DEVELOPMENT OF A SUSTAINABLE WASTEWATER MANAGEMENT STRATEGY FOR PALESTINIAN RURAL AREAS

By

Malvena Al-Jamal

Student Number: 1015238

Supervisor: Dr. Omar Zimmo

Co-supervisor: Dr. Nidal Mahmoud

A thesis submitted in partial fulfillment of the requirements
for the Masters Degree in Water Engineering to
the Faculty of Graduate Studies at Birzeit University-Palestine

Birzeit, 2004

DEVELOPMENT OF A SUSTAINABLE WASTEWATER MANAGEMENT STRATEGY FOR PALESTINIAN RURAL AREAS

By

Malvena Al-Jamal

This thesis was prepared under the supervision of Dr. Omar Zimmo and has been approved by all members of the Examination Committee.

Dr. Omar Zimmo
(Chairman of the Committee) ………………………………

Dr. Ziad Al-Mimi
(Member) ………………………………

Dr. Ihab Barghothi
(Member) ………………………………

Date of Defense: December 18, 2004

ACKNOWLEDGEMENTS

First of all, I would like to express my thanks to my mentor Dr. Omar Zimmo, for giving me the opportunity to undertake this project, and for his comments, guidance and support throughout the various stages of this study.

Gratitude is also expressed to Dr. Nidal Mahmoud for his advice and assistance.

I deeply thank Dr.Ziad Al-Mimi who also advised me and encouraged me strongly.

Gratitude is also expressed to employees who work in the Palestinian water institutions especially PWA, PARC and PHG, for letting me consume some of their precious time to participate in meetings and the data collection phase for the work, in particular the following persons:
Dr. Ihab Barghohti, Eng. Jammal Burnat, Ms Majda Alawnah, Mr. Subhi Sarhan, Eng. Ousama Naser, and Ms Linda Tamimi.

Most of all, my deep gratitude goes to my parents and husband in particular. It is greater than I can adequately express, for, without their unlimited encouragement, it could have never been undertaken. I am also indebted to my sisters, brothers, mother-in-law, father-in-law, and sister-in-law for their support, help, and encouragement.

Malvena Al-Jamal, December, 2004.

ABSTRACT

As in most countries of the region, unsewered communities in Palestine rely mainly on cesspools for wastewater disposal. Actually, 92% of the rural houses discharge their wastewater to cesspits and open sewers (PCBS, 2000). Wastewater either percolates from the cesspools into the soil, or evacuated by vacuum trucks, or discharged untreated into wadi beds. These malpractices resulted in the contamination of water resources and caused various environmental nuisances. The concept of appropriate sanitation systems for those communities has been either ignored or forgotten. No comprehensive studies have been made to investigate the key factors influencing technology selection of sanitation systems in Palestine (Abu Madi et. al, 2000).

The purpose of this research study is to develop a sustainable wastewater management strategy in small rural Palestinian communities of the West Bank so as to accelerate the expansion of wastewater services to these areas. The study traces the present status of rural sanitation in the West Bank. Various relevant economical, technical, socio-cultural and environmental circumstances in these areas, which influence the development of wastewater services, are reviewed. A planning tool for comparing and assessing the sustainability of different wastewater systems is presented. The selection criteria for sanitation systems are critically reviewed and discussed. Based on these criteria, the adoption of a focused sanitation strategy for rural areas is recommended. The guiding principles of the proposed strategy are also presented. To translate these principles into practice, an overview and analysis of various enabling technologies and their potential application within the framework of the strategy is offered.

The developed strategy recommended the application of holistic but decentralized management approach within the water cycle and the use of low cost sewerage, which are more suited to the socio-cultural and environmental circumstance in small communities of Palestinian rural areas. This approach will facilitate accelerated and sustainable extension of wastewater services to small communities as it offers a great potential for cost reduction, accommodates the needed domestic water conservation efforts, reduces water inputs in wastewater management and thus eliminates unnecessary demand on freshwater, contains pollution, reduces associated environmental risks and increases reuse opportunities (Bakir, 2000).

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

1.1. Background

About 60 % of the Palestinian population is locating in rural and semi urban communities (Abu Madi et. al, 2000). Rural areas in the West Bank are scattered over approximately 450 small villages (PWA, 2003). Several attempts were made to develop wastewater management strategies for the urban Palestinian areas, however strategic planning for a wastewater management for rural communities is still lacking (Al-Sa'ad, 2000). These areas will not be connected to sewage networks for many years to come because of the population number, the comparatively low density (about 360P/Km^2), and topographical conditions (PWA, 2000).

Only 2% of Palestinian rural areas population is connected to a sewer system, while the rest of them use mainly unsealed cesspools and occasionally septic tanks (PCBS, 2000). Wastewater either percolates from the cesspools into the soil, or evacuated by vacuum trucks, or discharged untreated into wadi beds. These cesspits are characterized by high evacuating cost which exceeds 40 NIS /time and frequent desludging. There is no legal framework or management programs to control their design, installation, performance and maintenance. Emptying of these onsite facilities is often neglected and wastewater overflows from the pits to the road or gardens presenting a health risk and a significant potential source of ground water pollution.

The concept of appropriate sanitation system for those communities has not been given enough attention. No comprehensive studies have been made to investigate the key factor influencing the selection of treatment system. Besides, there is lack of knowledge about low cost technologies appropriate for these poor scattered communities.

Conventional sewerage, which is generally regarded by engineers, planners and politicians, as the desirable solution for small communities, is expensive and water intensive and therefore its application for small communities in Palestine cannot be justified (Bakir, 2000).

Rural communities also typically are short of the technical and management capacity to solve the sanitation problem alone. These communities often have village councils and water committees that are responsible for providing water and sanitation services. However, these committees suffer from the lack of needed fund, experience, and technical staff to manage such water and sanitation projects.

The development of sanitation sector was promoted by some non-governmental organizations (NGO's) among others PARC, PHG, SCF, and ANERA, who have constructed onsite treatment systems in different small Palestinian rural areas. The systems introduced by these institutions mainly included trickling filters, upflow gravel filters, sand filters, constructed wetlands proceeded by septic tanks, and waste stabilization ponds followed by sand filters. Some of these onsite treatment systems like those implemented by PARC and PHG showed good elimination of organic pollutants, while poor nitrogen removal was observed in most of these systems (Al-Sa'ad and Zimmo, 2000). Moreover, many of these systems didn't succeed to give the desired treatment efficiency due to lack in monitoring, following up of the treatment systems by the responsible agencies after the end of the construction phase, and the lack of public awareness (CORETECH, 2003; PARC, 2001).

1.2. Main goal and objectives

The general objective of this research study is to develop a sustainable wastewater management strategy in small rural Palestinian communities of the West Bank so as to accelerate the expansion of wastewater services to these areas.

The specific objectives of this study are:

1. Evaluating the present status of rural sanitation in the West Bank.
2. Assessment of possible sustainable wastewater treatment alternative options to be applied in the Palestinian rural areas.
3. Working out criteria for rural sanitation systems selection based on technological, economical, socio-cultural and environmental factors.
4. Development of a sustainable approach for rural wastewater management.

1.3. Methodology

To achieve the main objectives of this research study, the following research methodology will be adopted:

- Conduct a detailed literature review; collect and analyze all available local and international studies, technical reports and published data concerning:
  - Onsite wastewater treatment systems, collective small wastewater treatment systems, non-conventional wastewater collection systems for small communities.
  - Existing rural sanitation and water services in the West Bank
  - Wastewater characteristics and production rate in rural areas in the West Bank.
  - The general characteristics of the study area including its physical, social and demographic features.
- Meeting with researchers pertinent to this subject.
- Interviewing people working in non-government organizations operating in the sector of wastewater engineering
- Evaluation of available technical data on design, operation and evaluate process performance of existing small rural sanitation systems.
- Application of multicriteria decision making technique to develop a systematic planning tool to assess the sustainability of envisaged wastewater treatment technologies to be applied in Palestinian rural areas.

1.4. Thesis outline

The research study consists of seven chapters:

- A literature review, where an overview of wastewater management, centralized and decentralized wastewater treatment approach, wastewater collection systems, wastewater treatment technologies and on-site wastewater treatment systems for unsewered communities is presented. In addition, the multi-criteria decision making technique and the sustainable criteria used for assessment of wastewater treatment systems are discussed (chapter two).
- Background information and data about the study area, its physical, social and demographic features, water and wastewater services (chapter three).
- Presentation and assessment of wastewater management in Palestinian rural areas and (chapter four).

- Development of a sustainable wastewater management strategy in Palestinian rural areas and applying the multicriteria analysis in selecting wastewater treatment systems (chapter five).
- Presentation of the proposed wastewater management strategy to be applied in Palestinian rural areas (chapter six)
- The conclusions and recommendations are presented (chapter seven).

CHAPTER TWO
LITERATURE REVIEW

Wastewater management in small communities

The problem and the objectives

Commonly used onsite wastewater disposal systems (cesspits or percolation pits) fail to protect the water resources and environment because of their poor design, lack of maintenance and increased loading and development densities. Water resources are very scarce and are being depleted and polluted at an alarming rate. Accelerated extension of adequate wastewater management services to small communities in the West Bank is essential. These services must deliver the following specific benefits:

- Protection of public health and well being of the communities
- Meeting the increasing demand for convenience
- Protecting, from pollution, the water resources and the household and community environments
- Contributing towards the alleviation of the pressure on the scarce water resources.

The guiding principles

Adequate and effective wastewater services for small communities in the West Bank must be developed within the following principles in order to meet the intended benefits:

1. Solutions should be tailored to the social, cultural, environmental, and economic circumstances.
2. Wastewater is part of the total water cycle and it should be managed within the integrated water resources management processes.
3. Pollution must be contained and the domain in which wastewater is managed should be kept to the minimum practicable size (household, community, town, city, catchments) and wastes diluted as little as possible.
4. Minimum of consumptive use of energy, chemicals, and water and maximum of re-use of treated wastewater and of residues produced from the pollutants present in the wastewater.

Conventional Centralized wastewater treatment approach

Conventional centralized systems involve installing an extensive network of large sewer pipes throughout a community to collect wastewater and bring it to a central treatment plant, followed by disposal in a stream, body of water or any designated reuse alternative (Lettinga and Zeeman, 2001). Engineers, planners and politicians as the only potion for urban areas and the desirable solution for small communities generally regard them. However, conventional sewerage is expensive (they cost 80-90% of the entire wastewater collection and treatment) and water intensive and therefore its application for small communities in the West Bank cannot be justified (Otis, 1996). Recent research and development in the field of wastewater management suggests that centralized wastewater management is unsustainable from social, environmental and financial point of view (Hedberg, 1999; Braden and Ierland, 1999; Venhuizen, 1997b).

Centralized wastewater management systems have several disadvantages:

- Use of large quantities of high quality water for transportation of domestic wastewater
- Limited possibilities of reuse of nutrients and energy due to the production of very diluted wastewater
- Limited possibilities of reuse of treated water, as it is often far from the places where it can be used
- Production of large quantities of sludge, too heavily polluted with heavy metals to be used in agriculture
- High dependency on central services like electricity supply
- High investment costs in small low population density communities due to: long sewers, high capacity of pipes and tanks, large civil investments and/or high-tech technologies, and (long and large trunk sewers, extensive pressure mains, pumping stations, storage and distribution network for treated effluent).
- High risk of spreading pollution to humans and the environment during system failures or severe overload of treatment works.

Decentralized wastewater treatment approach

Decentralized wastewater management implies managing wastewater as close as practical to where it is generated and to where its potential beneficial reuse is located (CEHA, 1999). It may comprise several smaller subsystems for collection, treatment and reuse. Decentralization requires the choice of efficient and affordable wastewater treatment technologies, which can be placed close to the human residential areas without causing nuisance to the community. This may include utilization of both simple and sophisticated technologies.

The advantages of decentralized wastewater treatment are (Mahmoud, 2002):

- Direct and immediate benefit.
- Small concentrated and separable wastewater flows that can be treated effectively.
- Reuse of clarified wastewater at source
- Controllable quality of clarified wastewater
- Compost, fertilizer and biogas production
- Reduction in the water requirements for waste transportation
- Reduction in the risks associated with system failure
- Low installation costs

Non-conventional wastewater collection systems for small communities

Four different non-conventional sewerage systems have been developed over the past few decades including the settled sewerage system, the simplified shallow sewerage system, the pressure system, and the vacuum system. The later two systems are not appropriate for Palestinian rural areas as they need high usage of mechanical components that results in a high institutional requirements and high cost of O& M. On the other hand, the settled sewerage and the simplified sewerage are well tried and robust offering the same benefits and convenience as conventional sewerage at much lower cost and less demand on water for their operation (CEHA, 1999).

- The settled sewerage system: it is also called “small bore sewers” and “small gravity sewers”. It is designed to receive only the liquid portion of household wastewater where solids are removed in an interceptor tank. Settled sewerage systems are more cost effective than conventional ones due to the shallow excavations depth, use of small diameter pips (commonly 75-100 mm PVC), simple inspection chambers, and negligible power requirements. This system is appropriate where the housing densities are low; the elevation of the treatment plant is lower than all of the service area and where the land is too flat (EPA, 1992).

• Simplified sewerage system: It is designed to receive all the household wastewater, without any of the conventional sewer system's conservative design features. This resulted in small pipe diameter, shallow excavations, and simple inspection units. They are cost effective for high density; low income-housing areas where there is no space for on-site sanitation pits or for solids interceptor tank (EPA, 1992).

Onsite wastewater treatment approach

Introduction

Onsite wastewater treatment systems (OWTSs) are those systems that can be used for treatment and disposal of wastewater at or near the place where wastewater is generated. They present a sound method of household waste management in communities where the development density is low, land is available for system construction, and where soil and groundwater conditions permit system use.

Conventional onsite wastewater treatment systems

The three primary components of a conventional system are the soil, the subsurface wastewater infiltration system (SWIS; also called a leach field, disposal field or infiltration trench), and the septic tank.

- **Subsurface wastewater infiltration**

Subsurface wastewater infiltration systems (SWISs) are the most commonly used systems for the treatment and dispersal of onsite wastewater. It consists of a series of narrow, relatively shallow (0.6 to 1.5 m) trenches filled with a porous medium usually gravel. Perforated pipe is installed to distribute the wastewater over the infiltration surface. Infiltrative surfaces are located in permeable, unsaturated natural soil or imported fill material so wastewater can infiltrate and percolate through the underlying soil to the ground water. Biochemical oxygen demand, suspended solids, fecal indicators, and surfactants are effectively removed within 2 to 5 feet of unsaturated, aerobic soil (EPA, 2002). However, nitrates and chlorides also leach readily to ground water because they are highly soluble and are non-reactive in soil.

- **Septic tanks**

The septic tank is the most commonly used wastewater pretreatment unit for onsite wastewater systems. The tank provides primary treatment by creating quiescent conditions inside a covered, watertight rectangular, oval, or cylindrical vessel, which is typically buried. In addition to primary treatment, the septic tank stores and partially digests settled and floating organic solids in sludge and scum layers (Baumann *et al*., 1978). A septic tank removes many of the settleable solids, oils, greases, and floating debris in the raw wastewater, achieving 60 to 80 percent removal rates (Baumann *et al*., 1978; Boyer and Rock, 1992; University of Wisconsin, 1978). Typical septic tank BOD removal efficiencies are 30 to 50 percent (Boyer and Rock, 1992; University of Wisconsin, 1978).

Need for more sophisticated treatment systems

Conventional systems work well if they are installed in areas with appropriate soils and hydraulic capacities; designed to treat the incoming waste load to meet public health, ground water, and surface water performance standards; installed properly; and maintained to ensure long-term performance. These criteria, however, are often not met. System densities in some areas exceed the capacity of even suitable soils to assimilate wastewater flows and retain and transform their contaminants. In addition, many systems are located too close to ground water or surface waters and others, particularly in rural areas with newly installed public water lines, are not designed to handle increasing wastewater flows. Conventional onsite system installations might not be adequate for minimizing nitrate contamination of ground water, removing phosphorus compounds, and attenuating pathogenic organisms (e.g., bacteria, viruses). This may cause human disease as methemoglobinemia, eutrophication and low dissolved oxygen in water resources. Threats to public health and water resources underscore the importance of introducing more sophisticated systems when conventional ones fail at providing the looked forward treatment results.

Today there are several alternatives for the conventional onsite wastewater treatment systems.

Three different onsite systems set-ups are discussed below.

- **Septic tank and Intermittent Sand Filter system:**

Intermittent sand filters (ISFs) are shallow beds of sand [600 to 760 mm) provided with a surface distribution system and an underlain system. Septic tank effluent (gray water or combined wastewater) is applied periodically to the surface of the sand bed. The treated liquid is collected in the underdrain system located at the bottom of the filter. The effluent from the filter is commonly discharged to a disposal field or disinfected and discharged to surface waters

High removal efficiency of around 90% was observed for organics, ammonium and TSS at hydraulic loading of 0.11-0.2 m^3/m^2/day and organic loading of 20-40 gBOD/m^2/day (Admon et.al; 2002).

- **Septic tank and Mound system:**

The mound system is essentially an intermittent sand filter that is placed above the natural surface of the ground. Trenches or beds are constructed in sand placed of above the natural soil. Septic tank effluent is pumped or dosed through a pressure distribution system placed in a gravel layer. Mound systems have been used in locations where: (1) the soils are permeable and the water table is shallow, (2) the underlying strata are highly porous and conventional systems should not be used, (3) slopes are less than 12 percent, and (4) the soils are slowly permeable. While conventional mound systems have been used where the soils are slowly permeable, they have only been partially effective because the applied effluent, which accumulates under the mound usually, cannot be transported away from under the mound.

- **Septic tank and Trickling filter system:**

Trickling filter systems are typically constructed as beds of media through which wastewater flows. Oxygen is normally provided by natural or forced ventilation. Flow distributors or sprayers distribute the wastewater evenly onto the surface of the medium. Typical trickling filters systems are capable of achieving BOD and TSS removal efficiencies of more than 85% and 50% respectively (Metcaff and Eddy, 1991). Nitrification is achievable at low loading rates in warm climates. Limited denitrification has been noted in nitrifying filters when oxygenation is poor and within dead zones (anaerobic portions) of the filter. Fecal coliform reductions are 1 to 2 logs, while Nitrogen removal varies from 0 to 35 percent might be expected (EPA, 1992).

Wastewater segregation approach

Segregating the various individual waste streams into two major fractions may modify the characteristics of domestic wastewaters: the toilet wastes, commonly referred to as the black water, and the other household wastes, commonly referred to as gray water or sullage (Figure 2.1). Reuse of treated gray water in non-potable water uses such as household landscaping, gardening, and toilet flushing is now established. Dual plumbing for waste drainage is common where toilet drains are kept separate from other drains until outside the house. The in-house segregation of domestic wastewaters offers means of enhancing the conventional methods of treatment and disposal, and of facilitating the development of alternative strategies for wastewater management.

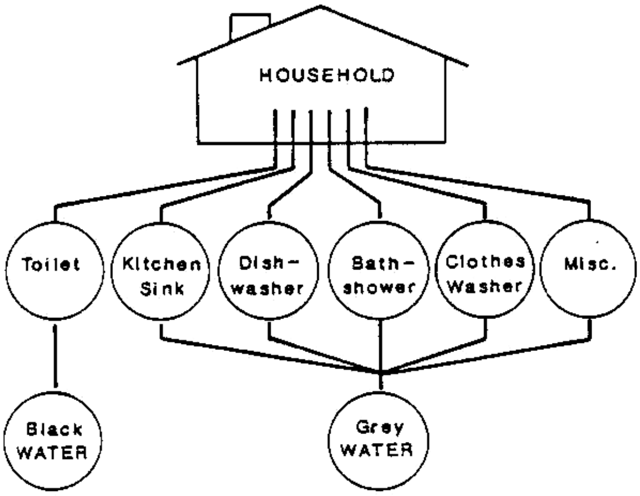

Figure 2.1: Segregation of household wastes into toilet waste as black water and gray water including: kitchen sink, dish washer, bath-shower, clothes washer and others (Siegrist, 1977)

Black water Management

Various strategies have been proposed to enable segregation and separate management of domestic toilet wastes. Those strategies that appear most feasible for residential use at present are outlined in Figure 2.2.

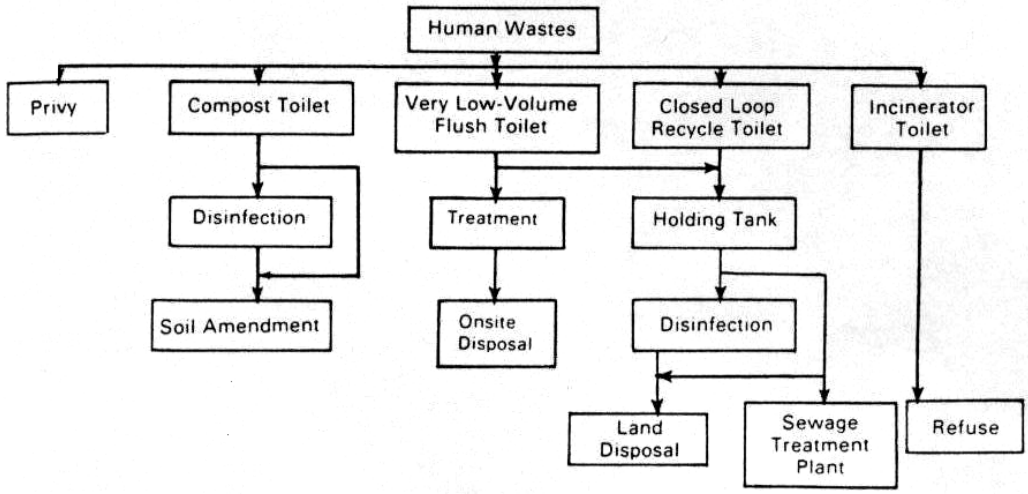

Figure 2.2: Strategies for black water management including disposing to privy, compost toilet, very low-volume flush toilet, closed loop recycle toilet or incinerator toilet (USEPA, 1980).

A BRIEF DESCRIPTION OF ALTERNATIVE TOILET SYSTEMS FOLLOWS:

• Composting Toilets: these units accept toilet wastes (and sometimes garbage wastes) and utilize the natural process of composting to effect their decomposition. The heat from aerobic decomposition destroys pathogenic organisms, decomposes organic wastes into humus-like material and drives off the water content of the wastes.

• Incinerating Toilets: these toilets are small self-contained units, which utilize the process of incineration to burn the solid wastes and evaporate the liquids. The incineration is usually fuelled by propane/natural gas, electricity or a combination of the two and usually lasts for 10 or 15 minutes followed by a 5-minute cooling period.

• Recycle Toilets: these toilets utilize a flushing liquid in a closed loop to cleanse the toilet bowl and transport the waste materials. The process used to purify the flushing medium varies considerably between systems, but commonly includes separation, aeration, filtration or a combination thereof. Purification normally takes place in a treatment/storage tank installed outside the structure containing the toilet fixture.

- Low Volume Flush Toilets: these toilets use low volumes of water as a flushing medium with compressed air or a vacuum being used to assist in the flushing. Other devices used to minimize toilet flows include toilet tank inserts or dual flush cisterns.

Apart from using the earlier described non-conventional toilets, the denitrification system for black water can also be used. Black water contains about 90% or more of the total nitrogen contained in household wastewater. Under certain site conditions, such as well-aerated permeable soils, wastewater will nitrify to nitrate within a few feet of soil. Because nitrates are soluble compounds, the pollutant will travel with the groundwater, and if sufficient dilution is not available the top groundwater layer can contain nitrates above the drinking water limit of 10 mg/I of nitrate nitrogen (NO_3 as N). Where site conditions are unfavorable for subsurface nitrogen disposal (such as in sensitive areas), a separate black water system is required (waterless toilets), or a denitrification step should be considered. Biological denitrification involves two steps. The first step is called nitrification, where organic and ammonia nitrogen contained in black water is converted to nitrate (NO_3) under aerobic conditions. The second step is called denitrification, where nitrate is converted to nitrogen gas under anaerobic conditions with a carbon source present in the gray water (Laak, 1986)

Gray water management

When segregated systems is used and toilet wastes are managed by an alternative toilet system, gray water can typically be treated and disposed of through a septic tank/soil absorption system. Although gray water does contain pollutants and must be properly managed, gray water is simpler to manage than total residential wastewater, primarily due to a reduced flow volume.

A number of diverse management strategies for gray water have been proposed and these are shown in Figure 2.3.

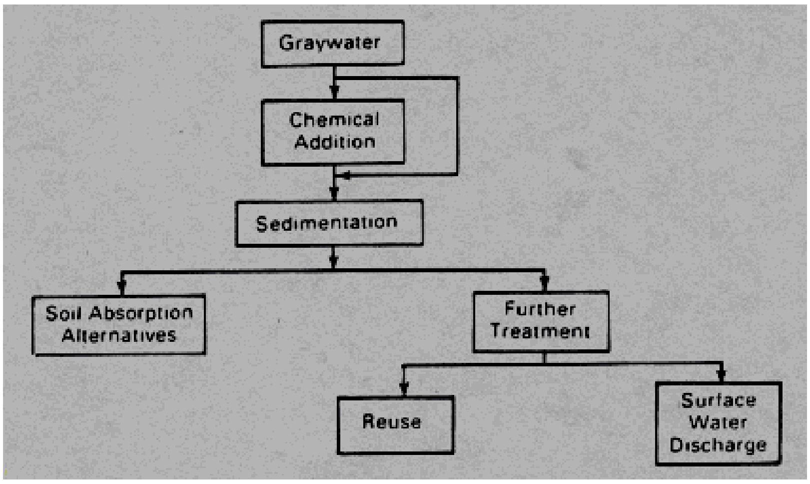

Figure 2.3: Strategies for Grey water Management including treatment by soil absorption alternatives or other treatment systems and then discharging to surface water or any other reuse alternatives (USEPA, 1980)

Grey-water may be disposed of by a number of soil absorption alternatives (as SWIS, intermittent sand filter system, and mound system) or by a trickling filter system adequately described in the literature. For more information see sections 2.5.2 and 2.6 While the Further Treatment options of Figure 2.3 are also described in the literature, several strategies are outlined below:

- Sand Filters: sand filters are a treatment alternative where pretreated effluent is passed through a filter of fine sand. The basis of this treatment process is similar to that which occurs in a conventional biological trickling filter using aerobic disintegration. Sand filters consistently remove significant amounts of nitrogen and phosphorus and reduce concentrations of organic material and suspended solids to low levels.

- Wetland Filters: in this system, gray water is piped to either a trench or bed where vegetation is grown specifically for the purpose of consuming wastewaters and nutrients. This form of treatment as high nitrogen and phosphorus removal rates can significantly improve effluent quality. Wetland filters are a suitable management option where sufficient land exists, particularly for use in the urban fringe and for larger rural/residential allotments.
- Disinfection/Irrigation: provided that gray water is retained in a sedimentation or retention tank and adequately disinfected, it could be reused above ground and spray irrigated. This reuse of treated and/or disinfected sullage conserves a valuable natural resource and returns nutrients to the land.

- Upflow anaerobic filter: One method of reducing the soluble BOD5 loadings and C/N ratio on sand filters and on leaching fields is the use of anaerobic upflow filters. An anaerobic filter has low cell yield and it is suitable for removing soluble BOD and SS. It can achieve removal rates exceeding 35% for both BOD and SS (Laak, 1986). An anaerobic Filter at extremely low loadings produces very low volumes of sludge, which need not be wasted.
- Recycle Systems: these systems are in-house wastewater treatment systems that can achieve a 39% reduction in wastewater flow, in which recycled gray water is used for non-body contact functions, such as toilet flushing and lawn irrigation (Anderson *et al*, 1981). See Figure 2.4. Home recycle systems offer significant water savings and waste flow reductions, however, they are only economically attractive under extreme water cost or wastewater disposal conditions (Anderson *et al*, 1981).

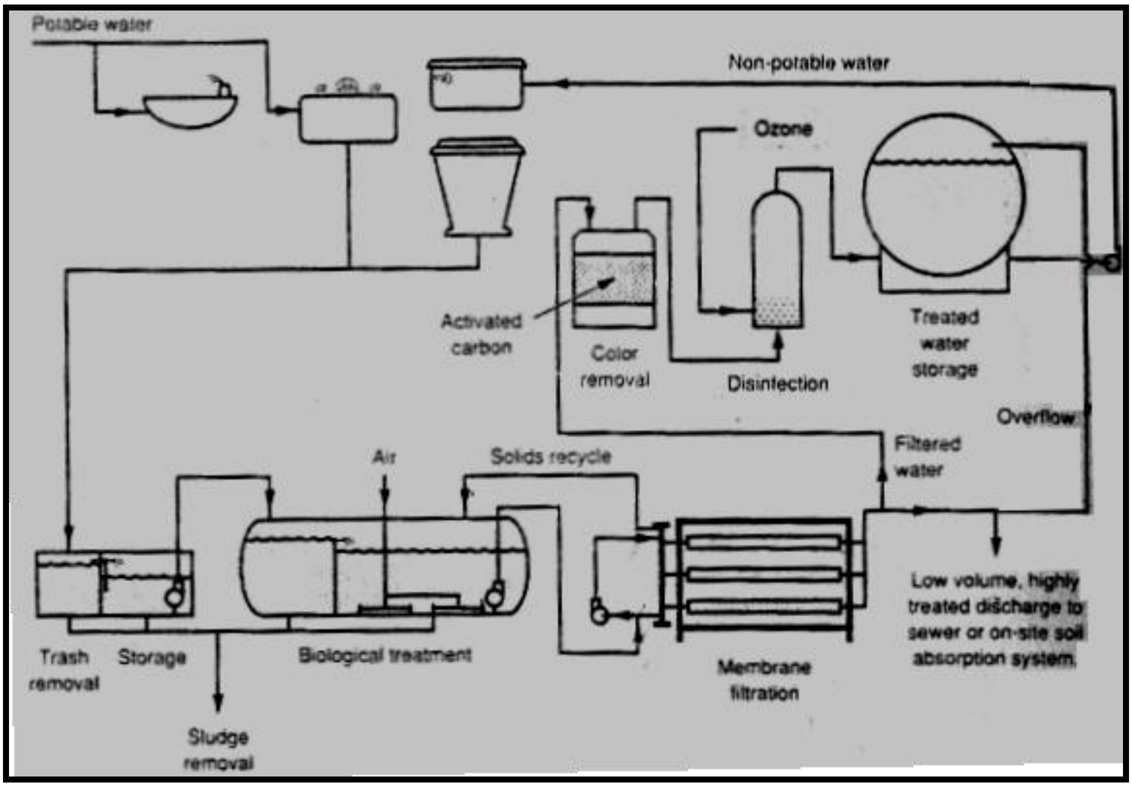

Figure 2.4: Typical flow diagram for a complete wastewater recycles system, Metcaff and Eddy (1991)

Types of small community systems

In many cases, traditional wastewater treatment strategies are inappropriate for the physical and economical characteristics of the small community. Onsite wastewater treatment technologies require land area to dispose of the wastewater generated. However, with increasing population densities in some rural areas the land availability for onsite systems is not always met. The current trends in wastewater treatment technology and the adoption of innovative management strategies have provided new alternatives for small communities. Wastewater treatment alternatives for small communities can be broadly defined under two category groupings: natural soil based systems and mechanical systems.

Technology Options for wastewater treatment in small communities

There are many technical alternatives from which small communities may choose in deciding how to collect and treat wastewater. Technologies discussed include natural systems including (constructed wetlands, waste stabilization ponds, recirculating sand filter), and mechanical systems including (trickling filter and extended aeration activated sludge). Trickling filters were previously discussed in section 2.6.

- **Constructed wetlands**

Constructed wetlands are artificial wastewater treatment systems consisting of shallow (usually less than 1 m deep) ponds or channels which have been planted with aquatic plants, and which rely upon natural microbial, biological, physical and chemical processes to treat wastewater.

Constructed wetlands have been classified by into two types. Free water surface (FWS) wetlands (also known as surface flow wetlands) that contain aquatic plants, which are rooted in a soil layer on the bottom of the wetland and water flows through the leaves and stems of plants. Vegetated submerged bed (VSB) systems (also known as subsurface flow wetlands), which have no standing water. VSB systems are more recommended for arid and semi-arid areas since evaporation is minimized as no water is exposed to air. Constructed wetland systems are capable of a BOD_5 and TSS removal efficiency of more than 80% and 95% respectively and can reduce nitrogen significantly (EPA, 1988). Fecal coliform removals of about 2 to 3 logs can also be expected (Crites *et al*., 1988).

- **Waste stabilization ponds**

Waste stabilization ponds (WSP) are shallow man-made basins into which wastewater flows and from which, after a retention time of several days (rather than several hours in conventional treatment processes), a well-treated effluent is discharged. WSP systems comprise a series of ponds: anaerobic, facultative and maturation. In essence, anaerobic and facultative ponds are designed for BOD removal of (50-70)% and maturation ponds for pathogen removal (feacal coliforms 4 log and helminthes 100%), although some BOD removal occurs in maturation ponds and some pathogen removal in anaerobic and facultative ponds (WHO/EMRA, 1987).

