditions in Tunisia but can generally be met by secondary treatment processes. Treatment of wastewater to a secondary level is necessary to prevent nuisances such as odor and insects, and the technologies recommended in this report—stabilization ponds and aerated lagoons—can provide secondary treatment. Therefore, there seems to be no pressing need to amend the legislation at this time.

SECTION II
PROBLEM IDENTIFICATION

As noted in Section I, this report focuses on the narrow topic of appropriate wastewater treatment technologies for small towns. To assure coverage of the broader picture, however, this section briefly discusses some more general topics that relate to wastewater treatment.

A. Health Hazards

The connection between improper treatment and disposal of sewage and human health is well documented. Conditions in Tunisia which could lead to epidemics include the following:

- Relatively high population densities in the towns.
- Discharge of gray water to the streets in towns that lack sewer systems.
- Discharge of untreated sewage to dry stream beds near the towns.
- Use of inadequately treated and undisinfected wastewater for irrigation, especially where small farmers may use it clandestinely to irrigate food crops.

Ministry of Health officials have reported that although the overall incidence of typhoid in Tunisia has not changed much since 1975, localized epidemics have occurred in El Hamma (Gabes), Sbitla (Kasserine), and Fernana (Jendouba). The ministry has noted a possible correlation between the incidence of typhoid and the amount of wastewater used to irrigate crops that are eaten raw, such as fruits and vegetables. A direct causal relationship has not, however, been established.

Although water related diseases have not to date posed a serious health hazard in Tunisia, local officials fear that serious problems may occur in the near future as the population and amount of wastewater increase.

B. Tourism Concerns

The tourist industry is extremely important to the economy of Tunisia. The proper treatment and disposal of wastewater is important to the continued exploitation of the tourist industry because of both the aesthetic degradation caused by inadequately treated wastewater and the potential health hazards. A water-related epidemic in a tourist area could be disastrous to the Tunisian economy.

C. Water Reuse

Tunisia is an arid country where water is especially valuable. Properly treated, reclaimed wastewater can be used for irrigation. It is estimated that approximately 20

percent of the treated wastewater in Tunisia is reused for irrigation, primarily of fiber crops (cotton), tree crops, and fodder. Much higher percentages of wastewater reuse have been achieved elsewhere in the Mediterranean area, and the GOT would like to increase the proportion that is reused in Tunisia.

An interesting possibility would be to have local farmers operate and maintain the wastewater treatment facilities in small towns in return for being allowed to use the treated wastewater for irrigation. Such arrangements would greatly reduce the government's burden of operating wastewater treatment facilities in small towns.

D. Institutional Capabilities

Governmental institutions that plan, design, construct, operate, and maintain wastewater treatment facilities are well developed in Tunisia. In general, the existing institutions appear able to carry out a program of providing wastewater treatment facilities in small towns, although a change of emphasis is needed and some relatively minor gaps in coverage were noted. An institutional analysis is provided in Section IV.

E. Financial Constraints

Development of a financial plan to provide wastewater treatment facilities to the small towns in Tunisia was beyond the scope of this assignment. An approach is presented at the end of Section VI, however, that would allow ONAS to proceed with a program in stages as financing becomes available.

SECTION III
THE NATIONAL WASTEWATER TREATMENT STRATEGY

The wastewater treatment sector in Tunisia has evolved in three phases. During the first phase, which is mostly complete, ONAS was established to manage wastewater treatment activities and wastewater treatment facilities were constructed in the largest cities and in the areas most important to the tourist industry. In the second phase, currently underway, wastewater treatment facilities are being constructed in the secondary cities. The third phase, which is expected to begin soon, will establish wastewater treatment facilities in the small towns of Tunisia.

Sewage collection systems (as distinguished from the treatment systems) have always been the responsibility of the municipalities. The number of cities and towns which have built sewage collection systems has increased steadily through the years, creating a corresponding increase in the need for wastewater treatment systems.

This section discusses the evolution of the national wastewater treatment strategy in Tunisia, especially as it affects the program for providing wastewater treatment facilities in small towns.

A. Large Cities

Quite logically, ONAS began the construction of wastewater treatment facilities in the largest Tunisian cities where problems were most acute and in areas that were especially important to the tourist industry. Protecting the environmental quality of the tourist areas is highly important to national economic development objectives.

As noted earlier, 25 wastewater treatment facilities were constructed to serve the largest cities and most important tourist areas. Operational data on many of the wastewater treatment plants, which were constructed during this phase and are already operating in Tunisia, are presented in Table V-4.

An organizational and institutional framework for the wastewater treatment sector was created during the first phase and included, among other developments:

- The establishment in 1974 of ONAS as the national technical agency for the wastewater sector.
- The establishment of a legal framework for water pollution control in Tunisia through law NT 106.002 (1989).
- The development of a National Strategy for Sewage Disposal in 1989.

- The establishment of personnel development programs within ONAS to train operators and technicians.

The first phase, encompassing the construction of wastewater treatment facilities in the large cities and important tourist locations, is now largely complete. These facilities, of course, need continuous renovation, modification, and enlargement. Thus, considerable activity continues in the large cities.

B. Secondary Cities

The current wastewater treatment focus in Tunisia is on the secondary cities. Some design and cost information on the treatment facilities which are under construction is presented in Table V-3.

Foreign consultants have designed all the wastewater treatment facilities for the large and secondary cities. Most have used some form of the activated sludge process, which involves intensive use of structures and equipment. During the second phase, ONAS has begun to lay the groundwork for treatment processes which rely less on equipment and concrete structures, such as stabilization ponds and aerated lagoons, and for future design of wastewater treatment facilities by Tunisian consultants. As part of this effort, ONAS staff engineers have designed two pilot projects with minor assistance from a professor from Germany.

C. Small Towns

The wastewater treatment strategy for Tunisian small towns is considerably influenced by other policies and goals. For example, SONEDE, the national organization in charge of the potable water supply, has a goal of providing piped water to every house in towns with populations of 2,000 or more by the year 2001.

Next, every town in Tunisia is required to have a development plan. The densities allowed in these plans are such that onsite wastewater treatment and disposal systems are technically impractical if each house has a piped water supply. Waterborne sewerage systems are therefore required.

Finally, the institutional and public inclination is toward waterborne sewerage systems. The national sanitation strategy adopted in 1989 envisioned that towns would have waterborne sewerage systems, and individual local governments build sewer systems to solve local problems. The public seems to expect that waterborne sewerage systems will ultimately be available in towns. Virtually every new house includes a water-flushed toilet, even if sewers are not yet available to serve it.

The preliminary planning for wastewater facilities in small towns is part of the SOTINFOR/SERAH report which is being completed in mid-1992. The next logical step is to begin to design and build wastewater treatment facilities in a few small towns, using the first projects as a testing and training ground for future projects.

D. Unsewered Areas

In sparsely populated rural areas, sewers are very expensive and onsite systems are more cost-effective. Even urban areas, however, have neighborhoods which lack sewer systems where the residents must rely on onsite systems.

It appears that no government agency has responsibility for overseeing the construction of onsite wastewater systems. Local health agencies provide health education information and local governments may provide some advice where unsewered areas fall within their boundaries. None of these government organizations, however, has a strong engineering staff.

Although ONAS will have no direct responsibility for building or maintaining onsite systems, it may be advantageous to have ONAS offer technical advice on the construction and maintenance of onsite systems because of its excellent technical capabilities.

SECTION IV
INSTITUTIONAL ANALYSIS

This section discusses the Tunisian institutions involved in the wastewater sector or that may influence it. In general, the institutional arrangements for this sector appear to be logical and efficient, and there appears to be no need for major institutional reform. ONAS, designated as the responsible technical wastewater agency, has a competent engineering and operations staff. Some minor gaps in institutional coverage were noted, and ways to cover them are suggested below.

A. ONAS

According to the 1989 national sanitation strategy, ONAS has responsibility for all technical matters pertaining to sanitary sewerage. This responsibility is reflected in the ONAS mission statement, which is included in Annex E. Annex E also includes the ONAS organization chart and information on ONAS staff training. Although other institutions are peripherally involved in activities or issues that affect wastewater treatment, ONAS is the sole agency responsible for technical matters pertaining to wastewater treatment. ONAS has assumed responsibility for overseeing the design and construction of all wastewater treatment plants and for operating and maintaining wastewater treatment plants in towns with populations of more than 20,000.

ONAS' staff has increased from 178 in August 1974 when the organization was formed to 2,065 today. As discussed in Section III, ONAS first provided sewerage service to the large cities and important tourist locations. Now it is concentrating on the secondary cities. In the near future, the focus will shift to small towns.

ONAS has developed a well-trained, competent technical staff. At present, this staff operates 25 wastewater treatment plants in the largest cities and will soon assume responsibility for an additional 20 plants which are under construction in secondary cities. For operations and maintenance, ONAS is divided into five regions, each with a large central maintenance facility which is well-equipped with tools and repair facilities. Nearly all repairs required on treatment plant equipment can be performed at these shops.

In the past, ONAS has contracted out the design work on wastewater treatment facilities to foreign engineering firms. More recently, however, ONAS itself has designed two pilot plants with limited foreign assistance from a German professor. Plans for the two pilot plants are presented in Annex F. These plants use a combined activated sludge-aerated lagoon system and an activated sludge-extended aeration technology, respectively, and are currently under construction.

In general, the institutional arrangements for wastewater treatment appear to be well covered in Tunisia; however, the following apparent gaps in institutional coverage were noted:

- ONAS' ability to do preliminary designs and to administer wastewater treatment facilities designed by Tunisian firms is not yet fully developed.

- ONAS' previous focus was on larger, more complex wastewater treatment facilities; its experience with smaller, less complicated systems is relatively limited.

- Arrangements have not yet been made to operate and maintain wastewater treatment plants in towns with populations between 2,000 and 20,000.

- Local governments are responsible for the design and construction of sewers within the towns and the quality of both the designs and the construction may have been poor in some cases.

- Little technical information and support appears to be available for on-site systems.

These apparent gaps are discussed briefly below.

In-Country Design. Tunisia appears to have sufficient technical capability to carry out the detailed design of stabilization ponds and aerated lagoons with little if any assistance from foreign engineering firms. A program to tap this capability by creating a Small Projects Design Team (SPDT) in ONAS is suggested in Section VI. The SPDT is expected to prepare preliminary designs of stabilization-pond or aerated-lagoon facilities for small towns and then administer the detailed design work by private Tunisian consulting engineering firms.

Focus on Large Systems. To date, ONAS has focused on larger scale, sophisticated wastewater treatment technologies such as activated sludge and aerated lagoon systems. Although these technologies appear to have been appropriate where they have been used, they are too complex and expensive for small-town use. ONAS needs to reorient its design approach toward smaller, simpler technologies. The design approach of an organization is a subtle, sensitive matter which is often much more difficult to modify than expected. The recommended program for forming and training a SPDT, which is proposed in Section VI, should help ONAS apply a small projects approach to future designs for small towns.

Plant Operation and Maintenance in Small Towns. Although ONAS provides operation and maintenance services at larger wastewater treatment facilities, it has no staff in small towns and may be unable to hire staff for small towns, due to current government budget restrictions. In addition, the creation of a separate wastewater treatment operations and maintenance staff in small towns served with stabilization ponds and aerated lagoons may be less cost effective than other institutional arrangements.

Design and Construction of Sewers. The PRIDE project team occasionally heard that the quality of sewer design and construction in small towns was sometimes poor. Few specific examples were cited and a further investigation of this problem was beyond the scope of this assignment. Since local governments have responsibility to design and construct the sewers, ONAS has little or no direct control of these functions. However, the performance of its wastewater treatment plants may be adversely affected if the quality of the sewers is poor and if large amounts of groundwater or sand are allowed to enter the systems and reach the plants. Section VI of this report suggests how ONAS could intervene in this area by providing technical information, but without becoming directly involved in designing and constructing the sewer systems.

On-site Systems. ONAS is not responsible for on-site systems, which are used in areas not served by waterborne sewerage systems. However, the other institutions which are responsible in these areas probably have very limited technical capabilities for dealing with the engineering aspects of on-site systems. Since many of these systems will later be connected to a sewerage system that does connect to a wastewater treatment plant designed by ONAS, it would be wise for ONAS to do whatever is possible to improve the design of on-site systems. In Section VI, suggestions are made for how ONAS might provide technical engineering information to other agencies which are dealing with on-site systems.

B. SONEDE

The Societé National pour l'Exploitation des Eaux (SONEDE) is the Tunisian government agency with overall responsibility for the potable water supply. As discussed elsewhere, SONEDE has adopted a policy of providing piped water to every house in towns with populations of 2,000 or more. As it does so, waterborne sewerage systems will be required to collect the wastewater from these houses.

The SONEDE organization has two features that may be particularly useful in providing wastewater services in small towns: technical personnel, and a revenue collection system.

Existing Operations and Maintenance Staffs. SONEDE has technical personnel in every small town to operate the water supply facilities. Since local government usually is not involved in technical activities, the SONEDE personnel might be called upon to operate and maintain wastewater treatment facilities in these towns. This possibility is discussed in Section VI.

Billing Departments. SONEDE charges local water users for the local water supply. Some additional funds will be needed to operate and maintain the wastewater treatment plants. The most practical means of collecting these funds may be to add a surcharge to the water bills.

C. Local Government

Local governments in the small towns have very limited resources and few technical capabilities. They are responsible for constructing, operating, and maintaining sewers, but as noted above, may carry out these responsibilities poorly in some cases. Although local governments operate and maintain wastewater treatment facilities, they do not necessarily have the technical staff that is required.

D. Other Agencies

Although ONAS and SONEDE are the major agencies in the wastewater and water supply sectors, several other agencies are involved in various activities which affect the wastewater sector. Some of these are discussed briefly below.

Ministry of Health. The most important aspect of water and wastewater systems is their potential contribution to public health protection. This potential can be fully realized only if the public is educated about the health implications of water and wastewater management. Local health posts are a primary means of disseminating information about the health-related aspects of water and wastewater use.

Local health posts may also be the public's primary source of information about proper design and use of on-site wastewater treatment and disposal systems, although the health agencies are unlikely to have strong engineering capabilities. It is suggested that ONAS support local health agencies by providing information on the engineering aspects of on-site systems, such as simple technical brochures for the health offices to distribute.

Ministry of Agriculture. The Ministry of Agriculture is very interested in promoting the reuse of treated wastewater for irrigation, and it has published discharge criteria for such use (see Annex D). ONAS, and any other agency operating wastewater treatment facilities whose effluent is or may be used for irrigation, needs to be aware of the role and discharge requirements of the Ministry of Agriculture. ONAS will also have to help the ministry assure that local farmers reuse the effluent in a safe manner.

Schools. Schools provide another means to educate the public about the health aspects of water and wastewater uses and the proper use of sewerage systems. For example, if excessive groundwater or sand is being admitted to sewer systems, due to the poor quality of the sewers or possibly illegal connections to the system, the operation and maintenance personnel at the wastewater treatment plant could arrange classes in the schools explaining the adverse effects of these activities. Information sheets could be sent home with students to educate families about these matters.

Industry. Industries that use the sewer systems can also adversely affect the operation and maintenance of the wastewater treatment plants if they discharge substances that are toxic or that otherwise interfere with the performance of the collection system or treatment plant or the reuse of the treated effluent. Coordination with connected industries and sampling and analysis of their wastewater effluents will be required. Industries that use

up a major portion of the capacity of wastewater treatment facilities should be asked to pay for this capacity or for plant expansions which are necessary to serve them.

SECTION V
SMALL-SCALE WASTEWATER TECHNOLOGY ASSESSMENT

This section presents various criteria that must be considered in selecting wastewater technologies for use in small systems, identifies and discusses the technologies that appear most relevant for small towns in Tunisia, and compares the alternative secondary treatment technologies.

A. Selection Criteria for Small-scale Wastewater Treatment Technologies

Wastewater facilities are complex in numerous ways. First, the physical structures and equipment themselves are often complex. Second, because the treatment processes are biological, they do not always perform as expected. Finally, a wastewater facility is dramatically affected by the actions of the many people involved in planning, designing, building, operating, and using the system. Because of these complexities, a variety of criteria must be considered in the process of selecting the most appropriate wastewater technology.

The criteria for selecting a wastewater technology can be divided into those related primarily to its performance and those related to its cost. The first three criteria—level of treatment, reliability, and ease of O&M—address performance characteristics. The cost-related criteria concern land, capital, and O&M requirements. A number of other criteria, such as energy use and compatibility with possible wastewater end-uses, are also used to compare alternatives and are discussed in the overview of the appropriate technologies.

A1. Level of Treatment

In selecting a wastewater treatment technology, the level to which the wastewater will be treated must be considered. Usually primary treatment (sedimentation) alone is not sufficient. Primary effluent is malodorous, quickly becomes septic (especially in warm climates), and contains a high concentration of pathogens. Moreover, sedimentation produces raw sludge as a side stream. The raw primary sludge is also malodorous and requires further treatment, which typically is complex and expensive. The preferred process for treating primary sludge is usually anaerobic digestion. Two treatment plants that were visited in Tunisia have separate primary treatment and anaerobic digestion facilities. In both cases, the digesters had proven difficult and expensive to operate and were not in service when the PRIDE project team visited.

For smaller facilities, it is usually more effective and economical to use a secondary treatment (biological) process with a relatively long detention time, without separate primary treatment, than to provide a system that includes separate primary and secondary treatment processes. The long detention time results in a sludge that is relatively stable and inoffensive. As a design rule of thumb in the United States, engineers rarely provide

separate primary facilities if the flow is less than 1 million U.S. gallons per day (4,000 cubic meters per day). Since the largest towns under consideration in this project have populations of only 10,000 and flows of only 1,000 m^3/da, separate primary treatment facilities should probably not be used in Tunisia.

A review of the existing wastewater treatment facilities in Tunisia, as well as those under construction, reveals that few included separate primary facilities. This indicates the European design engineers who have worked in Tunisia agree that separate primary treatment is not a desirable choice.

The legislation governing discharge of wastewater in Tunisia (see Annex D) requires that the BOD and suspended solids not exceed 30 milligrams per liter. These concentrations can be achieved only by secondary or higher treatment.

A2. Reliability

The wastewater technologies that are used must be reliable. Ideally, there should be well proven experience with the technology selected, i.e., numerous installations should have been operating under similar conditions for many years. New and even older processes, which have not been used under local conditions, should be considered unproven. Frequently a technology appears attractive in theory, but unforeseen problems arise upon implementation. (See Annex G for some examples with the overland flow system.)

A second factor in determining reliability is whether the process performs well under a wide variety of high- or low-flow levels and loads, or other unusual conditions (i.e., the process should be relatively stable). Processes, such as stabilization ponds and aerated lagoons, which involve large volumes relative to the flow, tend to react slowly and thus tend to be stable and reliable.

A3. Ease of Operation and Maintenance

The ease with which a technology can be operated and maintained depends on at least the following factors:

- Complexity
- Requirement for skilled operators
- Requirement for skilled maintenance personnel
- Availability of energy
- Availability of equipment and spare parts
- Flexibility
- Compatibility
- Potential for nuisances

Simple systems are preferable to complex systems. Systems that can be controlled reasonably well manually are more likely to function properly than those requiring

complicated automatic control systems. Systems with less mechanical equipment usually are easier to operate and maintain.

Consideration must be given to whether the skills required of the operations and maintenance staff will be available. Often, persons with the skills needed for complicated wastewater facilities command higher salaries elsewhere and thus cannot be attracted or retained. For example, the rate of staff turnover at the Alexandria, Egypt, wastewater treatment plants was once 67 percent per year because staff members with any technical training could get much higher pay in the oil exporting countries. Consequently, it was impossible to keep the equipment in operating condition.

If energy is required for technology, it must be consistently available. If there are frequent or prolonged power outages, a technology which relies on electric energy probably will fail.

Technologies which rely on imported equipment or parts are more likely to have longer down times when equipment fails than those using locally produced materials or equipment.

A wastewater technology needs the flexibility to function under various conditions, as when part of a facility is out of service during construction of additions, under emergency conditions, or under varying flow or load conditions. A particularly important aspect of a flexible wastewater technology is the capacity for future upgrading or expansion. In wastewater treatment plants, flexibility is often dramatically improved by relatively minor additions of piping and valving which allow the wastewater to be routed to more than just the normal points.

Compatibility in wastewater technology is the ability to function well with other wastewater technologies or ancillary facilities. For example, wastewater technologies that involve large ponds are likely to be more compatible with irrigation schemes, since the ponds provide storage for irrigation water.

Finally, consideration should be given to the potential that a technology will create odor, noise, insect problems, or aesthetic or other nuisances.

A4. Land Requirements

The amount of land required for different wastewater treatment technologies varies enormously. Data in Table V-7 show that stabilization pond systems may require around four square meters per user while equipment- and structure-intensive technologies, such as the activated sludge process, may require less than one square meter per user. In essence, in choosing between these alternatives, the designer trades land for equipment and structures. Land-intensive treatment technologies are feasible only where large areas of land are reasonably available at a moderate price.

A5. Costs

In selecting wastewater technology, cost is always a major criterion. In general, costs can be divided into initial (capital) costs and continuing (operation and maintenance) costs. Often there is a trade-off between the two. One alternative may have low initial costs, but high operating and maintenance costs, while a second has high initial costs, but low continuing costs. Where the two types of costs vary, they are usually made comparable by reducing them to present worth. This comparison technique is most useful when site- and design-specific data are available; thus, it was not employed in this analysis. However, it should be emphasized that present worth analysis should be used to determine which site-specific design minimizes costs over the operating life of the treatment plant and thus offers the best opportunity for project sustainability.

B. OVERVIEW OF APPROPRIATE TECHNOLOGIES

As discussed above, it appears that wastewater treatment systems for Tunisia must provide at least a secondary level of treatment to avoid nuisances and to comply with environmental legislation. Discussed below are the three general categories of secondary treatment facilities that appear most appropriate for use in small towns in Tunisia:

- Stabilization ponds
- Aerated lagoons
- Activated sludge

All these processes can produce a secondary effluent of satisfactory quality if properly designed and operated. In other words, the level of treatment is comparable among these alternatives.

On-site systems for areas that are not provided with sewers, and small bore sewers as an alternative to conventional gravity sewers, also show promise for selected use in Tunisia. They are discussed below.

B1. Stabilization Ponds

The stabilization pond technology is defined for the purposes of this report as non-mechanically aerated lagoon systems in general, which can include anaerobic lagoons, facultative lagoons, and/or maturation ponds. Stabilization ponds, also called oxidation ponds, consist of constructed ponds that rely on natural processes for treatment. No electrical or mechanical equipment is required, except for piping and valving. The ponds usually have earthen sides and bottoms, although surfacing of concrete or similar materials on the banks near the waterline can help control weeds, or riprap (large stones) can control erosion. Figure V-1 presents a general schematic of this process.

Stabilization ponds are used at Côte Nord (Tunis), Moknine, Gafsa and El Jem. In the United States, about 7,000 stabilization pond installations are in operation, a technology also widely used elsewhere in the Mediterranean area.

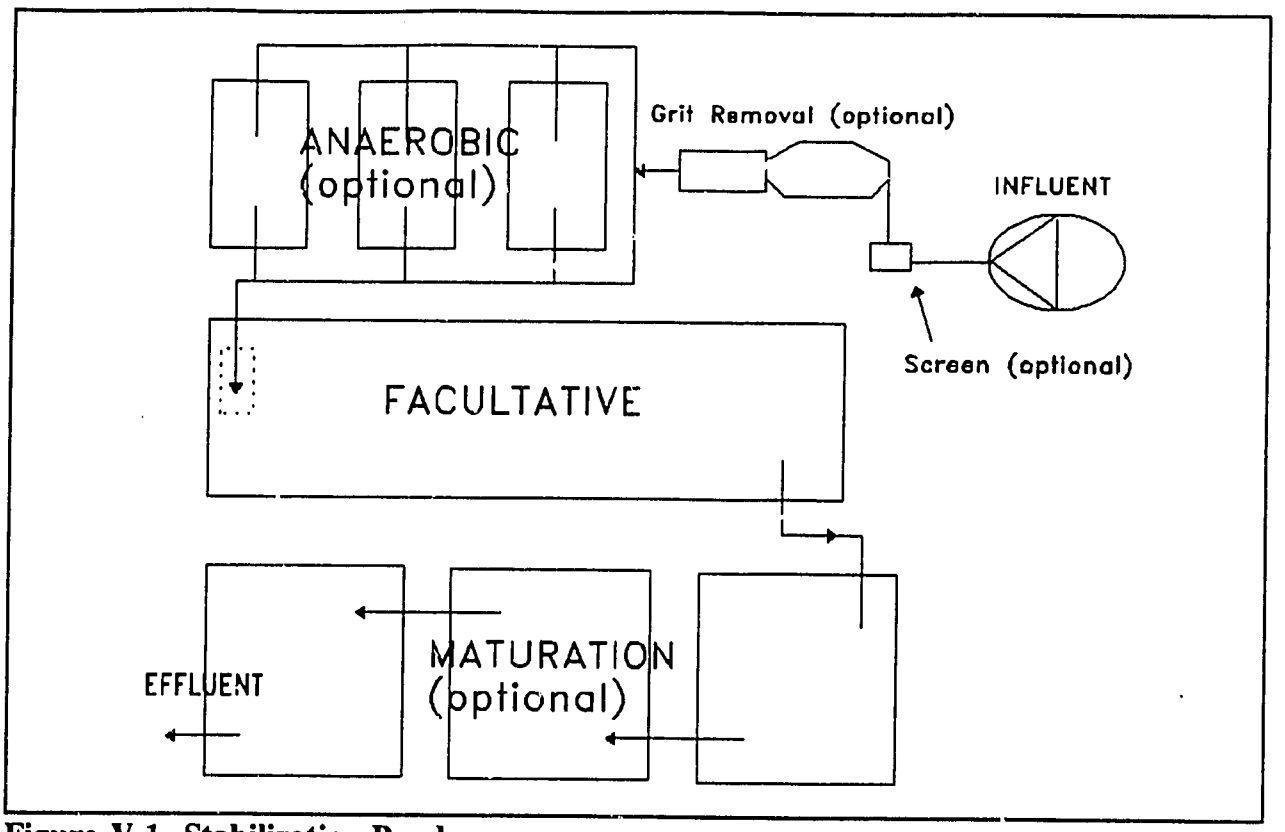

Figure V-1. Stabilization Ponds

To achieve secondary treatment, a minimum detention time of approximately 30 days is usually required. Detention times in maturation ponds are sometimes much longer to allow further die-off of pathogens.

In facultative lagoons a combination of aerobic and anaerobic processes are used. In the upper layers of the lagoon, the wastewater is aerated by transfer of atmospheric oxygen through the surface and the creation of oxygen within the water by algae. The amount of oxygen created by algae usually is much greater than the amount that is transferred through the surface. In the upper and middle levels of the lagoon, bacteria aerobically oxidize the organic pollutants. In the lowest levels of the lagoon, sludge settles and is digested anaerobically.

Because anaerobic lagoons can be loaded more heavily than facultative lagoons per unit of surface area, use of anaerobic lagoons may reduce the amount of land needed for the treatment plant. The major disadvantage of using anaerobic lagoons is the greater risk of odors and insects. The effluent from an anaerobic lagoon is essentially a septic primary effluent and is not suitable for release to the environment without further treatment.

Facultative lagoons can be used as a first treatment unit, or they may follow anaerobic lagoons. Because the surface of facultative lagoons is aerobic, odor nuisances are less likely. However, odors can occur if the lagoon is mixed by high winds or as a result of the inversion of water layers which typically occurs in the spring and autumn due to temperature changes.

Maturation ponds always follow facultative lagoons or other secondary treatment processes and are used primarily to provide long detention times to allow the bacterial quality of the effluent to improve. Since maturation ponds are shallow and lightly loaded, they remain aerobic throughout their depth and rarely cause odor nuisances.

The principal operational requirement of stabilization ponds is an occasional change of the point to which the flow is directed. Maintenance requirements consist mainly of clearing weeds away from the edges to prevent insects, and breaking up any mats of floating materials to prevent them from causing odors. Sludge must be removed from the ponds, but only infrequently (typically once every two to four years from anaerobic lagoons and once every 10 to 20 years from facultative lagoons or maturation ponds). Unskilled labor can do the operations and maintenance.

Mechanical aerators are occasionally added to stabilization ponds as a means to overcome nuisances. The aerators can supplement temporary shortages of oxygen, mix the pond, and break up scum mats. Unless enough aerators are added to completely mix the stabilization pond, it will not be converted into an aerated lagoon.

The advantages of oxidation ponds include the following:

- Simple operation and maintenance, which unskilled labor can perform.

- No requirement for energy, equipment, or spare parts. Because oxidation ponds use natural systems, they continue to operate reasonably well under virtually all conditions.

- A high degree of flexibility and compatibility. Because of the large volume involved, conditions change slowly within the lagoons. Peak flows and loads are dampened out. Slugs of toxic materials are diluted, often to concentrations which cause no serious disturbance of the process. If expanded capacity is required as municipalities grow and conditions require more treatment capacity, stabilization ponds can be easily and inexpensively upgraded to aerated lagoons or activated sludge systems by adding mechanical equipment.

- Better bacteriological quality of the effluent than in processes with shorter detention times, because pathogens die during the long detention time.

The major disadvantage of stabilization pond systems is that they require a large land area. Stabilization pond designs for climates such as Tunisia's usually need about two square meters of land per person served for the treatment processes, a requirement that probably will double when needs for levees, access roads, etc., are considered. Thus, the land requirement for a plant serving a population of 2,000 to 10,000 might range from 0.8 hectares to 4 hectares. The land requirements for the larger installations might be reduced somewhat by using anaerobic lagoons.

Stabilization ponds can also cause odor or insect nuisances, although these can be

controlled to some extent and are usually minor.

B2. Aerated Lagoons

Aerated lagoons are physically similar to stabilization ponds except that mechanical aeration is provided. Historically, they were developed when overloaded stabilization ponds were fitted with mechanical aeration devices to supplement the oxygen that was being supplied by natural means. It was found that soon after the aerators were put into operation the algae disappeared and the microbial flora resembled that of activated sludge. Aerated lagoons are now designed as completely mixed activated sludge systems without sludge return. Figure V-2 presents a general schematic of this process.

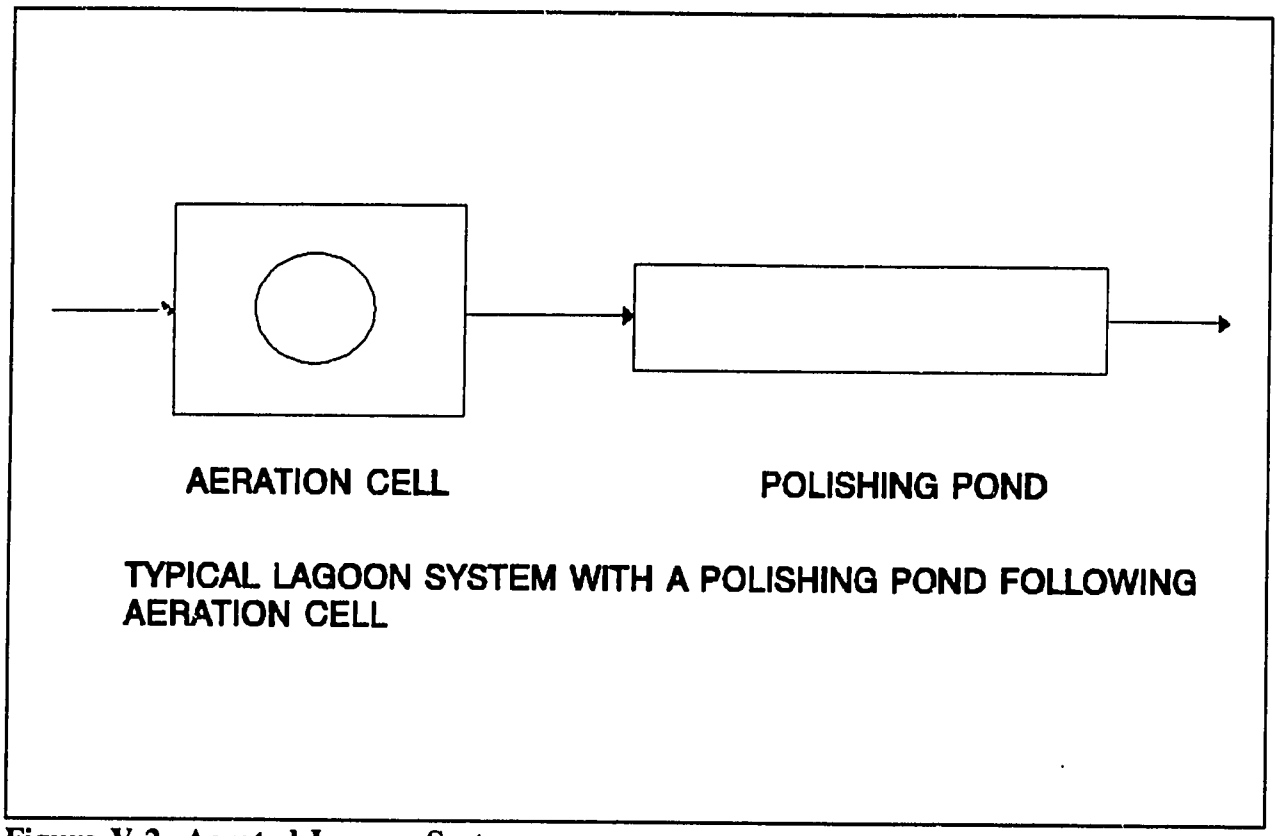

Figure V-2. Aerated Lagoon System

Aerated lagoons are already in use in Tunisia at Sfax and Lella Meriem. Four additional aerated lagoon plants are currently under construction at Houmt Souk, Kasserine, Mehdia, and Tabarka as part of the program for 20 secondary cities.