- **Recirculating sand filter**

Recirculating sand filter are open sand lifters designed to recirculate the filtrate, it is similar to an intermittent sand filter with the following exceptions: (1) effluent from a septic tank or other treatment unit is recirculated through the filter, (2) the effective sand size is larger, and (3) the loading rate based on the effluent flowrate is greater than that for an intermittent sand filter. RSFs produce a high quality effluent with approximately 85 to 95% BOD and TSS removal (Metcaff and Eddy, 1991). In addition, nitrification and denitrification may be achieved in RSFs.

- **Extended aeration activated sludge**

The extended aeration process is one modification of the activated sludge process, which provides biological treatment for the removal of biodegradable organic wastes under aerobic conditions. It is characterized by low loading rates and long hydraulic and solids retention times. Hydraulic retention times are typically 24 hours, with solids retention times of 20 to 40 days. Air may be supplied by mechanical or diffused aeration to provide the oxygen required to sustain the aerobic biological process. In a well-operated facility, BOD and SS removals can be expected to range from 85 to 95 percent (EPA, 1980). Because of the long aeration times, biodegradable toxic compounds are likely to be removed

An overview of multi-criteria decision making technique (MCDM)

Multicriteria decision-making (MCDM) incorporates decision-making and multicriteria analysis (MCA). MCA is the analysis of multiple elements to find a balanced solution for the problem tackled in the decision making process (Keeney, 1992). It establishes preferences between options by reference to an explicit set of objectives that the decision making body has identified, and for which it has established measurable criteria to assess the extent to which the objectives have been achieved (Dodgson *et al*., 2000). The MCA main concepts are addressed here, which are essential to understand the methodology proposed in this thesis.

2.10.1. The performance matrix

A standard feature of multi-criteria analysis is a *performance matrix*, or consequence table, in which each row describes an option and each column describes the performance of the options against each criterion. The individual performance assessments are often numerical, but may also be expressed as 'bullet point' scores, or color-coding.

2.10.2. Stages in MCDA

Table 2.1 describes what has to be done at each step of applying the MCA.

Table 2.1: Applying MCDA: Detailed steps (Dodgson *et al.*, 2000)
1. Establish the decision context. 1.1 Establish aims of the MCDA 1.3 Consider the context of the appraisal. **2. Identify the options to be appraised.** **3. Identify objectives and criteria**. 3.1 Identify criteria for assessing the consequences of each option. 3.2 Organize the criteria by clustering them under high-level and lower-level objectives in a hierarchy. **4. 'Scoring'. Assess the expected performance of each option against the criteria. Then assess the value associated with the consequences of each option for each criterion.** 4.1 Describe the consequences of the options. 4.2 Score the options on the criteria. 4.3 Check the consistency of the scores on each criterion. **5. 'Weighting'. Assign weights for each of the criterion to reflect their relative importance to the decision.** **6. Combine the weights and scores for each option to derive an overall**

Table 2.1: Applying MCDA: Detailed steps (Dodgson *et al*., 2000)
value. 6.1 Calculate overall weighted scores at each level in the hierarchy. 6.2 Calculate overall weighted scores.

Sustainable criteria for assessment of wastewater treatment systems in Palestinian rural areas

The choice of criteria is crucial. The criteria form the basis of the whole method of decision support and the internal connection between the onsite analysis, the technology information tool, and the evaluation tool. To define the list of sustainability criteria a representation of technology-environment-interaction was used as shown in Figure 2.5.

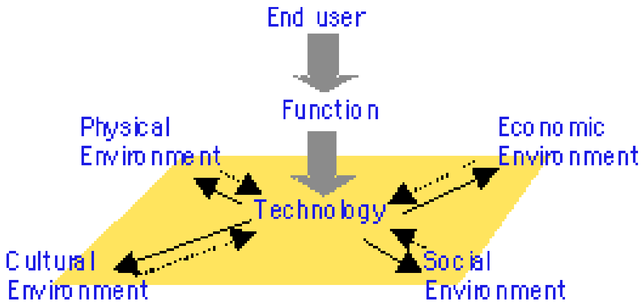

Figure 2.5: Description of the interaction between technology and the environmental factors

Based on this figure, a list of sustainability criteria and limiting constraints were defined. A brief description of each is presented in the following sections.

2.11.1. Technical criteria

Including durability, ease of maintenance, ease of operation, reliability, ease of construction, future expand, retention time. The technology should be reliable (endure shock loads and temperature changes).

The Palestinian rural areas communities lack the expertise for operation and maintenance of sophisticated sanitation facilities. Thus, the process should be fairly easy to operate, maintained and to construct.

Besides, technology to be chosen should have the state or quality of being durable, the power of uninterrupted or relatively long continuance in any condition. Technology process's with less retention time and more flexible to be expanded to meet future expanding requirements was given higher scores.

2.11.2. Economic criteria

Including construction cost, O & M cost, and land cost. The lower the financial costs (construction, operation and maintenance and land cost), the more attractive the technology is. The people must be willing to pay and able to cover at least the operation and maintenance cost of the total expenses. The ultimate goal should be full cost recovery although, initially, this may need special financing schemes, such as cross-subsidization, revolving funds, and phased investment programmes.

Land cost is a very important criterion. Where land is abundant, low cost natural treatment systems are usually appropriate, since they require little maintenance, are easy to operate and provide adequate treatment. Where land is scarce and expensive, mechanized, energy-intensive treatment processes, which require less land, may be more cost-effective than natural systems.

2.11.3. Environmental criteria

Including emissions (in water and sludge: BOD, N, and Pathogens), land area required/space, soil dependent, odor, noise, insects, visual, optimal water resource reuse, sludge production, use of chemicals, health risk, groundwater contamination.

Average, or typical, efficiency and performance of the technology are usually the criterion considered to be best in comparative studies. The possibility that the technology might remove other contaminants than those, which were the prime target, was considered an advantage.

The effluent quality should meet the effluent standards set in Table 2.2, adopted from the draft Palestinian standards for treated Domestic wastewater /PS 742 for fodder irrigation purposes.

Table 2.2 Draft- Palestinian standards for treated domestic wastewater for fodder crops irrigation, all values are maximum value and in mg/L except as otherwise indicated

Quality parameter	BOD_5	COD	Dissolved oxygen DO	Total dissolved solids TDS	Total suspended solids TSS	Ph	Color (PCU[1])
Value	250	700	>1	2000	250	6-9	-

Quality parameter	FOG	Phenol	$NO3^-$-N	MBAS	NH_4^+-N	T-N	PO_4^{-3}-P	CL^-
Value	12	0.002	50	50	-	-	-	350

Quality parameter	SO_4^{-2}	CO_3^{-2}	HCO_3	Na^+	Mg	Ca	SAR	Residual Cl_2 [(2)]	Al	As	Be	Cu
Value	1000	6	520	230	60	400	9	-	5	0.1	0.1	0.2

Quality parameter	F	Fe	Li	Mn	Ni	Pb	Se	Cd	Zn	CN	Cr	Hg	V
Value	1	5	5	0.2	0.2	5	0.02	0.01	2	0.1	0.1	0.001	0.1

Quality parameter	Co	B	Mo	Pathogens	TFCC[(3)]	Ameoba & Gardia(Cyst/L)	Nematodes (eggs/L)
Value	0.05	3	0.01	-	-	-	<1

[(1)]Color unit is measured by Platinum Cobalt unit

[(2)] Retention time should not be less than 30 min

[(3)] Most probable number per 100 ml

More details about the effluent standards of different reuse purposes as assigned in the draft Palestinian standards for treated Domestic wastewater /PS 742 are presented in Appendix II.

The effluent of the system should be controlled to be employed for reuse purposes. Besides, technology with less land area requirement, soil dependent, sludge production, use of chemicals was given higher scores. The chosen technology should be able to prevent and reduce adverse impacts on water resources that may result in ground water contamination and public health hazards.

Above and beyond, it should abate factors that may lead to public nuisance such as odors, noise and insects. Technologies (especially onsite ones) with better visual scene were given higher scores.

2.11.4. Social-cultural criteria

It includes institutional requirements, cultural acceptance, participation, awareness, and responsibility.

Residents' knowledge, attitude, opinions, and prejudices about waste disposal can determine whether a treatment technology will work in a particular culture or not.

In Palestinian rural areas there are people who have a strong objection to the use of reclaimed wastewater in irrigation. They are Muslims by majority, and they live in clans (Hamolah) where individuals are much dependent and influenced by the clan and the society. There, religion, traditions (culture) and politics influence the perception of individuals, clans and societies. Any sort of change in the society is not accepted without being permitted by those actors. However, most of them are not rigid, but subject to conditional change except for some postulates and taboos like Taharah and Najassah (impurities).

Therefore, it is important to develop a list of sanitation and reuse systems that are preferred and encouraged by the communities and do not contradict with their socio-cultural and religious values.

Another important criterion is the institutional requirements of wastewater management. In Palestinian rural areas few governmental agencies are adequately equipped for wastewater management. In order to plan, design, construct, operate and maintain treatment plants, appropriate technical and managerial expertise must be present. This could require the availability of a substantial number of engineers with postgraduate education in wastewater engineering, access to a local network of research for scientific support and problem solving, access to good quality laboratories, and experience in management and cost recovery. In addition, all technologies (including those thought "simple") require devoted and experienced operators and technicians who must be generated through extensive education and training.

Jordan's experience with wastewater management in small rural communities

Jordan is considered one of the water scarce countries. Consequently, recycled wastewater in Jordan is considered as an important water resource in the wastewater management policy. Twenty two percent of the Jordanian population lives in rural areas (small communities). The present wastewater management practices are simple disposal through cesspools and septic tanks with gray water discharged to house gardens. Several attempts were made to develop a sanitation strategy for the unsewered communities in order to protect public health and the environment. A strategy encouraging the improvement of effectiveness of on-site sanitation with a building code requirement and improved design, installing sewerage only where it is cost-effective (higher water use, more dense housing area), adopting simplified sewerage criteria to limit cost, utilizing a new low cost, sustainable treatment suitable for restricted irrigation was adopted (Saidam, 2000; Najjar, 2000). The later was implemented in Ein Al-Baida, which is a rural area in Tafila governorate. This project started on May 1st 2001. Twenty-three households are benefiting from the services of the project by installation of gray water recovery and pretreatment and implementation of on-site modular treatment plants for two houses. The beneficiaries were trained to make the O&M of the gray water and drip irrigation systems. Inter-Idamic Network on Water Resources Development constricted a rectangular gray water treatment plant unit based on PARC design at a household and a circular one designed and Management (INWRDAM) was constructed in the other household (Al-Jayyousi *et al*, 2002).

After implementation of the project many surveys were conducted over the beneficiaries and the revealed results showed 78% of them believes that there is no harm in gray water reuse in agriculture. It was evident from the benefit cost analysis that the project contribute to sound economic benefits. An analysis for a sample of treated gray water showed a 82%, 96%, 93%, 76% reduction in the TSS, O&G, BOD, (FC/100ml)^10 respectively (Al-Jayyousi *et al*, 2002).

The Egyptian experience with wastewater management in rural communities

As in the case of almost all rural areas in the Middle East, the Egyptian rural areas suffer from inadequate financial resources, insufficient water, lack of space, difficult soil condition, and limited institutional capabilities. In areas without sewerage network, wastewater is often collected in septic tanks, sanitary pit privy or other form of on-site systems (as subsurface soil adsorption fields.) Unfortunately, in many of the long inhabited village areas in Egypt they are overloaded. This situation has led the government to go toward a strategy based on introducing systems having a low cost for operation and maintenance, reduced staff requirements, quicker solution for environment conflicts, low investment, reduced area requirements, absence of mechanical equipment, low production of excess sludge, and of course suitable for warm climate. The UASB technology was introduced in the town of Sanhour in Fayoum by the Water Pollution Department Control Department of the NRC in cooperation with Wagnengen University. The performance data showed the effectiveness of UASB reactor removing up to 85% of the COD and about 85% of the incoming Suspended solids. Removal of fecal coliforms did not exceed one log. Therefore, an adequate polishing step was required. It was found that the best combination was between the UASB as a primary treatment and Trickling filters as a secondary treatment (Darwish and Ismail, 2001).

United States experience with wastewater management in small rural communities

More than a million homes in America still lack basic indoor plumbing, and many small communities have central wastewater systems that need extensive repair (USEPA, 2002). These conditions pose serious health and environmental problems for residents. Consequently, different organizations were found to help rural people to improve the quality of life in their communities. Among them is the Rural Community Assistance Program (RCAP) that was established in 1969. The RCAP's activities are carried out in rural areas with population of 2,000 or less, and in minority communities, underserved rural areas or rural areas with a high percentage of low-income individuals. Louisiana's rural communities are example of the earlier mentioned communities. In 1991, Louisiana's Nonpoint Assessment Report (NPS) indicated that improperly functioning septic tanks and unsewered or poorly sewered communities have been identified as major contributors to water quality and public health problems. It is estimated that 1,323,600 people treat and dispose of their wastewater in individual septic tank systems in Louisiana (LDEQ, 1993). Those systems, which are present on undersized lots or unsuitable soils, malfunctioned due to widespread saturation of the soil. Consequently, Louisiana's Department of Environmental Quality conducted a nonpoint source pollution management program to correct the earlier mentioned septic tanks problems. The program included educational programs on septic tank problems oriented to the parish sanitarians and the State Department of Health and Hospitals, and recommendations on referring to Louisiana's State regulations concerning community and private sewage disposal systems under the State Sanitary Code. In summary, the code provides information on general requirements, responsibilities, and controls for individual and community sewage treatment facilities.

CHAPTER THREE

THE STUDY AREA

3.1. General

The study area is limited to small, low income, unsewered rural communities with population number ranges between 100-4000 persons in the West Bank. These rural areas comprise approximately 75 % of the Palestinian built up areas. They are scattered over approximately 412 small villages within the eight districts of the West Bank that are shown in Figure 3.1 (PWA, 2003). A full data about these villages is presented in Appendix I.

The Jordanian valley and the Dead Sea bound the West Bank from the east and by the green line (1948 cease fire line) from the west, north and south. The total area of the West Bank covers 5820 Km^2 (ARIJ, 1996). It can be divided into four topographic zones: the Jordan valley Region, the Eastern slopes, the central highlands Region, which includes a range of mountains and their western slope areas and the Semi-Coastal Region, which comprises the northwestern plain parts of the West Bank (MOPIC, 1998).

3.2. Physical features

3.2.1. Geology and hydrogeology

The West Bank comprises of main ten formations that are distributed throughout the West Bank: the Kobar, the lower and upper Kahil, the Hebron, the Bethlehem, the Jerusalem, the Jenin sub-series, the Abu Dis, the Yatta, and the Malih formations. These formations compose of different layers as limestone, chalk, marl, dolomite, and sandstone. The presence of the earlier mentioned layers in the formations result in their being as good aquifers or aquiclude. The Kalih and Kobar formations in the Northeastern part near Tubas town, the lower and upper Kahil formation at the northwest of Ramallah city, the Hebron formation whose outcrops are spread all over the West Bank, Bethlehem formation at the north of Bethlehem, and the Jerusalem formation are all

CONSIDERED AS GOOD AQUIFERS DUE TO THE PRESENCE OF DOLOMITE OR LIMESTONE LAYERS. HOWEVER, THE PRESENCE OF CHALK OR MARL LAYERS RENDER THE REMAINING FORMATIONS AS AQUICLUDE AS IN THE CASE OF UPPER BEIT KAHIL FORMATION WHOSE OUTCROPS ARE SEEN SOUTH OF RAMALLAH, ABU DIS

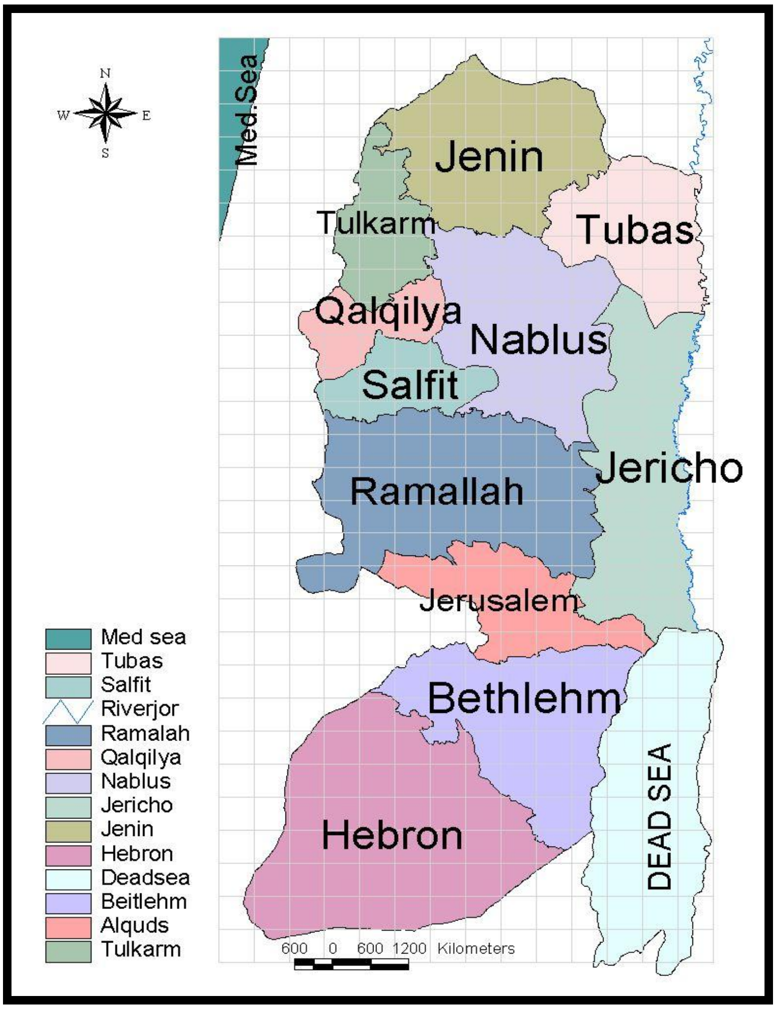

Figure 3.1: The eight districts comprising the West Bank

formation, Yatta formation, Bethlehem formation in the south, and Jenin sub-series in the north around Jenin city. The precipitation is almost the only source of replenishing these aquifers. Water levels vary from one place to another within each aquifer. It varies from130-160 m below ground level (bgl) in Jerusalem and Bethlehem while it goes to 200-300 m in Hebron and Upper and Lower Beit Kahil. However, water levels in the Jenin Sub-series can be found at 50 m bgl (MOPIC, 1998).

3.2.2. Soil

There are main eight different soil types with different properties in the West Bank.

a) Grumusols: this type of soil association covers the northern and middle parts of the West Bank districts. It is found in areas with smooth to gentle sloping topography. Its slope is less than 8% (MOPIC, 1998; ARIJ, 1996). It is originally formed from fine textured alluvial aeolian sediments.

b) Terra Rosa, Brown Rendzinas and Pale Rendzinas: this type of soil association covers most of the lands of the central mountains and the coastal areas of the West Bank districts. Their parent materials are dolomite and hard limestone. Their soil depth varies between 0.5 to 2 meters (MOPIC, 1998).

c) Brown Rendzinas and Pale Rendzinas: it covers mainly the hilly and mountainous lands in the central, eastern and southern parts of the West Bank. Its depth varies between 0.5 to 2 m (MOPIC, 1998;ARIJ, 1996). It has a crumby structure and a loamy or clay texture. Its parent material is soft chalk and marl.

d) Brown Lithosols and Loessial Arid Brown soil: this type of soil association covers the hilltops, plateau and foot slopes of the eastern slopes of the eastern districts of the West Bank as Nablus. The parent rocks of this soil association are chalk, marl, limestone and conglomerates.

e) Regosols: this type of soil association characterizes the badlands along the Jordan valley terrace exarpment lands. The soil parent materials are sand, clay and loess. This soil has pale brown, loamy, and very fine and weak texture. It has large amounts of salt contents. A hard shell with low permeability is formed on the top of this soil after the falling of very little amounts of rain.

f) Loessial Serozems: it dominates the central areas of the Jordan valley. This soil is typical at plateaux and moderates slopes. Its parent materials are loessial sediments, gravel and highly salted calcareous loamy sediments. It has a weak structure and suffers from extensive erosion due to runoff, limited salt leaching capability, which causes salt accumulation.

g) Bare rocks and Desert Lithososls: it covers the southern eastern parts of the West Bank districts along the Dead Sea. It is characterized by slight low depth of soil and bare rocks. It is found in flat areas or moderate slopes. It is originally formed from dolomite, chalk and limestone. Likewise, it has a weak structure with salty content and easily eroded.

h) Brown Lithososls: it is concentrated in the steep slopes of hills in the eastern slopes of the West Bank. It has a very low depth. Its parent materials are limestone, dolomite, and chalk.

Moreover, it has a low permeability with a very dry content and can be easily eroded (MOPIC, 1998;ARIJ, 1996).

3.2.3. Climate

The West Bank has in general a Mediterranean climate, which is characterized by a short raining winter and a dry summer .The annual average precipitation is between 450-500 mm, C, and the annual average °and the annual average temperature ranges between 15-20 evapotranspiration is between 1900-2600 mm. The high rainfall quantities occur in the northern, middle and partially in the eastern and southern parts of the West Bank governorates (MOPIC, 1998). The West Bank may be divided into four climatic zones: the Jordan valley Region, with a semi-tropical climate, the Central Highlands Region with Mediterranean climate and finally the Semi-Coastal Region with a semi-humid Mediterranean climate.

3.2.4. Sensitive areas and agricultural suitability

The West Bank governorates as shown respectively in Figure 3.2 and Figure 3.3, is divided into a number of sensitive recharge areas (highly sensitive, locally highly sensitive, sensitive, moderately sensitive, and not sensitive areas), and a number of agricultural suitability areas (high-suitability, moderate-suitability, moderate-low-suitability, and low-suitability areas).

Furthermore, other areas were defined as areas that need to be protected from contaminates such as Dead Sea Coast and the Alluvial Aquifer in the Jordan valley, and the areas where development is constrained by the physical nature of the surface cover such as in the Jenin plain areas. As it is apparent from the sensitivity map, most of the sensitive aquifer recharge areas are found in the west and northwest, while in the east and southeast, the areas are in general less sensitive The recharge areas were classified in accordance with the following criteria: Lithology, structure, rainfall, hydrogeology, water quality, water level, topography, slope and land use, and evaporation (MOPIC, 1998). It was recommended by MOPIC that certain types of development should not take place in sensitive areas, in order to protect ground water quality, which may be sensitive to infiltration of pollutants.

3.3. Socio-economic and demographic features

The total number of population of the West Bank is 2.385 million persons with an average population density of 428 persons/Km^2 (PCBS, 2004). The average number of persons per household is 7 persons/household and the annual growth rate is

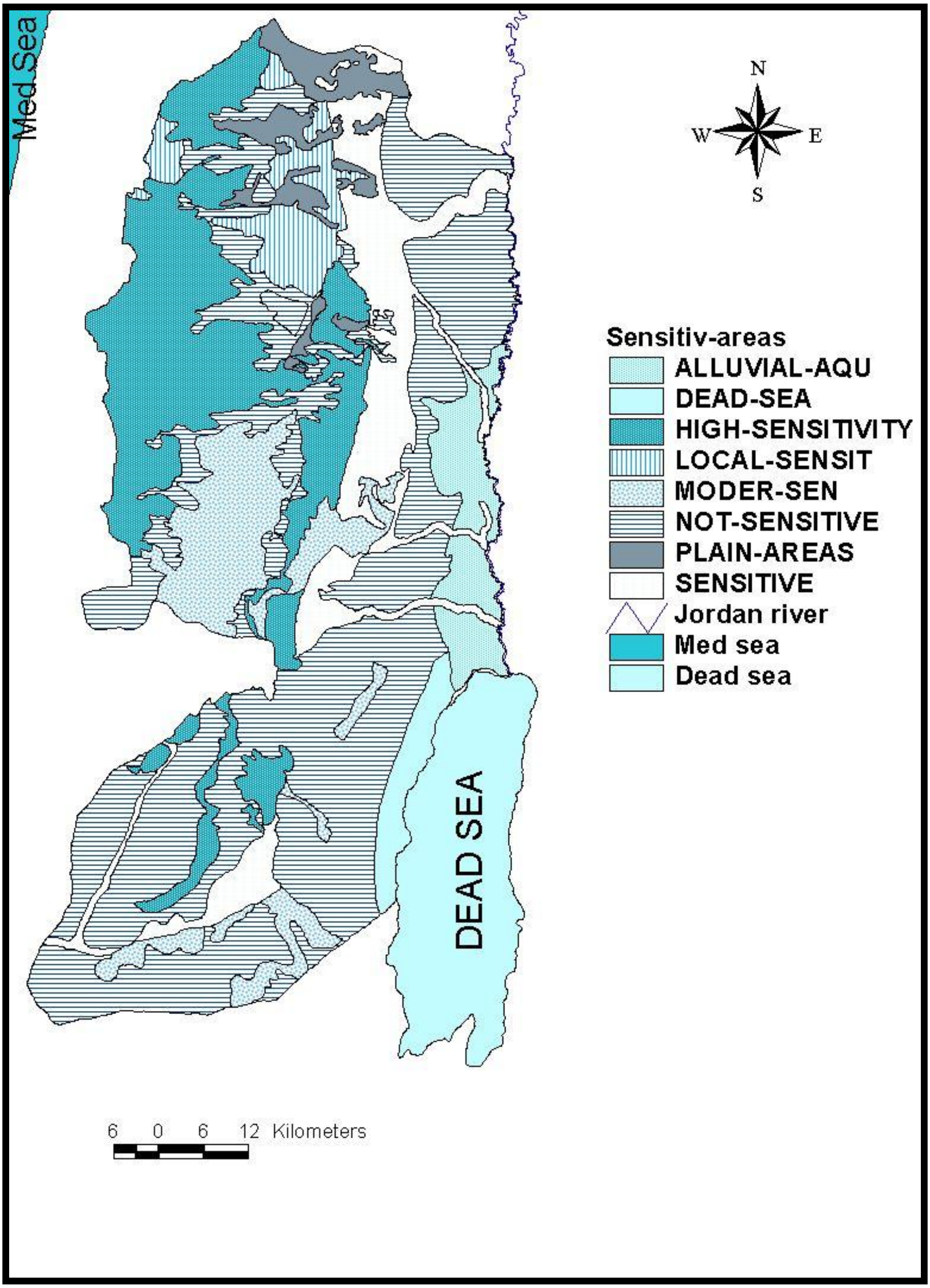
Med Sea
N
W
E
S
Sensitiv-areas
ALLUVIAL-AQU
DEAD-SEA
HIGH-SENSITIVITY
LOCAL-SENSIT
MODER-SEN
NOT-SENSITIVE
PLAIN-AREAS
SENSITIVE
Jordan river
Med sea
Dead sea
DEAD SEA
6 0 6 12 Kilometers

Figure 3.2: The West Bank recharge areas sensitivity classification map, (PWA, 2003)

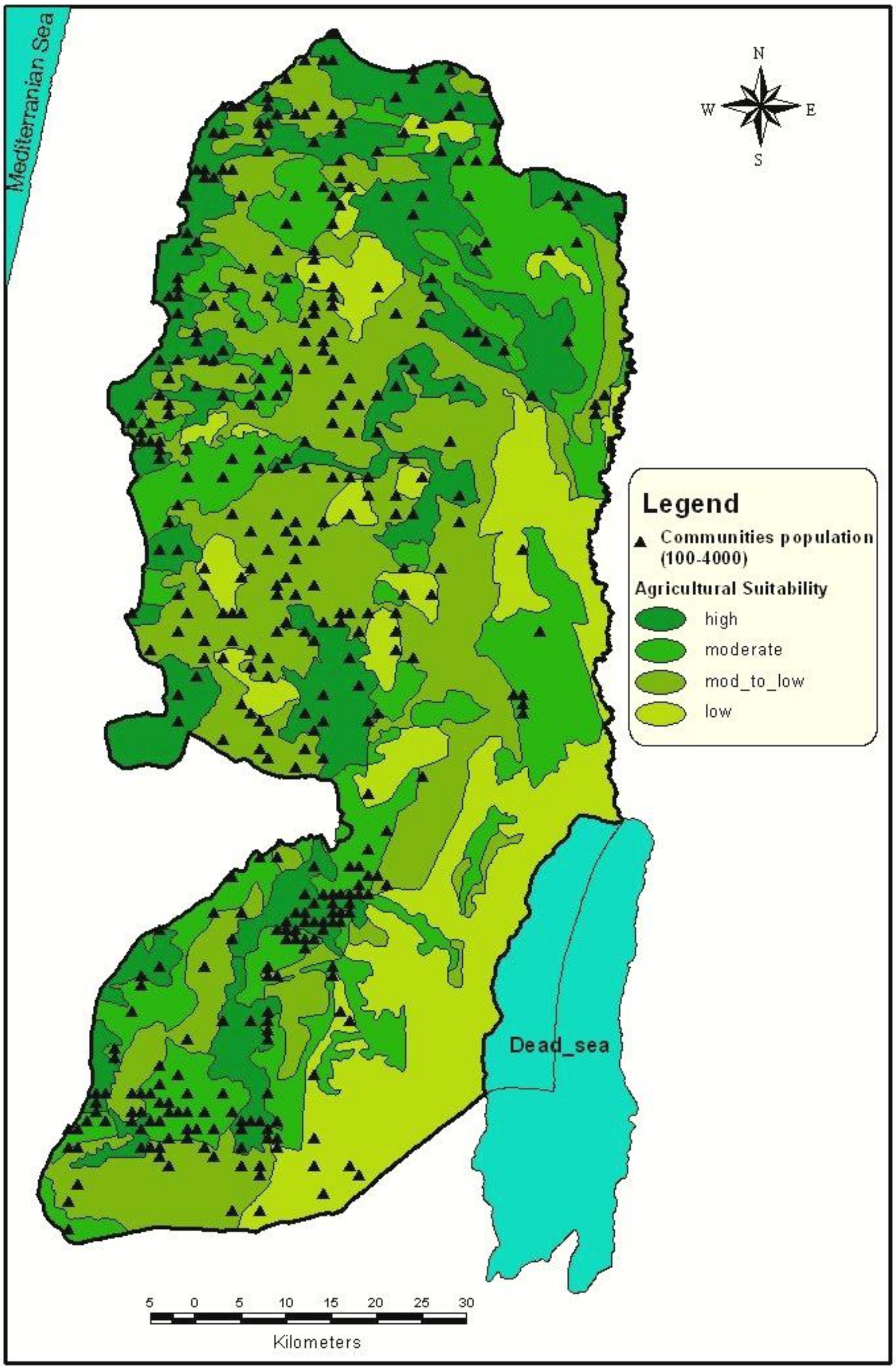

Figure 3.3: The West Bank agricultural-areas suitability classification map, with a presentation of small communities (population 100-4000 c), (MOPIC, 1998; PWA, 2003)

approximately 3% (PCBS, 2000). The population is distributed into three clusters: the urban areas, rural areas and camps. The ministry of local authority MOLA with reference to the following criteria classifies these areas:

a) All the centers of districts are classified as urban areas.

b) Every community with total number of population exceeds 10,000 is considered as urban except for camps.

c) Every community with total number of population between 4000-9999 is considered urban if at least four of the following services are available: water network, sanitary network, electricity network, a health care center with a residential doctor for the whole week, a high school, and postal office.

d) Every community of which the above motioned criteria don't apply is considered as rural community

The above-mentioned criteria are not applicable for the camps, which are communities, supported by UNRWA.

Municipal councils administrate13% of the Palestinian communities, while 56% of the Palestinian communities have village council or project committee, 1% of the communities have local councils and the remainder 30% of the communities have a camp director (PCBS, 1998).

People in small rural communities lives in houses concentrated around the village center where there might be some services like small markets, coffee shops and the mosque. However, few families living are living in houses isolated and away from the center as seen in Figure 3. 4.