Aerated lagoons can achieve BOD reductions of greater than 90 percent at detention times of two to six days. Detention times of less than two days are not recommended as they are too short to permit the development of a healthy flocculent sludge. The sludge concentration in aerated lagoons depends upon the strength of the raw wastewater and typically ranges from only 200 to 400 mg/l, as compared to typical concentrations of 2,000 to 4,000 mg/l in activated sludge systems. Fecal coliform reduction is only 90 to 95 percent.

Because an aerated lagoon is highly mixed, the suspended solids concentration in the

effluent is the same as in the basin (i.e., in the range of 200 to 400 mg/l) which greatly exceeds the goal of 30 mg/l. Some sort of unaerated lagoon or clarifier is therefore necessary following the aerated lagoon to allow the activated sludge to settle.

Mechanical aeration can be provided by bubbling air through the wastewater, by surface aerators, and by various types of aspirators, among other methods. The most common aeration device is a floating surface aerator. The mechanical aeration systems are usually electrical, so a reliable source of electric power is required.

The mixing caused by the aeration of the lagoon brings the microorganisms into contact with the organic load in the wastewater which speeds up the digestion process. Aerated lagoons can therefore be loaded at a greater rate than stabilization ponds and require less land. Because of the mixing, the contents of the lagoon are usually sufficiently turbid to allow little growth of algae.

The operational and maintenance requirements of aerated lagoons are similar to those of stabilization ponds, i.e., removal of weeds and breaking up of floating mats, plus operation and maintenance of the mechanical and electrical aeration equipment. The turbulence caused by aeration tends to suppress the growth of weeds and the development of floating mats, hence less of this type of maintenance is usually required than for stabilization ponds. Aerated lagoons are usually designed so that sludge removal is needed only at rather long intervals, every 10 to 20 years, for example.

The main advantage of aerated lagoons over stabilization ponds is that significantly less land is required because the detention times are shorter (typically six days versus thirty) and the pond depths can be greater (typically 3.5 meters versus 2.0 meters). The typical land requirement for the aerated lagoon treatment process, not including the land needed for access roads, operations buildings, etc., is around 0.3 square meter per person served.

The main disadvantages of aerated lagoons over stabilization ponds are the needs for electric power and mechanical and electrical maintenance for the aeration equipment.

B3. Activated Sludge

In the activated sludge process, a mass of aerobic, free floating organisms is mixed with wastewater in an aeration basin. The organisms consume the organic pollutants and reproduce. The mixture of wastewater and organisms, which is called "mixed liquor," is then passed to a settling tank where the organisms settle out. The clarified wastewater is released over a system of weirs. Most of the activated sludge which has settled to the bottom of the clarifier is returned to the head of the aeration basin to treat more wastewater. A portion of the activated sludge is removed from the system as a waste sludge stream to keep the amount of activated sludge organisms in the system stable. Figure V-3 presents a general schematic of this system.

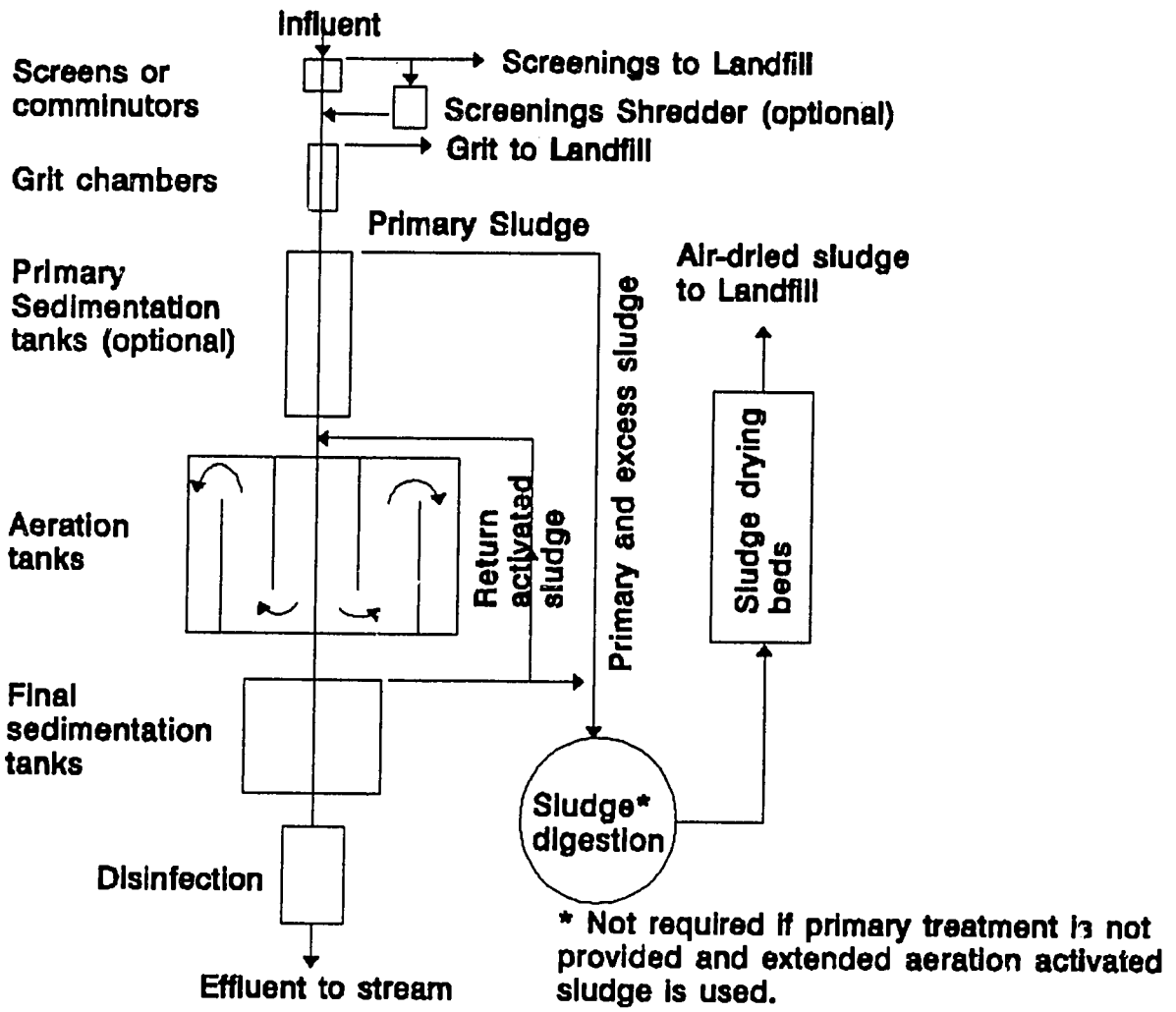

Figure V-3. Typical Complete Activated Sludge Treatment Process

The feature that most distinguishes the activated sludge process from the other two processes is that sludge is returned to the aeration basin. Return of a concentrated stream of organisms from the clarifier allows maintenance of a high concentration of organisms in the aeration tank. The mixed liquor concentrations in activated sludge processes often range from 2,000 to 4,000 mg/l compared to concentrations of only 200 to 400 mg/l in aerated lagoons and even lower concentrations in oxidation ponds. Since the amount of treatment that is achieved is proportional to the concentration of organisms, a much higher level of treatment can be obtained for a given volume of wastewater in an activated sludge process than in an aerated lagoon or oxidation pond process.

There are numerous variations of the activated sludge process. Distinguished on the basis of loading, the two most common variations are conventional activated sludge, with a detention time of approximately four to eight hours, and extended aeration, with a detention time of 24 to 36 hours. Obviously the conventional activated sludge configuration requires a much smaller volume than the extended aeration configuration, since it has a much smaller detention time, but it produces a large amount of sludge that is not stable and is difficult to treat. By contrast, the extended aeration process produces much less sludge and it is relatively stable. Sludge from extended aeration processes usually can be dried on gravity sludge drying beds with little or no odor. Sludge from conventional activated sludge processes normally creates a significant odor nuisance if discharged to sludge drying beds without further treatment.

For smaller flows, it is usually more practical and economical to use the larger extended aeration process without sludge treatment facilities than to use the smaller conventional activated sludge system with sludge treatment facilities. In design practice in the United States, it is rare that the conventional activated sludge process is used for flows of less than 1.0 million U.S. gallons per day (4,000 m^3/da).

An activated sludge system has three major components: the aeration tank, the aeration system, and the clarifier (settling tank or sedimentation basin).

The aeration tanks can be reinforced concrete tanks, earthen basins lined with concrete or a similar material, a lined ditch shaped like a race track, a steel or concrete tank with concentric zones, etc. They can be square, rectangular, or round. The tendency is to consider different shapes of aeration tanks as different types of activated sludge processes. For example, the oxidation ditch is often referred to as a separate process. This is, however, a fallacy. The type of activated sludge process is determined by the amount of organisms relative to the amount of organic load that is applied, not by the configuration of the aeration tank. The ONAS design for a small "package plant" (*variante compacte*), which appears in Annex F, is correctly labeled as using the extended aeration (*aeration prolongée*) process (i.e., the shape of the tankage is not important to the biological process that goes on inside the tank).

The aeration devices that are used can also take many forms. In some of them, air is bubbled into the wastewater through fine or coarse diffusers. Fine bubble diffusers are more efficient because the small bubbles have a larger surface area per unit volume of air, but they

tend to clog more easily than coarse bubble diffusers. Coarse bubble diffusers can be manufactured by merely drilling holes in a pipe, but the efficiency of such systems is low. Aeration can be achieved by surface aerators, which can take the form of a large impeller that sprays the wastewater out in thin sheets, or of brushes which splash through the surface of the wastewater. Various kinds of aspirated (jet) aerators are also available. Often the type of aeration device is related to the configuration of the aeration tank; for example, the brush aerator is often used with the oxidation ditch tank configuration because the configuration of the brush keeps the wastewater in motion around the race track-shaped ditch. Aeration devices can be fixed or floating. Fixed devices are often easier to access and service because they usually have service platforms, but they may require removal of the aeration tank when the lower parts of the aerator are being serviced. Floating aeration devices can usually be removed and serviced without emptying the tank.

The clarifier portion of the activated sludge process is also available in numerous configurations. Traditionally, it has been a circular or rectangular tank, separate from the aeration tank. The clarifier can, however, be built into a portion of the aeration tank, such as in the configuration of the patented Biolac system, or float in the aeration tank, in which case it is sometimes referred to as a *boat clarifier*. Except in very small clarifiers, there usually is some sort of moving mechanical sludge removal equipment. Some sludge removal devices scrape sludge to a hopper from which it is sucked to pump. Other sludge removal devices suck up the sludge with large amounts of water.

Because of the large number of possible combinations of aeration tanks, aeration systems, and clarifiers, and because of the sometimes unpredictable performance of activated sludge systems, their design is very complex and requires a great deal of practical experience, as well as a theoretical understanding of the process.

Approximately 40 of the existing and under construction plants utilize some form of the activated sludge process, which is widespread in Tunisia.

The main advantage of activated sludge systems is that they are compact. The area needed for the treatment processes alone is approximately 0.2 square meters per person served, but the total land area required is much larger. The activated sludge process is so compact that the amount of land needed for access roads, operations buildings, pump stations, etc. is relatively large compared to the area used by the treatment process alone. Due to the compact nature of the activated sludge process, a large amount of treatment can be performed in a relatively limited space. A minor advantage is that activated sludge processes have less potential to cause odor or insect problems.

The major disadvantages of activated sludge systems include:

- High capital and operating costs
- The need for skilled operators and maintenance personnel
- The need for large amounts of energy
- The need for imported equipment and spare parts

A minor disadvantage is that their relatively short detention times reduce the concentration of pathogens much less than the longer detention times involved in aerated lagoon and stabilization pond technologies.

Because activated sludge systems are complicated and costly, consideration should be given to pumping the wastewater to a remote site where a simpler technology can be used.

B4. Onsite Systems

Sewerage systems become prohibitively expensive where the population density is low. For areas of low density, and even for densely settled parts of towns where a sewerage system is not yet available, on-site sanitary systems are the only practical solution for providing adequate sanitation.

In general, the two types of onsite systems are waterborne and dry. Waterborne systems commonly include septic tanks with leach fields or cesspools, although some have holding tanks from which wastes are trucked. Dry systems involve pit privies or latrines. These systems are described well in various publications (Kalbermatten, 1980) and will not be covered in detail here. The Kalbermatten publication is available in French.

Various types of onsite systems are already widespread in Tunisia where sewer systems are not available. In such areas, people frequently discharge their gray water to the public streets, but both law and custom reportedly forbid the discharge of water from toilets. The residents of areas that have a piped water supply but not a sewer system are thus already using some sort of onsite system, at least for the wastewater from toilets. Although investigation of these onsite systems was beyond the scope of this assignment, earlier literature has reported that some houses have holding tanks, from which little leaching occurs, and thus wastewater must be trucked away frequently and at high cost.

As discussed elsewhere in this report, the national sanitation strategy in Tunisia envisions every town with a population of 2,000 or more with water piped into all houses and a waterborne sewerage system. The general public appears to anticipate that waterborne sewerage will ultimately be available, because virtually every new house built in Tunisia has a water-flushed toilet. As a result, public acceptance of dry sanitation (privies) is unlikely.

The national sanitation strategy also envisions that ONAS will be responsible for having all the sewerage systems designed and for operating the ones in larger towns. Because of its role as the leading wastewater technical agency in Tunisia, it seems logical that ONAS should be a source of technical information about onsite systems, even though it will not design, construct, or operate these systems.

B5. Small Bore Sewers

Small bore sewer systems are not known to exist in Tunisia. While they may prove useful in certain situations, their use is recommended only in a limited fashion until greater

experience is acquired under Tunisian conditions. Their principal features are discussed here.

Small bore sewers are designed to receive only the liquid portion of wastewater for off-site treatment and disposal. Grit, grease, and large solids are separated from the wastewater in an interceptor tank, which often is a conventional septic tank upstream from the small bore sewer system. Because small diameter sewers carry only liquid, they do not have to follow the hydraulic grade line, i.e., they need not slope continuously downward. They may even run uphill in places, as long as they remain below the hydraulic grade line. Often this results in shallower trenches than are feasible with conventional gravity sewers. Because of the storage available in the interceptor tanks, the diameters can be smaller, which also reduces the trench sizes required.

Design criteria are presented in various publications (Otis, 1980; EPA, 1980) and will not be repeated here.

Extreme care must be taken to avoid introducing large solids into a small bore sewer system. One precaution is to limit the size of the outlet pipe from the interceptor tank to no larger than the sewer pipe. Strict enforcement of prohibitions against illegal connections usually is needed but may be difficult to arrange. Because the local population is accustomed to large diameter gravity sewers, they may illegally connect to a small bore sewer system not realizing that large solids from the raw sewage will quickly plug up the system.

The frequent problem of excessive sand in the sewers is of special concern. While the interceptor tanks in a small bore sewer system should remove the sand that reaches them, the existing conventional sanitary sewers also should not receive large amounts of sand. The fact that they appear to be receiving excessive sand indicates that storm drains are connected to the sanitary sewer systems or that the pipes are broken in places. Because of the small size of small bore sewers it is difficult to clear blockages from them. It may be virtually impossible to clear out significant amounts of sand if it collects at low points in the system.

The major operational requirement for small bore sewer systems is regular pumping of the interceptor tanks and disposal of the septage from these tanks.

Because the continuing cost of pumping the collector tanks is relatively high, the life cycle costs of small bore sewer systems may equal or exceed those of conventional sewers. Capital costs are site-specific and vary considerably, but usually are less than those for conventional sewers. Much of the cost savings for the sewers is offset, however, by the cost of the interceptor tanks which must precede the small bore sewers. Some savings are usually achieved at the wastewater treatment plant since screening, grit removal, and grease removal facilities are usually not needed because the interceptor tanks have removed all but the liquid component of the flow. The savings at the wastewater treatment plant will be largely offset, however, if septage from the interceptor tanks is trucked to the plant.

The operating costs will be significantly higher for small bore services than for conventional sewer systems due to the need to pump the septic tanks.

Small bore sewer systems may be especially suitable in the following situations:

- When costs of conventional sewerage are high due to a high groundwater table, rolling terrain, rock close to the surface, and/or low population densities. Most of these conditions, except for high groundwater near the coast, do not appear to occur often in Tunisia.

- When existing towns are very congested, with narrow streets that leave little room for conventional sewers (for example, Egyptian villages).

- When septic tank systems are in place but the leach fields have failed.

In general, small bore sewer systems appear to be a less attractive choice in Tunisia than in other countries for these reasons:

- Most smaller Tunisian towns seem to be built on hills, where natural slope is such that conventional sewers can parallel the surface slope and need not be very deep.

- Due to the universal town planning in Tunisia, the streets are wide with plenty of room for conventional sewers.

Because the effect of excessive sand on small bore sewers is unknown, because the local population is unfamiliar with small bore sewers, and because this technology is new in Tunisia, small bore sewers are an experimental technology. Small bore sewers should be substituted for conventional sewers only in carefully considered situations and limited applications until experience with them is gained under Tunisian conditions.

B6. Less Appropriate Wastewater Treatment Technologies

Numerous other technologies considered during the fieldwork in Tunisia were discussed with Tunisian engineers. For various reasons, most were deemed less appropriate for use in Tunisia than the technologies presented above (in some cases based on additional information developed after the PRIDE project team left Tunisia).

The less appropriate technologies are discussed briefly in Annex G.

C. Comparison of Secondary Treatment Alternatives

The three secondary treatment alternatives which were presented above (stabilization ponds, aerated lagoons, and activated sludge) are compared below. A summary of the comparison is presented in Table V-1. Onsite sewer systems and small bore sewers serve other functions than secondary treatment and thus are not included in this comparison.

Table V-1. Summary of Comparison of Technical and Operational Considerations for Secondary Treatment Alternatives

Criterion	Stabilization Ponds	Aerated Lagoons	Activated Sludge
Level of Treatment	Secondary. Occasional excursions of algae.	Secondary. Settling required.	Secondary
Reliability	Very high	High	Moderate
Ease of Operation and Maintenance	Very easy	Easy	Difficult
Complexity	Very low	Low	Very high
Personnel Skill Levels Required	Very low	Low	Very high
Energy	Not required	Required, but occasional interruptions can be tolerated.	Required continuously and in large amounts.
Equipment and Spare Parts	Not required	Modest requirement	Large amounts required
Flexibility	High	High	Low
Compatibility with Irrigation	High	High	Low
Potential for Nuisances	Moderate	Moderately low	Low
Land Requirements	Very high	Moderate	Very low

C1. Technical and Operational Considerations

Level of Treatment. Stabilization ponds, aerated lagoons, and activated sludge systems all can provide secondary levels of treatment, i.e., BOD and suspended solids concentrations of 30 mg/l or lower, if properly designed and operated. Stabilization ponds occasionally discharge higher levels of suspended solids and BOD in the form of algae, especially during spring and autumn when the upper and lower levels of facultative ponds tend to turn over. Although the BOD and suspended solids in the algae cells technically violate the discharge requirements, they tend to be less offensive than similar quantities of BOD and suspended solids in raw wastewater. Based on the observations of discharges in Tunisia, it appears that occasional excursions above the specified concentrations of 30 mg/l would do little harm.

Because of their relatively long detention times, stabilization ponds tend to reduce the level of pathogenic organisms more than aerated lagoon or activated sludge systems, which may be important in Tunisia since disinfection is not practiced.

Reliability. All three processes are used in Tunisia, although activated sludge systems are more common than either aerated lagoons or stabilization ponds.

Because of their large volume capacities, stabilization ponds and aerated lagoons handle peak loads and flows well. In contrast, activated sludge systems are sensitive to peak loads and flows. Peak organic loads may exceed the capacity of the aeration systems, causing the system to go anaerobic and allowing the activated sludge to die. Peak flows can sweep the activated sludge out of the final clarifiers, which stops the process.

Discharges of toxic materials into the wastewater stream are more likely to affect activated sludge systems than aerated lagoons or stabilization ponds since the large volumes in the latter two processes tend to dilute the toxic material as it enters the wastewater treatment plant.

The availability of energy, equipment, and spare parts greatly affects the reliability of activated sludge systems since they involve much equipment. Stabilization ponds are unaffected by the availability of energy, equipment, and spare parts since they contain no equipment. Aerated lagoons are somewhat affected if energy, equipment, or spare parts are unavailable but only in a limited way and only if these components are unavailable for protracted periods.

Complexity. Activated sludge systems are complex, with numerous pieces of equipment critical to the operation of the system; the operational requirements are similarly complex. By contrast, the oxidation pond technology involves no mechanical or electrical equipment other than piping and valving. The aerated lagoon technology is only slightly more complex, requiring an aeration device.

Requirement for Skilled Personnel. Activated sludge systems require skilled operations and maintenance personnel. It may be very difficult to find and retain such personnel in small Tunisian towns, since they often can find higher paying jobs in treatment plants in the larger cities or other industries.

The two primary operation and maintenance tasks for a stabilization pond are cutting weeds and breaking up floating mats. Unskilled labor can perform these and the other tasks required. Aerated lagoons require similar operation and maintenance, except that the mechanical/electrical aeration system must also be operated and maintained, which requires more skill.

Availability of Energy. Power is generally available and reliable in Tunisia; hence, energy is not a major constraint in the selection of wastewater treatment processes. As noted above, however, a power failure has no effect on stabilization ponds, and a limited effect on aerated lagoons, but a major effect on activated sludge systems.

Availability of Equipment and Spare Parts. To date, most equipment used in wastewater treatment facilities in Tunisia has been imported. The needed equipment and spare parts might be unavailable in the future, however, due to a shortage of foreign exchange or because the manufacturer has gone out of business or no longer makes the model used in Tunisia. Obviously, activated sludge systems depend heavily on the availability of equipment and spare parts, but stabilization ponds are totally unaffected. Aerated lagoons are more affected than stabilization ponds since they contain aerators, but they usually are relatively simple devices and one type can easily substitute for another.

Flexibility and Compatibility with Irrigation. In general, stabilization ponds and aerated lagoons are more flexible than activated sludge systems. The treatment capacity of stabilization ponds can be increased by isolating a portion of the ponds as an anaerobic first stage or by adding aeration equipment and converting part or all of the stabilization pond system to an aerated lagoon system. The capacity of an aerated lagoon system can be increased by adding more aerators. To expand the capacity of an activated sludge system, however, it usually is necessary to build an additional parallel treatment train, which is relatively costly and time-consuming.

Stabilization ponds and aerated lagoons are compatible with irrigation schemes since they have a large capacity to store treated water. Activated sludge systems have a steady throughput and no storage capacity, which is not especially compatible with irrigation needs since these tend to be intermittent.

Nuisances. Because activated sludge processes have a high degree of mechanization and control, they have relatively low potential for causing odor or insect nuisances. Stabilization ponds often create minor odor nuisances, particularly on a seasonal basis, and can create insect nuisances, especially if weeds are allowed to grow around the edges. The potential for nuisances from aerated lagoon systems is similar to that from stabilization ponds except that the aeration systems provide some control.

C2. Economic Considerations

The costs of secondary treatment facilities depend on site-specific factors. Capital costs vary considerably depending on the length of trunk sewer that is needed to get from the town to the site of the treatment plant, the topography of the terrain, and soil conditions. Earthwork at a site that is constricted, steep, rolling, and/or cut by drainage courses (wadis) may be several times more expensive than earthwork at a relatively open and gently sloping site. Rock or a high groundwater table at the site also dramatically increase the cost of earthwork. Finally, the per capita capital cost of wastewater treatment facilities varies considerably with scale. Large treatment facilities generally have much lower per capita capital costs than small treatment facilities.

Operation and maintenance (O&M) costs also vary significantly from facility to facility, depending on the level of service. For the small towns considered in this project, a major determinant of O&M costs probably is whether they must have an entirely separate staff for the wastewater facility or whether existing staff such as the SONEDE personnel who

operate the water system or the municipal staff can care for the wastewater facility part time. There are usually large economies of scale in the O&M costs, (i.e., the per capita O&M cost for a large facility is lower than for a small facility).

C2a. Per Capita Capital Costs

As discussed above, reasonably detailed capital and O&M costs probably can be developed only on a case by case basis, taking into consideration the specific characteristics of a given site. Development of such detailed costs was beyond the scope of this study; however, some cost data were obtained from Tunisia and elsewhere which provide a general insight into the probable level of costs that may be encountered. Per capita capital cost data are presented in Table V-2 and are discussed below. Except as otherwise noted, none of the capital costs include the cost of land.

Table V-2. Capital Costs of Wastewater Treatment Facilities ($US/Capita)

Source	Stabilization Ponds	Aerated Lagoons	Activated Sludge
Arthur, J. (1983)*	19 - 31	46 - 55	
SOTINFOR/ SERAH (1992)	55 - 125		
Plants under construction (from V-3)		35	62
ONAS, range**	56 - 89	67 - 100	111 - 156
ONAS, pricing**	78	111	111

The values shown are indicative only and not directly comparable. See text.

* Figures derived from this source were adjusted to 1991 dollars assuming a 5% p.a. cost escalation.

** Figures provided by ONAS to team are presumably recent but year is not known.

According to a report prepared for the World Bank (Arthur, 1983) capital costs in an area somewhat similar to Tunisia were:

- $US19/capita to $US31/capita for stabilization ponds
- $US46/capita to $US55/capita for lagoons with partial aeration
- $US86/capita to $US94/capita for aerated lagoon systems with polishing ponds

These figures have been adjusted to 1991 dollars assuming 5 percent per annum cost escalation.

Volume 2 of Report A1 of the recent feasibility study in Tunisia (SOTINFOR/ SERAH, 1992), page 104, reviewed the capital costs of the facultative lagoons at Gafsa and El Jem and of two prototype designs, deriving the following formula for the cost of facultative lagoon systems:

$$\text{Cost} = 24{,}700 \ (\text{Daily BOD load in kg})^{0.53}$$

Using this formula, the per capita cost of facultative lagoons ranges from approximately $US55 to $US125 per capita for towns of 10,000 to 2,000 population. The facultative lagoon at El Jem, which was the closest in size to the facilities that will be needed in the small towns, had a unit cost of about $US45 per capita. The SOTINFOR/SERAH study had relatively few data on facultative lagoons, and the data that were available were for considerably larger plants than needed in small towns. The accuracy of the above equation is therefore questionable.

Capital cost information on the 20 wastewater treatment projects now under construction in the secondary cities in Tunisia is presented in Table V-3 on the following page. Four of these cities will use aerated lagoon technology. The average cost per capita for these four systems was estimated at 312 Tunisian dinars per m^3/da of capacity. Assuming 100 liters per day per capita (lpcd) and a conversion rate of 0.9 TD/$US, the average unit cost of these four aerated lagoon systems is $35US, which is somewhat more economical than Arthur reported but in the same general range.

Using the same assumptions as above, the average per capita costs of the other plants now under construction in the secondary cities of Tunisia was US$62 for extended aeration and US$75 for oxidation ditches. The extended aeration cost has been entered in Table V-3.

The ONAS staff has proposed in their Urgent Wastewater Treatment Program proposal (see Annex H) the following range of per capita capital costs for wastewater facilities:

Type of Treatment	Capital Cost $US/capita
Facultative lagoons	56 to 89
Aerated lagoons	67 to 100
Extended aeration activated sludge	111 to 156

To estimate the cost of the proposed urgent program (see Annex H), ONAS used per capita capital costs of $US78 (70TD) for stabilization ponds with aerators and $US111 (100TD) for aerated lagoons and activated sludge systems. The source of these prices is not mentioned in Annex H. The price of aerated lagoons is expected to be closer to the prices of stabilization ponds than to the price of activated sludge systems.

TABLE V-3. COSTS OF WASTEWATER TREATMENT PLANTS UNDER CONSTRUCTION IN TUNISIA

(Les Nouvelles Stations d'epuration)

Cities (Villes)	Characteristics of the Plant (Caracteristiques de la station			Cost of Civil Works (Cout GC) 1000 DT	Cost of Equip-men (Cout Eq.) 1000 DT	Total Cost (Cout total) 1000 DT	Design Engr. (Bureaux d'etudes)	Cost of Capacity DT/m3/ Day
	Type	Design Flow (Debit) m3/day	Design BOD Load (Charge) kgBOD5/day					
Mahres	OD	780	400	447	286	733	ICN	940
Ouardanine	OD	1160	600	515	428	943	ICN	813
Sayada	OD	1160	600	501	428	929	ICN	801
Kalaa Saghira	OD	1450	500	476	357	833	ICN	574
Zarzis	OD	1330	600	635	428	1063	ICN	799
Sahline	OD	2560	750	607	445	1052	ICN	411
Sidi Bouzid	OD	2100	900	960	213	1173	ICN	559
Grombalia	OD	2445	1050	558	623	1181	ICN	483
Menzel Bouzelfa	OD	1395	700	557	415	972	ICN	697
Soliman	OD	1257	700	597	415	1012	ICN	805
El Jem	OD	1840	600	769	200	969	ICN	527
Nefta	OD	1335	600	599	400	999	ICN	748
Ksour Essef	OD	1381	500	416	400	816	ICN	591
Houmet Essouk	AL	3500	1500	600	724	1324	SC	378
Kasserine	AL	15000	7500	959	1494	2453	SC	164
Mehdia	AL	10220	4500	1237	1780	3017	SC	295
Gabes	EA	17260	9050	2227	3200	5427	SC	314
Beja	EA	14000	7800	3300	3450	6750	DOR	482
Jendouba	EA		3400	2130	2832	4962	DOR	649
Mejez el Bab	EA		1970	1570	1886	3456	DOR	780
Tabarka	AL		1825	1060	1199	2250	SC	409

Source: Table provided during team visit

Abbreviations:
OD: Oxidation Ditch
AL: Aerated Lagoon
EA: Extended Aeration
DT: Tunisian Dinars (Dinars Tunisien)
ICN: Ing. Conseil Neerlandais
SC: Scandiaconsult (Sweden)
DOR: Dorsch (Germany)

Average Cost of Capacity by Type of Treatment

	TD/ M3/Day	TD/ Capita	$US/ Capita
Aerated Lagoons	312	31	35
Extended Aeration	556	56	62
Oxidation Ditches	673	67	75

Assumption: Per capita consumption is 100 liters per capita per day.

CONCLUSION: The per capita cost of extended aeration and oxidation ditch facilities is about twice as much as for aerated lagoons.

Because the size of the facility dramatically affects per capita cost, and site conditions similarly affect lagoon systems, it is difficult to generalize about per capita costs for a given facility. However, based on the data from the plants under construction in Tunisia (see Table V-3), it appears that the capital costs of activated sludge systems are about twice those of aerated lagoon facilities.