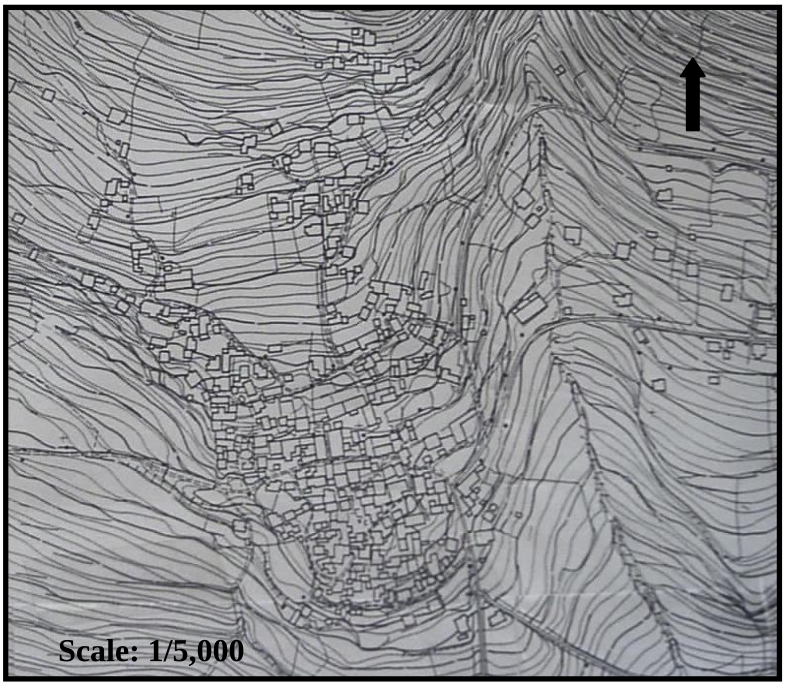

Figure 3.4: Topograhpic map of Beit Amaran village (Nablus),(CEP,2003)

The dominant economic activity in the rural areas in the West Bank is agriculture, particularly in the plains around Jenin, Tulkaram and Jericho. On the other hand, other activities as few industries in material construction, pharmaceutical industries and food process in Ramallah, agro-processing and stone quarrying and cutting in Nablus, stone and marble quarrying and cutting, agro processing, clothing, shoe-making, textile and leather production, furniture making, ceramics and glass in Hebron, trade in Ramallah and Nablus, stone cutting in Bethlehem, financial services as money-changers in Ramallah and Nablus, tourist services in Jericho and Bethlehem, and livestock raising in Bethlehem form the main components of the West Bank economic base. In the past some of the rural communities relied to large extent on wage labor in the Israeli labor market, however, many Palestinian labors lost their jobs during the period shortly preceding the Al-Aqsa Intifada and the first quarter 2004. The average monthly income for people living in the West bank is 1500NIS (PCBS, 2004).

3.4. Water resources and supply services

Palestine is experiencing a severe water crisis caused by the lack of control over the Palestinian water resources (Abu-Zahra, 2000). The average per capita water consumption by the Palestinian rural areas population is approximately 60 l/c/d, which is less than the WHO Table 3.1 shows the total and per capita .(PCBS, 2000) minimum standards of 100 l/c/d domestic water supply by governorate for the year 1997.

Table 3.1: The West Bank total and per capita domestic water supply by governorate for the year 1997, (PCBS, 2000)

Governorate	Per Capita water supply (L\c\d)
West Bank	84
Jenin	68
Tubas	92
Tulkaram	129
Nablus	109
Qalqiliya	68
Salfit	77
Ramallah& Al-Bireh	100
Jericho	129
Bethlehem	67
Hebron	57

Groundwater is the main source of water in the West Bank. Furthermore, there are other water resources such as springs, wadis and seasonal lake.

3.4.1. Conventional water resources in Palestine

a) Groundwater: It is the main water source of water in the West Bank. The West Bank aquifer system, has three main drainage basins (see Figure3.5)

- The western basin that is supplied and recharged from the West Bank Mountains, located within the boundaries of the West Bank and Israel. The total Palestinian water consumption from this basin is only 22 Mm^3\year (Abu-Zahra, 2000).
- The northeastern basin, which is located inside the West Bank near Nablus and Jenin and drains into the Eocene and Cenomanion-Turoian aquifer under the north of the West Bank. The total Palestinian water consumption from this basin is 42 Mm^3\year (Abu-Zahra, 2000).
- The eastern basin, which is located within the West Bank and the springs from which represents 90% of spring discharge in this area. The total Palestinian water consumption from this basin is 54 Mm^3\year (Abu-Zahra, 2000).

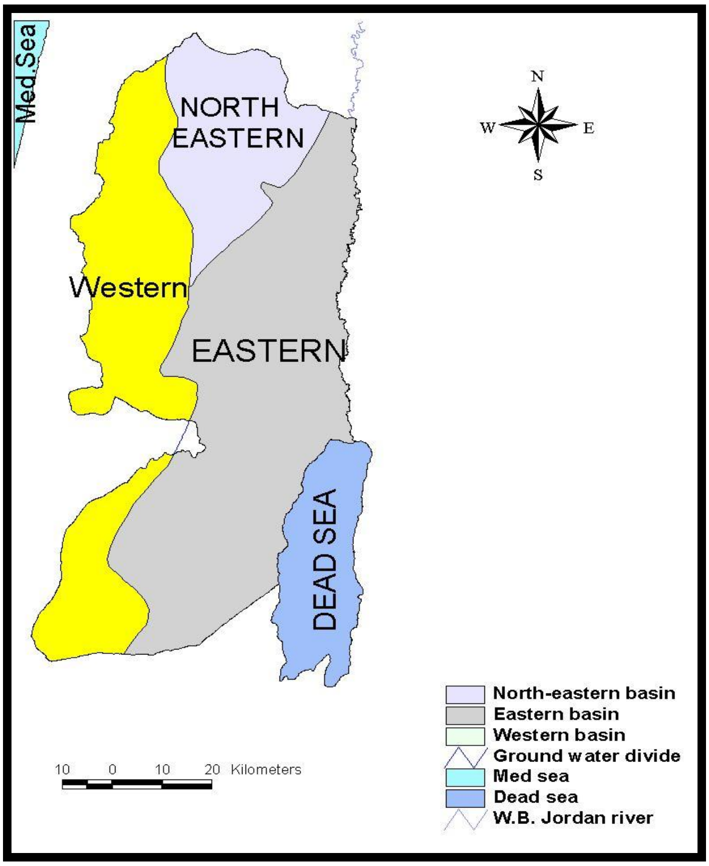

Figure 3.5: The West Bank main basins map, (PWA, 2003)

However, the Palestinians are prevented from fully utilizing the West Bank underground water resources. The drainage basins discharge approximately 600-660 Mm^3 annually, the West Bank Palestinians exploit currently 115-123 Mm^3, the remaining amount is exploited by the Israelis (Abu-Zahra, 2000).

b) Springs: there are 297 sprigs in the West Bank, 114 out of which are considered to be the main ones with substantial yield quantities (Abu-Zahra, 2000). Usually there are fluctuations in the yield of some of these springs in the different years, depending on the rainfall quantities, and thus the recharge to groundwater. However, their average annual yield is estimated to be around 60.8 Mm^3/Y (Abu-Zahra, 2000).

c) Wadis and seasonal lakes: only four wadis are permanent in the West Bank, all of which flow to the east and reach the River Jordan. These are wadi Fara', Qilt, Maleh and Auja. The quantities of lost flooded surface water are estimated to be 70 Mm^3/y (Abu-Zahra, 2000). In addition to these wadis, there are seasonal lakes in the West Bank, especially Marj Samur in the Jenin governorate. They are like the wadis, which are of the seasonal type as they flow only in the winter season during the flood periods, which happen for just few days every year.

3.4.2. Non-conventional water resources

a) Cisterns: cisterns act as a major source of domestic water supply in the localities that do not have water supply networks. It is estimated that 66 Mm^3/y is utilized from the cisterns (Abu-Zahra, 2000).

b) Wastewater reuse: the reuse of wastewater has been carefully investigated in many studies performed for the water sector in the West Bank. The main issues concerning the reuse of wastewater such as the collection system, treatment plants, regulations, standards and guidelines are not available yet.

3.4.3. Water supply services

For the year 2001, around 77% of the inhabitants residing in 294 localities in the West Bank have piped water supply systems, while 23% of inhabitants residing in 151 localities do not have this service (PWA, 2003). Full data about small rural communities with/without water networks is presented in Appendix I. As presented in Table 3.2, communities without water network use other water resources alternatives as water wells, cisterns, springs, and purchasing water tanks.

Table 3.2 Distribution of the West Bank governorates by the alternative substitutes (springs, water wells, rain water collection wells, and purchasing water tanks) for the public water, (PCBS, local community survey, 1998)

Governorate	Alternative for the network				
	Other	**Purchasing water tanks**	**Springs**	**Rain water collection wells**	**Water wells**
Jenin	-	58	2	53	1
Tubas	-	16	3	10	3
Tulkaram	-	14	-	16	6
Nablus	1	37	19	37	6
Qalqiliya	-	13	1	11	5
Salfit	1	6	6	8	-
Ramallah& Al-Bireh	3	8	9	14	3
Jericho	1	2	2	1	2
Jerusalem	1	4	-	4	-
Bethlehem	3	9	1	11	1
Hebron	-	101	21	118	8
West Bank	10	268	64	238	35

3.5. Water resources contamination due to present wastewater disposal practices in the West Bank

Present wastewater disposal practices as using cesspits or discharging wastewater to near wadis have resulted in a great damage to many water resources in the West Bank (Mahmoud, 2002). Pollution indicators such as high concentration of NO_3^{-1}, CL^{-1}, and fecal coliforms have been found in many samples taken from different wells and springs in the West Bank as shown in tables 3.3 and 3.4. As shown in these tables, the springs and wells' nitrate (NO_3^{-1}), chloride (Cl^{-1}) and total coliforms (T-Col) concentrations respectively exceed the WHO drinking water quality standard of 45 mg/l, 250mg/l, and 2.2MPN/100cm^3. Full data about the springs and wells with high concentrations of NO^{-3} that exceed 45mg/l are presented in Appendix III. In addition to the contamination of springs and wells, wastewater percolation may result in the contamination of rainwater collection cisterns if they are located few meters away from the cesspits or in a location below cesspit level.

Table 3.3: Point Name, locality, governate, NO^{-3} (mg/l), CL (mg/l), and T-Col ($MPN/100cm^3$) concentrations of the West Bank contaminated springs due to wastewater percolation for the year (2000), (PWA, 2003)

Spring number	**Point Name**	**Locality**	**Governate**	**NO^{-3} (mg/l)**	**CL (mg/l)**	**T-Col ($MPN/100cm^3$)**
1	Al Balad	Beit Imrin	Nablus	45	132	48
2	Al Balad	Iraq burin	Nablus	105	105	999
3	Al Balad	Burin	Nablus	70	55	999
4	Al Balad	Iraq burin	Nablus	105	105	17
5	Al Balad	Beit Imrin	Nablus	45	132	18
6	Al Balad	Yasuf	Salfit	47	74	28
7	Al Hammam	Bir Zeit	Ramallah	88	78	34
8	Al Hammam	Bir Zeit	Ramallah	88	78	98
9	Al Sharqiyyah	Jaba'	Jenin	52	76	120
10	Battir	Battir	Behtlehem	49	49	35
11	Battir	Battir	Behtlehem	49	49	134
12	Beit Al Ma'	Nablus	Nablus	46	70	13
13	Beit Al Ma'	Nablus	Nablus	46	70	32
14	Flaiflah	Bir Zeit	Ramallah	77	51	8
15	Flaiflah	Bir Zeit	Ramallah	77	51	880
16	Haskah	Halhul	Hebron	51	56	15
17	Irtas	Artas	Behtlehem	53	65	999
18	Irtas	Artas	Behtlehem	53	65	127
19	'Itan	Artas	Behtlehem	85	52	7
20	Jurish	Jurish	Ramallah	445	145	112
21	Therweh	Halhul	Hebron	94	94	47
22	Unqor	Dura	Hebron	96	104	880

Table 3.4: Point Name, locality, governate, NO^{-3} (mg/l), CL (mg/l), and T-Col ($MPN/100cm^3$) concentrations of the West Bank contaminated wells due to wastewater percolation for the year (2000), (PWA, 2003)

Well number	**Point Name**	**Locality**	**Governate**	**NO_3^{-1} (mg/l)**	**CL^{-1} (mg/l)**	**T-Col ($MPN/100cm^3$)**
1	'Abdallah Muhammad 'Abed	Qalqilya	Qalqilia	52	142	28
2	'Abed Al Kareem Zaid	Tinnik	Jenin	51	107	29
3	Al Fawwar - Hebron	Al Fawwar	Hebron	94	80	3
4	'Anabta Municipality	'Anabta	Tulkarm	96	111	3
5	'Arrana Local Council	'Arrana	Jenin	63	419	14
6	'Azzun Village Council	Azzun	Qalqilia	45	58	9
7	Jameel 'Awartani	'Anabta	Tulkarm	58	126	35
8	Muhammad Qaddurah	Habla	Qalqilia	51	66	16
9	Rafeeq Hamdallah	Iktaba	Tulkarm	55	60	55
10	Saleem Abu Farhah	Al Jalama	Jenin	63	312	5
11	Tubas Water Project	Ras Al-Far'a	Tubas	64	86	17

3.6. Wastewater production

Aforementioned, most of the small rural communities are not connected to water networks. They may use other water supply alternatives such as purchasing water tanks, springs, rainwater collection wells, water wells, and cisterns. Consequently, wastewater production expected from these areas is dependent on available water resources. Based on information about water supply services availability in these areas, with an assumption that 80% of consumed water is discharged as wastewater. A rough estimate of quantities of wastewater produced from rural areas with population number less than 4000 persons is presented in Table 3.5. Approximately, an amount of 14 Mm^3 of wastewater is discharged yearly from these areas. Full data about each rural community wastewater production with population less than 4000 persons is presented in Appendix I.

Table 3.5 Distribution of the wastewater production from the West Bank rural communities (population less than 4000 persons) by population number

Population number	Percentage of the total population number	Wastewater production (m^3/day)
< 1000	8.6 %	2157
1000-2000	27.0 %	7457
2000-3000	34.4 %	9093
3000-4000	30.0 %	7670
Total	100 %	26,377

3.7. Characteristics of wastewater

Unfortunately, the characteristics of wastewater in the Palestinian rural areas have not been subjected to good analysis due to lack of collection networks in most of these built up areas (Mahmoud, 2002). Hardly any institutions as PARC and PHG have made wastewater-sampling analysis for few wastewater parameters prior to conducting some of the wastewater treatment plants in different Palestinian rural areas (see Table 3.6). Most of the other wastewater treatment plants implemented in variant Palestinian rural areas by different institutions were designed based on estimated values for the different wastewater parameters.

Table 3.6 Domestic wastewater characteristics at different rural locations in the West Bank (Zimmo, 2003; PHG, 2004)

Location	Parameters							
	BOD (mg/L)	TSS (mg/L)	COD (mg/L)	NO3-N (mg/L)	NH4-N (mg/L)	pH	EC (microS/cm)	Kj-N (mg/L)
Sarrah	1180	1720						
Nuba	546		120					80

Location	Parameters							
	BOD (mg/L)	**TSS (mg/L)**	**COD (mg/L)**	**NO3-N (mg/L)**	**NH4-N (mg/L)**	**pH**	**EC (microS/cm)**	**Kj-N (mg/L)**
[a]Hebron/site#1			150[b]	0.8[b]	60[b]	7.1[b]	2248[b]	
[a]Hebron/site#2			1000[b]	0[b]	120[b]	7.2[b]	4290[b]	
Birzeit			735					
Deir-Samit			1300					

[a]Site #1, and site #2 are located at two rural areas in the southern part of Hebron district
[b]Samples taken after wastewater passing through primary sedimentation

Moreover, results of the analysis of gray and black wastewater from a house located in a rural area (Bilien village /Ramallah) are reported in Table3.7.

Table 3.7: Characteristics of wastewater at Bilien village (at pilot plant, one house, 13 persons), (Mustafa, 1997)

Parameters	**Gray wastewater**		**Black wastewater**	
	Range	**Median**	**Range**	**Median**
BOD (mg/l)	222-375	286	255-322	282
COD (mg/l)	600-850	630	566-643	560
BOD: COD	1.6-2.58	2.25	2.1-2.7	2.26
Dissolved Oxygen (DO in mg/l)	5.24-6.5	5.9	5.5-7.0	6.25
Temperature C°	18.5-25.4	22	15-16	15.7
NH_4^+-N (mg/l)	7-12	10	371	
Kj-N (mg/l)	16-17	16.7	292-381	358
Phosphate total (mgP/l)	15-17	16	34	34
PO_4^- ($mgPO_4^-$/l)	45-52	49	------	------
Sulfate SO_4^- (mg/l)	52-54	53	46	------
NO_3^- (mg/l)	0-1.3	1	------	------
Total Suspended Solids (mg/l)	94-181	125	------	------
Settling Solids (ml/l)	0.3	4.5	1.7	------
Total dissolved Solids (mg/l)	628-1212		2540	------
Chloride (mg/l)	180-220	200	773	------
PH	6.6-7.4	7	8-8.5	8.2

Cations$^+$ (mg/l)	K	Mn	Na	Mg	Ca	Cu	Fe	Pb	Zn
Gray wastewater	18.37	0.06	87.58	27.15	64.1	0.0014	0.777	0.133	0.00

From the above tables, it can be concluded that the wastewater has a high COD, Nkj, phosphorous, sulphate, ammonia, and solids concentration. This is attributed to low water consumption and people habits (like discarding the remaining food and used cocking oil in kitchen sinks) (Mahmoud, 2002). The domestic wastewater COD concentration is more than twice as strong as gray wastewater. While it is extremely low, in the case of black wastewater. However the ammonium concentration in the black wastewater (360mgKj-N/L) is much higher than the gray wastewater concentration of 17mgKj-N/L due to the presence of urine in the fist one.

3.8. Sewage disposal facilities

Often national and donor policies prioritize urban development projects and over rural projects. Likewise, wastewater management has been neglected throughout the West Bank and especially in the rural areas and small communities (Al-Sa'ad, 2000; Mustafa, 1997). While around 2.81 Mm3 of wastewater is produced monthly in the West Bank (PCBS, 1998), sewage collection networks are limited and inadequate. For the year 1997 a large percentage of wastewater is still collected in cesspits and open sewers. The percentage reaches 92.2 % of the rural houses (PCBS, 2000). Besides, only 1.8% of houses in the West Bank rural areas are connected to wastewater networks (PCBS, 2000). The commonly used cesspits capacity, which are designed and constructed without a concrete lining in order to allow seepage inside the ground, ranges from 5-50 m^3. These cesspits are emptied 2 to 3 times a year and 32% of the Palestinian families own a well close to the cesspits with a separating distance between them less than 30 m (PCBS, 2000). Besides, 50% of the wastewater produced by the Palestinian communities is discharged raw into wadis, while 137 communities dispose its produced wastewater at a distance less than one kilometer from the wadis (PCBS, 2000).

CHAPTER FOUR

WASTEWATER MANAGEMENT IN PALESTINIAN RURAL AREAS

4.1.*Present status of wastewater management in Palestinian rural areas*

The Palestinian rural communities mostly depend on cesspits and occasionally septic tanks for disposal of their excreta. There is no legal framework or management programs to control their design, installation, performance and maintenance. Emptying of these onsite facilities is often neglected and wastewater either percolates into the soil, or overflows from the pits to the road or gardens, or evacuated and discharged untreated into dry wadi beds (see Figure 4.1).

Figure 4.1: Wastewater disposal practices in unsewered rural areas in Palestine (PWA, 2003)

4.2. *Current situation of institutional wastewater management agencies in rural Palestine*

Several institutions including mainly the Palestinian Water Authority (PWA), local committees and village councils, local and international NGO's and institutions, work in the wastewater sector in the Palestinian rural areas.

I. The Palestinian Water Authority

Since 1996, the PWA is responsible for regulation of the Palestinian wastewater policy, including collection, treatment, sludge handling and reuse. It is the Palestinian legal body that is responsible of:

- Licensing and approving all wastewater projects and activities including wastewater and storm water collection, treatment, reuse, and/or disposal
- Ensuring and overseeing the efficiency and compliance of these activities and projects initially and during operation, according to approved regulations, specifications and

standards.

However, and due to the existing complicated political circumstances in the West Bank and the insufficient wastewater management expertise staff, the PWA faces great challenges in enforcing its regulations. Coordinating with relevant wastewater sector development agencies like the NGO's and donors is still poor. The main issues concerning the management of wastewater such as the collection systems, treatment plants, regulations, standards, and regulations are not available yet.

II. Local Committees and Village Councils

Approximately one quarter of all Palestinian villages have village councils. These local bodies manage and develop public services in the village including the supply of sanitary services. Local committees are formed wherever a village council does not exist. The councils and committees are generally unqualified from technical, administrative and financial viewpoints, which lead to inefficient management. Besides, village people have little influence if any in the establishment or operation and maintenance of those services

III. Local NGO's and International organizations

Many non-governmental organizations (NGOs), scientific and technical groups, professional and other associations working on wastewater management in Palestine such as Palestinian Hydrology Group (PHG), Palestinian Agricultural Relief Committee (PARC), Applied Research Institute Jerusalem (ARIJ), Centre for Environmental and Occupational Health Sciences (CEOHS) and Water Studies Institute (WSI) at Bir-Zeit University, Water and Environmental Studies Institute at An-Najah National University (WESI), WSERU Water and Soil Environmental Research Unit at Bethlehem University (WSERU), and the United Nations Relief and Works Agency for the Palestinian Refugees in the Near East (UNRWA)

International organizations of various statuses such as United Nations Development Program (UNDP), World Bank (WB), and German Agency for Technical Co-operation (GTZ), US Agency for International Development (USAID), Save the Children Federation (SCF), America Near East Refugee Aid (ANERA), and (CARE) conducted some wastewater infrastructure projects.

The aforementioned organizations and institutions operate under severe constraints: poor capacities, high political instability and uncertainty, and inadequate sources of funding.

Moreover, co-ordination among the institutions is poor, which result in vagueness in their roles in the management process of the wastewater services. Consequently, a new institutional management approach with a clear legal framework for optimizing wastewater management in rural Palestine should be developed.

4.3. Wastewater treatment facilities in the West Bank unsewered rural areas

Many NGO's institutions have implemented some onsite and collective wastewater treatment systems of different types and sizes in the range between 5-and 1000 inhabitants over the last 8 years. The systems are listed in Table 4.1.

Table 4.1: List of the location, treatment systems main parts, number of units, treatment objective, and size of onsite and small collective treatment systems erected by NGO's in rural Palestine, (Al-Sa'ad, 2000; ANERA, 2003; PARC, 2001; PHG, 2004, SCF, 1998)

Site	Treatment system main parts	Units	Treatment objective	Size
Aba	ST + TF + SF	38	Reuse/Treated Gray WW	500 PE
Aba school	ST + TF + SF	1	Reuse/Treated Gray WW	20 PE
Aldowareh	SDT	-----	Reuse/Treated mixed WW	-----
Al-Samu'school	ST + Multilayer TF + PP	1	Reuse/Treated mixed WW	50 PE
Alwalajeh	SDT	-----	Reuse/Treated mixed WW	-----
Bani Naim	SDT	-----	Reuse/Treated mixed WW	-----
Beit Dokko	Anaerobic Pond + TF + SF + PP	1	Reuse/Treated Gray WW	200 PE
Beit Rema	ST + CW + UASB	-----	Reuse/Treated mixed WW	-----
Biddo	ST-UFGF	-----	Reuse/Treated Gray WW	-----
Bilien	ST-UFGF	-----	Reuse/Treated Gray WW	-----
Deir Ghassana	ST + CW + UASB	-----	Reuse/Treated mixed WW	-----
Deir Samet	2ST + 4UF	-----	Reuse/Treated mixed WW	300 PE
Foqeen	ST-UFGF	-----	Reuse/Treated Gray WW	-----
Hosan	ST-UFGF	-----	Reuse/Treated Gray WW	-----
Jericho	ST + UF Gravel Filter + SF	1	Reuse/Treated Gray WW	30 PE
Kharas	UASB + CW	1	Reuse/Treated mixed WW	1000 PE
Nuba	UASB + CW	1	Reuse/Treated mixed WW	1000 PE
Oareen	SDT	-----	Reuse/Treated mixed WW	-----
Sair	SDT	-----	Reuse/Treated mixed WW	-----
Sarrah	ST + CW	1	Reuse/Treated mixed WW	560 PE
Talita Komi	WSP + SF	1	Reuse/Treated mixed WW	1000 PE
Tamoun	SDT	-----	Reuse/Treated mixed WW	-----
Terqoia	ST-UFGF	-----	Reuse/Treated Gray WW	-----
Turmus Ayya school	ST + Multilayer TF + PP	1	Reuse/Treated mixed WW	50 PE
ST = SEPTIC TANK; TF = TRICKLING FILTER; PP = POLISHING POND; UF = UPFLOW FILTER; WSP = WASTE STABILIZATION POND; SDT= SUBSURFACE DRAINAGE TECHNIQUE; CW = CONSTRUCTED WETLAND; UASB = UPFLOW ANAEROBIC SLUDGE BLANKET; ST-UFGF = SEPTIC TANK-UPFLOW GRAVEL FILTER				

Some of the aforementioned small treatment plants are briefly described in the following paragraphs:

a) Birzeit university treatment plant:

The treatment plant is designed to treat sewage from all the facilities of the university so as to be used for landscape irrigation at Birzeit university campus. The system utilized is activated sludge process.

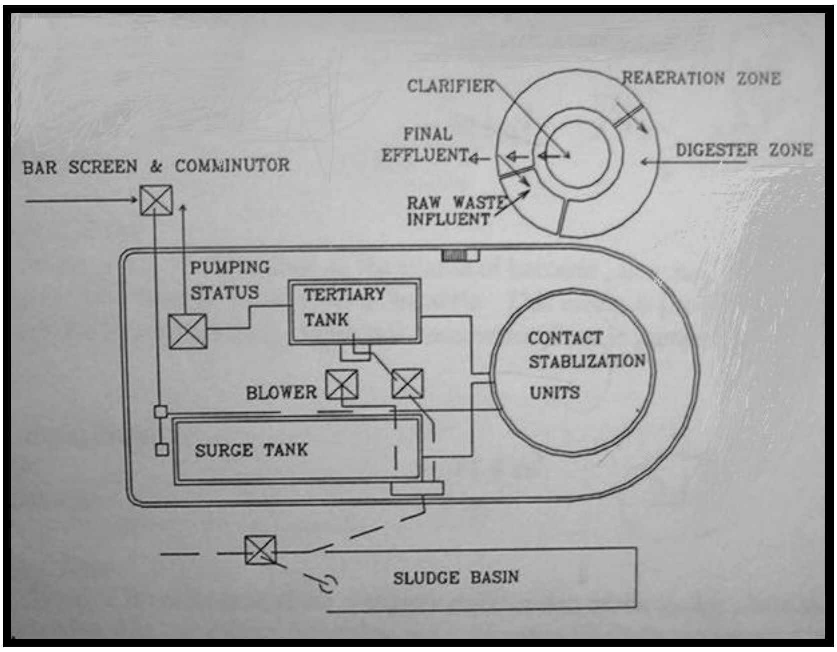

Figure 4.2: Layout of Birzeit Treatment plant

As shown in Figure 4.2 the treatment plant consists of a communitor with a bar screen, surge tank, tertiary tank which consists of three parts: a sand filter well A, well B, and the chlorination unit in well C, a sludge basin, main treatment unit (circular part) which consists of the core of the clarifier and three chambers surrounding the clarifier: contact zone, digester zone, and rearation zone). The core of the clarifier is made of a circular steel chamber with a concrete fill provided at the bottom.

The treatment system design was based on the following parameters:

- Designed flow rate 568 m^3/d

- A clarifier surface rate of 20m/d
- A contact zone detention time of 3Hrs
- A rearation zone retention time of 8Hrs
- A sand filter organic load of 20.4 Kg/d
- A sand filter rate of filtration of 0.0403 m/min

Effluent from the treatment plant is subjected to weekly testing. A COD and suspended solids removal efficiency of 85% is achieved. The effluent COD concentration of Birzeit treatment plant is less than 110 mg/l. High nitrification efficiency (70%) could be maintained at 15°C, and 60% of the oxidized nitrogen is denitrified, which characterize Birzeit treatment plant as a good alternative where high nitrogen removal is essential (Al-Sa'ad and Zimmo, 2003).

b) Save the children federation (SCF) treatment system:

Typical treatment systems' design supported and constructed in different rural areas by SCF. It was implemented in Tamoun, Oareen, Aldowareh, Sair, Bani Naim and Alwalajeh between 1989 and 1998. The reclaimed wastewater was used for agricultural basis. The system utilized is subsurface drainage technique (SDT).

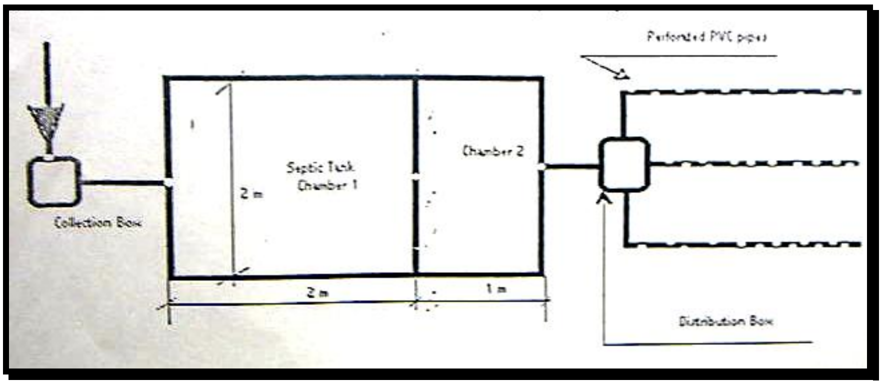

Figure 4.3: Plan view of the subsurface drainage technique

As shown in Figure 4.3 The SDT unit consists of three main parts: (1) the sewer line from the house (2) the sedimentation tank (3) and the penetration field. A distribution box outside the septic tank connects it with the penetration field.

The farmers were trained at the start of the project on how to construct and supervise the plants components in their house gardens. They were encouraged to contribute to the costs of the SDT unit by providing the labor and making a small financial contribution (SCF, 1998).

c) Bani-Zeid sanitation project:

Under the supervision of PHG, a sanitation project is under construction in villages of Beit Rema and Deir Ghassaa in Rammallah district (PHG, 2001). The project includes a sewage network with a wastewater treatment plant lying between the two villages. The treatment plant includes three-compartments-septic tank, constructed wetland, UASB fiberglass tank, and a concrete collection tank. The effluent is to be used for irrigation purposes.

d) ANERA wastewater treatment plants:

ANERA foundation has implemented few on-site wastewater treatment plants in few schools in some Palestinian villages. The onsite treatment plants are simply made of a collecting manhole connected to a three-compartments reinforced concrete septic tank. The effluent is allowed to pass out of the septic tank through a perforated PVC 4" pipe under a 20cm gravel layer.

e) Deir Samet treatment plant:

As a part of Deir Samet sanitation project, a treatment plant was implemented in Deir Samet in Hebron district by year 2002 under the supervision of PHG foundation. The effluent was designed to be used in the irrigation of olive trees in fields found close to the treatment plant. The treatment plant capacity is 15 m^3/d including the wastewater discharged from 40 houses in the village that are found to be close to the wadi found in this area (PHG, 2002).

The system utilized was gravel filters. It consists of two-compartments septic tank, four-compartments upflow filters and a collecting tank. The excess sludge is dried on gravel beds so as to be used late as soil fertilizers.

The septic tank and biofilter hydraulic retention times are 12.4 and 3.3 days respectively. The raw wastewater COD concentration is 1300 mg/l and reaches a concentration of 84 mg/l after passing the 4 filter compartments (PHG, 2002). The effluent is odorless and colorless with high transparency (PHG, 2002).

The produced amounts of reclaimed wastewater are sold with a price of 2NIS\m^3 to the farmers. These amounts of money are collected by the village council and are used in the costs of operation and maintainace.

Before the implantation of the project, the PHG foundation held few public awareness workshops for the farmers.

f) Sarrah village treatment plant:

Under the supervision of PHG foundation a treatment plant was constructred in Sarrah village at south of Nablus district. The effluent was designed to be used for agricultural purposes. The treatment plant capacity is 30 m^3/d including the wastewater discharged from 80 houses (PHG, 2004).

The system utilized was subsurface flow wetlands. It consists of three-compartments reinforced concrete septic tank, subsurface flow wetlands and a collecting tank.

The raw wastewater BOD_5 concentration is 1180 mg/l and reaches a concentration of 275 mg/l after passing the SFW. Additional reduction in TSS concentration also takes place resulting in an effluent of 345 mg\l COD concentration, which presents a 81% removal efficiency (An-Najah National University, 2001).

g) Nuba village treatment plant:

Under the supervision of PHG foundation a treatment plant was constructed in Nuba village in Hebron district. The effluent is to be used for agricultural purposes. The treatment plant receives wastewater from the western part of the village serving about 1000 people (equivalent to 100 m^3/d) (PHG, 2004).

The system utilized was subsurface flow wetlands. It includes a bar screen, upflow anaerobic sludge blanket (UASB) equipped with a sludge withdrawal pump and a gas collection and combustion facility, wetlands for secondary treatment, effluent storage tank equipped with a pump to allow reuse options, and sludge treatment using sludge drying beds.

Table 4.2 illustrates the removal efficiencies of pollutants in overall stages of treatment.

Table 4.2: Values of different parameters of the influent and effluent of Nuba village wastewater treatment plant with their overall removal efficiencies (PHG, 2004)

Parameter	In	Out	Removed %
COD (mg/l)	1200	< 100	92
BOD (mg/l)	546	< 20	96
Kj-N (mg/l)	80	< 15	81

The final effluent characteristics are coping with standards and the effluent itself is reusable. Implementing workshops to aware the beneficiaries about the wastewater treatment plant design, performance and benefits were conducted. Questionnaires, assessing different water and wastewater relevant issues, were prepared and distributed over the community.

h) Kharas village treatment plant:

Under the supervision of PHG foundation a treatment plant was constructed in Kharas village in Hebron district. The effluent was designed to be used for agricultural purposes. The treatment plant receives wastewater from 120 houses, 2 schools and many commercial enterprises (PHG, 2004).