C2b. Per Capita Operation and Maintenance (O&M) Costs

According to the World Bank report (Arthur, 1983), the annual per capita O&M costs (adapted to 1991 dollars) in another Mediterranean country were as follows:

- $US1 for stabilization ponds
- $US10 to $US22 for aerated lagoons

Data on O&M costs at existing wastewater treatment plants in Tunisia, extracted from the World Bank feasibility study (SOTINFOR/SERAH, 1992) and the ONAS annual report (ONAS, 1991), are summarized in Table V-4. The per capita O&M cost at Lella Marie, the smallest aerated lagoon facility in Tunisia, was 9.664 TD/capita/year, (i.e., about $US11/capita/year), in 1989, which is in the same range reported by Arthur. By contrast, the average unit O&M cost in 1989 and 1990 for the four facultative lagoon systems shown in Table V-4 was only 0.907 TD/capita/year, i.e., about $US1/capita/year. For comparison, this O&M cost and the average unit O&M costs from Table V-4 (on the following page) for other treatment technologies are summarized below:

Treatment Technology	O&M Costs $US/Capita/Year
Facultative Lagoons	1.00
Oxidation Ditches	2.80
Extended Aeration Activated Sludge	3.10
Conventional Activated Sludge	6.70

Considerable care must be taken in using the data presented above. First, the reported O&M costs appear to be low based on information available from other countries, although the O&M cost of facultative lagoons matches that reported by Arthur. Second, the data are averages of the data from individual plants which vary widely in size. The low level of reported O&M costs may indicate that the systems are not being adequately maintained. As the systems age, more maintenance may be required. O&M costs are also known to vary significantly with differences in scale. Generally, O&M is much less costly per capita in large plants than in small ones; thus, average unit costs over both large and small plants may not necessarily be valid. The plants in Table V-4 are arranged in order of increasing flow. It can be seen that the higher unit O&M costs tend to be near the top of the list, i.e., at the plants with smaller flows. Specifically, it can be noted that the O&M cost is above 3TD/capita/year for nine of the 11 plants with the smallest flows, while none of the nine plants with the largest flows has an O&M cost as high as 3TD/capita/year.

TABLE V-4 OPERATIONS & MAINTENANCE (O&M) COSTS AT EXISTING WASTEWATER TREATMENT PLANTS IN TUNISIA
(Couts d'Exploitation)

Station	Flow (Debit) 1990 1000 m3/ day	O&M Costs 1989 TD/cap/yr (1)	O&M Costs 1990 TD/cap/yr (2)	Average O&M Costs TD/cap/yr (3)	Type
El Ghedir		0.551	0.610	0.581	?
Tanit	0.138	11.674	16.306	13.990	TF
Lalla Mariam	0.578	9.664		9.664	AL
Suihel	1.014	11.169		11.169	ASC
SE3, Nabeul	1.253	4.286	5.523	4.905	OD
Dar Jerba	1.510	8.023	10.478	9.251	ASC
Sidi Slim	1.707	12.375	12.724	12.550	ASC
SE1, Nabeul	2.019	4.718	3.903	4.311	ASEA
Sidi Mehrez	2.069	5.526	4.524	5.025	ASC
Moknine	3.228	0.762	0.750	0.756	FL
SE2, Nabeul	3.428	2.755	3.343	3.049	ASEA
Rades	3.719	0.574		0.574	FL
Dkhila	4.286	2.330	3.240	2.785	ASC
Gafsa	4.469	0.681	0.765	0.723	FL
SE4, Nabeul	7.929	1.300	1.587	1.444	ASC
Kairouan	12.951	0.900	1.010	0.955	ASEA
Cotière Nord	13.757	1.886	1.262	1.574	FL
Sud Meliane	26.591	1.606		1.606	OD
Charguia	31.113	1.027		1.027	ASC
Choutrana	76.437	0.792	1.115	0.954	OD
Source*	1	3	3	4	2

NOTES:
(1) Couts d'exploitation 1989, DT/Eqh/an
(2) Couts d'exploitation 1990, DT/Eqh/an
(3) Couts moyens d'exploitation, DT/Eqh/an

ABBREVIATIONS:
SE1 = Treatment Station (Station d'Epuration) #1
ASC = Activated Sludge (Conventional) (Boue activee a moyenne charge)
ASEA = Activated Sludge - Extended Aeration (Boue activee a faible charge)
AL = Aerated Lagoon (Lagunage aere)
FL = Facultative Lagoon (Lagunage Facultatif)
OD = Oxidation Ditch (Chenal d'oxydation)
TF = Trickling Filter (Filtre bacterien)

*Sources of information:
1. ONAS, Rapport Annuel D'Exploitation des Stations d'Epuration, 1990, Page 15.
2. ONAS, Rapport Annuel D'Exploitation des Stations d'Epuration, 1990, Page 7.
3. Sotinfor/Serah, Etude de Factibilite D'Assainissement 2001, Rapport A1, Volume 3, Les Stations d'Epuration, 1992, Table 5-1, Page 81
4. Average of the two previous columns, without escalation of 1989 prices.

To reduce the effect of the size of the plants on the analysis, the O&M costs presented in Table V-4 for plants ranging in actual flow in 1990 from 2,000 to 5,000 m^3/da were extracted and placed in Table V-5 for analysis. Four activated sludge plants and three facultative lagoon plants have flows in this range. The average per capita O&M costs for plants of similar size were found to be:

Treatment Technology	O&M Costs $US/Capita/Year
Facultative lagoons	0.76
Activated sludge systems (all types)	4.21

TABLE V-5. OPERATION & MAINTENANCE (O&M) COSTS AT PLANTS WITH FLOWS OF 2,000 TO 5,000 CUBIC METERS/DAY (Couts d'Exploitation)

Station	Flow (Debit) 1990 1000 m3/ day	O&M Costs 1989 TD/cap/yr (1)	O&M Costs 1990 TD/cap/yr (2)	Average O&M Costs TD/cap/yr (3)	Type
SE1, Nabeul	2.019	4.718	3.903	4.311	ASEA
Sidi Mehrez	2.069	5.526	4.524	5.025	ASC
Moknine	3.228	0.762	0.750	0.756	FL
SE2, Nabeul	3.428	2.755	3.343	3.049	ASEA
Rades	3.719	0.574		0.574	FL
Dkhila	4.286	2.330	3.240	2.785	ASC
Gafsa	4.469	0.681	0.765	0.723	FL

See Table V-4 for notes.

Average O&M Costs By Type of Treatment

	TD/Cap/ Year	$US/Cap/ Year
Facultative Lagoons	0.684	0.76
Activated Sludge Processes	3.792	4.21

The O&M costs of aerated lagoons will be higher than those of facultative lagoons because of the added costs of electricity, but still significantly lower than the O&M costs of activated sludge systems.

C3. Priority Ranking of Appropriate Secondary Treatment Technologies

Based on the cost data and the discussions presented above, per capita costs have been roughly estimated for stabilization ponds, aerated lagoons, and activated sludge plants They are presented in Table V-6. Because these figures are site-dependent and very approximate, they should be used only for general planning purposes. In particular, the O&M costs appear to be too low, although they are based on Tunisian data. As noted above, this may result from somewhat less than adequate maintenance levels.

Table V-6. Suggested Per Capita Costs for Use in Preliminary Planning

	Stabilization Ponds	Aerated Lagoons	Activated Sludge
Capital costs $US/capita	50	75	125
Operation & Maintenance Costs $US/capita per year	1.00	2.00	4.00

The values shown have been roughly estimated based on figures presented in Table V-2 for use in planning purposes and may not be applicable at a specific site. See text.

One point to note is that the technologies with the lowest capital costs also have the lowest O&M costs. Thus, a present worth analysis will not change the relative ranking of the technologies.

As noted in the text, a key difference between the lagoon technologies (stabilization ponds and aerated lagoons) and the activated sludge technology is that the former require larger amounts of land, and it is often suggested that lagoon technologies cannot be used near heavily built up areas because the price of land is too high. The World Bank feasibility study (SOTINFOR/SERAH, 1992, Volume 2, page 104) estimated the cost of land at 60,000TD/ha in suburban areas, 30,000TD/ha in rural zones, and 15,000TD/ha in rural zones with minimal value for agriculture, i.e., about $US6, $US3, and $US1.50 per square meter, respectively.

Using these land cost values and the amounts of land required per capita by each technology (which were presented earlier), the per capita land costs for various treatment technologies at various land costs have been estimated and are presented in Table V-7. The total per capita capital costs, including land costs, of the secondary treatment technologies at different land costs are presented at the bottom of Table V-7.

An interesting conclusion from the data in Table V-7 is that even when the cost of land is considered, the stabilization pond technology is still more advantageous economically than technologies that require more equipment and structure. This conclusion suggests that

stabilization ponds should be strongly considered as the technology of choice, even for larger towns.

Table V-7. Total Per Capita Capital Costs Including Land

	Stabilization Ponds	Aerated Lagoons	Activated Sludge
Capital Cost of Treatment Facilities*[1]	50	75	125
Land Required** Square Meters/Capita	4.0	0.6	0.4
Land Cost Per Square Meter (1992)*[2]			
Urban	6.00	6.00	6.00
Rural	3.00	3.00	3.00
Low Value Rural	1.50	1.50	1.50
Land Cost Per Capita*			
Urban	24	4	2
Rural	12	2	1
Low Value Rural	6	1	-
Total Cost of Treatment Facilities With Land*			
Urban	74	79	127
Rural	62	77	126
Low Value Rural	56	76	125

*$US/capita

**The total land area in this table is assumed to be twice the area quoted in the text as required for the treatment process alone. The additional land is needed for access roads, operations buildings, etc.

[1] From Table V-6, Section V.

[2] Source: SOTINFOR/SERAH, 1992.

SECTION VI
RECOMMENDED IMPLEMENTATION PROGRAM

The strategy, institutional arrangements, and appropriate technologies for wastewater treatment systems in small Tunisian towns have been discussed in previous sections of this report. This section presents a recommended pilot program to implement the planning, design, and construction of wastewater treatment facilities in small towns. The term *pilot* is used in this report because it is in the scope of work for the assignment and elsewhere. The term often implies that the program is unproven, but in this report, it means the first stage of implementation. It does not mean unproven.

The objectives of the pilot program recommended in this section are:

- To develop within ONAS the capability to effectively and efficiently plan and oversee the design of wastewater facilities for small towns.

- To demonstrate this capability by actually constructing a few wastewater treatment facilities in small towns, i.e., to establish a track record.

The staff of ONAS developed a list of 44 towns, from among the 119 covered by this report, to which they assign the highest priority for receiving wastewater treatment services during the implementation program. The criteria they used to prioritize these towns and the cost estimates they derived are included in Annex H.

A. Changes in Emphasis

The implementation program recommended here is generally quite similar to the one used in the past, with two major changes of emphasis. First, to successfully design stabilization pond and aerated lagoon systems for small towns, it is necessary to develop both a "think-small" approach and special expertise with small treatment facilities.

Second, it is believed that if the stabilization pond and aerated lagoon technologies are used, virtually all the planning and design work could be done in-country using Tunisian engineers and firms, rather than foreign consultants.

In the past, foreign consultants have designed the major wastewater treatment facilities in Tunisia. In the course of working with these consultants, ONAS has developed a competent engineering staff. The ONAS engineering staff has begun to gain design experience by designing two treatment plants with minimal assistance from abroad. It is believed that with some additional experience and training, the ONAS staff could do the preliminary design and oversee a program that has stabilization pond and aerated lagoon facilities designed for small towns by Tunisian consulting firms.

Because the design of activated sludge systems is much more complex, foreign engineering experts may be needed for a few more years to help design activated sludge systems.

The belief persists that small wastewater facilities are easier to design than large ones but it is generally unfounded. In fact, it may be more difficult to design small facilities than large ones because resources of all types are severely restricted at a small facility and the design may require much more ingenuity. By focusing on the special needs of small facilities, the design staff gains extensive experience with the practical features and limitations of small facilities and develops an ability to think on a small scale, (i.e., to select design solutions appropriate for small facilities). However, it is difficult to reorient engineers who are experienced with large facilities.

B. Planning and Engineering

B1. Establishment of Small Projects Design Team

It is recommended that ONAS establish a Small Projects Design Team (SPDT) within its existing design section to oversee the design and construction of stabilization pond and aerated lagoon systems in small towns. Following are the specific responsibilities which such a team should have:

- Prepare and maintain priority lists of towns where wastewater treatment plants should be built next.

- Evaluate the availability of land to determine if stabilization ponds or aerated lagoons are feasible.

- For towns where stabilization ponds or aerated lagoons are the most appropriate technology, select a site and prepare a preliminary design for the facility. The design will include a general site plan, the treatment processes to be used (for example, two anaerobic lagoons in parallel, one facultative lagoon at present with another in the future, and three maturation ponds at present and three more in the future), the design criteria and/or major dimensions of the treatment facilities, and an approximate hydraulic profile.

- Contract out the detailed design of the facilities (grading plans, structural plans, electrical plans, etc.) to private Tunisian consulting firms.

- Review the designs and tender documents prepared by the private consulting firms.

- Acquire the land needed for the treatment plant.

- Let the project out for bidding by local contractors. Select the lowest responsible bidder, and award a contract for construction.

- Provide oversight during construction. The construction work should be inspected day-to-day by an onsite inspector, who might be obtained from ONAS or a local consulting firm.

The SPDT should comprise several design engineers plus supporting technicians to draft and survey, and clerical help as required. Existing ONAS staff should probably be used so that they become familiar with ONAS procedures and the treatment plants already built. These personnel, however, would have to be freed from other duties to allow time to handle the projects for the small towns. Several persons should be designated as team members so that they could back each other up when one of them is not available.

B2. Familiarization Component

Because some stabilization ponds and aerated lagoons have been built in Tunisia, the ONAS staff is somewhat familiar with these technologies. However, because foreign consultants have designed most of these facilities, ONAS has had little hands-on experience. A familiarization component is therefore recommended in the pilot phase. The familiarization component should have two parts, dissemination of technical literature and a series of site visits, as discussed below.

B2a. Dissemination of Technical Literature

The engineers designated for the SPDT should be supplied with textbooks and manuals (in French and/or Arabic where available) on the design of stabilization ponds and aerated lagoon systems. The technical literature should include videos and operator training materials if available.

The technical literature should cover not only design theory, but also the practical aspects of design, including lists of acceptable and unacceptable practices, examples of good and bad designs, and discussions of problems that have occurred.

B2b. Site Visits

To increase team members' confidence in stabilization ponds and aerated lagoons, it is recommended that they be sent on several site visits to observe these technologies. These visits might include:

- Visits to all stabilization pond and aerated lagoon facilities in Tunisia.
- Visits to such facilities in Egypt and/or Jordan.
- Visits to such facilities in the United States.

The sites that are chosen for the visits should include both large facilities, such as Amman, Jordan, or Bakersfield, California, to demonstrate that stabilization pond and aerated lagoon technologies can serve cities of more than 100,000 population, and to very

small installations serving only a few hundred persons.[1] The facilities visited should include some anaerobic ponds and economy models that do not have separate grit removal or lined banks. It would also be desirable for some installations to include the use of the treated effluent for irrigation.

The ideas and information obtained during these site visits may encourage the team members to prepare more economical designs by using less conservative design criteria, using anaerobic lagoons, and omitting items such as grit chambers, linings on the bottoms of lagoons, and linings on the banks.

B3. Design Phase

It is recommended that the pilot phase include the assistance of a foreign engineer who is experienced in designing small treatment systems to work alongside the SPDT engineers on a few initial projects. The design phase should involve case studies, familiarization with the practical aspects of the process, and supervised practice designs by each SPDT engineer.

B3a. Case Studies

The first work should be case studies in which SPDT engineers prepare preliminary designs for a few sites, including sites where higher technologies were used in the past, such as Kairouan or the Tabarka airport. The design produced for each case study should then be compared to the one that was actually built, and the relative advantages and disadvantages of each should be discussed.

B3b. Practical Familiarization with the Project Process

The foreign engineer should organize discussions to acquaint the SPDT with the practical aspects of designing, constructing and operating stabilization ponds and aerated lagoons. The topics covered should include preparing preliminary designs, hiring consultants, reviewing designs, bidding, acquiring land, overseeing construction, and financial management. This part of the training should include discussions/lectures by Tunisian officials on the procedures for obtaining land, government financial accounting procedures, and the requirements for public participation in the process. Lectures and discussions should also be held with local consulting engineers and with local contractors to acquaint the ONAS staff with the capabilities, approaches, and problems of these organizations.

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[1]The treatment plant in Amman is currently operating at organic loadings and flow levels that significantly exceed its design capacity, and is experiencing problems due to inadequate O&M levels and underdesign. However, it may still serve as a useful example that low technology systems can be used effectively to serve fairly large cities. The Amman plant will be upgraded in the near future so that it can successfully meet the demand for treatment.

B3c. Supervised Design

After the case studies, each engineer on the SPDT should prepare a preliminary design for one small town, with the foreign engineer providing suggestions.

To allow the supervised projects to move forward promptly after the preliminary design is completed, funding should be available to design and construct the first three wastewater treatment plants before the foreign engineer provides technical assistance in the design phase.

B4. Evaluation Phase

During the design phase, the foreign engineer should design a monitoring and evaluation program to be used to gauge the effectiveness of the small town wastewater treatment program. The program should address the following topics at a minimum:

- Technology selection
- Preliminary design preparation
- Preparation of detailed designs by private consultants
- Bidding procedures and results
- Construction and inspection processes
- Startup and operation of the new plants
- Suggestions for the ongoing program

When the first-phase wastewater treatment plants in the small towns have been operating for awhile, it is recommended that a foreign consultant, preferably the one who participated in the design phase, evaluate the activities and results. This evaluation probably should occur about two years after the design phase.