The system utilized was subsurface flow wetlands. It includes a bar screen, upflow anaerobic sludge blanket (UASB) equipped with a sludge withdrawal pump and a gas collection and combustion facility, wetlands for secondary treatment, effluent storage tank equipped with a pump to allow reuse options, and sludge treatment using sludge drying beds.

The BOD of the final effluent was 19 mg/l and Ammonia of less than 20 mg/I and nitrate of 9 mg/I. The UASB tank achieved about 80% of organic load removal (PHG, 2004).

After. 1.5 year of operation, the treatment plant shows good performance with no odor no malfunctioning and the beneficiaries accept it (PHG, 2004).

i) Three on-site wastewater treatment systems in rural areas in Hebron district:

Under the supervision of PHG foundation three on-site wastewater treatment systems were constructed in the rural areas of the southern part of the Hebron district. The effluent is to be used for agricultural purposes. These systems treat about 1-2 m^3/d of wastewater (PHG, 2004). These sites have a sewerage pipes length of: l0m, 80m, 260m for sites number 1,2,3, respectively (PHG, 2004).

These systems have the following technologies: sedimentation tank, upflow biofilters, facultative /duckweed lagoon, sand filter, and effluent storage tank.

Data about the performance of some units of the treatment plants at site number one is shown in Table 4.3

Table 4.3: Data about the characteristics of an onsite wastewater treatment plant (at a rural area in Hebron district) effluent after passing through the biofilter and the facultative lagoon (site number one) (PHG, 2004)

Parameter	In	Out	% Removal
COD (mg/l)	150	11	93
NO_3-N (mg/l)	0.8	1.5	-
NH_4-N (mg/l)	60	21.5	64
pH	7.1	8.3	-
EC (micro-s/cm)	2248	1933	-

j) PARC on-site treatment plants:

Under the supervision of the department of irrigation and environment at PARC foundation, 300 on-site treatment plants were implemented in different rural areas in the West Bank and Gaza (PARC, 2001). Some of the treatment plants were implemented in Bilien and Biddo villages in Ramallah, in Terqoia and Hosan villages in Hebron, and Foqeen valley in Bethlehem.

The plants have been built for treatment of gray wastewater from one house or a number of with an equivalent wastewater flow houses reach 30 with 7 to 20 inhabitants in each house range between 500 l/d to 20,000l/d (PARC, 2001). The effluent is used mainly for irrigation in the house garden with a drip irrigation network, and the black wastewater is discharged into the existing cesspit or to a modified one.

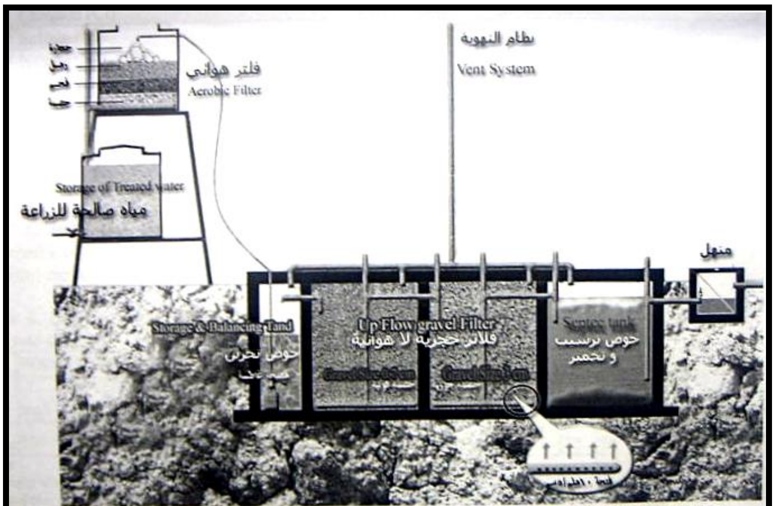

Figure 1: Sketch of the septic tank - upflow gravel filter household gray wastewater treatment plant.

Figure 4.4: PARC Septic Tank-Upflow Gravel Filter onsite treatment system

The system utilized in those on-site treatment plants was Septic Tank-Upflow Gravel Filter (ST-UFGF). The main treatment part is anaerobic process followed aerobic multi-layer filter (sand, coal, and gravel). The layout of the pilot plant is shown in Figure 4.4. The treatment plant consists of a four-compartments tank including a septic tank, two upflow graduated gravel filter and a balancing tank, a multi-layer aerobic filter, and a storage tank.

The values of the design parameters of the treatment plant units as mentioned in the design report (PARC, 2001) are listed below:

- The retention time of the wastewater in the septic tank is 1.5 to 2 days.

- The organic loading of the gravel filter is 0.3 Kg BOD /day for 10 persons household.
- The minimum hydraulic retention time is one day in the gravel filter.

The gray wastewater characteristics were mentioned in Table 3.7. A COD removal efficiency of 76-88% was obtained. No fecal coliforms were found in the treated gray effluent (PARC, 2001). The treated effluent has a BOD and COD concentrations suitable to be reused for unrestricted irrigation. PARC restricted the use of treated gray wastewater to trees and plants eaten cooked.

The plants resulted in the reduction of times of evacuating the cesspits from 12 to 4 times a year and in saving of about 23$ per month in this regard. About 15m^3 of the treated gray wastewater per month is used for irrigation. The total amount saved in water consumption and cesspit evacuating is about 270$ /year (PARC, 2001).

k) PARC wastewater collective treatment plant:

By year 2000, six collective treatment plants have been constructed is different rural areas in the West Bank as Beit Dikko village (Mustafa, (2000).

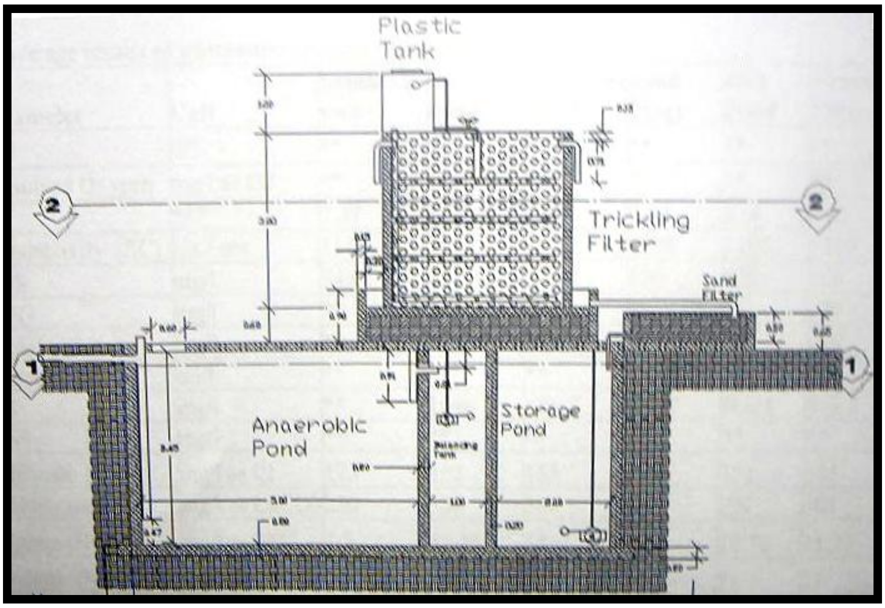

Figure 4.5: PARC gravel filter wastewater collective treatment plant

The system used was an upflow anaerobic fravel filter. It consists of anaerobic pond, gravel filter, sand filter and a polishing pond as shown in Figure 4.5. It has a capacity of 15 m^3/d (PARC, 2001). It is designed to serve about 300 persons with gray wastewater production of 50 l/c/d (PARC, 2001). The wastewater stays for at least two days in the anaerobic pond. The polishing pond has a three days storage capacity and contains a recirculation submerged pump. The sand filter effluent COD and BOD concentration respectively are 95mg/l, 26mg/l (PARC, 2001).

4.4.Assessment of wastewater management practices in Palestinian rural areas

The present practices of disposing generated wastewater presented in: (1) the using of cesspits (2) disposing in open areas (3) disposing directly in the street between houses (4) disposing directly in the backyard for irrigation or (5) discharging wastewater into dry wadis result in:

Public health threatening by:

- Causing ground and surface water pollution due to pathogens, nutrients, and toxic substances.
- Maximize risk from reuse of inadequately treated effluent for drinking water, irrigation, or other uses.
- Attracting flies and mosquitoes with the associated health risks.

Public nuisances rise by:

- Generating noxious odors caused by inadequate plumbing and treatment processes.
- Generating noxious odors or other nuisances related to transportation, reuse, or disposal of OWTS residuals (septage).

Environmental threatening by:

- Enhance adverse impacts on water resources (springs, wells, shallow groundwater, and surface water) due to pollutants discharged to onsite systems, e.g., toxic substances.
- Enhance nutrient over enrichment of surface waters.
- Attack sensitive aquatic habitat and biota.

Ineffective cost investment due to:

- The high evacuation cost and frequent desludging of the used cesspits.
- Ineffective reuse of treated wastewater that may present a potential source of: (1) water for irrigation, (2) non-drinking domestic use, (3) and a source for ground water artificial recharge.

After reviewing the onsite treatment systems so far implemented by the different NGO's institutions, it was recognized that most of them have in common tribulations represented in:

- Poor following up and supervising of the operation of the plants by the implementing institutions after completion of the project.
- Poor controlling of the commitment of the beneficiaries to the NGO's technical specifications while constructing the units.
- No carrying out of quality test to prove success and efficiency of the system.
- No utilizing of the reclaimed wastewater by the beneficiaries.
- The effluent concentrations didn't meet any of the standards set for any kind of irrigation.
- Absence of designing reports.
- No information about the design criteria and the standards used in setting the effluent concentrations.
- Leakage in treated and untreated wastewater.
- Some of the treated effluent has a bad smell.
- Non-acceptance of the using of reclaimed wastewater by the owners of the plants due to social, cultural and religious reasons.
- Unconvincing of the farmers to use the treated effluent for unrestricted irrigation as they are supposed to do.
- Unawareness of the chosen beneficiaries of the benefits of the treatment plant.
- Unqualified operators to hold the operation and maintainace works.
- Suffering of the employees, who are responsible for the supervision of the plants in the different districts, from lack in experience and knowledge in this field.
- Inappropriateness of the plants for more than 60% of the rural families in the West Bank for the following reasons: 1) some families live in buildings with no gardens 2) some families live in old buildings where it is difficult and expensive to change the combining plumbing system into a separated one.
- Absence of database concerning the quality of the influent and the effluent of the plants.

CHAPTER FIVE

Strategy development for a sustainable wastewater management in rural Palestine

5.1. The planning process of wastewater management

In the absence of proper management programs, the existing onsite wastewater disposal practices of using cesspools are inadequate, if not detrimental to the scarce ground and surface water resources and harmful to the environment and public health. Moreover they are socially unacceptable. Alternatives to these practices are needed.

By mentioning the relationship between both (bad) health and environment and (the lack of) sanitation systems the problem definition is mostly clear. The first phase of the planning cycle is followed by the second: formulating the objectives. These are definitely related to health, but they are also related to issues such abatement of nuisances, ground and surface water resource protection, and aquatic ecosystem protection, social acceptance, and affordability. Different wastewater management scenarios can be used to attain these objectives.

5.2. Sounding wastewater management scenarios for small communities in Palestinian rural areas

Scenario I: on-site management of wastewater.

I/a Onsite-segregated (gray water and black water) treatment and reuse.

I/b Onsite-combined wastewater treatment and reuse.

Scenario II: off-site management of wastewater: wastewater collection and transportation for treatment and reuse.

A simple practical planning tool is needed to select between the aforesaid scenarios.

5.3. The algorithm planning tool

A simplified algorithm was used as a guide for selection of appropriate wastewater management scenarios (See Figure 5.1). Planners need to use their own good judgment when special circumstances arise to identify and select the most appropriate technologies for a given community. However it is not advisable to base decisions solely

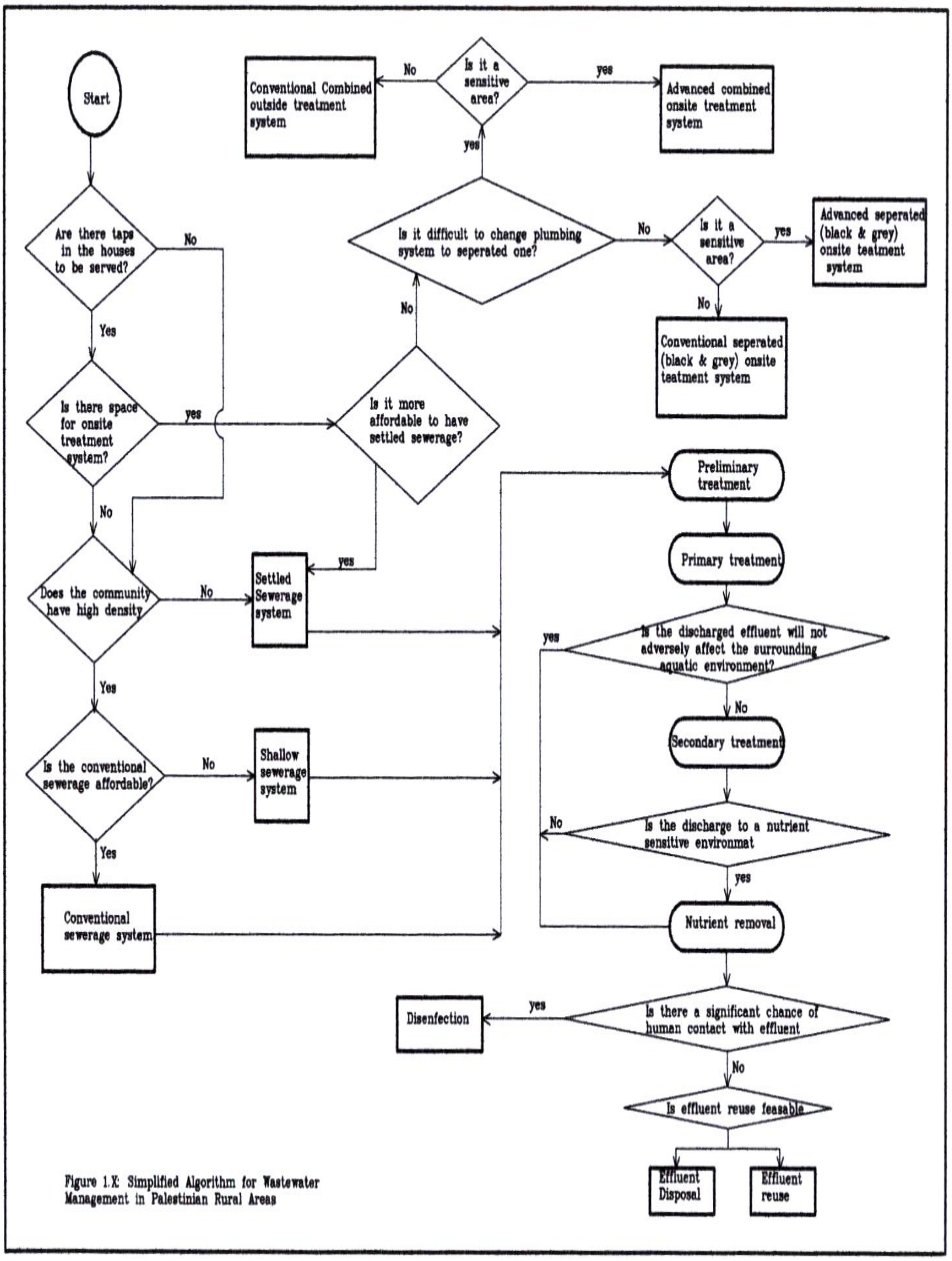

FIGURE 5.1: THE ALGORITHM-PLANNING TOOL FOR SELECTING BETWEEN DIFFERENT POSSIBLE WASTEWATER MANAGEMENT SCENARIOS IN PALESTINIAN RURAL AREAS

on these algorithms. They can be used as a quick scan, maybe even to check a decision/selection, but they cannot replace the careful gathering of data, the comparison of alternatives and the proper selection of the best option together with all actors involved.

5.4. Algorithm planning tool criteria

Below are the most important criteria for selecting appropriate technologies for sewage collection and domestic wastewater treatment. The relevance of each criterion in the decision process and its implementation in the decision tree is discussed. The water availability and population density are the main factors, which were used in choosing a domestic wastewater conveyance technology. Whereas, the main factors that were used in choosing domestic wastewater treatment technologies are water availability, housing or population density, land availability, and availability of opportunities for effluent reuse.

5.4.1. Water availability

The first question in the simplified algorithm is whether piped water is supplied to homes to as in the case of 45% of Nablus villages, be served. If little or no piped water is available 30% of Jenin villages, 33% of Tulkarm villages, 36% of Qalqiliya, 2% of Ramallah villages, and 7% of Salfit villages, the volume of wastes generated will be minimal, and excreta and other household wastes can be disposed of in household systems. Conventional water intensive sewage networks should be avoided in this case. For more details about the names of the West Bank villages with or without water networks refer to Appendix I.

5.4.2.Housing or Population Density

The population density in Palestinian rural areas can be classified into three categories as shown in Table 5.1. For dispersed rural homes as in the case of 69% of people living in small Palestinian communities, central sewage collection facilities may not be economical due to the high cost of piping wastewater to the central treatment facility. The housing density at which central systems become more economical compared to on-site systems varies widely. A list of small Palestinian communities population densities is presented in Appendix I.

Table 5.1 Distribution of the different categories of the projected population's density of the small Palestinian rural communities for the year 2004 according to the PWA database bank for the year 2003.

Population density category	Percentage
High (>1000P/Km^2)	6%
Moderate (400-1000P/Km^2)	25%
Low (<400P/Km^2)	69%

5.4.3. Land Availability

Where land space around houses is not available, as in the case of 6% of people living in small Palestinian communities with high population density (more than 1000P/Km^2), it is not possible to install onsite systems. In such cases the use of centralized approach is the only left choice

5.4.4. Social Considerations

Residents' knowledge, attitude, opinions, and prejudices about waste disposal can determine whether a treatment technology will work in a particular culture. It is influenced by socio-cultural and religious factors. Two contradictory attitudes towards the practice of use of reclaimed wastewater as a water source are found among the Palestinian people. There are people who have a strong objection to the use of reclaimed wastewater in irrigation. This was clearly seen in the evaluation reports submitted after running the treatment plants designed by PARC and SCF foundations. The treated effluent is not accepted by the owners of the plants due to social, cultural and religious reasons (PARC, 2001). Most of the subsurface soil treatment's systems effluents aren't used for reuse of disposal wastewater (Bethlehem University, 1998). On the other hand, untreated wastewater is used in crops irrigation in many areas in the West Bank such as in Wadi Al-Nar in the Bethlehem district, Wadi As-Samn in the Hebron district, Wadi Nablus and Wadi Al-Badan, Beit Eiba, and Zawata in the Nablus district, and Wadi El-Muqatta'a in the Jenin district (ARIJ, 1997). Raw eaten crops such as parsley, mint, pepper, lattice, onions and radish, and cooked vegetables such as cauliflower, eggplant and squash, as well as fruit trees, such as citrus are all irrigated with this source of water (Nashashibi, 1995). Farmers use raw wastewater due to scarcity of fresh water and the availability of valuable nutrients. Some people buy products irrigated with raw wastewater because they are cheap (Mustafa, 1997). These different attitudes and practices are to the wide variability in cultural beliefs, human behaviors, religious dogmas, public awareness, and educational background. According to Koranic edicts, the practice of reuse is accepted religiously provided impure water is transformed to pure water (tahur) by the following methods (Farooq and Ansari, 1983): self-purification, addition of pure water in sufficient quantity to dilute the impurities, or removal of the impurities by the passage of time or by physical effects. Consequently, it is well clear that the attitudes of the expected beneficiaries towards the acceptance of use of reclaimed wastewater should be taken into considerations before the implementing of such projects.

5.4.5. Opportunities for Reuse

Water quality requirements for the effluent reuse significantly affect treatment requirements. Wastewater in the West Bank can be used for many purposes including:

- Agriculture;
- Aquaculture;
- Industrial applications (e.g. cooling water);
- Recharge of aquifer;
- Non-potable applications (e.g. flushing toilets, landscape irrigation);
- Potable applications (e.g. drinking water, water in food industry).

It should be noted, however, that not all applications could be utilized in the West Bank due to the following constraints:

- Potable applications, mainly due to religious constraints;
- Non-potable applications, as this requires in most cases a dual pipe system which may not be feasible considering the high investment costs involved;
- Direct recharge of aquifers, for two reasons not preferable:

1. Israeli constraints. Israel consumes approximately 80% of the West Bank groundwater resources and do not allow aquifers to be recharged with treated wastewater due to the fear of contamination (Bookelman, 1997).
2. The West Bank aquifer is a karstic aquifer, with limestone cracks, through which pollution can take place very easily; therefore, extensive, thus expensive, treatment is needed to ensure that no contamination can take place (Bookelman, 1997).

- Considering the limited industrial activities in the West Bank, only reuse on small scale can be applied.

However, the opportunities for reuse cannot be neglected. Given the scarcity of water in the region and the rapid growth in demand, alternative sources of water are a prerequisite for sustainable water management in the future.

Taking into account the institutional constraints, full treatment of the total wastewater flow is the optimal option, but it may not be the optimal option in an economic sense. As prevention of transmission of diseases to workers and consumers is postulated as a basic condition for application of wastewater reuse, two alternative strategies could be implemented: Restricted irrigation and unrestricted irrigation.

The full treatment option of full wastewater flows to the guideline values for unrestricted irrigation is expensive, and might also be unnecessary. For example: if most crops cultivated with reclaimed wastewater are non-vegetable or are eaten cooked, full wastewater treatment is not necessary to avoid transmission of diseases, and treatment costs could prove unnecessarily high. Imposing restrictions on using reclaimed wastewater in irrigation of just food crops that are processed or cooked prior to consumption is found to a more conservative strategy from protecting public health point of view. Thus, in areas with available areas for agriculture, it is recommended to apply reclaimed wastewater for restricted irrigation.

As previously presented in Figure 3.2 (the West Bank recharge areas sensitivity classification map) and Figure 3.3 (the West Bank agricultural-areas suitability classification map), (section 3.2.4), there are areas in the West Bank that are not suitable for agricultural purposes, which is strongly dependent on aquifer recharge areas sensitivity. A combination of these figures gave the potential areas for reuse purposes. Hence irrigation with wastewater should be preferably being practiced in the non-sensitive areas. In areas, which are not suitable for agricultural reuse purposes wastewater may be treated in a small community, centralized plant to be conveyed later to the closest Palestinian rural area where these constraints are absent. However, The scope of this study does not provide for detailed development of reuse requirements and controls.

After identifying the problems, needs, and setting the planning goals, the following phase is to assess the sustainability of different wastewater treatment systems.

5.5. Selecting of appropriate sustainable treatment systems

This section makes the case for some very important features of the wastewater treatment systems evaluation process:

• No techniques or solutions are ecological or sustainable in themselves; the “best solution” is dependent on the local context (CORETECH, 2003; Eilerson, *et al*.; 2000)

• A sustainable solution demands a transparent decision process with a wide range of criteria, for example, environmental, technical, economic, and socio-cultural criteria.

Thus, there is a need for a clear method for drawing up relevant solutions to wastewater handling, and evaluating and choosing local systems. The planning tool should support decisions of sustainable sewage management. This does not mean that the method has to identify one best solution. By assessing a number of solutions relatively and in a transparent manner, the method makes it clear that the final choice of local infrastructural investments is always political (Eilerson, *et al.*; 2000).

5.6. Application of the Multicriteria decision analysis tool in selecting sustainable wastewater treatment systems

The Multicriteria decision analysis (MCDA) planning tool was used to assess the sustainability of different treatment systems to be used in unsewered rural areas in Palestine. Sustainable technology is defined as the technology that does not threat the quantity and quality (for instance diversity) of the resources (Eilersen *et al.*, 2000). The goal of the MCDA is to compare a large number of different wastewater treatment systems, including subsystems like compost toilets, vacuum systems, separation toilets, etc.

As it was shown in Figure 5.1, different treatment approaches can be applied including using combined-onsite wastewater treatment systems, onsite-segregated (gray and black) water treatment systems, and collective treatment plant systems for small communities.

5.7. Preliminary selection of wastewater treatment systems

The first stage in the selecting process included preliminary selection of different treatment systems. Full data about the advantages and disadvantages of possible treatment systems alternatives followed by a rough initial assessment and pre-screening are presented in Tables 5.2, 5.3, 5.4, and 5.5.

Table 5.2: Primary selection of onsite-combined wastewater treatment systems for small communities including systems' type of treatment, advantages, and disadvantages.

Treatment system	Type of treatment	System advantages	System disadvantages	Notes
Disposal field	Removing of soluble carbonaceous BOD and ammonia, suspended solids, and pathogens	• Simple • High treatment efficiency that can be used for drip irrigation or can be surface discharged after disinfection • Low energy requirements • Do not require skilled personnel to operate • No chemical requirements • Any suitable media found locally can be used in construction • Construction costs are low • It can be blend into surrounding landscape	• The land area required may be a limiting factor (space requirement) • Odor problems could result • Clogging of soil is possible • Sensitive to extremely cold temperatures • Not suitable for locations with: low soil permeability, shallow impervious substratum, shallow soils over openly fractured bedrock, high soil permeability, steep slopes, small lots, sensitive groundwater areas, high groundwater	Accepted but there is need for pre-sedimentation
Intermittent Sand Filter	Removing of soluble carbonaceous BOD and ammonia, suspended solids, and pathogens	• The effluent is collected in the under-drain system • May be used in locations with shallow soil over impervious layer, shallow soil over fractured bedrock, high soil permeability, high groundwater if it is combined with a disposal field • Simple • High treatment efficiency	• Less treatment efficiency with reference to BOD, SS, and pathogens than disposal field	Accepted but there is need for pre-sedimentation

Treatment system	Type of treatment	System advantages	System disadvantages	Notes
Intermittent Sand Filter (continue)		that can be used for drip irrigation or can be surface discharged after disinfection • Low energy requirements • Do not require skilled personnel to operate No chemical requirements • Any suitable media found locally can be used in construction • Construction costs are low • It can be blend into surrounding landscape • Better efficiency than disposal field with respect to NH^{4+}, NO^{3-}		
Disposal beds or pits (cesspools) sewage pit	Storage of untreated wastewater	• Suitable for very deep soil and a great separation from groundwater • No power requirements • Low O&M costs	• They contaminate the underlying groundwater	Not accepted: • Its flooding may cause groundwater contamination and a serious public health hazard • Its evacuating costs after its clogging are high
Blind cesspit	Storage of untreated wastewater	• No power requirements • Low O&M • Low land requirements	• Need for very regular evacuating • High evacuating costs	Not accepted: • High evacuating costs • Its flooding may

Treatment system	Type of treatment	System advantages	System disadvantages	Notes
Blind cesspit (continue)				cause groundwater contamination and a serious public health hazard
Mound system	Removing of soluble carbonaceous BOD and ammonia, suspended solids, and pathogens	May be used in locations where: the soil is permeable and the water table is shallow, the underlying strata are highly porous and conventional systems should not be used, slopes are less than 12 percent, the soils are slowly permeable	Partially effective because the applied effluent accumulate under the mound	Accepted but there is need for primary treatment of suspended solids
Recycle treatment system	Removing of solids, residual organics, microorganisms, suspended solids and pathogens	• High treatment efficiency • Effluent is used as flush water in toilets	• Very expensive • Sophisticated system	Not accepted: due to its high capital and operation costs
Septic tank	Suspended solids removal and anaerobic digestion of these solids	• Low cost • Limited operation attention • No energy requirement • Simple construction • Durable • Little space (it is build underground)	• Low treatment efficiency • Sludge should be pumped every 3 years • Effluent not odorless	Accepted but: • There is need for additional treatment • It must be water tight
Trickling filter	Removing of soluble carbonaceous BOD and ammonium	• Wastewater is reused • Small land requirement • High treatment efficiency • Ease of construction	• High incidence of clogging • Long rest period required • Odors • Moderate O&M requirements, skilled operator necessary	Accepted but • There is need for primary clarifier and it should be followed by a

Treatment system	Type of treatment	System advantages	System disadvantages	Notes
Trickling filter (continue)		• Low cost • Can be designed to provide nitrification	• Require a rotating sprinkler and a pump to operate • Sensitive to flow fluctuations • Considerable amounts of excess sludge	settling tank • Recycling is necessary to dilute strengthen of incoming wastewater and to maintain the biological slime layer in a moist condition
Imhoff tank	Removing of settleable solids and anaerobic digestion of these solids	• Durable • Little space because of being underground • Odorless effluent	• Less simple than septic tank • Needs very regular desludging	It is preferred to use septic tank due to its simplicity in construction
Ponds	Soluble carbonaceous BOD and ammonium removal	• Not sensitive for fluctuation in effluent flow and quality • Simple operation • Low power requirements • Simple construction • Little maintenance and operation • Sludge disposal required only at 10 to 20 years intervals • High treatment efficiency	• Large land areas requirement • Very sensitive to low temperatures • Odors • Mosquitoes are difficult to control • Can negatively impact ground water if an inadequate liner is installed or if a n existing liner is damaged	Accepted in case of land availability and away from residential areas and it should be followed by filtration to reduce suspended solids

Table 5.3: Primary selection of collective wastewater treatment systems for small communities/ cluster of homes including systems' type of treatment, advantages, and disadvantages

Treatment system	Type of treatment	System advantages	System disadvantages	Notes
Oxidation ditch	• Carbonanaeous BOD removal • Nitrification	• Provide very high quality effluent • Very land efficient • Low sludge production and stabilized • High reliability with sufficient operator attention • Nitrogen removal likely • Short hydraulic retention time • No need for primary sedimentation • No odors • Not sensitive for flow and load variations • Can be expanded to meet increased plant loadings	• Need for close skilled operator supervision • High maintenance requirements for aerators • High power consumption • Protection from aerator freezing problems necessary in cold climates • Potential for rising sludge due to denitrification in final clarifier • Requires routine monitoring • Moderately sensitive to sock loadings • Potential freezing problems in cold climates • Possibility of poor settleability of mixed liquor suspended solids (MLSS) due to formation of pinpoint flocks • Blower noise and sludge handling odor potential	Accepted • Need for final clarifier
Constructed wetlands	• Carbonaceous BOD removal • Nitrification	• Low construction cost • Simple O& M • Excellent removal of BOD5 and suspended solids from primary septic tank effluent	• Lack of generally agreed upon design factors • Large land requirements • Mosquito Hx. • Start up problems in establishing	Accepted • Need for primary treatment • Evaporation is minimized with SSF

Treatment system	Type of treatment	System advantages	System disadvantages	Notes
Constructed wetlands (continue)		• Process stability under varying environmental conditions • No power requirements	the desired aquatic plant species • Hot climate may periodically dry up at a site with low water flow rates	
Recirculating sand Filter	Removing of soluble carbonaceous BOD, ammonia, suspended solids, and pathogens	• Moderately non-expensive to construct • Low maintenance cost • Low energy requirements • Do not require highly skilled personnel to operate • Produce high quality effluent (better than extended aeration package plants and stabilization ponds) • Stable process • Little intervention by operating personnel • Can be easily expanded • Not sensitive to variations in hydraulic and organic loading • Complete nitrification is achieved • Effluent turbidity is very low	• More land area than package plants, less than lagoons • The amount of head required exceed 1m • Odors do occur but low • Dependent on temperature • Clogging	Accepted • Need for primary treatment
Septic tank	**SUSPENDED SOLIDS REMOVAL AND ANAEROBIC DIGESTION OF**	• Low cost • Limited operation attention • No energy requirement • Simple construction • Durable • Little space (it is build	• Low treatment efficiency • Sludge should be pumped every 3 years • Effluent not odorless	Accepted but: • There is need for additional treatment • It must be water tight

Treatment system	Type of treatment	System advantages	System disadvantages	Notes
Septic tank (continue)	**THESE SOLIDS**	underground)		• Need for multiple compartments
Trickling filter	Removing of soluble carbonaceous BOD and ammonium	• Wastewater is reused • Small land are requirement • High treatment efficiency • Ease of construction • Medium capital and running cost • Can be designed to provide nitrification	• High incidence of clogging • Long rest period required • Odors • Moderate O&M requirements, skilled operator necessary • Require a rotating sprinkler and a pump to operate • Sensitive to flow fluctuations • Considerable amounts of excess sludge • Limited ability to expandability to meet increased plant loadings • Relatively high power requirements • Regular sludge from settling tanks • Fly nuisance	Accepted but • There is need for primary clarifier and it should be followed by a settling tank • Recycling is necessary to dilute strengthen of incoming wastewater and to maintain the biological slime layer in a moist condition
Physical/ chemical treatment	Removing of nitrogen, phosphorus and heavy metals	• Very small land area requirement • Reliable • High effluent quality	• Difficult handling and disposal of sludge • High operation costs • Complex operating process • Need for close operation and skilled operator supervision	**NOT ACCEPTED DUE TO ITS SOPHISTICATED OPERATION AND VERY HIGH COSTS**
Imhoff tank	Removing of settleable solids and	• Durable • Little space because of	• Less simple than septic tank • Needs very regular desludging	It is preferred to use septic tank due to

Treatment system	Type of treatment	System advantages	System disadvantages	Notes
	anaerobic digestion of these solids	being underground • Odorless effluent		its simplicity in construction
Rotating biological contactors (continue)	Soluble carbonaceous BOD and ammonium removal	• High effluent quality • Small land requirement • Can be easily expanded • Easy to operate	• Need for close skilled operator supervision • High maintenance requirements • High power consumption • Odor, nuisance and flies problems • High cost • Mechanical complexity • Moderately sensitive to influent flow and load variation	Not accepted due to: • Its mechanical complexity • The need for prefabricated units (rotating discs) • High operation costs
Extended Aeration activated sludge	• Carbonanaeous BOD removal • Nitrification	• Suitable for small communities • Provide very high quality effluent • Very land efficient • Low sludge production and stabilized • High reliability with sufficient operator attention • Nitrogen removal likely • Short hydraulic retention time • No need for primary sedimentation • No odors • Can be expanded to meet increased plant loadings	• Need for close skilled operator supervision • High maintenance requirements for aerators • High power consumption • Protection from aerator freezing problems necessary in cold climates • Potential for rising sludge due to denitrification in final clarifier • Requires routine monitoring • Moderately sensitive to sock loadings • Potential freezing problems in cold climates • Possibility of poor settleability of mixed liquor suspended solids	Accepted • Need for final clarifier

Treatment system	Type of treatment	System advantages	System disadvantages	Notes
			(MLSS) due to formation of pinpoint flocks • Blower noise and sludge handling odor potential • Complex operation • Need relatively level topography	
Ponds	• Soluble carbonaceous BOD and ammonium removal • Anaerobic sedimentation • Anaerobic degradation and sludge stabilization • Pathogen removal and aerobic degradation in maturation ponds	• Not sensitive for fluctuation in effluent flow and quality • Simple operation • Low power requirements • Simple construction • Little maintenance and operation • Sludge disposal required only at 10 to 20 years intervals • High treatment efficiency • Low capital cost requirements • Many means of upgrading is available • Low skilled labor is needed for O&M • Low operation costs • Efficient in removing excreted pathogens • Extremely robust	• Large land areas requirement • Very sensitive to low temperatures • Odors • Mosquitoes are difficult to control • Can negatively impact ground water if an inadequate liner is installed or if a n existing liner is damaged • Long solids detention times (20 days) • Need for effluent polishing from algae • High water loss in arid and semi-arid areas	Accepted in case of land availability and away from residential areas • It should be followed by filtration to reduce suspended solids • If the soil have a coefficient of permeability less than 10-7 m/s no need for pond lining • Regarded as the first choice in Israel

Table 5.4: Primary selection of onsite-gray water treatment plant systems for small communities including systems' type of treatment, advantages, and disadvantages.

Treatment system	Type of treatment	System advantages	System disadvantages	Notes
Disposal field Disposal field (continue)	Removing of soluble carbonaceous BOD and ammonia, suspended solids, and pathogens	• Simple • High treatment efficiency that can be used for drip irrigation or can be surface discharged after disinfection • Low energy requirements • Do not require skilled personnel to operate • No chemical requirements • Any suitable media found locally can be used in construction • Construction costs are low • Labor is manual • It can be blend into surrounding landscape	• The land area required may be a limiting factor (space requirement) • Odor problems could result • Clogging of soil is possible • Sensitive to extremely cold temperatures • Not suitable for locations with: low soil permeability, shallow impervious substratum, shallow soils over openly fractured bedrock, high soil permeability, steep slopes, small lots, sensitive groundwater areas, high groundwater	Accepted but there is need for pre-sedimentation
Intermittent Sand Filter	Removing of soluble carbonaceous BOD and ammonia, suspended solids, and pathogens	• The effluent is collected in the under-drain system • May be used in locations with shallow soil over impervious layer, shallow soil over fractured bedrock, high soil permeability, high	• Less treatment efficiency with reference to BOD, SS, and pathogens than disposal field	Accepted but there is need for pre-sedimentation

Treatment system	Type of treatment	System advantages	System disadvantages	Notes
Intermittent Sand Filter (continue)		groundwater if it is combined with a disposal field • Simple • High treatment efficiency that can be used for drip irrigation or can be surface discharged after disinfection • Low energy requirements • Do not require skilled personnel to operate No chemical requirements • Any suitable media found locally can be used in construction • Construction costs are low • Labor is manual • It can be blend into surrounding landscape • Better efficiency than disposal field with respect to NH^{4+}, NO^{3-}		
Upflow Anaerobic filter	Removing of soluble carbonaceous BOD and ammonium	• High treatment efficiency • Low power consumption • Moderate operation and maintenance • Low sludge volume production • No need for wasting sludge • Not sensitive for flow fluctuations	• Odor nuisance due to H2S gas production • Turbid effluent	Accepted • Need for primary treatment and final clarifier

Treatment system	Type of treatment	System advantages	System disadvantages	Notes
Disposal beds or pits (cesspools) sewage pit	Storage of untreated wastewater	• Suitable for very deep soil and a great separation from groundwater • No power requirements • Low O&M costs	• They contaminate the underlying groundwater	Not accepted: • Its flooding may cause groundwater contamination and a serious public health hazard • Its evacuating costs after its clogging are high
Blind cesspit	Storage of untreated wastewater	• No power requirements • Low O&M • Low land requirements	• Need for very regular evacuating • High evacuating costs	Not accepted: • High evacuating costs • Its flooding may cause groundwater contamination and a serious public health hazard
Mound system	Removing of soluble carbonaceous BOD and ammonia, suspended solids, and pathogens	May be used in locations where: the soil is permeable and the water table is shallow, the underlying strata are highly porous and conventional systems should not be used, slopes are less than 12 percent, the soils are slowly permeable	Partially effective because the applied effluent accumulate under the mound	Accepted but there is need for primary treatment of suspended solids
Recycle treatment system	Removing of solids, residual organics, microorganisms, suspended solids and pathogens	• High treatment efficiency • Effluent is used as flush water in toilets	• Very expensive • Sophisticated system	Not accepted: due to its high capital and operation costs
Septic tank	Suspended solids	• Low cost	• Low treatment efficiency	Accepted but:

Treatment system	Type of treatment	System advantages	System disadvantages	Notes
	removal and anaerobic digestion of these solids	• Limited operation attention • No energy requirement • Simple construction • Durable • Little space (it is build underground)	• Sludge should be pumped every 3 years • Effluent not odorless	• There is need for additional treatment • It must be water tight
Trickling filter **Trickling filter (continue)**	Removing of soluble carbonaceous BOD and ammonium	• Wastewater is reused • Small land are requirement • High treatment efficiency • Ease of construction • Low cost • Can be designed to provide nitrification	• High incidence of clogging • Long rest period required • Odors • Moderate O&M requirements, skilled operator necessary • Require a rotating sprinkler and a pump to operate • Sensitive to flow fluctuations • Considerable amounts of excess sludge	Accepted but • There is need for primary clarifier and it should be followed by a settling tank • Recycling is necessary to dilute strengthen of incoming wastewater and to maintain the biological slime layer in a moist condition
Imhoff tank	Removing of settleable solids and anaerobic digestion of these solids	• Durable • Little space because of being underground • Odorless effluent	• Less simple than septic tank • Needs very regular desludging	It is preferred to use septic tank due to its simplicity in construction
Ponds	Soluble carbonaceous BOD and ammonium removal	• Not sensitive for fluctuation in effluent flow and quality • Simple operation • Low power requirements • Simple construction	• Large land areas requirement • Very sensitive to low temperatures • Odors • Mosquitoes are difficult to control • Can negatively impact ground	Accepted in case of land availability and away from residential areas and it should be followed by

Treatment system	Type of treatment	System advantages	System disadvantages	Notes
		• Little maintenance and operation • Sludge disposal required only at 10 to 20 years intervals • High treatment efficiency	water if an inadequate liner is installed or if a n existing liner is damaged	filtration to reduce suspended solids
Rotating biological contactors	Soluble carbonaceous BOD and ammonium removal	• High effluent quality • Small land requirement • Can be easily expanded • Easy to operate	• Need for close skilled operator supervision • High maintenance requirements • High power consumption • Odor, nuisance and flies problems • High cost • Mechanical complexity • Moderately sensitive to influent flow and load variation	Not accepted due to its mechanical complexity and the need for prefabricated units (rotating discs) and high operation costs

Table 5.5: Primary selection of onsite-black water treatment systems for small communities including systems' type of treatment, advantages, and disadvantages.

Toilet system	Modifications	Treatment method	System advantages	System disadvantages	Notes
Composting toilet	• Heating element provided	• Aerobic decomposition	• Elimination of water from the cycle • Approximate 35% reduction in water consumption • Significant reduction in wastewater value	• High capital cost • Significant O&M requirements • Possible fly and odor nuisance • Slight fire hazard • Continuous power	• Owner's dedication is necessary • Not recommended due to its high capital cost,

Toilet system	Modifications	Treatment method	System advantages	System disadvantages	Notes
Composting toilet (continue)			and pollution load • Low energy requirements • Well developed technology for on-site application • Fair data base on field performance • Low-medium system complexity • The compost can be efficiently recycled into nature's biochemical cycle at the site (soil and plants).	supply require with most units • Incorrect or lack of O & M and/or overloading leads to a serious operating problems • Limited capacity • Power outage or equipment malfunction cause process upsets • Composted residue handled and disposed of by the user • No local commercial availability	crucial correct operation and adequate maintenance for performance
Incinerating toilet	• Oil fired • Gas fired • Electrically operated	• Waste incineration	• Waterless process • Water conservation of approximate 35% • Complete combustion produces minimal amount of ash residue for disposal	• Frequent residue removal • Rapid corrosion of metallic equipment • Short useful life • Air pollution, odors, untreated residue disposal problems during malfunctions • Dependency on fuel • High capital and operating costs • Slight explosion and fire hazard	• Not recommended due to its operational problems, high capital and operating costs

Toilet system	Modifications	Treatment method	System advantages	System disadvantages	Notes
				• Limited data on on-site field performance • Medium system complexity • No local commercial availability	
Chemical toilet	• Portable • Re-cycling • Fresh water flush • Charged with a bactericidal inhibitor and an odor- and color masking compound	• No treatment provided, waste decompositio n inhibited prior to off-site disposal	• Decreased water usage for water carriage • Substantial reduction of water volume	• Substantial capital cost • High operating cost • Risk of illegal waste discharges • Regular removal of waste for on-site disposal required • Regular chemical and flush water replenishment is required • Low-medium system complexity • No local commercial availability	• Not recommended due to its conditioned waste storage for subsequent off-site disposal which does not substitute for permanent solution to waste disposal problems
Microwave toilet		• Water decomposition by microwave irradiation			• Research stage
Denitrification system	• Black water is disposed to a septic tank, and then it is aerated in a	• Denitrification	• High treatment efficiency • Low power consumption • Moderate operation	• Odor nuisance due to H_2S gas production	• Suitable in areas where high ground water table level, and high soil

Toilet system	Modifications	Treatment method	System advantages	System disadvantages	Notes
Denitrification system (continue)	permeable soil (in a subsurface underdrained sand filter). Finally denitrification takes place under anaerobic condition with carbon source presents in the grey water in an upflow anaerobic filter		and maintenance • Low sludge volume production • No need for wasting sludge • Not sensitive for flow fluctuations • Low construction cost		permeability, sensitive areas
Low volume flush toilet and the dual flush toilet	• Compressed air or a vacuum being used to assist in the flushing • The toilet water tank is elevated		• Reduction in the water required for flushing • Reduced water use will not clog sewers		• Dual flush toilet is recommended to reduce the flushing water for urine

Toilet system	Modifications	Treatment method	System advantages	System disadvantages	Notes
Modified cesspit	• The cesspits walls are made of semi-perforated holes (bricks), surrounded by a layer of gravel	• Infiltration	• No power requirements • Low O&M • Low land requirements • Low construction cost • It is already used in some Palestinian villages	• No agreed upon design criteria • No data about field performance •	• More research and data about its field performance is essential
Blind cesspit **Blind cesspit (continue)**			• No power requirements • Low O&M • Low land requirements • Low construction cost	• Need for very regular evacuating • High evacuating costs • Possible fly and odor nuisance	Not accepted: • High evacuating costs • Its flooding may cause groundwater contamination and a serious public health hazard
Recirculating Flush toilet	• Biological • Flushing liquid: Synthetic liquid, oil, other	• Waste liquification by enzymes and bacteria (biological) • Treatment is limited to flushing liquid for recycling, waste storage	• Residue is reduced to liquid waste fraction • Sludge waste residue is eliminated during the process (biological) • Total waste volume generated considerably reduced • Requirement for water or sewer	• Operational problems arise due to process sensitivity (biological) • Possible odor problems • Regular enzyme recharging required (biological) • Heating element may be required (biological) • Large on-site space	• Not recommended due to its inherited process sensitivity, relative complexity and operational problems, limit technology development for

Toilet system	Modifications	Treatment method	System advantages	System disadvantages	Notes
Recirculating flush toilet (continue)		for ultimate disposal	connection eliminated • High sanitary standard in difficult condition • Water consumption decreased	requirements as compared to discharging units • Untreated waste stored on in the house • Waste removal for ultimate disposal is necessary • Health hazards and low aesthetic quality during incomplete waste-flushing liquid separation • Special disposal methods necessary for flushing liquid • Poor data on field performance • High system complexity • No local commercial availability	on-site installation

The second stage included a more detailed assessment based on local criteria and local preference. Four main categories of criteria with their subdivisions formed the broad basis for the assessment: economy, environment, technicality, and society.

5.8. The high-level and low-level objectives hierarchy

The above-declared criteria were clustered under high-level and low level objective in two hierarchy value-trees for both of the community-wastewater treatment technologies and the onsite-wastewater treatment technologies as shown respectively in Figures 5.2 and 5.3.

Organizing the criteria and objectives in this way facilitated scoring the option on the criteria and examining the overall results at the level of objectives. The most important trade-off between the objectives appears at the top of the hierarchy. This is often between costs and benefits. Thus, the very top objective is the overall result, taking both costs and benefits into account. The three objectives (technicality, society, and environment) have been clustered under the higher level objective "Benefits", the costs of the technology has been separated and represented as a separated high level objective, with its sub-costs represented beneath as criteria.

UNDER THE ENVIRONMENT OBJECTIVE, THE SUB-ENVIRONMENT CRITERIA AS OPTIMAL WATER USE, SPACE, PATHOGEN REMOVAL, BOD REMOVAL, SLUDGE PRODUCTION, HEALTH RISK, ODOR, NOISE, INSECTS, VISUAL, NITROGEN REMOVAL, AND USE OF CHEMICALS WERE REPRESENTED BENEATH WITH REGARD TO THEIR IMPORTANCE. THE OPTIMAL WATER USE HAS BEEN GIVEN SIGNIFICANCE TO COMPLY WITH THE OVERALL TREATMENT POLICY, WHICH EMPHASIZE ON EMPLOYMENT OF THE EFFLUENT FOR REUSE PURPOSES. THE SAME IS DONE WITH THE OTHER HIGH LEVEL OBJECTIVES (THE SOCIETY AND TECHNICALITY). THE SOCIAL AND THE TECHNICAL SUB-CRITERIA OF THE CULTURAL ACCEPTANCE AND THE RETENTION TIME CRITERIA HAVE ALSO BEEN GIVEN SIGNIFICANT IMPORTANCE.

5.9. Assigning normalized scores and weights to the sustainable criteria

To illustrate the principle of the assessment of wastewater treatment systems, their evaluation was tentatively transformed into a normalized score between 0 and 100 for all the criteria. Based on intensive literature review each system performance of the septic tank-disposal field, septic tank-intermittent sand filter, septic tank-mound system, and septic tank-trickling filter systems as onsite-combined treatment systems, septic tank-constructed wetland, septic tank-recirculating

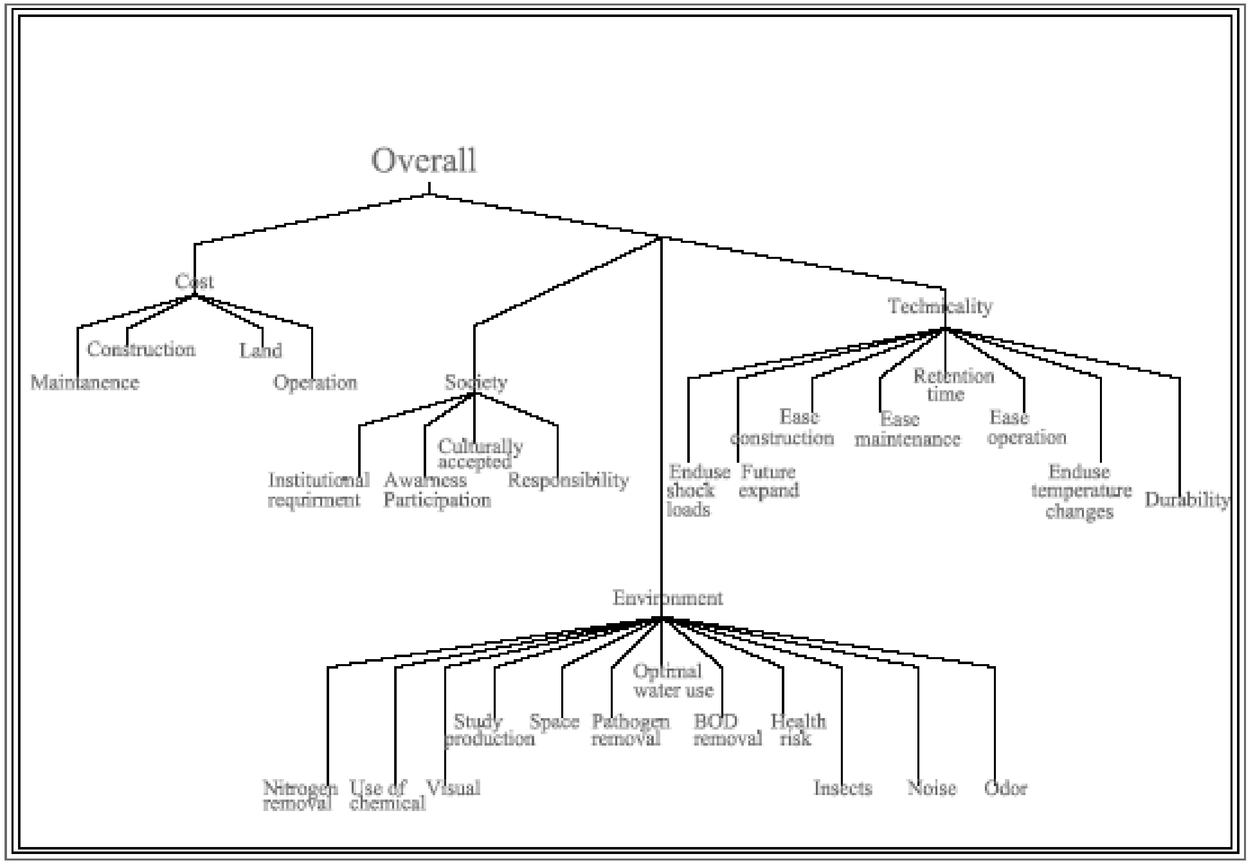

FIGURE 5.2: THE HIERARCHY TREE OF THE HIGH AND LOW LEVELS OBJECTIVES OF COMMUNITY WASTEWATER TREATMENT TECHNOLOGIES.

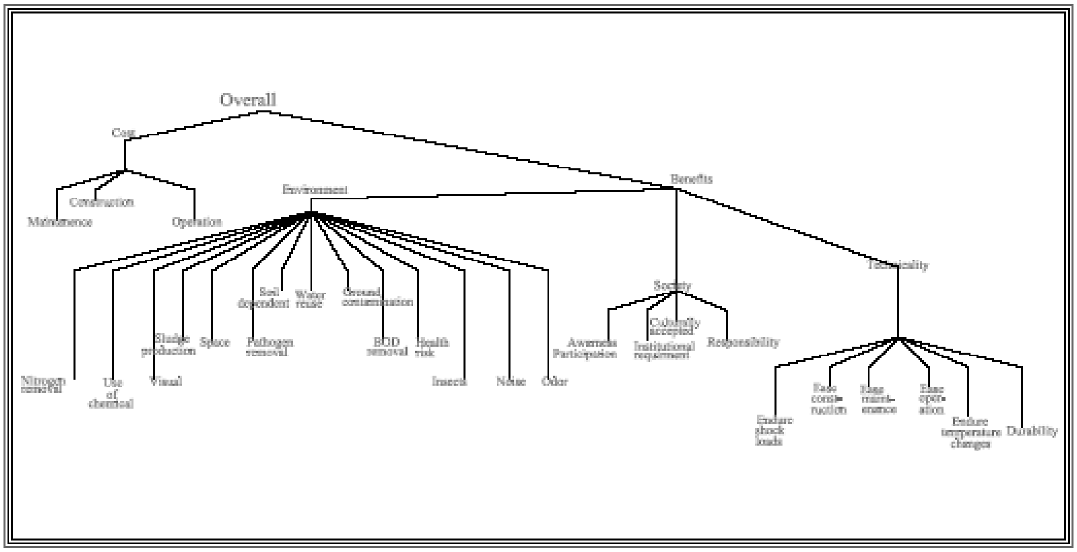

FIGURE 5.3: THE HIERARCHY TREE OF THE HIGH AND LOW LEVELS OBJECTIVES OF ONSITE WASTEWATER TREATMENT TECHNOLOGIES.

sand filter, septic tank-trickling filter, extended aeration activated sludge, pond-trickling filter, pond-recirculating sand filter, pond-constructed wetland, and waste stabilization ponds systems as collective-wastewater treatment plants for small communities / cluster of homes, the septic tank-upflow anaerobic filter, septic tank-disposal field, septic tank-intermittent sand filter, septic tank-mound system, and septic tank-trickling filter systems as onsite-gray water treatment systems was assessed with regard to the sustainability evaluation criteria. A brief description of each of the aforementioned systems was earlier presented in sections 2.5.2, 2.6, 2.7.2, 2.7.3, and 2.9.

However, the preference scales still can’t be combined because a unit of preference on one does not necessarily equal a unit of preference on the other. Thus, based on literature review and experts consultation, appropriate weights were set (for onsite-combined treatment systems, collective-treatment plant systems for small communities/cluster of homes, and onsite-gray water treatment systems) to all the criteria to weight the scales for their relative importance. The assignment of scores for each criterion is crucial, as is the selection of an appropriate weight for it, relative to the weighting of the criterion. The assigned weights were driven from the value trees presented earlier in Figures 5.2 and 5.3.

Under the evaluation of collective treatment plant systems for small communities (Table 5.7); the land cost criterion was given the highest weighted economical criterion, while it wasn’t stated under the evaluation of onsite-treatment systems (tables 5.6 and 5.8), where it is assumed to be provided by the home owners as these systems lie in their own properties. All the proposed treatment systems were assumed to be culturally accepted. This criterion was considered as an unavoidable prerequisite before implementing any of the wastewater treatment strategies. Moreover, it was assumed that public awareness programmes to promote wastewater treatment and reuse of reclaimed wastewater are conducted in the early stages of implementing any sanitation project. These programmes should guarantee the arising of the beneficiaries’ responsibilities, participation, awareness; willingness to pay and the cultural acceptance of reuse reclaimed wastewater.

Finally, the overall performance score for each option was calculated by simply multiplying the option's score on a criterion by the importance weight of the criterion, then summing the products to give the overall preference score for that option. The final obtained results are summarized in tables 5.6, 5.7, and 5.8.

Table 5.6: Multi criteria matrix for sustainable evaluation of onsite-combined treatment systems

Criteria	Highest score	Septic tank + Disposal field	Septic tank + Intermittent Sand Filter	Septic tank + Mound system	Septic tank + Trickling filter
Economical criteria					
Construction cost	25	15	10	5	25
O & M cost	10	8	8	10	5
Total score	**35**	**23**	**18**	**15**	**30**
Environmental criteria					
Land area required/space	2	1	0.5	0	2
Soil dependent	4	0	3	3	4
Odor	1	1	1	1	0
Noise	1	1	1	1	0
Insects	1	1	1	1	0
Visual	1	1	1	0	0
Optimal water resource reuse	4	0	3	0	4
Pathogen removal	2	2	1	1	1
BOD removal	2	2	1.5	1.5	1.5
Nitrogen removal	1	0	0	0	1
Sludge production	2	2	2	2	0
Use of chemicals	1	1	1	1	1
Health risk	2	2	2	0	1
Groundwater contamination	4	0	3	3	4
Total score	**28**	**14**	**21**	**14.5**	**19.5**
Technical criteria					
Durability	2	2	2	0	1
Ease of construction	4	4	4	2	2
Endure shock loads	3	3	3	3	0
Endure temperature changes	3	2	2	2	2
Ease of maintenance	4	4	4	0	2

Criteria	Highest score	Septic tank + Disposal field	Septic tank + Intermittent Sand Filter	Septic tank + Mound system	Septic tank + Trickling filter
Ease of operation	4	4	4	3	2
Total score	**20**	**19**	**19**	**10**	**9**
Social- cultural criteria					
Institutional requirements	6	6	6	3	2
Awareness /participation	6	6	6	5	2
Culturally accepted	7	7	7	7	7
Responsibility	6	6	6	5	2
Total score	**25**	**25**	**25**	**20**	**13**
Final total score (108)	**108**	**81**	**83**	**59.5**	**71.5**
Final total score (100)	**100**	**75**	**76.9**	**55**	**66.2**

We can see from Table 5.6 that the system of septic tank with intermittent sand filter is the most sustainable alternative and got the highest score. This alternative can be considered the most appropriate one in locations where conventional treatment systems (septic tank-disposal field) are not suitable (due to low soil permeability, shallow impervious substratum, shallow soils over openly fractured bedrock, high soil permeability, steep slopes, small lots, sensitive groundwater areas, and high groundwater). However, in such locations with limited space availability, it seems that the trickling filter system would be the most appropriate treatment system to be implemented.

Table 5.7: Multi criteria matrix for evaluation of collective wastewater treatment plants for small communities/cluster of homes

Criteria	Highest score	Septic tank + constructed Wetland	Septic tank + Recirculating Sand Filter	Septic tank + Trickling filter	Extended Aeration Activated Sludge	Pond + Trickling filter	Pond + Recirculating Sand Filter	Pond + constructed Wetland	Waste Stabilization Ponds
Economical criteria									
Construction cost	20	5	8	15	0	17	10	8	19
Land cost	30	10	20	30	25	10	18	5	0
O & M cost	15	12	10	8	0	10	11	14	15
Total score	**65**	**27**	**38**	**53**	**25**	**37**	**39**	**27**	**34**
Environmental criteria									
Land area required/space	2	0.5	1	2	2	0.5	0.5	0.5	0
Odor	1	0.5	0.5	0.5	1	0	0	0	0
Noise	1	1	1	0.5	0	0.5	1	1	1
Insects	1	0	0.5	0	1	0	0	0	0
Visual	1	1	1	1	1	1	1	1	1
Optimal water resource reuse	4	1	4	4	4	2	2	1	0
Pathogen removal	2	1.5	1.5	1.5	2	2	2	2	2
BOD removal	2	2	2	2	2	2	2	2	2
Nitrogen removal	1	1	1	1	1	1	1	1	1
Sludge production	2	1	1	0	2	1	1.5	2	2

Criteria	Highest score	Septic tank + constructed Wetland	Septic tank + Recirculating Sand Filter	Septic tank + Trickling filter	Extended Aeration Activated Sludge	Pond + Trickling filter	Pond + Recirculating Sand Filter	Pond + constructed Wetland	Waste Stabilization Ponds
Use of chemicals	1	1	1	1	1	1	1	1	1
Health risk	2	2	2	2	2	2	2	2	2
Total score	**20**	**12.5**	**16.5**	**15.5**	**19**	**13**	**13**	**13.5**	**12**
Technical criteria									
Durability	2	2	2	1	1	1	2	2	2
Ease of construction	4	2	2	2	0	2	2	3	4
Endure shock loads	3	3	3	2	1	2	3	3	3
Future expand	3	1	1	1	3	1	1	0	0
Retention time	6	1	3	3	6	3	3	0	0
Endure temperature changes	3	3	2	2	2	2	2	3	2
Ease of maintenance	4	3	2	2	0	2	2	4	4
Ease of operation	4	3	2	2	0	2	2	4	4
Total score	**29**	**18**	**17**	**15**	**13**	**15**	**17**	**19**	**19**
Social-cultural criteria									
Institutional requirements	6	2	3	3	0	3	4	6	6

Criteria	Highest score	Septic tank + constructed Wetland	Septic tank + Recirculating Sand Filter	Septic tank + Trickling filter	Extended Aeration Activated Sludge	Pond + Trickling filter	Pond + Recirculating Sand Filter	Pond + constructed Wetland	Waste Stabilization Ponds
Awareness /participation	6	6	6	6	6	6	6	6	6
Culturally accepted	7	7	7	7	7	7	7	7	7
Responsibility	6	6	6	6	6	6	6	6	6
Total score	**25**	**21**	**22**	**22**	**19**	**22**	**23**	**25**	**25**
Final total score (139)	**139**	**78.5**	**93.5**	**105.5**	**76**	**87**	**92**	**84.5**	**90**
Final total score (100)	**100**	**56.5**	**67.3**	**75.9**	**54.7**	**62.6**	**66.2**	**60.8**	**64.7**

We can see from Table 5.7 that the septic tank-trickling filter has got the highest score. This system has small land requirements, moderate operation and maintenance and medium capital and running costs. However, in case of land availability, the WSPs would be the most appropriate alternative due to their low construction and running costs, simple operation and maintenance and high treatment efficiency. The extended aeration activated sludge system has got the lowest score. It is not considered as an appropriate treatment system in Palestinian rural areas due to its high capital and running costs, need for close skilled operator supervision, and high power consumption.

Table 5.8 Multi criteria matrix for evaluation of onsite-gray water treatment systems

Criteria	Highest score	Septic Tank + Upflow Anaerobic filter	Septic tank + Disposal field	Septic tank + Intermittent Sand Filter	Septic tank + Mound system	Septic tank + Trickling filter
Economical criteria						
Construction cost	25	25	15	10	5	25
O & M cost	10	5	8	8	10	5
Total score	**35**	**30**	**23**	**18**	**15**	**30**
Environmental criteria						
Land area required/space	2	2	1	0.5	0	2
Soil dependent	4	4	0	3	3	4
Odor	6	0	6	6	6	5
Noise	1	0	1	1	1	0
Insects	1	0	1	1	1	0
Visual	1	0	1	1	0	0
Optimal water resource reuse	4	4	0	3	0	4
Pathogen removal	2	1	2	1	1	1
BOD removal	2	1.5	2	1.5	1.5	1.5
Nitrogen removal	1	1	0	0	0	1
Sludge production	2	2	2	2	2	0
Use of chemicals	1	1	1	1	1	1
Health risk	2	1	2	2	0	1
Groundwater contamination	4	4	0	3	3	4
Total score	**33**	**21.5**	**19**	**26**	**19.5**	**24.5**
Technical criteria						
Durability	2	1	2	2	0	1

Criteria	Highest score	Septic Tank + Upflow Anaerobic filter	Septic tank + Disposal field	Septic tank + Intermittent Sand Filter	Septic tank + Mound system	Septic tank + Trickling filter
Ease of construction	4	2	4	4	2	2
Endure shock loads	3	3	3	3	3	0
Endure temperature changes	3	2	2	2	2	2
Ease of maintenance	4	2	4	4	0	2
Ease of operation	4	2	4	4	3	2
Total score	**20**	**12**	**19**	**19**	**10**	**9**
Social- cultural criteria						
Institutional requirements	6	2	6	6	3	2
Awareness /participation	6	2	6	6	5	2
Culturally accepted	7	7	7	7	7	7
Responsibility	6	2	6	6	5	2
Total score	**25**	**13**	**25**	**25**	**20**	**13**
Final total score (113)	**113**	**76.5**	**86**	**88**	**64.5**	**76.5**
Final total score (100)	**100**	**76.1**	**76.1**	**77.9**	**57.1**	**67.7**

Table 5.8 points to the system of septic tank-intermittent sand filter as the most sustainable alternative as an onsite-gray water treatment system and got the highest score. This alternative can be considered the most appropriate alternative in locations where conventional treatment systems (septic tank-disposal field) are not suitable (due to low soil permeability, shallow impervious substratum, shallow soils over openly fractured bedrock, high soil permeability, steep slopes, small lots, sensitive groundwater areas, and high groundwater). However, in such locations with limited space availability it seems that both of the trickling filter and the upflow anaerobic filter system would be the most appropriate treatment systems to be implemented. The later is used as a denitrification step for nitrified nitrogen found in black water.

CHAPTER SIX

Proposed strategy for wastewater treatment in Palestinian rural areas

Introduction

Wastewater management is inadequate in Palestinian rural areas. Non-existing sewage systems and unregulated cesspits with seepage that pollutes aquifers, contributes to wastewater and contamination problems (Mahmoud, 2002). Untreated sewage wastewater in rural villages often flows freely into streets, agriculture fields, and wadis, contaminating food and water, and directly contributing to a critical community and environmental health risks.