C. Notional Schedule and Budget

A very approximate notional schedule and budget for the pilot phase program described above is presented in Table VI-1 on the following page. The schedule and budget presented are extremely preliminary. The figures are the authors' rough estimates and are not derived from any other source.

C1. Technical Literature

The cost of supplying technical literature to ONAS should include not only the literature itself, but the time needed for knowledgeable persons to select, collect, and ship the material. This technical assistance is roughly estimated to cost $US5,000 and to take about one month.

Table VI-1. Proposed Pilot Program
(Cost figures are author's estimates)

Phase/ Activity	Cost of Technical Assistance	Capital Cost of Construction	Time Required, Months	Cumulative Time Required, Months
Technical Literature	$5,000	None	1	1
Site Visits	$39,000	None	2	3
Design Phase	$60,000	$4,000,000	6	9
Evaluation Phase	$15,000	None	1	About month No. 24
Full Scale Implementation	None	$46,000,000	24	Depends on funding availability

C2. Site Visits

It has been assumed that the site visits would include a two-week tour to Egypt/Jordan and another two-week tour to sites outside the Near East, such as the United States, at a cost of $US3,000 and $US5,000 per person, respectively. Assuming that three engineers are sent on each tour, the total cost would be about $US24,000 for the travel and per diem costs for the Tunisian engineers. Payments to the hosts who would guide the party in Egypt/Jordan and in the United States might add another $US15,000. It is suggested that these tours be spread over at least two months to avoid fatiguing the team.

C3. Design Phase

The major cost for the technical assistance during the design phase would be for the foreign engineer, which might be approximately US$15,000 per month including transportation and per diem. It is difficult to estimate how long the foreign engineer should work with the SPDT engineers, especially since they are not likely to be available full time. It is probably sufficient for the foreign engineer to be available only part-time or intermittently, but this might be difficult to arrange unless the foreign engineer's time could be shared with another project. One of the German aid program engineers assigned to ONAS as advisors might be assigned to one of these positions. To estimate the notional budget for the proposed pilot program, it has been assumed that a foreign engineer would be assigned for four months, which could cost approximately US$60,000.

Again, it is noted that financing should be in place for the supervised design projects prior to commencement of the design phase so that these projects move into construction without long delays. The ONAS urgent program presented in Annex H estimated a cost of

45TD million for 44 installations, i.e., about $US1.1 million each for the wastewater treatment plants in small towns. Assuming that each of three ONAS engineers in the SPDT will design a project for one town, funding for a total of three facilities, or about $US3.3 million, should be available. Since the first projects undertaken may be larger than average, this funding estimate for construction probably should be rounded up to $US4 million.

C4. Evaluation Phase

The major technical assistance cost during the evaluation phase would be for one month of a foreign engineer. As above, it is assumed that this would cost about $15,000.

C5. Full-Scale Implementation

According to the ONAS urgent program (Annex H), the total construction costs would be 45TD million, or approximately $US50 million. If $US4 million is used during the evaluation phase, an additional $US46 million would be needed during the full-scale implementation program, which might start before the pilot phase is completed.

In scheduling the design and construction of projects, the time requirements noted below probably are reasonable for planning purposes:

Activity	Months Required
Preliminary design and preliminary land acquisition	3
Detailed design and final land acquisition	6
Bidding and contract award	3
Construction and startup	12

The total time between the beginning of preliminary design and initial plant operation is therefore about two years for a typical project.

D. Operation and Maintenance

Institutional capabilities to operate and maintain wastewater treatment facilities in small towns were discussed in Section IV of this report. It appears that no agreement has been reached on who should operate and maintain wastewater treatment facilities in towns with populations of less than 20,000. SONEDE may be the institution that can best operate and maintain wastewater facilities in small towns, possibly with the help of regional ONAS maintenance yards for repairs to major equipment.

Resolution of institutional arrangements for the small towns is beyond the scope of this assignment. It is recommended that as one of its first tasks, the ONAS Small Projects Design Team address this issue and initiate discussions with the institutions involved.

The preliminary design report that is prepared for each wastewater treatment facility in a small town should include a section on operations and maintenance. This section should include at least the following:

- A discussion of what institution will have responsibility for operating and maintaining the system. The potential for private sector ownership and/or management of these systems may be considered. The discussion should also consider the potential for a water users group approach to managing small wastewater treatment systems.

- A list and discussion of the operation and maintenance tasks required.

- The estimated time required to do the operation and maintenance and the costs of these activities.

E. Priorities

The current *Sanitation 2001* study follows the stated national priorities, which are:

- Protecting the economy, especially tourism
- Providing wastewater treatment where sewer systems exist and are discharging untreated sewage
- Serving locations with known problems

ONAS has produced its own report (see Annex H) in which it prioritizes the towns where population ranges from 2,000 to 10,000. The system used in prioritizing is explained in Annex H and includes the following criteria:

- Existence of a public sewer system
- Percent of population connected to sewer system
- Sanitary situation in the town
- Location of town on the coast (creating tourist potential)

These criteria appear to provide a rational basis for prioritizing the towns. Based on the speed and thoroughness with which the ONAS staff prepared Annex H, they appear to have an excellent grasp of the wastewater situations in the small towns and are well prepared to set priorities.

The wastewater treatment priorities should be established according to Tunisia's national environmental quality priorities to ensure that water quality standards are maintained, consistent with sustained national development.

It is recommended, however, that towns selected to receive wastewater treatment services in the early phases of the implementation program be limited to those that can use stabilization ponds or aerated lagoons.

F. Financing

Development of a financing program for wastewater facilities in Tunisia's small towns was beyond the scope of this assignment; however, the financing needed for the pilot program was discussed above.

A portfolio approach is recommended for financing in which ONAS' competence to implement projects would first be developed and demonstrated by the pilot program. After completing the pilot program, the SPDT would continue to plan and design projects as financing permits. At a minimum, the SPDT will maintain a list of small towns that should next receive wastewater facilities and will be prepared to proceed on these projects as financing becomes available. The number of projects undertaken at one time depends on the amount of financing available.

The accomplishment of the pilot program described in this section would give the SPDT a track record that should build the financing institutions' confidence that money spent on wastewater facilities in small towns is money well spent.

Funds will be needed to cover the continuing cost of operating and maintaining wastewater treatment facilities in small towns. In Table V-6, it is estimated that the annual O&M cost will be approximately 1 Tunisian dinar per capita for stabilization pond systems and 2 TD/capita for aerated lagoon systems. Assuming about five people per house, the total annual O&M costs per house will be 5 to 20 TD, or approximately 0.5 to 1.0 TD per month. The most practical means of collecting these charges probably is to have SONEDE include them as a surcharge on the water bills, and turn the collected funds over to ONAS. This arrangement is reportedly used in the cities.

In any case, GOT should seriously consider the development of financing and cost-recovery mechanisms to support capital and O&M expenditures over the life of each wastewater treatment plant to ensure financial sustainability of the services provided. GOT should develop a comprehensive small-scale wastewater treatment strategy that gives due consideration to the role of financing in planning, implementing, and managing these systems.

SECTION VII
CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The conclusions discussed at various points in this report are summarized below:

1) Tunisia's wastewater treatment plants have been well designed and constructed, and they are operating reasonably well. The wastewater treatment technology used in most of these plants and in most plants currently under construction in secondary cities is the relatively complicated activated sludge process. Because of the size of these plants and their locations in heavily developed areas, this choice of technology appears to have been justified.

2) Less complicated and less costly wastewater treatment technologies are needed for small towns. The most appropriate and cost-effective technologies identified in this study are the stabilization pond process and the aerated lagoon process. Both processes are already used at a few locations in Tunisia; thus, there is some local experience with them.

3) ONAS, the Tunisian institution charged with providing wastewater treatment facilities, appears capable of serving the small towns if its staff can become more familiar with the appropriate technologies and reorient their approach to small-scale design.

4) No institution appears to have been charged with operating and maintaining wastewater treatment facilities in towns with populations of less than 20,000. ONAS, SONEDE, or the municipality could provide such services. SONEDE appears to be in the best position to provide O&M services because it will have technically trained staff working in each small town where a wastewater treatment facility is built. If simple wastewater treatment technologies such as the stabilization pond process are used, unskilled labor can perform the required maintenance. Local farmers may be able to do so in return for being allowed to use the treated wastewater for irrigation.

5) Some funds will be required to cover the cost of operating and maintaining the wastewater treatment facilities. The most convenient means of collecting these funds from users of the system is to add a surcharge to the water bill.

6) The Tunisian discharge standards may be slightly stricter than necessary, but treatment of wastewater to a secondary level will be necessary in most cases to avoid nuisances. The most appropriate wastewater treatment processes identified in this report can generally achieve secondary treatment and comply with the current standards. The existing standards therefore do not need to be changed.

B. Recommendations

The recommendations of this report are discussed in previous sections and summarized below:

1) Stabilization ponds should be used as the wastewater treatment technology in small Tunisian towns wherever sufficient land is available.

2) Where the availability of land is restricted, aerated lagoons should be used as the wastewater treatment technology, if possible.

3) Activated sludge systems should be used for wastewater treatment only where the available land is very restricted and in the largest towns under consideration. In most cases, consideration should be given to pumping the wastewater to a more distant site where more land is available rather than constructing activated sludge systems.

4) In choosing the appropriate technology for a specific site, the capital construction and O&M costs should be evaluated on a present worth basis to identify the least-cost option.

5) ONAS should establish a Small Projects Design Team (SPDT) to oversee the design and construction of wastewater treatment facilities in small towns. Training of this team should include: dissemination of technical literature; site visits to stabilization pond and aerated lagoon facilities in Egypt, Jordan, and the United States; case studies; familiarization with the process of accomplishing a project; and a program of actual design experience supervised by a foreign engineer.

6) The SPDT should initiate discussions to determine what institution will provide the operations and maintenance staff for the wastewater treatment facilities in small towns. The potential for private sector ownership and/or management of these facilities, and for their management by water users groups, should be considered.

7) GOT should develop a comprehensive strategy for financing, planning, implementing, and maintaining small-scale wastewater treatment systems.

8) GOT should consider developing capital and O&M cost financing and recovery mechanisms. These mechanisms are necessary to assure financial sustainability of the collection and treatment systems.

9) ONAS should prepare preliminary designs for the wastewater treatment facilities, but should contract out the detailed designs to private Tunisian consulting firms. Private Tunisian contractors should do the construction.

10) Consideration should be given to having ONAS serve as the source of technical information on the design and construction of sewer systems, which is the responsibility of the local governments, and of on-site wastewater facilities. This role should involve publishing technical manuals and information for use by other agencies.

ANNEX A
SCOPE OF WORK
SMALL WASTEWATER TREATMENT SYSTEMS ASSESSMENT

The PRIDE team was requested to assist USAID/Tunisia and the newly formed Ministry of the Environment and National Physical Planning in assessing appropriate technologies for treating wastewater effluents in medium to small towns (generally defined as less than 6,000 inhabitants). The assignment was designed to:

- Determine the extent of the problem;
- Identify technologies currently in use (most frequently the diversion of untreated effluent into the nearest dry riverbed);
- Assess the possibilities of using simple but improved technologies in use in the United States or elsewhere (e.g. stabilization ponds, aerated lagoons) to treat effluents and reduce environmental and health damage; and
- Gauge the interest in conducting pilot activities, along with a possible design for such activities.

Specific tasks in the assignment included, but were not limited to, the following:

1. Meet with PRIDE staff and other wastewater treatment specialists prior to departure from the U.S. (2 days);
2. Meet with USAID/Tunisia staff for detailed briefings (1 day);
3. Conduct assessment with Ministry of Environment and other GOT staff (12 days). Activities to be undertaken include but are not limited to:

   a. Document review and interviews (problem identification).
   b. Field trips to small- and medium-sized urban agglomerations to view wastewater handling and disposal methods (problem verification).
   c. Identify and assess alternative wastewater treatment technology utilized in the United States and elsewhere, as well as technologies being piloted by the GOT and other donor organizations (e.g. German bilateral aid).
   d. Assess capability of Tunisian institutional resources to conduct pilot tests of appropriate alternative technologies.
   e. Assess support capabilities at community level (operations, maintenance, etc.) for pilot technologies.
   f. Assess feasibility and policy environment for preparation of action plan for development and implementation of national strategy.

4. Write up findings, deliver preliminary report to GOT and USAID/Tunisia prior to departure (five days, with perhaps five additional days necessary if the development of a national strategy action plan appears feasible).

5. Report finalization after departure, with draft designs and scopes of work for follow-up activities (six days).

The following notional schedule was proposed:

1.	Scope of work discussions	March 2-6
2.	Team configuration/recruitment	March 9-13
3.	Approval of team and SOW	March 6-20
4.	Team briefing in D.C.	First week of April
5.	Arrival in Tunis	Second week of April
6.	Draft Report	Late April
7.	Final Report	Late May

ANNEX B
PERSONS CONTACTED AND SITES VISITED

Monday, April 20

1. USAID/Tunis

   James A. Graham, Mission Director
   Fathi Kraiem, Urban Development Program Specialist, RHUDO/NENA
   Hafid Lakhdhar, Population and Family Planning

2. Ministry of Environment

   H.E. Saleh Jebali, Minister of the Environment
   M. Abdel Latif, Chef du Cabinet, Ministry of Environment
   M. Houcine Essaied El Bech, S. Directeur de la Planification et de Développement
   Fathi Kraiem
   Hafid Lakhdhar

3. ONAS

   M. Abderrahman Gannoun, Chef de Département, Développement
   M. Hajj Ali Habib, Directeur des Etudes
   Mme. Benzarti, Directrice de la Coopération Internationale
   M. Houcine Essaied El Bech
   M. Farid Sakli, Assistant Director of Studies
   M. Daoud Ayad, Assistant Director of Studies
   Fatih Kraiem
   Hafid Lakhdhar

Tuesday, April 21

1. ONAS: M. Houcine Essaid El Bech accompanied the PRIDE team on visits to three wastewater treatment stations in the Greater Tunis area:

   a) Choutrana Wastewater Treatment Plant
      M. Ben Massaoud, Chef de District, District Ariana
      M. Kalai, Chef de Station

   b) Côtière Nord (North Coast) Wastewater Treatment Plant
      M. Snoussi, Chef de District, District Côtière Nord
      M. Bouchoucha, Chef de Station

c) Cherguia Wastewater Treatment Plant
M. Ben Hamed, Chef de Station
M. Fathi Oueslati, Directeur, Maintenance et Matériaux Fixes
M. Felfoul Ahmed, Directeur des Matériaux Roulants
M. Jrad Roussine, Engineer, Responsable du DMMR (Division Maintenance Matériaux Roulants)

Wednesday, April 22

1. ONAS/Tunis: M. Marouani, Responsable de la Recherche, accompanied the PRIDE team to Nabeul to visit the sites listed below.

2. ONAS/Nabeul: The following individuals at ONAS/Nabeul, which is the regional office of ONAS for the northeast region of Tunisia, received the PRIDE team and accompanied them to sites in the governorate of Nabeul:

   a) M. Ben Mansour, Chef de Département, Département Nord Est
   b) M. Ben Saleh, Directeur de l'Exploitation in Nabeul
   c) M. Kamoun, Directeur de l'Exploitation Nord Est

3. Research/Purification Station #3 (SE#3) in Nabeul

   Professor Haddad

4. Purification Station #4 (SE#4) in Nabeul

   M. Rhouma, Chef de Station

5. The PRIDE team and ONAS members then visited the following villages which lacked wastewater treatment facilities:

   a) Maamoura
   b) Som'a
   c) Tazaarka
   d) Korba
   e) Takelsa
   f) Soliman (station construction under way)
   g) Bou Argoub

Thursday, April 23

1. ONAS/Tunis: M. Haj Ali Nourredine of ONAS/Tunis accompanied the PRIDE team on their visits to Sousse and Kairouan.

2. ONAS/Sousse: The team visited the ONAS office in Sousse, which is responsible for wastewater facility planning, operations and maintenance in six gouvernerates (Sousse, Monastir, Kairouan, Kasserine, Sidi Bouzid, and Mahdia).

3. Messadine:
M. 'Aoun, Directeur de l'Exploitation Centre

4. M'saken: the team drove through this town.

5. ONAS/Kairouan: M. Hlioui, Chef de District de Kairouan, accompanied the team to the wastewater treatment station in Kairouan.