ACCELERATED EXTENSION OF WASTEWATER MANAGEMENT SERVICES TO PALESTINIAN RURAL AREAS IS ESSENTIAL TO ADDRESS SERIOUS CONCERNS OVER WATER SCARCITY, POLLUTION AND PROTECTION OF PUBLIC HEALTH.

The recommended strategy should provide wastewater services that are:

- Robust, efficient and equally convenient.
- Cost effective
- Environmentally responsible and responsive to the water scarcity.

The proposed wastewater management strategies to be applied in Palestinian rural areas

- **Decentralizing wastewater management:** Decentralized wastewater management for Palestinian small communities fully satisfies the above objective without compromising the guiding principles and its wide application should be considered wherever possible. Conventional centralized wastewater management conflicts with the majority of the guiding principles and thus its application should be avoided wherever possible.
- **Incremental or phased development to overcome financial constraints:** To overcome the financial constraints faced in providing wastewater services to small communities, it is essential to develop these services in a phased manner while not compromising at any phase the stated objectives and guiding principles.

Existing onsite systems (cesspools) can be replaced by low cost treatment alternatives in the first phase. Conventional subsurface soil absorption onsite systems (consisted primarily of a septic tank and a soil absorption field) have been recognized as a most appropriate technique for onsite wastewater treatment. As shown in Table 6.1 these systems are considered as appropriate treatment systems to be applied in non-sensitive areas with low population density as Al-Hashimiya village in Jenin, Ramin in Tulkarm, Deir Sharaf in Nablus, Deir 'Ammar in Ramallah, and Fasayil in Jericho.

However, this is contingent on the site being appropriate for such a system as noted earlier. Septic tank-intermittent sand filter system can be applied in locations where conventional treatment systems are not suitable. Villages as Al Jab'a in Hebron, Beit 'Ur Al-Fauqa in Ramallah, Jaba' in Jerusalem, Wadi Fukin in Bethlehem, Al Jab'a in Jerusalem, and Yanun in Nablus with low population density and lie in sensitive recharge areas are example of those villages where more advanced onsite treatment systems are appropriate to be used. (See table 6.1).

Nevertheless, in such locations with limited space availability it seems that the trickling filter system would be the best treatment system to be implemented. This alternative has a reasonably low capital and running costs. Land requirement is the lowest among the other alternatives due to the high towers that can be built to a height of 2 to 4 meters using rock stones or any appropriate media. This is applicable in villages with low-moderate population density as Kafr Qaddum in Qalqiliya, Al Lubban Ash-Sharqiya, Deir Al-Hatab and 'Azmut in Nablus, Kafr 'Abbush and An Nazla Ash-Sharqiya in Tulkarm, and Mirka in Jenin (Table 6.1).

A COMMUNITY TREATMENT PLANT CAN BE ADDED WHEN ONSITE SYSTEMS BECOME OVERLOADED OR THE SOIL MAY NO LONGER ACCEPT THE EFFLUENT. VEHICLES CAN INITIALLY COLLECT THE EFFLUENT FROM THE ONSITE SYSTEMS. WHEN FINANCIAL RESOURCES BECOME AVAILABLE, A NETWORK OF COST EFFECTIVE CAN BE ADDED TO COLLECT THE EFFLUENT FROM THE ONSITE SYSTEMS TO THE COMMUNITY TREATMENT FACILITY.

- **Wastewater transportation/collection when needed:** Should the circumstances no longer allow the use of onsite wastewater management systems, the onsite wastewater management service must be upgraded and the effluent from the onsite systems must be transported and managed through a community system applying the principles of decentralized wastewater management.

In certain settings in Palestinian rural areas, e.g. high-density low-income communities, it’s more appropriate to employ a system for wastewater management for a cluster of houses rather than installing individual ones for each single household. In such cases, there is a need to install a sewage collection system.

Wastewater collection and conveyance has been a major obstacle to wastewater expansion services to Palestinian small communities due to the high costs entailed. Affordable and less-water-intensive alternatives to the conventional sewerage collection systems will be needed if proper wastewater management services are to be provided to such communities.

The settled sewerage (small bore sewers) and the simplified sewerage are appropriate for small communities in Palestinian rural areas. Simplified sewerage is most appropriate in high-density, low-income housing areas where there is no space for on-site sanitation pits or for the solids interceptor tanks of settled sewerage. It can be applied in villages as Kufeirit in Jenin, Al Juneid in Nablus, Beit Sira in Ramallah, and Ar Rihiya in Hebron. Reclaimed wastewater can be reused in agricultural purposes in these villages as they lie in non-sensitive recharge and high agricultural suitability areas. In villages as Zububa in Jenin, Nazlat 'Isa in Tulkarm, Haris in Salfit, and Al Midya in Ramallah reclaimed wastewater can be used for agricultural purposes due to availability of high suitable areas for this purpose, but it is recommended to have effluent nutrient removal as these villages lie in moderate sensitive areas. However, in locations with no available suitable areas for agriculture like Az-Zawiya in Jenin and Deir Nidham in Ramallah, reclaimed wastewater can be conveyed to the closest areas where it can be used in agriculture (Table 6.1).

Settled sewerage is appropriate for low-density small communities. Settled sewers comply with the guiding principles and offer great opportunities for faster and sustainable extension of wastewater services to Palestinian rural areas where water supplies are scarce. This is the case in Beit Dajan in Nablus, Raba in Jenin, and Hajja in Qalqiliya. High agricultural suitability and non-sensitive areas is dominant in these villages. In villages as Sir in Jenin, Saffarin in Tulkarm, Bruqin in Salfit, and Qaryut in Nablus reclaimed wastewater can be used for agricultural purposes due to availability of high suitable areas for this purpose, but it is recommended to have effluent nutrient removal as these villages lie in moderate sensitive areas. However, in locations with no available suitable areas for agriculture and with high sensitivity recharge areas like Yasid and Jurish in Nablus reclaimed wastewater can be conveyed to the closest areas where it can be used in agriculture (Table 6.1).

Settled sewers can be used to upgrade the overloaded onsite wastewater systems. Existing leach-pits should be replaced with interceptor tanks and connected to small-bore sewers. It will be necessary to locate interceptor tanks where they are accessible to sludge tankers. In some cases this will mean that several houses will have to be connected to a single interceptor tank situated reasonably close to the road.

After conveying the small community generated wastewater through the appropriate sewerage system, it should be treated in a community treatment plant. It is recommended to use a septic tank-trickling filter system. This system has small land requirements, moderate operation and maintenance, high treatment efficiency, and medium capital and running costs. It is appropriate to be applied in villages as Kufeirit in Jenin, Al Juneid in Nablus, Beit Sira in Ramallah, and Arrihiya in Hebron. However, in case of land availability, the WSP's would be the best alternative due to their low construction and running costs, simple operation and maintenance and high treatment efficiency. They are the most simple of all comprehensive waste treatment processes. Where land is readily available and where the climate is warm, the simplicity, efficiency and reliability of waste stabilization ponds recommend their use (UNEP, 1988). This is true in villages like Jalbun in Jenin Far'ata in Qalqiliya, Seida in Tulkarm, and Kafr Qallil in Nablus (Table 6.1).

- **Reducing wastewater generation:** Wastewater flows must be reduced through comprehensive domestic water demand management interventions including awareness drives, water pricing, the use of low-volume flush toilets and other water saving devices and fixtures. Reduced wastewater flows reduce the spread of pollution, and the infrastructure requirements and cost of wastewater services. The efficient use of water through water conservation measures and reduction of loads of pollutants are necessary to reduce the quantity of the waste generated. Wastewater flow modification through the reduction of pollutants' loads can greatly reduce the requirements of onsite wastewater treatment and also encourages onsite wastewater treatment and also encourages onsite recycling and reuse. Methods of reducing pollutant loads include refraining from disposing of food residue through kitchen sinks, dumping sanitary napkins into toi1ets and the use of environmentally friendly detergents containing less phosphorous compounds.

- **Separation of black and grey wastewater**: onsite wastewater segregation is to be considered in areas where so far no, or limited, sanitary services are available, it is not difficult and expensive to change the combining plumbing system into a separated one, and there is enough space for onsite treatment units.

When toilet wastewater is collected with or without a very limited amount of flushing water, the so-called night soil production, it could be digested in accumulation systems (Elmitwalli, *et al*, 2000). The digested slurry can be used in agriculture as soil conditioner and fertilizer. PARC institution has already introduced this approach. The system utilized in those on-site treatment plants was Septic Tank-Upflow Gravel Filter (ST-UFGF). Grey wastewater can be treated in conventional subsurface soil adsorption systems. They can be used in villages like 'Ein Ad-Duyuk al Foqa in Jericho, Beit Iksa in Jerusalem, Kafr Qud in Jenin, and Jammala in Ramallah. However, in locations as Al-Walaja in Bethlehm, An Nabi Samwil in Jerusalem, and Burqa in Ramallah, where conventional treatment systems are not suitable (sensitive recharge areas), it is recommended to use intermittent sand filter.

However, in such locations with limited space availability it seems that the trickling filter or the upflow anaerobic filter systems would be the best treatment systems to be implemented. Grey and black wastewater can be collected separately in two septic tanks. Then nitrogen found in black wastewater can be nitrified in a subsurface sand filter. These systems can be applied in villages like Zeita Jamma'in in Nablus, Mirka in Jenin, Kafr Rumman in Tulkarm, Falamya in Qalqiliya, and Mazari' an Nubani in Ramallah.

Table 6.1 represents the proposed sustainable wastewater management strategies to be applied in most of the Palestinian rural areas that lie in the West Bank, with population number between 100-4000 persons. The proposed strategies were set with relevance of each criterion in the decision process and its implementation in the decision tree of the algorithm-planning tool (Figure 5.1).

Proposed elements for an effective wastewater systems management program

For a wastewater system to be a viable alternative, it is vitally important that it is planned, designed, operated and maintained in accordance with an effective management program. Such a program should allow for the provision of technical assistance to homeowners as well as regulation enforcement. Concerned authorities should have a clear policy on this through the issuance and enforcement of regulatory standards and guidelines on the overall management of wastewater treatment systems. This may be accomplished through the preparation and dissemination of a total management manual and educational program. A comprehensive management program should include procedures and working instructions pertaining to the planning, design, installation and maintenance of wastewater treatment systems. A management program would include identifying the site suitability for a system application for a certain setting during the planning phase.

Financial incentives to homeowners by local municipalities (village councils) to cover, at least, part of the entailed costs of new designs and construction ought to be considered.

Onsite systems should be given significant attention in the wastewater management process. The use of the Geographical Information System (GIS) for the management of existing and planning for future systems can be extremely effective in ensuring the promotion of onsite wastewater systems application. GIS can greatly facilitate tracing the functioning of existing systems, planning for future ones, identifying sensitive areas and provide easy to use maps for educational purposes (Douglas, 1998).

Institutional reform is required to encourage wider application and effective operation and maintenance of decentralized management. Like centralized systems, decentralized wastewater systems require effective operation and maintenance that must not be under estimated by planners, operators and the public. The operation and management requirements of decentralized systems vary in nature from those of centralized systems. Current institutional setup, which is geared for centralized wastewater management, cannot effectively manage decentralized

TABLE 6.1 PROPOSED SUSTAINABLE WASTEWATER MANAGEMENT STRATEGIES TO BE APPLIED IN THE WEST BANK PALESTINIAN RURAL AREAS WITH POPULATION NUMBER BETWEEN 100-4000 PERSONS, WITH RELEVANCE TO THEIR DENSITY CATEGORY, WATER NETWORK AVAILABILITY, RECHARGE AREA SENSITIVITY, SUITABLE AGRICULTURAL AREAS AVAILABILITY.

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
'Arab ar Rashayida	Bethlehem	High	Yes	Not-sensitive	Low	Shallow Sewerage-Reclaimed transition
'Ayda Camp	Bethlehem	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Abu Nujeim	Bethlehem	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Al 'Asakira	Bethlehem	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Al 'Aza Camp	Bethlehem	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Al 'Iqab	Bethlehem	High	No	High-sensitivity	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Al Beida	Bethlehem	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Al Fureidis	Bethlehem	High	Yes	High-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Al Halqum	Bethlehem	High	Yes	High-sensitivity	Moderate	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Al Khas	Bethlehem		Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Al Ma'sara	Bethlehem	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Al Maniya	Bethlehem	High	Yes	High-sensitivity	Moderate	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Al Manshiya	Bethlehem	High	Yes	High-sensitivity	Moderate	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Al Walaja	Bethlehem	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Ar Rawa'in	Bethlehem	High	No	Not-sensitive	Low	Shallow Sewerage-Reclaimed transition
Artas	Bethlehem	Moderate	Yes	Not-sensitive	High	Shallow Sewerage-Agricultural reuse

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Ash Shawawra	Bethlehem	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Ath Thabra	Bethlehem	High	No	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Battir	Bethlehem	Moderate	Yes	Not-sensitive	Moderate	Shallow Sewerage-Agricultural reuse
Beit Falouh	Bethlehem	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Beit Ta'mir	Bethlehem	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Bureid'a	Bethlehem	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Dar Salah	Bethlehem	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Dhahrat an Nada	Bethlehem	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Fakht al Jul	Bethlehem	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Harmala	Bethlehem	High	Yes	High-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Hindaza	Bethlehem	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Juhdum	Bethlehem	High	Yes	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Jurat ash Sham'a	Bethlehem	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Khallet al Balluta	Bethlehem	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Khallet al Haddad	Bethlehem	High	Yes	High-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Khallet al Louza	Bethlehem	High	No	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Khallet al Qaranin	Bethlehem	High	No	High-sensitivity	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Khallet an Nu'man	Bethlehem	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Khallet Hamad	Bethlehem	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Khirbet ad Deir	Bethlehem	High	Yes	High-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Kisan	Bethlehem	High	Yes	High-sensitivity	Moderate	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Marah Ma'alla	Bethlehem	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Marah Rabah	Bethlehem	High	Yes	High-sensitivity	Moderate	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Rakhme	Bethlehem	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Ras al Wad	Bethlehem	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Umm 'Asla	Bethlehem	High	Yes	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Umm al Qasseis	Bethlehem	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Umm Salamuna	Bethlehem	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Wadi al 'Arayis	Bethlehem	High	Yes	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Wadi an Nis	Bethlehem	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Wadi Fukin	Bethlehem	Low	Yes	High	Moderate	Advanced-Onsite-Treatment
Wadi Rahhal	Bethlehem	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Wadi Umm Qal'a	Bethlehem	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
'Abda	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
'Anab al Kabir	Hebron	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
'Arab al Fureijat	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
'Irqan Turad	Hebron	High	Yes	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Abu al 'Asja	Hebron	High	Yes	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Abu al 'Urqan	Hebron	High	No	Moderate	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
Abu al Ghuzlan	Hebron	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Ad Deirat	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Ad Duweir	Hebron	High	No	Sensitive	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Ad Duwwara	Hebron	High	Yes	High-sensitivity	Moderate	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Al 'Uddeisa	Hebron	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Al Bira	Hebron	High	Yes	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Al Burj	Hebron	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Al Buweib	Hebron	High	No	Moderate	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Al Faqir	Hebron	High	No	Not-sensitive	Low	Shallow Sewerage-Reclaimed transition
Al Heila	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Al Hijra	Hebron	High	Yes	High-sensitivity	Moderate	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Al Jab'a	Hebron	Low	Yes	Sensitive	Moderate	Advanced-Onsite-Treatment
Al Karmil	Hebron	High	Yes	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Al Khamajat	Hebron	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Al Kum	Hebron	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Al Majd	Hebron	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Al Muntar	Hebron	High	Yes	Moderate	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Al Muwarraq	Hebron	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
An Najada	Hebron	High	No	Not-sensitive	Low	Shallow Sewerage-Reclaimed transition
Ar Ramadin	Hebron	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Ar Rawa'in	Hebron	High	No	Sensitive	Low	Shallow Sewerage-Reclaimed transition
Ar Rifa'iyya	Hebron	High	No	Moderate	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Ar Rihiya	Hebron	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
As Sikka	Hebron	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
As Simiya	Hebron	High	Yes	Moderate	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
As Sura	Hebron	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
At Tabaqa	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Az Zuweidin	Hebron	High	No	Not-sensitive	Low	Shallow Sewerage-Reclaimed transition
Beit 'Amra	Hebron	High	Yes	Moderate	Moderate	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Beit 'Einun	Hebron	High	Yes	High-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Beit ar Rush al Fauqa	Hebron	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Beit ar Rush at Tahta	Hebron	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Beit Maqdum	Hebron	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Beit Mirsim	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Bir Musallam	Hebron	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Birin	Hebron	High	No	Sensitive	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Biyar al 'Arus	Hebron	High	No	Sensitive	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Deir al 'Asal al Fauqa	Hebron	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Deir al 'Asal at Tahta	Hebron	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Deir Razih	Hebron	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Fuqeiqis	Hebron	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Hadab al 'Alaqa	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Hadab al Fawwar	Hebron	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Hitta	Hebron	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Hureiz	Hebron	High	No	Sensitive	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
I'zeiz	Hebron	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Imneizil	Hebron	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Imreish	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Iskeik	Hebron	High	No	Sensitive	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Jala	Hebron	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Karma	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Khallet 'Arabi	Hebron	High	No	Sensitive	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Khallet al 'Aqed	Hebron	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Khallet al Maiyya	Hebron	High	No	Moderate	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Khallet Salih	Hebron	High	No	Moderate	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Kharsa	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Khashem al Karem (Makhfar um adaraj)	Hebron	High	No	Moderate	Low	Shallow Sewerage-Reclaimed transition
Khirbet ad Deir	Hebron	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Khirbet al Hasaka	Hebron	High	No	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Khirbet Bir al 'Idd	Hebron	High	No	Not-sensitive	Low	Shallow Sewerage-Reclaimed transition
Khirbet Salama	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Khirbet Tawil ash Shih	Hebron	High	No	Moderate	Low	Shallow Sewerage-Reclaimed transition
Kureise	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Kurza	Hebron	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Kuziba	Hebron	High	Yes	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Ma'in	Hebron	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Marah al Baqqar	Hebron	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Qafan al Khamis	Hebron	High	Yes	High-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Qalqas	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Qila	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Qinan an Najma	Hebron	High	No	Sensitive	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Qinan Jaber	Hebron	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Qurnet ar Ras	Hebron	High	No	Moderate	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Rabud	Hebron	High	Yes	Moderate	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Rafada	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Ras al Jora	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Ras at Tawil	Hebron	High	Yes	High-sensitivity	Moderate	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Safa	Hebron	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Shuyukh al 'Arrub	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Tawas	Hebron	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Turrama	Hebron	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Umm Lasafa	Hebron	High	No	Not-sensitive	Low	Shallow Sewerage-Reclaimed transition
Wadi 'Ubeid	Hebron	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Wadi as Sada	Hebron	High	No	Sensitive	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Wadi ash Shajina	Hebron	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Zif	Hebron	High	Yes	Sensitive	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
'Aba	Jenin	High	No	Sensitive	Low	Shallow Sewerage-Reclaimed transition
'Anin	Jenin	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
'Anza	Jenin	Low	Yes	Local-sensitivity	Moderate	Advanced-Onsite-Treatment
'Arab as Suweitat	Jenin	High	No	Sensitive	Low	Shallow Sewerage-Reclaimed transition
'Arabbuna	Jenin	Low	No	Sensitive	High	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
'Arrana	Jenin	Low	No	Plain areas	High	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Ad Damayra	Jenin	High	No	Plain-areas	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
Al 'Araqa	Jenin	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
al 'Asa'asa	Jenin	High	Yes	Plain-areas	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Al 'Attara	Jenin	Low	No	Plain areas	Moderate-low	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Al Fandaqumiya	Jenin	Moderate	Yes	Not-sensitive	Low	Shallow Sewerage-Reclaimed transition
Al Hashimiya	Jenin	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment
Al Jalama	Jenin	Moderate	Yes	Plain areas	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Al Khuljan	Jenin	High	No	High-sensitivity	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Al Manshiya	Jenin	High	No	Plain-areas	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Al Mansura	Jenin	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Al Mughayyir	Jenin	Low	Yes	Not-sensitive	Moderate	Conventional-Onsite-Treatment
Al Mutilla	Jenin	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Ar Rama	Jenin	Low	Yes	High	Moderate	Advanced-Onsite-Treatment
Ash Shuhada	Jenin	High	Yes	Plain-areas	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
At Tarem	Jenin	High	Yes	High-sensitivity	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
At Tayba	Jenin	Moderate	Yes	High	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
Az Zababida	Jenin	Moderate	Yes	Sensitive	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Az Zawiya	Jenin	Moderate	Yes	Local-sensitivity	Low	Shallow Sewerage-Reclaimed transition

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Barta'a ash Sharqiya	Jenin	Low	Yes	High	High	Advanced-Onsite-Treatment
Beit Qad	Jenin	Low	No	Plain areas	High	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Bir al Basha	Jenin	High	No	Plain-areas	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
Dahiyat Sabah al Kheir	Jenin	High	Yes	Plain-areas	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Deir Ghazala	Jenin	Low	Yes	Plain areas	High	Advanced-Onsite-Treatment
Dhaher al 'Abed	Jenin	High	No	High-sensitivity	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Dhaher al Malih	Jenin	High	Yes	High-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Fahma	Jenin	Moderate	Yes	Not-sensitive	Moderate	Shallow Sewerage-Agricultural reuse
Fahma al Jadida	Jenin	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Faqqu'a	Jenin	Low	No	Sensitive	Moderate-low	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Imreiha	Jenin	High	No	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Jalbun	Jenin	Low	No	Not-sensitive	High	Settled Sewerage-Agricultural reuse/Conventional-Onsite treatment
Jalqamus	Jenin	Low	Yes	Sensitive	Moderate	Advanced-Onsite-Treatment
Kafr Qud	Jenin	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment
Khirbet 'Abdallah al Yunis	Jenin	High	Yes	High-sensitivity	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Khirbet ash Sheikh Sa'eed	Jenin	High	Yes	High-sensitivity	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Kufeirit	Jenin	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Mashru' Beit Qad	Jenin	High	No	Plain-areas	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Mirka	Jenin	Low	Yes	Plain areas	Low	Advanced-Onsite-Treatment

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Misliya	Jenin	Low	No	Local-sensitivity	High	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Nazlat ash Sheikh Zeid	Jenin	High	Yes	High-sensitivity	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Raba	Jenin	Low	No	Not-sensitive	Moderate	Settled Sewerage-Agricultural reuse/Conventional-Onsite treatment
Rummana	Jenin	Low	Yes	Plain areas	High	Advanced-Onsite-Treatment
Sir	Jenin	Low	No	Local-sensitivity	High	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Ti'innik	Jenin	Low	Yes	Plain areas	High	Advanced-Onsite-Treatment
Tura al Gharbiya	Jenin	High	Yes	High-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Tura ash Sharqiya	Jenin	High	Yes	High-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Umm ar Rihan	Jenin	High	Yes	High-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Umm at Tut	Jenin	Low	Yes	Sensitive	High	Advanced-Onsite-Treatment
Umm Dar	Jenin	High	No	High-sensitivity	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Wad ad Dabi'	Jenin	High	No	Sensitive	Low	Shallow Sewerage-Reclaimed transition
Zabda	Jenin	Low	No	High	Moderate-low	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Zububa	Jenin	High	Yes	Plain areas	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
'Ein ad Duyuk at Tahta	Jericho	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
'Ein as Sultan Camp	Jericho	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Al 'Auja	Jericho	Low	Yes	Not-sensitive	Moderate	Conventional-Onsite-Treatment
An Nuwei'ma	Jericho	Low	Yes	Not-sensitive	Moderate	Conventional-Onsite-Treatment
Az Zubeidat	Jericho	High	Yes	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Ein ad Duyuk al Foqa	Jericho	Low	Yes	Not-sensitive	Moderate	Conventional-Onsite-Treatment
Fasayil	Jericho	Low	Yes	Not-sensitive	Low	Conventional-Onsite-Treatment
Marj al Ghazal	Jericho	High	Yes	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Marj Na'ja	Jericho	High	Yes	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
'Arab al Jahalin	Jerusalem	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Al Judeira	Jerusalem	Moderate	Yes	High	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Al Khan al Ahmar (Tajammu' Badawi)	Jerusalem	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Al Qubeiba	Jerusalem	Moderate	Yes	Moderate	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
An Nabi Samwil	Jerusalem	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Ash Sheikh Sa'd	Jerusalem	High	Yes	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Az Za'ayyem	Jerusalem	High	Yes	Sensitive	Low	Shallow Sewerage-Reclaimed transition
Beit Duqqu	Jerusalem	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Beit Hanina al Balad	Jerusalem	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Beit Ijza	Jerusalem	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Beit Iksa	Jerusalem	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment
Beit Surik	Jerusalem	Moderate	Yes	Moderate	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
Jaba'	Jerusalem	Low	Yes	High	High	Advanced-Onsite-Treatment
Kharayib Umm al Lahim	Jerusalem	High	No	Moderate	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
Mikhmas	Jerusalem	Low	Yes	Sensitive	High	Advanced-Onsite-Treatment
Qalandiya	Jerusalem	Low	Yes	High	High	Advanced-Onsite-Treatment

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Rafat	Jerusalem	Moderate	Yes	Moderate	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
'Ammuriya	Nablus	Low	No	Not-sensitive	Low	Settled Sewerage-Reclaimed transition/Conventional-Onsite treatment
'Asira al Qibliya	Nablus	Low	No	High	Moderate-Low	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
'Ein Shibli	Nablus	High	Yes	Sensitive	Moderate	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
'Einabus	Nablus	Moderate	Yes	Not-sensitive	Moderate-Low	Shallow Sewerage-Agricultural reuse
'Iraq Burin	Nablus	High	No	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
'Urif	Nablus	Moderate	No	High	Moderate-Low	Settled Sewerage -Nutrient removal-Agricultural reuse
Al 'Aqrabaniya	Nablus	High	No	Sensitive	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Al Badhan	Nablus	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Al Juneid	Nablus	High	Yes	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse
Al Lubban ash Sharqiya	Nablus	Low	Yes	Moderate	Low	Advanced-Onsite-Treatment
An Naqura	Nablus	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment
An Nassariya	Nablus	High	Yes	Sensitive	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
As Sawiya	Nablus	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment
Azmut	Nablus	Low	Yes	High	High	Advanced-Onsite-Treatment
Beit Dajan	Nablus	Low	No	Not-sensitive	High	Settled Sewerage-Agricultural reuse/Conventional-Onsite treatment
Beit Hasan	Nablus	High	Yes	Sensitive	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Beit Iba	Nablus	Moderate	Yes	Not-sensitive	Moderate-low	Shallow Sewerage-Agricultural reuse
Beit Imrin	Nablus	Low	Yes	Local-sensitivity	Low	Advanced-Onsite-Treatment
Beit Wazan	Nablus	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Bizzariya	Nablus	Moderate	Yes	Local-sensitivity	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Burin	Nablus	Low	No	Not-sensitive	Moderate-Low	Settled Sewerage-Agricultural reuse/Conventional-Onsite treatment
Burqa	Nablus	Low	Yes	Local-sensitivity	Low	Advanced-Onsite-Treatment
Deir al Hatab	Nablus	Low	Yes	High	High	Advanced-Onsite-Treatment
Deir Sharaf	Nablus	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment
Duma	Nablus	Low	No	Sensitive	Moderate-low	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Furush Beit Dajan	Nablus	High	No	Sensitive	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Ijnisinya	Nablus	Low	Yes	Local-sensitivity	Low	Advanced-Onsite-Treatment
Jalud	Nablus	Low	No	High	High	Settled Sewerage-nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Jurish	Nablus	Low	No	High	Low	Settled Sewerage-reclaimed transition/Advanced-Onsite treatment
Kafr Qallil	Nablus	Moderate	No	Not-sensitive	Moderate-Low	Settled Sewerage-Agricultural reuse
Madama	Nablus	Moderate	No	Not-sensitive	Moderate-Low	Settled Sewerage-Agricultural reuse
Majdal Bani Fadil	Nablus	Low	No	Sensitive	High	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Nisf Jubeil	Nablus	Low	Yes	Local-sensitivity	Moderate-low	Advanced-Onsite-Treatment
Odala	Nablus	High	Yes	High-sensitivity	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Osarin	Nablus	Moderate	No	High	Moderate-Low	Settled Sewerage -Nutrient removal-Agricultural reuse
Qaryut	Nablus	Low	No	High	Moderate-low	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Qusin	Nablus	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Rujeib	Nablus	Moderate	Yes	High	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Sabastiya	Nablus	Moderate	Yes	Not-sensitive	Moderate-low	Shallow Sewerage-Agricultural reuse
Sarra	Nablus	Moderate	No	Not-sensitive	Moderate-Low	Settled Sewerage-Agricultural reuse
Talluza	Nablus	Low	Yes	Local-sensitivity	Moderate-low	Advanced-Onsite-Treatment
Telfit	Nablus	Moderate	No	High	Moderate-low	Settled Sewerage -Nutrient removal-Agricultural reuse
Yanun	Nablus	Low	No	High	Moderate-Low	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Yasid	Nablus	Low	No	Local-sensitivity	Low	Settled Sewerage-reclaimed transition/Advanced-Onsite treatment
Yatma	Nablus	Moderate	Yes	Not-sensitive	High	Shallow Sewerage-Agricultural reuse
Zawata	Nablus	Moderate	Yes	Local-sensitivity	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
Zeita Jamma'in	Nablus	Low	Yes	High	High	Advanced-Onsite-Treatment
'Arab ar Ramadin al Janubi	Qalqiliya	High	No	High-sensitivity	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
'Azzun 'Atma	Qalqiliya	High	Yes	High-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
'Isla	Qalqiliya	High	Yes	High-sensitivity	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
'Izbat al Ashqar	Qalqiliya	High	No	High-sensitivity	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
'Izbat at Tabib	Qalqiliya	High	No	High-sensitivity	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
'Izbat Jal'ud	Qalqiliya	High	No	High-sensitivity	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
'Izbat Salman	Qalqiliya	High	No	High-sensitivity	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Ad Dab'a	Qalqiliya	High	No	High-sensitivity	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Al Funduq	Qalqiliya	Low	Yes	High	Moderate	Advanced-Onsite-Treatment
Al Mudawwar	Qalqiliya	High	No	High-sensitivity	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
An Nabi Elyas	Qalqiliya	High	Yes	High-sensitivity	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Baqat al Hatab	Qalqiliya	Low	No	High	Moderate-low	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Beit Amin	Qalqiliya	High	No	High-sensitivity	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
Falamya	Qalqiliya	Low	Yes	High	High	Advanced-Onsite-Treatment
Far'ata	Qalqiliya	Low	No	Not-sensitive	Moderate	Settled Sewerage-Agricultural reuse/Conventional-Onsite treatment
Hajja	Qalqiliya	Low	No	Not-sensitive	Moderate	Settled Sewerage-Agricultural reuse/Conventional-Onsite treatment
Immatin	Qalqiliya	Low	No	High	Moderate	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Jayyus	Qalqiliya	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Jinsafut	Qalqiliya	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Jit	Qalqiliya	Low	Yes	Not-sensitive	Moderate	Conventional-Onsite-Treatment
Kafr Laqif	Qalqiliya	Low	Yes	High	High	Advanced-Onsite-Treatment
Kafr Qaddum	Qalqiliya	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Khirbet Sir	Qalqiliya	Low	Yes	High	High	Advanced-Onsite-Treatment
Ras 'Atiya	Qalqiliya	High	Yes	High-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Ras at Tira	Qalqiliya	High	No	High-sensitivity	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Sanniriya	Qalqiliya	Low	Yes	High	Moderate	Advanced-Onsite-Treatment
'Abud	Ramallah & Al Bireh	Low	Yes	High	Low	Advanced-Onsite-Treatment

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
'Abwein (Bani Zeid ash Sharqiya)	Ramallah &Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
'Arura (Bani Zeid ash Sharqiya)	Ramallah &Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
'Atara	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
'Ein 'Arik	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
'Ein Qiniya	Ramallah & Al Bireh	Low	No	Moderate	Moderate-low	Settled Sewerage-Nutrient removal-agricultural reuse/Advanced-Onsite treatment
'Ein Samiya	Ramallah & Al Bireh	High	No	Sensitive	Low	Shallow Sewerage-Reclaimed transition
'Ein Siniya	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
'Ein Yabrud	Ramallah & Al Bireh	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Abu Qash	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Abu Shukheidim	Ramallah & Al Bireh	High	Yes	Moderate	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Ajjul	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Al Janiya	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Al Lubban al Gharbi	Ramallah & Al Bireh	Low	Yes	High	High	Advanced-Onsite-Treatment
Al Mazra'a al Qibliya	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Al Midya	Ramallah & Al Bireh	High	Yes	High	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Al Mughayyir	Ramallah & Al Bireh	Low	Yes	Sensitive	Moderate-low	Advanced-Onsite-Treatment
An Nabi Salih (Bani Zeid al gharbiya)	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
At Tayba	Ramallah & Al Bireh	Low	Yes	Moderate	Low	Advanced-Onsite-Treatment
At Tira	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Badiw al Mu'arrajat	Ramallah & Al Bireh	High	No	Moderate	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
Beit 'Ur al Fauqa	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Beit Nuba	Ramallah & Al Bireh	High	No	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Beit Sira	Ramallah & Al Bireh	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Beitillu	Ramallah & Al Bireh	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment
Beitin	Ramallah & Al Bireh	Moderate	Yes	High	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Bil'in	Ramallah & Al Bireh	Moderate	Yes	Not-sensitive	Moderate-low	Shallow Sewerage-Agricultural reuse
Budrus	Ramallah & Al Bireh	Moderate	Yes		High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Burham	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Burqa	Ramallah & Al Bireh	Low	Yes	Moderate	High	Advanced-Onsite-Treatment
Deir 'Ammar	Ramallah & Al Bireh	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment
Deir 'Ammar Camp	Ramallah & Al Bireh	High	Yes	Not-sensitive	Moderate-low	Shallow/Conventional Sewerage-Agricultural reuse