6. Kairouan Wastewater Treatment Plant
M. Mhiri, Chef de Station de Kairouan

7. Haffouz: The Secretary General of the municipality and a technician received the team and accompanied them to the wadi where wastewater is discharged.

Friday, April 24

1. ONAS/Tunis: The PRIDE team presented their observations, based on their first week of activities, to the staff of ONAS and representatives from USAID, including the following:

M. Abderrahman Gannoun
M. Hajj Ali Habib
Mme. Benzarti
M. Houcine Essaied El Bech
M. Marouani
M. Farid Sakli
M. Daoud Ayad
M. Fetih Kraiem
M. Hafid Lakhdhar

Tuesday, April 28

1. ONAS/Tunis: The PRIDE team presented their preliminary report outline and a preliminary list of alternative technologies under consideration to the following:

A. In M. Gannoun's office:

M. Abderrahman Gannoun
Mme. Benzarti
M. Haj Ali Habib
M. Abid Najib

B. In the office of M. Mlika, Président Directeur Général of ONAS:

M. Mlika Mohamed Mehdi, Président Directeur Général, ONAS
M. Abderrahman Gannoun
Mme. Benzarti

Wednesday, April 29

1. ONAS/Tunis: Julie Bourns met with the following individuals to gather background information for the report:

Mme. Benzarti
M. Haj Ali Habib
M. Abid Nejib, Ingénieur Statisticien, Planification

Thursday, April 30

1. ONAS/Tunis: The PRIDE team presented the technologies they will recommend in their report to the following individuals:

M. Abderrahman Gannoun
M. Hajj Ali Habib
M. Abid Nejib
M. Marouani
M. Houcine Essaied El Bech
M. Farid Sakli
M. Daoud Ayad
Mme. Benzarti
M. Fatih Kraiem
M. Hajj Ali Nourredine

Thursday, May 7

1. Ministry of Environment, Tunis: The PRIDE team presented their findings to the following individuals:

H.E. Saleh Jebali, Minister of the Environment
John McCarthy, U.S. Ambassador to Tunisia
James A. Graham, USAID/Tunis Mission Director
M. Mohamed Mehdi Mlika, Président Directeur Général, ONAS
M. Abderrahman Gannoun
Mme. Benzarti
Hafid Lakhdar, USAID/Tunis
Fatih Kraiem, RHUDO
Lane Smith, RHUDO

ANNEX C
SUMMARY OF SOTINFOR/SERAH
FEASIBILITY STUDY FOR "SANITATION 2001"

An exhaustive study of the sanitation requirements in 199 smaller towns in Tunisia has recently been prepared by Groupement SOTINFOR/SERAH, a local consulting group. The World Bank funded the study, which is occasionally referred to as the "World Bank Study." (This should not be confused with the World Bank Technical Note No. 7, by J. Arthur, dealing with stabilization ponds, which has also been frequently referenced.)

The reports that were available are extremely thorough, clearly and logically arranged, technically sound, and professional. Because of the thoroughness and the excellent quality of these reports, it was decided that further collection by the PRIDE project team of the type of data covered in the SOTINFOR/SERAH reports was unnecessary.

Four volumes from this study, entitled "Etude de Factibilité d'Assainissement 2001," were made available to the PRIDE consulting team. The three volumes from Report A1 are dated April 1992 and thus have just been issued. The introductory note to Report A2, dated March 1992, is only slightly older. Unfortunately, some volumes of the report are still in preparation and were not available to the team. These presumably include an introductory volume which explains the relationships among the various volumes. The four volumes received were:

Report A1

Volume 1: Synthèse, Annexe 3: Les Monographies des Communes du Département Sud.

Volume 2: Les Prévisions et les Normes de Calcul et d'Investissement.

Volume 3: Les Stations d'Epuration.

Report A2

Note Introductive au Rapport A2 "Classification des Agglomerations, Les Critères de Surclassement des Projets et Communes."

A translation of the titles of each of these volumes and a brief description of its contents are presented below. Based primarily on the titles, the complete report apparently will contain:

Report A1

Volume 1: Synthesis. Presumably this is a summary of the study. There probably is an annex for at least four of the five districts into which ONAS is divided. The fifth district, Greater Tunis, was mostly excluded from the study. As noted above, the team received only Annex 3, which covered the South Region.

Volume 2: The Forecasts and Criteria for Calculation and Investment.

Volume 3: The Wastewater Treatment Plants.

Report A2

Only an introductory report was received. We do not know how many volumes Report A2 will have when it is finished.

We understand that the final report will estimate the amount of investment required to provide all 199 towns with complete coverage with sanitary sewers and a wastewater treatment plant, and a priority ranking showing the order in which the facilities should be built.

Discussed below are what appear to be the more important contents of each report received.

Report A1, Volume 1, Synthesis, Annex 3: Monographs of the Towns of the South Region, April 1992

This volume briefly describes each town in the ONAS South Region. The towns are listed by governorate on the second page. A standard format is used to describe each town. The standard headings of the sections are as follows:

I. Geographical and Physical Setting
II. Development Perspectives
III. Potable Water Supply
IV. Existing Sanitary Situation
IV.1. Sanitary Status
IV.2. Characteristics of the Existing Infrastructure (Sewers)
IV.3. Operations and Maintenance Capabilities
V. Previous Studies
VI. Required Priority
Sewers (Réseaux)
Treatment (Epuration)

Volume 2, The Forecasts and Criteria for Calculation and Investment

Chapter 1

Chapter 1, entitled "Population and Water Consumption," is a thorough and traditional sanitary engineering approach to estimating the wastewater flows and loads from each town. Populations were based on the growth rate between 1975 and 1984, and extrapolated for the years 1990, 1996, 2001, and 2011. The percent of houses with piped water supplies and the consumption per capita per day were obtained from SONEDE, the national water supply organization. It was assumed that 100 percent of the houses would have piped water supplies by the year 2001.

It was assumed that domestic sewage flows would be 80 percent of domestic water consumption, and that the percent of population sewered would increase in a linear fashion from the present percentage to 100 percent in 2001.

Water consumption and sewage flows were estimated separately for institutional users.

Tourist water consumption was based on an assumed flow per hotel bed of 450 liters/bed/day for deluxe hotels and 400 liters/bed/day for economy hotels. Sewage flow was assumed to be 80 percent of the water consumption.

Industrial flows were assumed to come primarily from industrial parks which have been reserved. It was assumed that water consumption in industrial areas would be 40 cubic meters per hectare per day and that 50 percent of the water consumption would find its way to the sewer system.

BOD loadings were based on the amount of BOD contributed per day or on the BOD concentration in the sewage flow.

The methodology followed and the estimates made appear to be reasonable.

Chapter 2

Chapter 2, entitled "Criteria for Calculations" (Les Normes de Calculs), Section II.1, presents design criteria for primary (trunk) and secondary (collector) sewers, pump stations, and wastewater treatment facilities. Peak flows were estimated and used to select the pipe sizes required. It was assumed that there would be 200 linear meters of secondary sewers per hectare of residential area.

Section II.2 presents capital costs for various wastewater facilities. Cost of sewers is broken down into cost of the pipe and installation costs for each of three regions. The total cost of secondary sewers is estimated as approximately 8,500 TD per hectare in residential areas.

Section II.4 presents the bases for calculating the sewer use charges in 1990 and 2001 but does not say what these charges are.

Section II.5 states that a data file has been developed on each town and that the cost and income for the priority program and the total project are included, but these are not given.

Volume 3. The Wastewater Treatment Plants

Volume 3 discusses the 16 existing treatment plants that are not in the major urban centers. The information was obtained from ONAS using questionnaires and various existing documents. Each treatment plant is discussed separately. In general, the plants perform quite well and meet the discharge standards most of the time.

At the back of this report, detailed operating cost data are given and analyzed in various ways, such as by average flow, percent of capacity used, etc.

Introductory Note to Report A2

This note is only eight pages long. Section 1 gives the objectives of the sanitation sector as presented in the fifth (1977-81) through the eighth (1992-96) five-year plans. Section 2 lists three criteria for prioritizing towns to receive sanitation facilities, as follows:

- Effectiveness of investment compared to sanitary services already in place
- Sensitivity of the environment, including protection of public health and the economic resource base
- Size of population served

These three criteria are then discussed. A priority ranking is said to have been established for each community but these are not given. Presumably they are presented in Report A2, to which this is but an introductory note.

ANNEX D
TUNISIAN EFFLUENT DISCHARGE STANDARDS

SELECTED WASTEWATER DISCHARGE CRITERIA					
Parameter	Unit	Point of Discharge[1]			Reuse for Agriculture[2]
		Ocean	Stream Bed	Public Sewer	
BOD_5	mg/l	30	30	400	30
Suspended Solids	mg/l	30	30	400	30
Nitrate	mg/l	90	50	90	NR[3]
Organic and Ammonia Nitrogen	mg/l	30	1	100	NR
Phosphorus	mg/l	0.1	0.05	10	NR
Fecal Coliforms	no./ 100 ml	2000	2000	NR	NR
Fecal Streptococci	no./ 100 ml	1000	1000	NR	NR
Intestinal Nematode Eggs	no./ 1000 ml	NR	NR	NR	1

[1] From Tunisian Standard (Norme Tunisienne) 106.002, entitled "Protection of the Environment: Discharge of Effluents in Public Waterways" ("Rejets d'effluents dans le Mileu Hydrique"), 1989.

[2] From Tunisian Standard (Norme Tunisienne) 106.03, entitled "Protection of the Environment: Utilization of Treated Wastewater for Agricultural Purposes—Physico-Chemical and Biological Specifications" ("Utilisation des Eaux Usées Traitées à des Fins Agricoles— Specifications Physico-chimiques et Biologiques"), 1989.

[3] NR = No Requirement

ANNEXE E
LA FORMATION A L'ONAS

A. Introduction

Partant du principe qui affirme que le premier capital d'une entreprise est son capital humain, l'Office National de l'Assainissement ne cesse de manifester son désir de réaliser son propre centre de Formation, pour faire de son personnel sa force de frappe. Le centre servira à former et perfectionner le personnel de l'ONAS et sera élargi à la Formation du personnel des communes et même de la région maghrébine et africaine. Ce projet "centre de Formation" a fait l'objet de plusieurs discussions avec des partenaires tunisiens et étrangers et toutes les parties ont conclu que le besoin d'une solution rapide, à la Formation du personnel de l'ONAS, est grand.

B. Mission de l'ONAS

L'ONAS a pour mission d'assurer la gestion, l'exploitation, l'entretien, le renouvellement et la construction de tout ouvrage d'assainissement qu'il s'agisse, de réseaux, de stations de pompage ou de stations d'épuration à l'intérieur des périmètres communaux et dans les zones touristiques ou industrielles. L'Office contrôle également les rejets industriels et la réutilisation des eaux épurées.

C. Besoins en Formation

C1. Dimension Nationale du Centre

C1a. Besoins ONAS

L'Office est un organisme jeune. Il a été créé en Août 1974.

Lors de sa création, l'ONAS comptait 178 personnes. Il en a actuellement 2.065 se répartissant comme suit:

- 75 pour-cent exécution
- 19 pour-cent maîtrise
- 6 pour-cent cadre

Près de 70 pour-cent ont moins de 40 ans. Donc l'ONAS a un personnel jeune qui a besoin de formation continue.

D'après les études déjà faites pour l'élaboration du projet de contrat programme de l'ONAS, une augmentation de 100 agents par an est prévue.

Cependant l'augmentation réelle de l'effectif de l'ONAS reste liée aux projets et à leurs réalisations.

Etant donné l'intérêt que porte l'Etat à la lutte contre la pollution et la protection de l'environnement, l'ONAS se voit de plus en plus sollicité dans la lutte contre la pollution hydrique sur tout le territoire de la République. Ainsi 20 stations d'épuration seront bientôt opérationnelles avec tout ce qu'elles nécessitent comme réseaux et stations de pompage.

Aux nouvelles réalisations s'ajoutent un programme de prise en charge des communes.

C1b. Besoins des communes

Les petites et moyennes communes dont la prise en charge n'est pas programmée à court terme et en vue de leur permettre d'accomplir leur tâche dans les meilleurs conditions techniques, l'ONAS est tenu de les assister notamment par la formation de leur personnel exploitant.

C2. Dimension Régionale

Par ailleurs et parmi les pays maghrébins, l'ONAS dispose d'une expérience riche en matière d'assainissement et souhaite en faire profiter les autres pays maghrébins, africains et arabes.

L'Office envisage d'organiser des cycles de formation à leur intention.

D. La Formation actuelle à l'ONAS

L'Office National de l'Assainissement étant le seul organisme national spécialisé dans l'assainissement en Tunisie, ressent toujours le besoin et le devoir de former et de recycler son personnel, en Tunisie ou à l'étranger, pour répondre à ses obligations. Pour cela, l'ONAS bénéficie de l'aide des Coopérations Allemande (GTZ), Suédoise (BITS), de la CEE, etc.

FORMATION ET RECYCLAGE DU PERSONNEL DE L'ONAS

L'année 1991 s'est caractérisée par une intense activité de formation et de recyclage du personnel de l'ONAS. En effet, de nombreuses actions ont été réalisées et ont touché toutes les catégories et abordé plusieurs aspects.

Les principales actions peuvent être ventilées comme suit:

- 16 actions inter-entreprises pour 18 agents
- 38 actions intra-entreprises pour 329 agents
- 8 stages obligatoires pour 20 étudiants
- des stages d'un an pour la formation de base de 25 agents de maîtrise dans les spécialités de l'assainissement
- Un cours du soir d'anglais
- Un cours du soir en informatique de gestion pour 13 participants

Les actions réalisées en "intra" ont touché les thèmes suivants:

- la comptabilité et la gestion financière
- la gestion du foncier
- la gestion administrative
- la planification
- les analyses de laboratoire et l'environnement
- la maintenance des équipements et du matériel
- la sécurité

Les actions en "inter" ont touché les thèmes suivants:

- la législation du travail
- le transit, l'importation et les aspects financiers et douaniers y afférent
- l'informatique
- la fiscalité
- la formation

L'ensemble des actions réalisées durant 1991 a enregistré 398 participations.

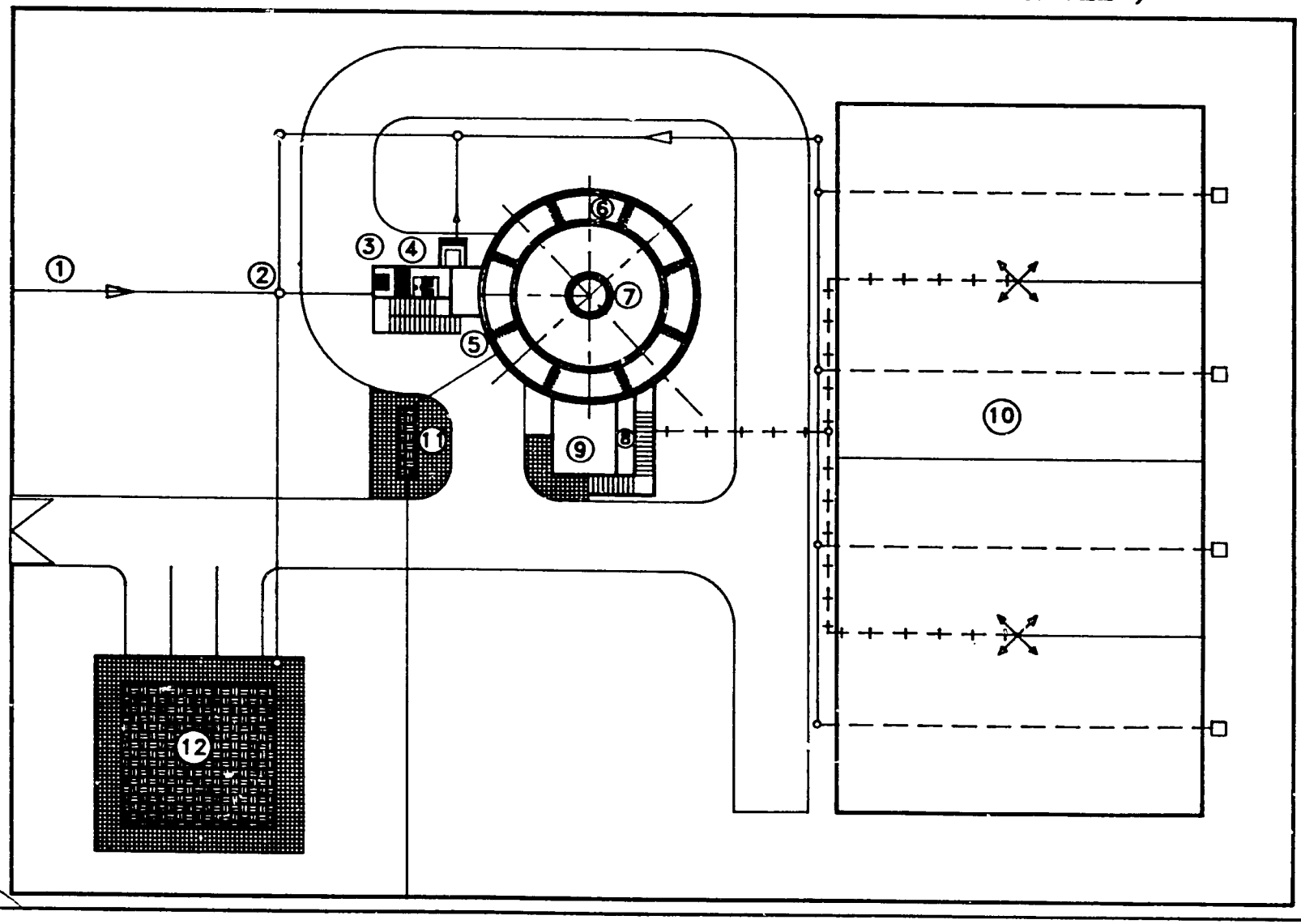
Le plan de formation de 1991 prévoyait 151 actions à réaliser pour 1952 participations d'agents, toutes catégories confondues.