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Deir Abu Mash'al	Ramallah & Al Bireh	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Deir as Sudan	Ramallah & Al Bireh	Moderate	Yes	Moderate	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
Deir Ibzi'	Ramallah & Al Bireh	High	Yes	Moderate	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Deir Jarir	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Deir Nidham	Ramallah & Al Bireh	Moderate	Yes	Not-sensitive	Low	Shallow Sewerage-Reclaimed transition
Deir Qaddis	Ramallah & Al Bireh	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Dura al Qar'	Ramallah & Al Bireh	Moderate	Yes	Moderate	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
Jammala	Ramallah & Al Bireh	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment
Jibiya	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Jifna	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Kafr 'Ein (Bani Zeid al gharbiya)	Ramallah & Al Bireh	High	Yes	Moderate	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Kafr Malik	Ramallah & Al Bireh	Low	Yes	High	Low	Advanced-Onsite-Treatment
Kafr Ni'ma	Ramallah & Al Bireh	Low	Yes	Not-sensitive	Low	Conventional-Onsite-Treatment
Kharbatha Bani Harith	Ramallah & Al Bireh	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment
Khirbet Abu Falah	Ramallah & Al Bireh	Moderate	Yes	High	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
Kobar	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Mazari' an Nubani (Bani Zeid ash S	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Qaddura Camp	Ramallah & Al Bireh	High	Yes	Moderate	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Qarawat Bani Zeid (Bani Zeid al gh	Ramallah & Al Bireh	Moderate	Yes	Moderate	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse
Rammun	Ramallah & Al Bireh	Low	Yes	Moderate	Low	Advanced-Onsite-Treatment
Rantis	Ramallah & Al Bireh	Low	Yes	High	High	Advanced-Onsite-Treatment
Ras Karkar	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Saffa	Ramallah & Al Bireh	Moderate	Yes	Moderate	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Shabtin	Ramallah & Al Bireh	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Shuqba	Ramallah & Al Bireh	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Silwad Camp	Ramallah & Al Bireh	High	Yes	High-sensitivity	Moderate-low	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Surda	Ramallah & Al Bireh	Low	Yes	Moderate	High	Advanced-Onsite-Treatment
Umm Safa	Ramallah & Al Bireh	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Yabrud	Ramallah & Al Bireh	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment
Bruqin	Salfit	Low	No	High	Moderate-low	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Deir Ballut	Salfit	Low	Yes	High	Moderate	Advanced-Onsite-Treatment
Deir Istiya	Salfit	Low	Yes	High	Moderate	Advanced-Onsite-Treatment

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Farkha	Salfit	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment
Haris	Salfit	High	Yes	High	Moderate	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Iskaka	Salfit	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment
Khirbet Qeis	Salfit	Low	Yes	Moderate	Moderate-low	Advanced-Onsite-Treatment
Kifl Haris	Salfit	Low	Yes	High	High	Advanced-Onsite-Treatment
Marda	Salfit	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Mas-ha	Salfit	Low	Yes	High	Moderate	Advanced-Onsite-Treatment
Qarawat Bani Hassan	Salfit	Low	Yes	High	Moderate	Advanced-Onsite-Treatment
Qira	Salfit	Low	Yes	High	High	Advanced-Onsite-Treatment
Rafat	Salfit	Low	Yes	High	Moderate	Advanced-Onsite-Treatment
Sarta	Salfit	Moderate	Yes	High	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Yasuf	Salfit	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
'Ein el Beida	Tubas	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Al Farisiya	Tubas	High	No	Sensitive	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Al Hadidiya	Tubas	High	No	Not-sensitive	Moderate	Shallow/Conventional Sewerage-Agricultural reuse
Al Malih	Tubas	High	No	Sensitive	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Ath Thaghra	Tubas	High	No	Sensitive	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Bardala	Tubas	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Kardala	Tubas	High	Yes	Not-sensitive	High	Shallow/Conventional Sewerage-Agricultural reuse
Ras al Far'a	Tubas	High	No	Sensitive	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Tayasir	Tubas	Low	No	Not-sensitive	Moderate	Settled Sewerage-Agricultural reuse/Conventional-Onsite treatment
Wadi al Far'a	Tubas	High	No	Sensitive	Moderate-low	Shallow Sewerage-Nutrient removal-Agricultural reuse

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
'Akkaba	Tulkarm	High	No	High-sensitivity	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
'Izbat Shufa	Tulkarm	High	Yes	High-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Al Hafasa	Tulkarm	High	No	High-sensitivity	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Al Jarushiya	Tulkarm	High	No	High-sensitivity	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
An Nazla al Gharbiya	Tulkarm	Low	No	Local-sensitivity	High	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
An Nazla al Wusta	Tulkarm	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
An Nazla ash Sharqiya	Tulkarm	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Ar Ras	Tulkarm	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Baqa ash Sharqiya	Tulkarm	High	No	Local-sensitivity	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Far'un	Tulkarm	Moderate	Yes	High	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Iktaba	Tulkarm	High	Yes	High-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Kafa	Tulkarm	High	No	High-sensitivity	Moderate	Shallow Sewerage-Nutrient removal-Agricultural reuse
Kafr 'Abbush	Tulkarm	Low	Yes	High	High	Advanced-Onsite-Treatment
Kafr al Labad	Tulkarm	Low	Yes	High	Moderate	Advanced-Onsite-Treatment
Kafr Jammal	Tulkarm	Low	Yes	High	High	Advanced-Onsite-Treatment
Kafr Rumman	Tulkarm	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Kafr Sur	Tulkarm	Low	Yes	High	High	Advanced-Onsite-Treatment
Kafr Zibad	Tulkarm	Low	Yes	High	High	Advanced-Onsite-Treatment
Khirbet at Tayyah	Tulkarm	Low	No	High	Moderate	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment

Community Name	District Name	Density category	Community with water network	Area sensitivity	Area-Agricultural Suitability	Proposed Strategy
Khirbet Jubara	Tulkarm	High	No	High-sensitivity	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Kur	Tulkarm	Low	No	High	High	Settled Sewerage-nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Masqufet al Hajj Mas'ud (Al Masqufa)	Tulkarm	High	No	High-sensitivity	High	Shallow Sewerage-Nutrient removal-Agricultural reuse
Nazlat 'Isa	Tulkarm	High	Yes	Local-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse
Nazlat Abu Nar	Tulkarm	Low	No	Local-sensitivity	High	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Ramin	Tulkarm	Low	Yes	Not-sensitive	Moderate-low	Conventional-Onsite-Treatment
Saffarin	Tulkarm	Low	No	High	Moderate-low	Settled Sewerage-Nutrient removal-Agricultural reuse/Advanced-Onsite treatment
Seida	Tulkarm	Moderate	No	Not-sensitive	Moderate-low	Settled Sewerage-Agricultural reuse
Shufa	Tulkarm	Low	Yes	High	Moderate-low	Advanced-Onsite-Treatment
Zeita	Tulkarm	High	Yes	Local-sensitivity	High	Shallow/Conventional Sewerage-Nutrient removal-Agricultural reuse

WASTEWATER SYSTEMS. INSTITUTIONAL REFORM MUST BE INTRODUCED TO RECOGNIZE THE DECENTRALIZED SYSTEMS AND THEIR MANAGEMENT REQUIREMENTS.

Proposed institutional framework for wastewater management in rural areas

It was indicated by the several researchers and experts that wastewater management is highly dependent on institutional structure (Feitelson and Haddad, 1998, a, and b, and Haddad, 2004).

THE VILLAGE COUNCIL IN PALESTINIAN RURAL AREAS UNDER CURRENTLY USED MANAGEMENT PRACTICES AND IN ORDER TO SEEK WATER AND WASTEWATER SERVICES PREPARES A DRAFT DESIGN AND SUMMARY OF THE INTENDED WATER AND/OR SANITATION PROJECT THROUGH LOCAL NGOS OR ANY ENGINEERING FIRM AND APPLIES THAT FOR APPROVAL AND FUNDING TO THE PWA WHICH IN THEIR PART NEED TO STUDY AND EVALUATE THE PROPOSAL. AFTER GRANTING APPROVAL PWA NEED TO GET THE APPROVAL OF THE ISRAELI SIDE THROUGH THE JOINT COMMITTEE. FINALLY, THEY HAVE TO GET A FINANCIAL ASSISTANCE FROM PWA, MLG OR ANY LOCAL AND/OR INTERNATIONAL NGOS, AND A TECHNICAL ASSISTANCE FROM LOCAL AND/OR INTERNATIONAL NGOS OR ANY ENGINEERING FIRM. FIGURE 6.1 DESCRIBES THE WHOLE PROCEDURES THROUGH WHICH ANY SANITATION PROJECT HAS TO PASS TO GET APPROVAL AND LICENSING FROM BOTH PALESTINIAN AND ISRAELI PARTS.

The main problems evolving are not only when seeking project approval and funding which takes years but also afterwards in implementing, maintaining, and operating it.

THE PROPOSED MANAGEMENT STRUCTURE CONSISTS OF CREATING A VILLAGE WATER AND WASTEWATER MANAGEMENT COMMITTEE, VWMC. IT INCLUDES FINANCIAL, TECHNICAL AND PLANNING UNITS. THIS COMMITTEE'S TASKS SHOULD COVER WASTEWATER COLLECTION, OPERATING AND MAINTENANCE OF

WASTEWATER TREATMENT PLANTS, PLANNING AND MANAGING OF WASTEWATER AND TREATED EFFLUENT

The VWMC may get technical assistance from NGOs or any engineering firm to help them in initiating, start-up, monitoring and evaluating the wastewater treatment process and to provide them with the proper training of the local technicians who will be responsible of the operation and maintenance works.

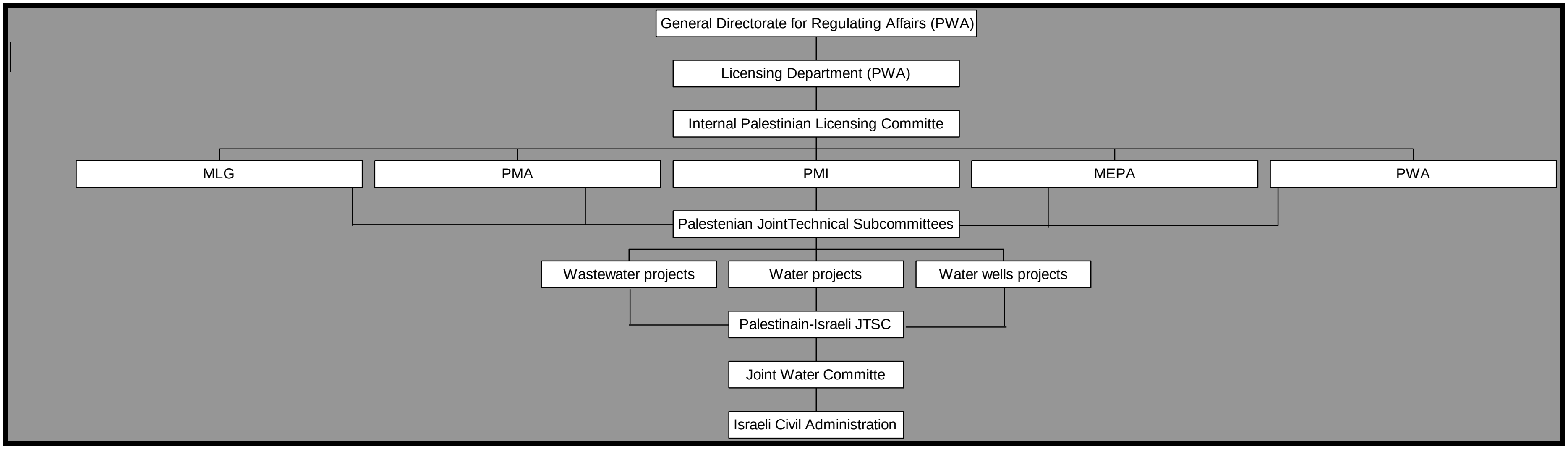

FIGURE 6.1: THE PROCEDURES THROUGH WHICH SANITATION PROJECT HAS TO PASS TO GET APPROVAL AND LICENSING FROM BOTH THE PALESTINIAN AND ISRAELI SIDES.

Notes:

MLG: Ministry of Local Government

PMA: Palestinian Ministry of Agriculture

PMI: Palestinian Ministry of Industry

MEPA: Palestinian Ministry of Environmental Affairs

JTSC: Joint Technical Sub-committees

The PWA should act as a regulator to ensure and oversee the efficiency and compliance of the wastewater management activities including installation and operation, according to approved regulations, specifications and standards. The village council should act as facilitators, supervisors and of the process and give guarantees of supportive investments needed to implement VWMC activities.

Figure 6.2 represents the proposed management framework of the village wastewater committee in Palestinian rural areas.

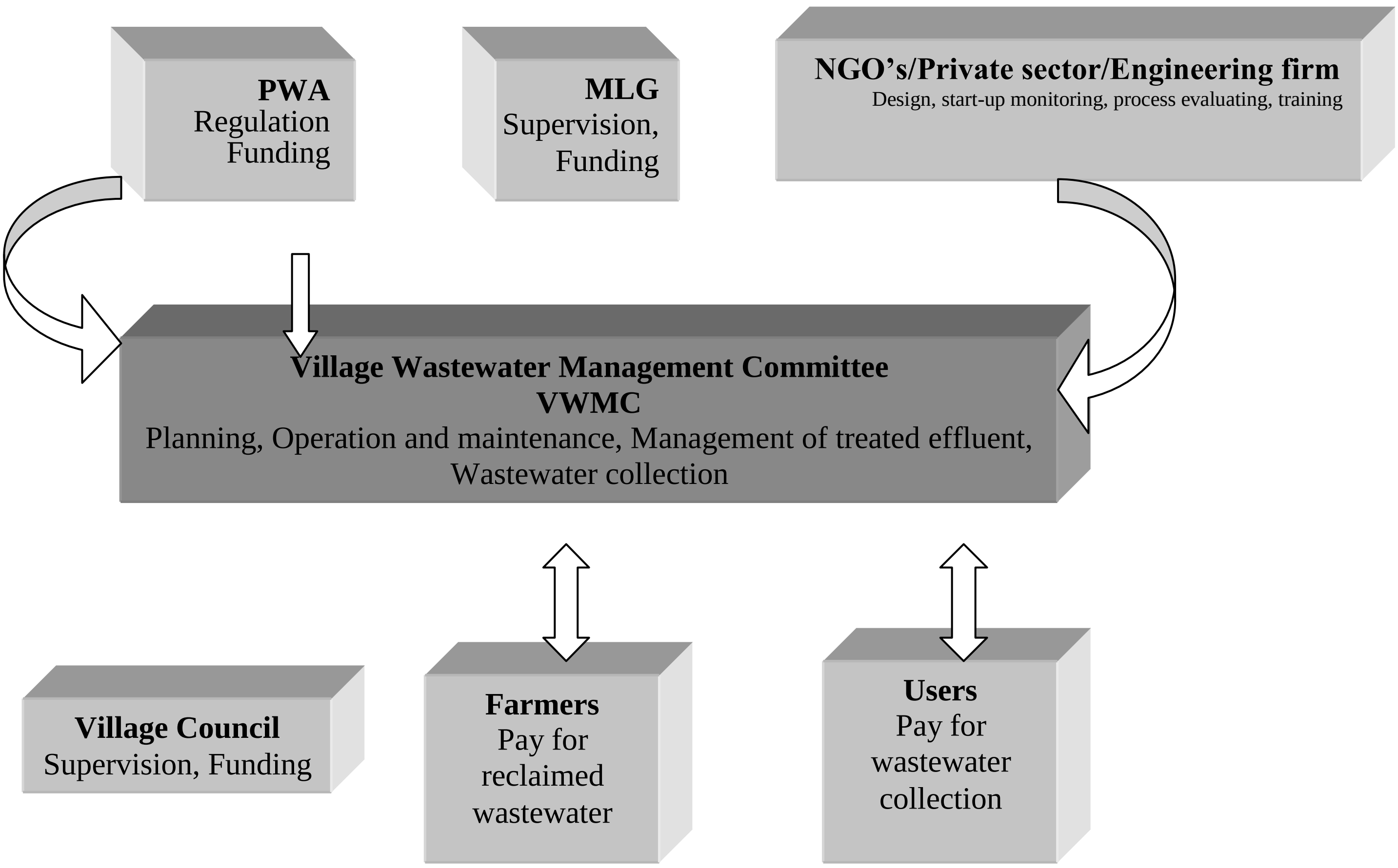

Figure 6.2: The proposed management framework of the wastewater management committee in Palestinian rural areas

Under such management structure and current political realities, the way to get approval and implementation of water and sanitation services in rural areas will be shorter than before.

Sources of revenue for the committee are user fees and revenue from the selling of reclaimed wastewater to farmers. The VMWC should include an executive body, which is responsible for fees collection for wastewater collection from users and buying treated effluent from farmers.

CHAPTER SEVEN

Conclusions and recommendations

Conclusions

1. Accelerated extension of wastewater management services to small communities in Palestinian rural areas essential to address concerns over the water scarcity, water pollution and protection of public health.

2. Provided that onsite wastewater systems are managed properly, they can provide a viable alternative to the treatment, disposal and/or reuse of wastewater. The septic tank followed by a conventional disposal field method is potentially, an effective and financially affordable technique of onsite wastewater management provided that site characteristics are appropriate. In the case of its incompatibility to local conditions, the intermittent sand filter system can be applied. Still, in such locations with limited space availability, it seems that the septic tank trickling filter and the up-flow anaerobic filter systems would be the most sustainable ones to be employed.

3. Should the circumstances no longer allow the use of onsite wastewater management systems, a community wastewater treatment plant should be added. In the later, a collection system is needed. The small diameter and the simplified sewage systems provide low cost and effective means of wastewater collection and conveyance. A septic tank trickling filter system offers a high sustainable alternative for use as a community treatment plant. However, in case of land availability, the WSP’s would be the best solution.

4. No technology is inherently sustainable. The sustainability of the total system of technologies at an actual site must be evaluated in a transparent and holistic assessment including a wide range of criteria.

5. Institutions involved in management of water and sanitation services in rural Palestine are relatively large in numbers. On the other hand, the efficiency in providing the needed services is very poor. The proposed VWWMC institutional management approach with its clear legal framework should lead to optimize wastewater management in Palestinian rural areas.

Recommendations

1. Holistic management of wastewater in Palestinian rural areas should start at home. Wastewater generation should be reduced by introducing water saving toilets and fixtures. Existing onsite systems must be improved and monitored to control pollution and to recover water for non-potable water uses. Should the circumstances not allow the use of onsite systems, wastewater must be transported and managed through a community system.

2. Given the looming water resource crisis in Palestinian rural areas, wastewater must be recognized as part of the total water cycle and therefore managed within the integrated water resources management process.

3. Unlike conventional sewerage systems, the non-conventional settled and simplified shallow sewerage are not water intensive and therefore they are more suited to the condition of small communities in Palestinian rural areas. More demonstration projects should adopt their application in Palestinian rural areas

4. Dependency on the external funds causes a slow development in the sanitation sector. Therefore, more attention should be given to solving the sanitation problems with local resources by choosing low-cost and appropriate technologies.

5. Onsite wastewater segregation consideration in areas where so far no, or limited, sanitary services are available, it is not difficult and expensive to change the combining plumbing system into a separated one, and there is enough space for onsite treatment units is highly recommended.

6. Onsite management systems ought to be controlled through environmental legislation and its instruments of administrative orders, regulations and bylaws. Enforcement of these regulations may be appropriately realized through construction permitting requirements by local municipalities or village councils in cooperation with environmental agencies.

7. Conducting applied research including (design parameters, social and cultural acceptance, management abilities and financial affordability) to establish the appropriateness for local conditions of any selected onsite system is advocated before any commitment to sanitation project implementation is made.

8. Ensure full public participation through education and public awareness programs. Information packages to local authorities; design engineers and homeowners should be provided.

REFERENCES

Abu Madi, M., Al-Sa`ed, R. Braadbart, O. and Alaerts, G. (2000). *Selection criteria for appropriate sanitation in the Palestinian rural and semi-urban communities.* Proceedings of the International Symposium on Water Sector Capacity Building and Research in Palestine, Birzeit University, Palestine.

Abu Zahra, B. (2000) *Water crisis in Palestine*, Ministry of Planning and International Cooperation, Ramallah, West Bank, Palestine.

Admon, S. **, Ghattas, B. *, Green, M**., Haj, Y. *, Hayeek, A.*, Omari, J.*, and Sabbah, L.* (2002) *Intermittent sand filtration for wastewater treatment in rural areas of the Middle East—A pilot study* , 5th Specialized conference on small water and Wastewater Treatment Systems, Istanbul- Turkey, *R&D Center- The Galilee Society, Shefa-Amr , ISRAEL, **Agricultural Engineering Department-Technion, Israel Institute of Technology, Haifa , ISRAEL.

Al-Jayyousi, O., Faruqui, N., and Wilson, B-L. (2002) *Greywater reuse is urban agriculture for poverty alleviation: a* case study in Jordan. Prepared by Inter-Idamic Network on Water Resources Development and Management (INWRDAM) for the International Development Research Center (IDRC) Ottawa, Canada.

Al-Sa'ad .R. and Zimmo, O.R. (2003) *Process performance evaluation of the contact stabilization system at Birzeit University Campus*. Department of Civil Engineering, Birzeit University, Birzeit, West Bank, Palestine.

Al-Sa'ad, R., (2000) *Wastewater management for small communities in Palestine,* Technical expert consultation on appropriate and innovative wastewater management for small communities in EMR counties, Palestinian Hydrology Group (PHG), Jerusalem, West Bank, Palestine

Anderson, D., Boyle, W., and Siegrist, R. (1981). *Performance evaluation of gray-water recycle systems,* AWWA Water Reuse II Symposium, Washington, D.C., U.S.A.

ANERA (2003) PERSONAL COMMUNICATIONS.

An-Najah National University (1998) *Evaluation report of subsurface drainage technique, Water* and Environmental studies Center, Nablus, West Bank, Palestine

An-Najah National University (2001) *Wastewater sampling analysis-Sarrah wastewater treatment unit, Water* and Environmental studies Center, Nablus, West Bank, Palestine

Applied Research Institute-Jerusalem ARIJ (1996) *Environmental profile for the West Bank,* Vol.4, Ramallah District, Jerusalem, Palestine.

Applied Research Institute-Jerusalem ARIJ (1996) *Environmental profile for the West Bank,* Vol.5, Nablus District, Jerusalem, Palestine.

Applied Research Institute-Jerusalem ARIJ (1996) *Environmental profile for the West Bank,* Vol.6, Jerusalem District, Jerusalem, Palestine

Applied Research Institute-Jerusalem ARIJ (1996) *Environmental profile for the West Bank,* Vol.7, Jenin District, Jerusalem, Palestine.

Applied Research Institute-Jerusalem ARIJ (1996) *Environmental profile for the West Bank,* Vol. 8, Tulkarem District, Jerusalem, Palestine.

Applied Research Institute-Jerusalem ARIJ (1997) *The status of the environment in the West Bank, Palestine*.

Bakir, H. (2000) *Sanitation and wastewater management for small communities in EMR countries*, Proceedings 4th Gulf Water Conference, Bahrain (Bahrain, WSTA).

Baumann, E., Jakubowski, W., Jones, E., and Nottingham, M. (1978). *Septic tanks in home sewage treatment*, Proceedings of the Second National Home Treatment Symposium, American Society of Agricultural Engineers, and St. Joseph, MI.

Bethlehem University (1998) *Report of the results of the save the Children Foundation wastewater samples*, Water and Soil environmental Research Unit (WSERU), Bethlehem, West Bank, Palestine.

Booklemen, S.A., (1997) *Wastewater treatment and reuse strategies for Jenin, Palestine*, M.Sc., Thesis, IHE, Delft, The Netherlands.

Boyer, J. and Rock, C. (1992). *Performance of septic tanks*, In Proceedings, ed. R.W. Seabloom, Seventh Northwest On-Site Wastewater Treatment Short Course and Equipment Exhibition, University of Washington, Seattle.

Braden, J., and Ierland E. (1999) *Balancing the economic approach to sustainable water management*, Water Science and Technology VOL. 39 NO. 5, pp.17-23.

Center For Engineering and Planning (CEP, 1995) *Physical planning for Palestinian rural communities,* Ramallah, West Bank, Palestine.

Center For Engineering and Planning (CEP, 2003) *Feasibity study for water network constuction in Beit Amaran village*, Ramallah, West Bank, Palestine.

CORETECH (2003). *Development of cost effective reclamation technologies for municipal wastewater and the appropriate use of the treated effluent under (Semi) arid conditions,* Work Package 1, International research Project, Birzeit University, Palestine.

Crites, R., Middlebrooks, J., and Reed, S. (1988). *Natural Systems for Waste Management and Treatment*, McGraw-Hill, Inc., New York.

Darwish .R. and Ismail.K. (2001) *The Egyptian experience with low cost-technology for wastewater collection and treatment*, Darwish Consulting Engineering, Cairo, Egypt.

Dodgson, J., Pearman, A., Phillips, L., and Spackman, M. (2000) *DLTR multi-criteria analysis manual,* NERA (National Economic Research Associates), London, United Kingdom.

Douglas,B. (1998) *The decentralized Approach: an innovative solution to community wastewater management* , Water Quality International, January/February edition.

Eilerson, A., Elle, M., Henze, M., Hoffmann, B., Mikkelsen, P., and Nielsen, S. (2000) *Assessing the sustainability of small wastewater systems. A context-oriented planning approach,* Technical University of Denmark, Lyngby, Denmark.

Elmitwalli, T., Leeuwen, M., Roeleveld, K., Sanders, W., and Zeeman, G. (2002) *Anaerobic biodegradability and digestion in accumulation systems for concentrated black water and kitchen waste*, Sub-Department of Environment Technology, Wageningen University, Wageningen, The Netherlands.

Environmental Protection Agency EPA (1998) *Onsite Wastewater Treatment Systems Technology Fact Sheet, Fixed-Film Processes,* EPA Office of Water, EPA Office of Research & Development, Cincinnati, Ohio.

EPA manual (1992) *Wastewater treatment /disposal for small communities*, US Environmental Protection Agency, OH, Washington, DC.

Farroq, S. and Ansari, Z. (1983) *Water reuse in muslim countries - an islamic perspective. Environ. Manag.* **7**(2), 119-123.

Feitelson, E. and Haddad, M. (1998) *A stepwise open-ended approach to the identification of joint management structures for shared aquifers*, Water International, the Journal of International Water Resources Association, Vol., 23, No. 4 pp. 227-237.

Feitelson, E. and Haddad, M. (1998) *Identification of joint management structures for shared aquifers,* World Bank Technical Paper No.415, Washington, 1998.

Haddad, M. (1998-a) *Planning water supply under complex and changing political conditions: Palestine as a case study*, Water Policy Journal, Vol. 1, 1998, pp.177-192.

Haddad, M. (2004) *Integrated water and waste management in rural areas in Palestine.* Environmental Engineering Department, University of Texas, Drawer Y, University Station, Austin TX 78713-8925, USA.

Hedberg, T. (1999) *Attitudes to traditional and alternative sustainable sanitary systems*, Water Science and Technology, VOL. 39 NO. 5, 9-16.

Keeney, R. (1992) *Value-Focused Thinking: a Path to Creative Decision Making,* Harvard University Press, Cambridge, Massachusetts

Laak, R. (1986). *Wastewater engineering design for unsewered areas*, Technomic Publishing, Inc., Lancaster, Pennsylvania.

Lettinga, G. and Zeeman, G. (2001*) Objectives of DESAR- Decentralized Sanitation and Reuse*, Section Environmental Technology, Wageningen University, Wageningen, The Netherlands.

Louisiana Department of Environmental Quality LDEQ (1993) *State of Louisiana nonpoint source pollution management program.* Louisiana, United Sates of America.

Mahmoud, N. (2002) *Anaerobic pre-treatment under low temperature (15°C) conditions in an integrated UASB–digester system*, Ph.D. Thesis, Wageningen University, Wageningen, The Netherlands.

Metcaff and Eddy (1991) *Wastewater engineering, treatment, disposal, reuse, 3rd ed.*, McGraw Hill Inc, New York.

MOPIC (1998) *Sensitive water resources recharge areas in the West Bank governerates*, Ministry of Planning and International Cooperation, Ramallah, West Bank, Palestine.

MOPIC (1998) *The valuable agricultural lands in the West Bank districts*, Ministry of Planning and International Cooperation, Ramallah, West Bank, Palestine.

Mustafa, J.Y. (1997) *Onsite wastewater treatment: Disposal reuse*, M.Sc, Thesis, IHE, Delft, The Netherlands.

Mustafa, J.Y. (2000) *Evaluation of on-site gray wastewater treatment plants performance in Bilien and Beit-Diko villages/Palestine*. Palestinian Agricultural Relief Committees (PARC), Jerusalem, West Bank, Palestine.

Najjar, M., (2000) *Wastewater management practices in small communities* (Jordan's experience), Technical expert consultation on appropriate and innovative wastewater management for small communities in EMR counties, Environmental Directorate, Water Authority of Jordan, Ministry of Water and Irrigation, Amman, Jordan.

Nashashibi, M. (1995) *wastewater treatment strategies in Palestine*, M.Sc., Thesis, IHE, Delft, The Netherlands.

Otis, R. (1996) Small Diameter Gravity Sewers: Experience in the United States, in: D. Mara (Ed.) Low-Cost Sewerage (Chichester, Wiley and Sons).

Palestinian Agricultural Relief Committees (PARC, 2001) *Evaluation of household gray wastewater treatment plants*, Ramallah, West Bank, Palestine.

Palestinian Central Bureau of Statistics (PCBS, 1998) *Local community survey,* Ramallah, West Bank, Palestine.

Palestinian Central Bureau of Statistics (PCBS, 2000) *Demography of the Palestinian population in the West Bank and Gaza strip,* Current status series, Ramallah, West Bank, Palestine.

Palestinian Central Bureau of Statistics (PCBS, 2000) *Survey of the wastewater services in the Palestinian territory,* Ramallah, West Bank, Palestine.

Palestinian Central Bureau of Statistics (PCBS, 2000) *Survey of the water services in the Palestinian territory*, Ramallah, West Bank, Palestine.

Palestinian Central Bureau of Statistics (PCBS, 2004) *Impact of Israeli measures on economic conditions of Palestinian households;* 8th round, Ramallah, West Bank, Palestine.

Palestinian Hydrology Group (PHG, 1998) *Evaluation of ST-SDT system in the West Bank south by Palestinian Hydrology Group*, Ramallah, West Bank, Palestine.

Palestinian Hydrology Group (PHG, 2001) *Bani Zeid sanitation project, Ramallah, West Bank, Palestine*.

Palestinian Hydrology Group (PHG, 2002) *Environmental evaluation of Deir-Samet sanitation and wastewater management project*, Ramallah, West Bank, Palestine.

Palestinian Hydrology Group (PHG, 2004) *Technical report about the sanitation projects implemented by the Palestinian Hydrology Group,* Ramallah, West Bank, Palestine.

Palestinian Water Authority, (PWA, 2000) *Water sector strategic planning study*. Final Report, Al-Bireh, West Bank, Palestine.

PALESTINIAN WATER AUTHORITY, (PWA, 2003) PALESTINIAN WATER AUTHORITY / HYDROLOGY DEPARTMENT/PWA- CENTRAL LABORATORY, AL-BIREH, WEST BANK, PALESTINE.

PALESTINIAN WATER AUTHORITY, (PWA, 2003) WATER RESOURCES AND PLANNING DIRECTORATE/DATA BANK DEPARTMENT, AL-BIREH, WEST BANK, PALESTINE.

Regional Centre for Environmental Health Activities CEHA (1999), *Technical Note: Sanitation and Wastewater Management for Small Communities* *in Eastern Mediterranean Region Countries*, World Health Organization (WHO), Amman, Jordan.

Saidam, M., (2000) *On-site wastewater management for small communities,* Technical expert consultation on appropriate and innovative wastewater management for small communities in EMR countries, Water Quality Studies Division, Environmental Research Center, Royal Scientific Society (RSS), Amman, Jordan.