ANNEX F

STATION D'EPURATION TYPE

POUR LES VILLES DE 5000 A 15000 HABITANTS

(VARIANTE COMPACTE–AERATION PROLONGEE)



LEGENDE

1 Arrivee des eaux brutes
2 Regard de vannage
3 Station de relevement des eaux brutes
4 Degrilleurs
5 Dessableur – Deshuileur
6 Bassin d'activation faible charge
7 Clarificateur
8 Station de pompage des boues en retour et des boues en exces
9 Local des machines
10 Lits de sechage des boues
11 Debimetre
12 Batiment de service

CARACTERISTIQUE DE LA STATION D'EPURATION

La station d'epuration est conçue selon le systeme boue active tres faible charge (aeration prolongee) les eaux usees brutes apres pretraitement,penetrant dans le bassin d'activation ou l'aeration se fait par injection A la sortie du decanteur secondaire,les boues suffisamment epaissies sont acheminees dans les lits de sechage.

DONNEES DE DIMENTIONNEMENT

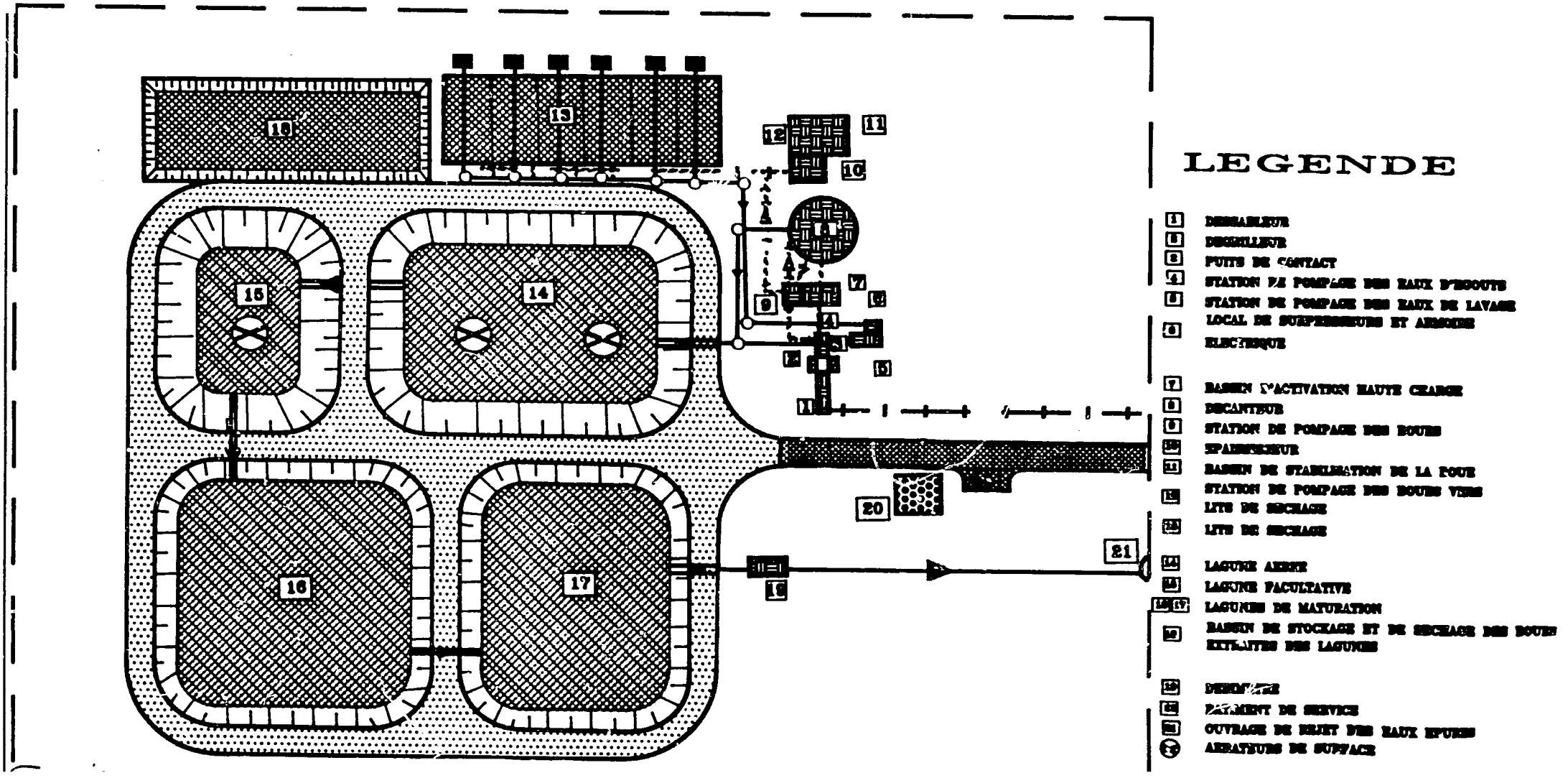
- Population en equivalent–habitants 5000
- Volume moyen journalier 500 m³/j
- Charge biologique en DBO 220kg/j
- Concentration en DBO 450mg/l
- Concentration en azote 70mg/l

AVANTAGES DE LA STATION D'EPURATION

- La superficie de la station d'epuration est tres reduite < 5000 m2
- Le cout de l'investissement est assez faible.
- Une exploitation relativement simple
- Le taux d'integration de l'utilisation des produits locaux est le plus eleve
- La qualite de l'eau epuree est conforme aux normes de rejet
- L'eau epuree est susceptible d'etre reutilisee dans l'agriculture .

STATION D'EPURATION TYPE

POUR LE TRAITEMENT DES EAUX RESIDUAIRES



ANNEX G
SUMMARY OF OTHER TECHNOLOGIES CONSIDERED

During the discussions between the PRIDE project team and the ONAS staff, the broadest possible spectrum of wastewater technologies was brainstormed, many of which were mentioned in the initial draft of the report. Many of the technologies previously discussed are not considered appropriate for use in Tunisia. Some are highly specialized subsets of the main technologies that are covered in this report, others are experimental, and some have costs and/or operating features that are considered inappropriate for Tunisia.

A few comments are offered below on some of the technologies that were discussed while the PRIDE project team was in Tunisia but which are not recommended in this report.

A. Vegetated Reed Beds

These systems have been used on a limited scale in England and Germany but are still considered to be experimental there. They require more land and are more costly than stabilization ponds and thus do not appear to offer any advantages for use in Tunisia over stabilization ponds.

B. Overland Flow Systems

These systems are intuitively appealing in that they seem foolproof and use all natural processes. The appearance of being foolproof is deceptive. Obtaining an even distribution of flow with the systems in California has been very difficult. The systems that are used to distribute the flow at the tops of the terraces must be extremely level over long distances (100 meters or more). Extremely precise grading is also required over very large areas. In practice, an even distribution of flow has been difficult to obtain.

In addition, severe mosquito problems have plagued many of these systems. Growth of mosquitos on the terraces can be controlled to an extent by having frequent drying periods between applications of wastewater, but the collection ditches at the bottoms of the slopes are usually quite flat and often become choked with thick growths of algae, which ponds water and allows mosquitos to breed.

C. Biolac System

A biolac aeration system is in operation at Oakdale, California, USA, in an aerated lagoon in parallel with an aerated lagoon equipped with floating aerators. The plant staff report that the Biolac system requires approximately the same level of maintenance as the floating aerators, especially because rags tend to wrap around the Biolac aeration tubes.

The plant staff at Oakdale has also noted that the degree of treatment in the lagoon served by the Biolac system is lower than in the lagoon served by floating aerators. The reduction in treatment may indicate that the Biolac system is not thoroughly mixing and is allowing some biological solids to settle out of the process. The difference in treatment has not, however, been thoroughly investigated and may be due to other reasons, such as an unequal division of flow between the two aerated lagoons.

D. Disinfection

Conventional disinfection of treated wastewater is provided through injection of chlorine gas. Where sewage treatment plant effluents are discharged to surface or ground waters used for recreation, shell fish breeding, drinking water and certain agricultural practices, disinfection is desirable. Chlorine disinfects the effluent and acts as a barrier to the transfer of disease causing organisms. It also reduces BOD, diminishes odor and can help prevent the formation of corrosive hydrogen sulfide.

Disinfection using ultraviolet light is widely used in Europe, but infrequently used in the United States. Ultraviolet disinfection does not require the input of chemicals but does have a high power cost. If disinfection is to be provided in Tunisia, consideration might be given to the use of ultraviolet disinfection technology.

E. Ultraviolet Disinfection

Ultraviolet disinfection systems may be a good choice for use in Tunisia if disinfection is to be provided, since such systems do not require the supply and handling of chlorine chemicals and avoid the risks associated with the use of chlorine.

Disinfection is not, however, practiced at present in Tunisia, and may not be required if there is little human contact with the treated wastewater.

ANNEX H
ONAS URGENT WASTEWATER TREATMENT PROGRAM

This summary of the ONAS Urgent Wastewater Treatment Program, prepared by the ONAS staff, suggests what a program to provide wastewater treatment plants in small towns should entail. The ONAS staff is to be commended for the speed and effectiveness with which this program was prepared.

The list of 199 towns in the SOTINFOR/SERAH study was sorted to determine the number of towns with populations between 2,000 and 10,000. It was found that there are 119 towns in this size range with a combined population of 581,000.

The need for wastewater treatment facilities in these small towns was prioritized using the following four criteria:

- Whether a public sewer system exists
- The percent of the population connected to the public sewer system
- Sanitary conditions
- Geographical location, specifically whether the town is in the coastal zone which is sensitive for tourism

These criteria yielded a list of 63 small towns of which 44 were judged to have the highest priority. Wastewater treatment facilities in these 44 towns will serve a population of about 350,000 inhabitants by 2001 and will treat a flow of about 30,000 cubic meters per day.

The costs of wastewater treatment facilities in these towns were based on unit costs of 70TD/capita for stabilization ponds and 100TD/capita for activated sludge systems. These unit costs do not include the cost of land, power and water supply, access roads, or piping to and from the plants.

ONAS estimates that the total cost of the wastewater treatment facilities in the 44 towns will be 45TD million ($US50 million). The average per capita cost of the program is 129 Tunisian dinars or $US143 per capita served.

ONAS suggests that 24 towns be included in a first phase, which will cost 25TD million, and that the other 20 towns be included in a subsequent phase. It is proposed that the Government of Tunisia fund 25 percent of the cost of the program, with foreign financing covering 75 percent.

PROGRAMME DE CONSTRUCTION DES STATIONS D'EPURATION DANS LES VILLES DE POPULATIONS COMPRISES ENTRE 2.000 ET 10.000 HABITANTS

A. Introduction

Dans le cadre de la protection de l'environnement, de l'amélioration du cadre de vie des citoyens et de la sauvegarde des ressources hydriques, l'ONAS envisage d'étendre son plan d'action relatif à la construction des Stations d'épuration pour les petites et moyennes communes (10.000 habitants) aux agglomérations de populations comprises entre 2.000 et 10.000 habitants.

B. Contenu du programme

B1. Hypothèse

B1a. Tri des agglomérations de populations comprises entre 2.000 et 10.000 habitants

Sur la base de l'étude de factibilité 2001, il a été au tri des agglomérations de populations comprises entre 2.000 et 10.000 habitants.

Le nombre de ces agglomérations est de 119, groupant une population de 581.000 habitants.

B1b. Sélection des agglomérations cibles

Les critères utilisés pour la sélection des agglomérations prioritaires sont les suivants:

- L'existence d'un réseau public d'assainissement
- L'importance du taux de branchement au réseau public d'assainissement
- L'état sanitaire
- La situation géographique

L'application de ces critères a permis de sélectionner 63 agglomérations dont 44 ont été jugées prioritaires.

B1c. Estimation du coût d'investissement

Les estimations des coûts d'investissement par équivalent-habitant (40 g DBO5/j/habitant) et par procédé ont été ajustées à partir des prix pratiqués habituellement dans des travaux similaires en Tunisie.

Ces coûts se présentent comme suit:

- Lagunage facultatif/aéré: 70 DT/Eq.H
- Lagunage aéré/boue activée: 100 DT/Eq.H

Ces coûts ne tiennent pas compte des frais d'acquisition de terrain, des frais d'alimentation en électricité et en eau potable, des frais d'aménagement des voies d'accès, ainsi que les coûts de réalisation des conduites d'amenées des eaux usées et de restitution des eaux épurées.

B2. Description du programme

Le programme proposé consiste à réaliser des stations d'épuration dans 44 agglomérations. Ces stations permettent de traiter environ 30.000 m^3/j et d'éliminer 15.000 kg DBO5/j, soit 350.000 Eq.h/j. Les procédés d'épuration qui vont être utilisés sont essentiellement le lagunage facultatif, le lagunage aéré et la boue activée à faible charge.

L'examen rapide des conditions locales des différentes agglomérations a permis de ventiler le nombre de stations d'épuration par type de procédé comme suit:

- Lagunage facultatif ou aéré: 26 stations (60 pour-cent environ)
- Lagunage aéré ou boue activée: 18 stations (40 pour-cent)

B3. Coût d'investissement du programme

Le coût d'investissement du programme est évalué à 45 millions de DT réparti comme suit:

- Travaux de génie civil	22 MDT
- Equipement	10 MDT
- Frais d'acquisition de terrains, frais d'alimentation en électricité et en eau potable, frais d'aménagement des voies d'accès, ainsi que les frais de la réalisation des conduites d'amenées des eaux usées et de restitution des eaux épurées	10 MDT
- Divers et imprévu	3 MDT
TOTAL:	45 MDT

B4. Planning de réalisation

Il est prévu de réaliser ce programme en deux tranches:

- La tranche prioritaire est programmée au cours du VIIIème plan. Elle intéresse les 24 agglomérations suivantes: Maâmoura, Tazarka, Haouria, Korbous, Bouargoub, Azmour, Hamman Zriba, Metline, El Alia, Sejnane, Ghar El Melh, Aousja, Aïn Drahem, El Ksour, Sers, Nabeur, Le Krib, Makthar, Hergla, Enfidha, Sidi Bou Ali, Bou Ficha, Meknassy et Mareth.

Le coût de cette tranche est estimé à 25 MDT.

- La deuxième tranche est programmée au cours du IXème plan. Elle intéresse les 20 agglomérations suivantes: Bir Mcharga, Amdoun, Sakiet Sidi Youssef, Kalaât Snane, Kalaâ Khasba, Menzel Salem, Bargou, Rouhia, Oueslatia, Haffouz, Hajeb Layoun, Touza, Bou Merdès, Souassy, El Galaâ, Metouia, Ouedhref, Zarrat, Jerba Midoun et Jerba Ajim.

Le coût de cette tranche est estimé à 20 MDT.

Ces coûts s'entendent à prix constant de l'année 1992.

C. Schéma de financement

Pour la réalisation de ce programme, le schéma de financement proposé est le suivant:

- Gouvernement tunisien: 25 pour-cent
- Participation étrangère: 75 pour-cent

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