Save the Children Foundation (SCF, 1998) *Subsurface drainage technique (SDT) community involvement*, Ramallah, West Bank, Palestine.

Siegrist, R., (1977) *Segregation and separate treatment of black and gray household wastewater to facilitate on-site surface disposal.* Small-scale waste management project report, University of Wisconsin, Madison, U.S.A.

U.S. Environmental Protection Agency EPA (1980) *Design Manual: Onsite Wastewater Treatment and Disposal System,* EPA Office of Water, EPA Office of Research & Development, Cincinnati, Ohio.

U.S. Environmental Protection Agency EPA (2002) *Onsite wastewater treatment systems manual*, Office of Water Office of Research and Development, Cincinnati, Ohio.

UNEP (1988) *Design manual for waste stabilization ponds in Mediterranean countries, Environmental Guidelines for Domestic Wastewater Management*, United Nations Environment Programme, Nairobi.

University of Wisconsin (1978). *Management of small waste flows*, EPA-600/2-78-173., U.S. Environmental Protection Agency, Cincinnati, OH.

Venhuizen, D. (1997a) *From wastewater to usable water, Water Technology*, VOL 20, NO 2, pp 96.

WHO/EMRA (1987) *Waste stabilization ponds, principles of planning and practice,* World Health Organization, Regional Office for Eastern Mediterranean.

Zimmo, O.R. (2003) B*irzeit University treatment plant*. Department of Civil Engineering, Birzeit University, Birzeit, West Bank, Palestine.

APPENDIX I: FULL DATA ABOUT RURAL COMMUNITIES WITH POPULATION NUMBER OF 100-4000 PERSONS IN THE WEST BANK DISTRICTS FOR THE YEAR (2004)

Tab le A I.1 Names, x-y coordinates, elevations, population number (mid 2004), densities, water network availability, and wastewater production of rural communities in the West Bank districts, (PWA, 2003)

Community Name	District Name	X (Km)	Y (Km)	Elevation (m)	Population mid 2004[a]	Density (P/Km2)	Community with water network	Commun wastewater pr (m3/d)
'Arab ar Rashayida	Bethlehem	171.9	108.6	650	1002	5964	Yes	54
'Ayda Camp	Bethlehem	168.92	125.2	770	3045	2734	Yes	163
Abu Nujeim	Bethlehem	169.15	118.77	780	731	6586	Yes	39
Al 'Asakira	Bethlehem	171.56	119.9	630	934	2708	Yes	50
Al 'Aza Camp	Bethlehem	169.2	124.76	700	1629	1972	Yes	87
Al 'Iqab	Bethlehem	172.43	119	620	833	13650	No	50
Al Beida	Bethlehem	167.6	119.65	840	326	4175	Yes	17
Al Fureidis	Bethlehem	172.7	119.67	680	669	3911	Yes	36
Al Halqum	Bethlehem	168.93	117.3	790	168	2078	Yes	9
Al Khas	Bethlehem	173.77	124.55	605	322	695	Yes	17
Al Ma'sara	Bethlehem	166.97	118.07	880	739	3731	Yes	40
Al Maniya	Bethlehem	170.72	114.43	780	728	7066	Yes	39
Al Manshiya	Bethlehem	168.48	116.5	770	339	5464	Yes	18
Al Walaja	Bethlehem	165.47	126.3	846	1583	231	Yes	85
Ar Rawa'in	Bethlehem	172.8	108	500	143	3408	No	9
Artas	Bethlehem	167.82	121.85	680	3421	796	Yes	183
Ash Shawawra	Bethlehem	175.35	122.08	600	2467	98695	Yes	132
Ath Thabra	Bethlehem	167	119.78	880	231	1859	No	14
Battir	Bethlehem	163.12	125.53	630	3941	602	Yes	211
Beit Falouh	Bethlehem	170.95	119.63	540	475	6791	Yes	25
Beit Ta'mir	Bethlehem	172.88	120.67	640	1084	8403	Yes	58
Bureid'a	Bethlehem	172.7	121.5	660	309	30924	Yes	17
Dar Salah	Bethlehem	174.8	124.05	600	931	3979	Yes	50
Dhahrat an Nada	Bethlehem	172.11	121.77	660	375	3711	Yes	20
Fakht al Jul	Bethlehem	174.67	121.9	530	238	5294	Yes	13
Harmala	Bethlehem	171.04	118.88	600	707	5523	Yes	38
Hindaza	Bethlehem	169.95	122.1	700	2007	19301	Yes	108
Juhdum	Bethlehem	175.9	123.58	620	1299	24060	Yes	70
Jurat ash Sham'a	Bethlehem	166.2	117.65	900	1400	4011	Yes	75
Khallet al Balluta	Bethlehem	161.47	119.55	950	160	7597	No	10
Khallet al Haddad	Bethlehem	168.23	118.5	820	391	2794	Yes	21
Khallet al Louza	Bethlehem	169.22	120.57	700	417	3450	No	25
Khallet al Qaranin	Bethlehem	170.4	119.36	600	130	2322	No	8
Khallet an Nu'man	Bethlehem	173.03	124.98	620	185	5276	Yes	10
Khallet Hamad	Bethlehem	170.7	121.65	680	445	1482	No	27
Khirbet ad Deir	Bethlehem	170.2	117.73	800	1461	11068	Yes	78
Kisan	Bethlehem	171.45	113.36	720	372	3347	Yes	20
Marah Ma'alla	Bethlehem	166.61	117.43	900	576	9598	Yes	31
Marah Rabah	Bethlehem	167.77	115.69	810	1061	10105	Yes	57

Community Name	District Name	X (Km)	Y (Km)	Elevation (m)	Population mid 2004[a]	Density (P/Km2)	Community with water network	Commun wastewater pr (m3/d)
Rakhme	Bethlehem	171.07	120.53	630	867	9218	Yes	46
Ras al Wad	Bethlehem	173.87	122	500	735	1683	Yes	39
Umm 'Asla	Bethlehem	176.76	122.8	559	152	3616	Yes	8
Umm al Qasseis	Bethlehem	174.3	123.44	610	341	5589	Yes	18
Umm Salamuna	Bethlehem	165.8	116.94	950	754	4833	Yes	40
Wadi al 'Arayis	Bethlehem	175.62	124.26	618	2026	12987	Yes	109
Wadi an Nis	Bethlehem	165.3	118	920	694	12391	Yes	37
Wadi Fukin	Bethlehem	159.8	124.84	660	1122	113	Yes	60
Wadi Rahhal	Bethlehem	165.96	119.28	930	532	40935	Yes	29
Wadi Umm Qal'a	Bethlehem	171.28	121.7	500	248	3307	No	15
'Abda	Hebron	152.38	97.15	750	164	5464	No	10
'Anab al Kabir	Hebron	142.84	89.71	570	283	5896	No	17
'Arab al Fureijat	Hebron	142.48	84.73	430	392	1759	No	24
'Irqan Turad	Hebron	164.47	112.76	800	469	3662	Yes	21
Abu al 'Asja	Hebron	150.94	94	610	576	115173	Yes	26
Abu al 'Urqan	Hebron	151.91	93.25	650	445	3936	No	27
Abu al Ghuzlan	Hebron	151	93.95	630	521	3217	No	31
Ad Deirat	Hebron	165.35	94.67	760	363	8062	No	22
Ad Duweir	Hebron	162.18	96.67	830	636	79496	No	38
Ad Duwwara	Hebron	163.55	107.3	1000	1554	7227	Yes	71
Al 'Uddeisa	Hebron	163.76	105.85	1010	1358	6658	Yes	62
Al Bira	Hebron	143.04	93.93	590	287	4490	Yes	13
Al Burj	Hebron	142	93.85	500	2272	3005	Yes	104
Al Buweib	Hebron	165	97	800	495	2605	No	30
Al Faqir	Hebron	168.8	92.4	690	378	11815	No	23
Al Heila	Hebron	160.4	97.77	770	918	35303	No	55
Al Hijra	Hebron	155.48	99.59	700	625	2648	Yes	29
Al Jab'a	Hebron	157.5	120.1	660	836	150	Yes	38
Al Karmil	Hebron	162.8	92.26	720	2704	4972	Yes	123
Al Khamajat	Hebron	154.94	106.04	800	133	2963	No	8
Al Kum	Hebron	146.6	104.5	450	1228	3733	Yes	56
Al Majd	Hebron	145.31	98.72	477	1677	9696	Yes	76
Al Muntar	Hebron	157.32	93.82	750	368	6242	Yes	17
Al Muwarraq	Hebron	147.04	103.93	450	539	10994	Yes	25
An Najada	Hebron	172.8	92.36	600	217	10873	No	13
Ar Ramadin	Hebron	141.8	87.53	550	2830	5054	No	170
Ar Rawa'in	Hebron	169.1	101.92	600	215	5125	No	13
Ar Rifa'iyya	Hebron	164.22	95.6	820	299	8806	No	18
Ar Rihiya	Hebron	157.4	97.52	785	3214	1208	Yes	147
As Sikka	Hebron	144.62	99.91	430	743	4673	Yes	34
As Simiya	Hebron	153.22	92.1	600	1571	11554	Yes	72
As Sura	Hebron	149.88	97.56	800	1646	102853	No	99
At Tabaqa	Hebron	151.5	100.56	899	1323	5109	No	79
Az Zuweidin	Hebron	169.3	95	630	542	1566	No	33
Beit 'Amra	Hebron	154.65	95.36	720	1566	4539	Yes	71
Beit 'Einun	Hebron	162.2	107.89	960	2248	7443	Yes	102
Beit ar Rush al Fauqa	Hebron	142.89	95.56	520	889	3706	Yes	41
Beit ar Rush at Tahta	Hebron	143.94	96.77	430	458	5516	Yes	21
Beit Maqdum	Hebron	147.24	104.74	450	659	7010	Yes	30

Community Name	District Name	X (Km)	Y (Km)	Elevation (m)	Population mid 2004[a]	Density (P/Km2)	Community with water network	Commun wastewater pr (m3/d)
Beit Mirsim	Hebron	141.82	95.64	490	266	1037	No	16
Bir Musallam	Hebron	148.52	109.12	410	176	3086	Yes	8
Birin	Hebron	163.82	99.65	908	161	5354	No	10
Biyar al 'Arus	Hebron	161.25	97.17	820	845	1656	No	51
Deir al 'Asal al Fauqa	Hebron	144.19	97.33	490	1705	7509	Yes	78
Deir al 'Asal at Tahta	Hebron	144.77	97.93	490	563	5025	Yes	26
Deir Razih	Hebron	154.05	97.55	800	303	3255	Yes	14
Fuqeiqis	Hebron	148.85	99.68	700	295	5567	No	18
Hadab al 'Alaqa	Hebron	149.7	96	790	495	6972	No	30
Hadab al Fawwar	Hebron	155.25	98.3	800	1707	10668	Yes	78
Hitta	Hebron	152.05	114.32	460	664	2178	Yes	30
Hureiz	Hebron	162	97.2	810	919	21372	No	55
I'zeiz	Hebron	157.84	93.18	765	659	36606	No	40
Imneizil	Hebron	160.2	87.1	820	247	3383	No	15
Imreish	Hebron	151.16	97.26	750	1143	2082	No	69
Iskeik	Hebron	145.79	97.22	530	154	15407	No	9
Jala	Hebron	156.85	114.33	850	233	1437	No	14
Karma	Hebron	152.63	95.45	700	1254	5315	No	75
Khallet 'Arabi	Hebron	154.94	96.27	710	178	2873	No	11
Khallet al 'Aqed	Hebron	148.73	97.3	790	192	4579	No	12
Khallet al Maiyya	Hebron	163.6	94.85	780	1169	3576	No	70
Khallet Salih	Hebron	160.79	93.52	_	390	21672	No	23
Kharsa	Hebron	151.7	99.23	870	3166	10278	No	190
Khashem al Karem (Makhfar um adaraj)	Hebron	173.6	90.59	540	546	3988	No	33
Khirbet ad Deir	Hebron	152.49	118.12	460	275	2839	Yes	13
Khirbet al Hasaka	Hebron	159.24	108	910	200	4761	No	12
Khirbet Bir al 'Idd	Hebron	162.55	87.1	660	134	4200	No	8
Khirbet Salama	Hebron	150.1	99.88	805	310	22167	No	19
Khirbet Tawil ash Shih	Hebron	170.12	88.75	590	173	3139	No	10
Kureise	Hebron	151.66	103.24	850	2098	12341	No	126
Kurza	Hebron	149.96	94.38	660	719	5992	Yes	33
Kuziba	Hebron	164.53	112.54	860	438	3912	Yes	20
Ma'in	Hebron	162.65	90.5	_	220	1408	No	13
Marah al Baqqar	Hebron	148.51	98.37	720	180	1750	No	11
Qafan al Khamis	Hebron	164.27	108.67	940	1199	8686	Yes	55
Qalqas	Hebron	158.92	100.1	860	837	5507	No	50
Qila	Hebron	150.32	113.2	470	846	3397	No	51
Qinan an Najma	Hebron	156.05	95.7	700	149	2562	No	9
Qinan Jaber	Hebron	160.65	92.25	770	379	1560	No	23
Qurnet ar Ras	Hebron	161.47	95.65	810	252	10097	No	15
Rabud	Hebron	151.58	94.15	660	563	2524	Yes	26
Rafada	Hebron	153.67	102.44	850	393	12293	No	24
Ras al Jora	Hebron	149.85	112.45	450	241	2910	No	14
Ras at Tawil	Hebron	163.87	108.13	940	610	9996	Yes	28
Safa	Hebron	159.6	116.68	650	1020	1808	Yes	46
Shuyukh al 'Arrub	Hebron	163.88	113.95	800	1270	37346	No	76
Tawas	Hebron	145.7	99.51	450	134	12219	Yes	6
Turrama	Hebron	153.05	98.77	830	518	4841	Yes	24

Community Name	District Name	X (Km)	Y (Km)	Elevation (m)	Population mid 2004[a]	Density (P/Km2)	Community with water network	Commun wastewater pr (m3/d)
Umm Lasafa	Hebron	164.84	94	750	517	6153	No	31
Wadi 'Ubeid	Hebron	150.65	99.85	805	139	23129	No	8
Wadi as Sada	Hebron	157.75	96.35	710	202	4813	No	12
Wadi ash Shajina	Hebron	153	97.71	780	525	10490	Yes	24
Zif	Hebron	162.77	97.4	840	842	10531	Yes	38
'Aba	Jenin	180.87	207.3	175	156	3397	No	9
'Anin	Jenin	166.25	211.9	400	3504	307	Yes	191
'Anza	Jenin	170.93	196.07	410	1890	399	Yes	103
'Arab as Suweitat	Jenin	179.2	205.7	280	473	15263	No	28
'Arabbuna	Jenin	184.47	213.12	240	805	125	No	39
'Arrana	Jenin	180.46	211.62	150	2020	257	No	97
Ad Damayra	Jenin	171.8	201.4	300	279	34831	No	17
Al 'Araqa	Jenin	169.03	208.6	280	2002	352	Yes	109
al 'Asa'asa	Jenin	169.35	192.83	350	439	48808	Yes	24
Al 'Attara	Jenin	165.49	192.58	350	1011	263	No	49
Al Fandaqumiya	Jenin	169.4	191.9	450	3169	777	Yes	172
Al Hashimiya	Jenin	171	207.9	350	891	327	Yes	48
Al Jalama	Jenin	179.74	212.74	120	2171	587	Yes	118
Al Khuljan	Jenin	163.94	206.82	280	459	19954	No	28
Al Manshiya	Jenin	172.35	205.88	260	151	25133	No	9
Al Mansura	Jenin	170.6	199.25	310	141	4861	Yes	8
Al Mughayyir	Jenin	186.62	203.2	310	2110	163	Yes	115
Al Mutilla	Jenin	188.5	202.88	450	248	2157	No	15
Ar Rama	Jenin	166.28	195.78	390	850	178	Yes	46
Ash Shuhada	Jenin	175.69	203.94	300	1638	25594	Yes	89
At Tarem	Jenin	168.1	207.6	400	375	3904	Yes	20
At Tayba	Jenin	167.57	213.5	300	2248	977	Yes	122
Az Zababida	Jenin	180.7	199	330	3640	636	Yes	198
Az Zawiya	Jenin	172.18	197.97	415	662	619	Yes	36
Barta'a ash Sharqiya	Jenin	158.95	208.68	200	3395	251	Yes	185
Beit Qad	Jenin	183.72	208.33	190	822	92	No	39
Bir al Basha	Jenin	171.9	202.86	265	1232	12439	No	74
Dahiyat Sabah al Kheir	Jenin	178.35	210.1	130	1372	19062	Yes	75
Deir Ghazala	Jenin	183.25	211.32	200	804	122	Yes	44
Dhaher al 'Abed	Jenin	159.18	206.29	180	350	6724	No	21
Dhaher al Malih	Jenin	164.25	208.82	390	204	22704	Yes	11
Fahma	Jenin	167.17	198.87	440	2298	511	Yes	125
Fahma al Jadida	Jenin	170	199.5	390	330	5790	Yes	18
Faqqu'a	Jenin	187.82	210.65	420	3288	326	No	158
Imreiha	Jenin	164	204.38	265	402	21164	No	24
Jalbun	Jenin	189.12	207.33	300	2349	245	No	113
Jalqamus	Jenin	184.56	203.43	390	1759	396	Yes	96
Kafr Qud	Jenin	171.53	206.94	310	855	157	Yes	46
Khirbet 'Abdallah al Yunis	Jenin	160.9	209.08	200	132	3148	Yes	7
Khirbet ash Sheikh Sa'eed	Jenin	160.45	208.6	310	205	9783	Yes	11
Kufeirit	Jenin	169.36	205.47	340	2305	3157	Yes	125
Mashru' Beit Qad	Jenin	184.65	209	185	365	7156	No	22
Mirka	Jenin	172.7	200.16	380	1465	333	Yes	80

Community Name	District Name	X (Km)	Y (Km)	Elevation (m)	Population mid 2004[a]	Density (P/Km2)	Community with water network	Commun wastewater pr (m3/d)
Misliya	Jenin	177.35	199.24	430	2122	235	No	102
Nazlat ash Sheikh Zeid	Jenin	166.68	207.68	390	687	16764	Yes	37
Raba	Jenin	185.63	199.36	480	2863	112	No	137
Rummana	Jenin	169.6	214.43	150	3178	329	Yes	173
Sir	Jenin	179.86	196.55	470	724	58	No	35
Ti'innik	Jenin	171	214	140	1032	206	Yes	56
Tura al Gharbiya	Jenin	164.56	208.28	385	1046	7689	Yes	57
Tura ash Sharqiya	Jenin	164.79	208	400	170	4607	Yes	9
Umm ar Rihan	Jenin	163.55	209.93	380	352	6397	Yes	19
Umm at Tut	Jenin	182.65	204.24	330	944	193	Yes	51
Umm Dar	Jenin	163.25	206.86	295	550	11217	No	33
Wad ad Dabi'	Jenin	181.4	206.57	210	349	6225	No	21
Zabda	Jenin	162.59	206.1	280	783	66	No	38
Zububa	Jenin	171.28	216.78	100	2002	1144	Yes	109
'Ein ad Duyuk al Foqa	Jericho	190.7	143.85	-150	756	35	Yes	78
'Ein ad Duyuk at Tahta	Jericho	191.6	141.75	-200	897	1549	Yes	93
'Ein as Sultan Camp	Jericho	192.2	142.83	-200	1890	4039	Yes	195
Al 'Auja	Jericho	194.17	151.21	-230	3724	35	Yes	384
An Nuwei'ma	Jericho	191.63	144	-140	1082	21	Yes	112
Az Zubeidat	Jericho	200.18	175.53	-270	1245	15957	Yes	128
Fasayil	Jericho	191.98	159.62	-250	836	19	Yes	86
Marj al Ghazal	Jericho	200	175	-270	357	21019	Yes	37
Marj Na'ja	Jericho	200.88	176.89	-270	712	11132	Yes	74
'Arab al Jahalin	Jerusalem	177.12	128.82	570	1131	5741	Yes	117
Al Judeira	Jerusalem	168.68	140.46	770	1990	975	Yes	205
l Khan al Ahmar (Tajammu' Badawi)	Jerusalem	180.97	135.36	250	916	21803	No	55
Al Qubeiba	Jerusalem	163.1	138.35	780	1941	630	Yes	200
An Nabi Samwil	Jerusalem	167.56	137.77	880	205	96	Yes	21
Ash Sheikh Sa'd	Jerusalem	174.54	126.88	650	2258	4409	Yes	233
Az Za'ayyem	Jerusalem	175.17	132.87	600	2307	8544	Yes	238
Beit Duqqu	Jerusalem	162.99	140.61	680	1501	279	Yes	155
Beit Hanina al Balad	Jerusalem	169.73	137.49	710	1300	82	Yes	134
Beit Ijza	Jerusalem	164.46	139.54	800	629	267	Yes	65
Beit Iksa	Jerusalem	167.13	136.31	770	1472	174	Yes	152
Beit Surik	Jerusalem	164.33	136.75	820	3582	628	Yes	370
Jaba'	Jerusalem	174.5	140.59	660	3039	227	Yes	314
Kharayib Umm al Lahim	Jerusalem	159	138.65	720	350	9451	No	21
Mikhmas	Jerusalem	176.23	142.15	620	1763	131	Yes	182
Qalandiya	Jerusalem	169.78	141.16	760	1083	275	Yes	112
Rafat	Jerusalem	168.29	142.01	780	1993	527	Yes	206
'Ammuriya	Nablus	169.95	163.4	680	296	95	No	14
'Asira al Qibliya	Nablus	170.53	176	572	2158	335	No	104
'Azmut	Nablus	179.38	181.1	460	2572	239	Yes	224
'Ein Shibli	Nablus	190.23	181.76	100	187	4449	Yes	16
'Einabus	Nablus	173.3	172.6	510	2096	523	Yes	183
'Iraq Burin	Nablus	172.8	178.7	750	728	7910	No	44
'Urif	Nablus	171.33	173.92	590	2680	675	No	129
Al 'Aqrabaniya	Nablus	186.25	183.6	-20	845	4310	No	51

Community Name	District Name	X (Km)	Y (Km)	Elevation (m)	Population mid 2004[a]	Density (P/Km2)	Community with water network	Commun wastewater pr (m3/d)
Al Badhan	Nablus	180.58	185	200	2286	25121	Yes	199
Al Juneid	Nablus	170.85	181.33	640	365	1303	Yes	32
Al Lubban ash Sharqiya	Nablus	172.93	164.08	570	2359	188	Yes	206
An Naqura	Nablus	169.1	185.75	430	1565	284	Yes	136
An Nassariya	Nablus	186.9	183.88	70	1278	6590	Yes	111
As Sawiya	Nablus	174.5	165.77	630	2172	201	Yes	189
Beit Dajan	Nablus	185.4	177.83	520	3389	77	No	163
Beit Hasan	Nablus	188.27	182.67	-35	1126	187585	Yes	98
Beit Iba	Nablus	170.17	182.74	420	3085	610	Yes	269
Beit Imrin	Nablus	170.77	188.83	420	2714	225	Yes	237
Beit Wazan	Nablus	170.45	181.88	520	1058	285	Yes	92
Bizzariya	Nablus	165.83	190.45	460	2031	475	Yes	177
Burin	Nablus	173.7	176.4	600	2429	127	No	117
Burqa	Nablus	168.54	189.55	450	3805	206	Yes	332
Deir al Hatab	Nablus	180.43	180.37	500	2131	185	Yes	186
Deir Sharaf	Nablus	168.03	184.5	320	2605	362	Yes	227
Duma	Nablus	184.8	162.77	610	2096	121	No	101
Furush Beit Dajan	Nablus	192.84	177.43	-160	1094	28785	No	66
Ijnisinya	Nablus	170.6	186.52	450	528	81	Yes	46
Jalud	Nablus	180.18	163.88	790	427	27	No	21
Jurish	Nablus	180.5	167.55	810	1306	159	No	63
Kafr Qallil	Nablus	176.18	177.47	620	2353	497	No	113
Madama	Nablus	171.84	176.81	500	1565	466	No	75
Majdal Bani Fadil	Nablus	184.52	165.65	650	2062	74	No	99
Nisf Jubeil	Nablus	170.93	187.7	400	478	95	Yes	42
Odala	Nablus	176.3	173.21	560	1022	10017	Yes	89
Osarin	Nablus	179.46	170.3	700	1539	703	No	74
Qaryut	Nablus	178.1	164.05	775	2331	311	No	112
Qusin	Nablus	167.65	182.78	500	1637	361	Yes	143
Rujeib	Nablus	177.97	177.69	540	3697	525	Yes	322
Sabastiya	Nablus	168.65	186.93	420	2743	541	Yes	239
Sarra	Nablus	168.2	179.61	500	2730	460	No	131
Talluza	Nablus	177.95	186.45	540	2531	44	Yes	221
Telfit	Nablus	177.84	165.79	680	2824	451	No	136
Yanun	Nablus	183.72	172.46	640	145	9	No	7
Yasid	Nablus	176.46	189.2	690	2163	235	No	104
Yatma	Nablus	175.48	168.35	600	2815	745	Yes	245
Zawata	Nablus	171.48	183.63	460	1794	504	Yes	156
Zeita Jamma'in	Nablus	167.61	171.58	435	1852	144	Yes	162
'Arab ar Ramadin al Janubi	Qalqiliya	149.65	175.55	130	178	4241	No	11
'Azzun 'Atma	Qalqiliya	151.57	170.02	160	1534	9187	Yes	83
'Isla	Qalqiliya	153.44	175.46	280	814	11972	Yes	44
'Izbat al Ashqar	Qalqiliya	151.96	171.9	140	384	25570	No	23
'Izbat at Tabib	Qalqiliya	153.43	176.44	250	193	5373	No	12
'Izbat Jal'ud	Qalqiliya	150	173	140	130	5418	No	8
'Izbat Salman	Qalqiliya	150.03	172.05	125	591	6569	No	35
Ad Dab'a	Qalqiliya	151.02	173.88	170	248	31006	No	15
Al Funduq	Qalqiliya	163.13	177.43	410	605	374	Yes	33
Al Mudawwar	Qalqiliya	151.35	172.2	140	203	2606	No	12

Community Name	District Name	X (Km)	Y (Km)	Elevation (m)	Population mid 2004[a]	Density (P/Km2)	Community with water network	Commun wastewater pr (m3/d)
An Nabi Elyas	Qalqiliya	151.9	176.8	170	1116	17432	Yes	61
Baqat al Hatab	Qalqiliya	161.06	179.13	450	1605	179	No	77
Beit Amin	Qalqiliya	152.2	170.85	140	1053	12108	No	63
Falamya	Qalqiliya	152.35	181.17	120	649	273	Yes	35
Far'ata	Qalqiliya	165.9	177.51	540	603	363	No	29
Hajja	Qalqiliya	162.68	178.75	410	2323	177	No	112
Immatin	Qalqiliya	165.09	177.48	420	2251	314	No	108
Jayyus	Qalqiliya	153.4	178.62	230	3038	242	Yes	165
Jinsafut	Qalqiliya	162.47	176.15	430	2094	224	Yes	114
Jit	Qalqiliya	166.33	180.06	500	2132	330	Yes	116
Kafr Laqif	Qalqiliya	158.74	176.55	330	904	317	Yes	49
Kafr Qaddum	Qalqiliya	164	180.85	360	3208	169	Yes	175
Khirbet Sir	Qalqiliya	155.68	178.1	250	494	183	Yes	27
Ras 'Atiya	Qalqiliya	149.2	173.97	145	1469	13855	Yes	80
Ras at Tira	Qalqiliya	151.06	174.32	446	365	14599	No	22
Sanniriya	Qalqiliya	154.73	170.6	290	2744	216	Yes	149
'Abud	Ramallah & Al Bireh	156.54	158.16	530	2252	150	Yes	180
'Abwein (Bani Zeid ash Sharqiya)	Ramallah & Al Bireh	169.26	160.5	650	3147	194	Yes	252
'Ajjul	Ramallah & Al Bireh	167.23	158.9	510	1329	200	Yes	106
'Arura (Bani Zeid ash Sharqiya)	Ramallah & Al Bireh	166.63	160.94	550	2718	248	Yes	217
'Atara	Ramallah & Al Bireh	169.3	156.28	820	2152	225	Yes	172
'Ein 'Arik	Ramallah & Al Bireh	163.52	146.03	550	1562	263	Yes	125
'Ein Qiniya	Ramallah & Al Bireh	164.24	148.2	530	740	297	No	36
'Ein Samiya	Ramallah & Al Bireh	181.6	155.4	500	161	3825	No	10
'Ein Siniya	Ramallah & Al Bireh	171.62	153.05	640	691	248	Yes	55
'Ein Yabrud	Ramallah & Al Bireh	173.93	150.52	820	3257	284	Yes	261
Abu Qash	Ramallah & Al Bireh	167.56	150.85	770	1431	301	Yes	115
Abu Shukheidim	Ramallah & Al Bireh	166.3	152.45	740	1704	1191	Yes	136
Al Janiya	Ramallah & Al Bireh	161.7	149.44	560	1072	142	Yes	86
Al Lubban al Gharbi	Ramallah & Al Bireh	153.9	160.15	290	1382	141	Yes	111
Al Mazra'a al Qibliya	Ramallah & Al Bireh	164.94	151.05	600	3888	294	Yes	311
Al Midya	Ramallah & Al Bireh	150.58	149.25	220	1195	5977	Yes	96
Al Mughayyir	Ramallah & Al Bireh	182.9	158.42	650	2207	152	Yes	177

Community Name	District Name	X (Km)	Y (Km)	Elevation (m)	Population mid 2004[a]	Density (P/Km2)	Community with water network	Commun wastewater pr (m3/d)
An Nabi Salih (Bani Zeid al gharbiya)	Ramallah & Al Bireh	161.97	158.15	570	481	169	Yes	38
At Tayba	Ramallah & Al Bireh	178.45	151.23	860	1947	96	Yes	156
At Tira	Ramallah & Al Bireh	162.13	142	620	1506	379	Yes	120
Badiw al Mu'arrajat	Ramallah & Al Bireh	180.18	148	655	731	17406	No	44
Beit 'Ur al Fauqa	Ramallah & Al Bireh	161.15	143.43	600	849	222	Yes	68
Beit Nuba	Ramallah & Al Bireh	154.32	140.68	235	268	5354	No	16
Beit Sira	Ramallah & Al Bireh	154.4	143.82	270	2603	1157	Yes	208
Beitillu	Ramallah & Al Bireh	161.25	153.43	550	2824	128	Yes	226
Beitin	Ramallah & Al Bireh	172.75	148.24	860	2795	559	Yes	224
Bil'in	Ramallah & Al Bireh	156.82	148.3	320	1608	403	Yes	129
Budrus	Ramallah & Al Bireh	148.58	152.6	225	1386	478	Yes	111
Burham	Ramallah & Al Bireh	166.6	155.1	680	518	326	Yes	41
Burqa	Ramallah & Al Bireh	174.22	144.85	730	2122	354	Yes	170
Deir 'Ammar	Ramallah & Al Bireh	160.1	152.7	540	2212	308	Yes	177
Deir 'Ammar Camp	Ramallah & Al Bireh	159.42	152.64	520	2042	15017	Yes	163
Deir Abu Mash'al	Ramallah & Al Bireh	156.65	156.17	460	3151	359	Yes	252
Deir as Sudan	Ramallah & Al Bireh	164.34	159.68	520	1995	443	Yes	160
Deir Ibzi'	Ramallah & Al Bireh	161.65	147.05	530	1905	1332	Yes	152
Deir Jarir	Ramallah & Al Bireh	177.6	152.7	900	3941	119	Yes	315
Deir Nidham	Ramallah & Al Bireh	160.94	156.63	590	833	429	Yes	67
Deir Qaddis	Ramallah & Al Bireh	154.42	150.7	385	1802	217	Yes	144
Dura al Qar'	Ramallah & Al Bireh	171.54	151.7	730	2509	602	Yes	201
Jammala	Ramallah & Al Bireh	158.88	153.31	510	1331	186	Yes	106
Jibiya	Ramallah & Al Bireh	165.35	156.03	870	146	88	Yes	12
Jifna	Ramallah & Al Bireh	170.3	152.2	655	1245	207	Yes	100

Community Name	District Name	X (Km)	Y (Km)	Elevation (m)	Population mid 2004[a]	Density (P/Km2)	Community with water network	Commun wastewater pr (m3/d)
Kafr 'Ein (Bani Zeid al gharbiya)	Ramallah & Al Bireh	161.52	161.65	400	1669	1451	Yes	133
Kafr Malik	Ramallah & Al Bireh	179.25	155.04	780	2753	53	Yes	220
Kafr Ni'ma	Ramallah & Al Bireh	159.15	148.35	480	3548	345	Yes	284
Kharbatha Bani Harith	Ramallah & Al Bireh	156.96	150.07	385	2662	374	Yes	213
Khirbet Abu Falah	Ramallah & Al Bireh	178.66	157.9	750	3756	459	Yes	300
Kobar	Ramallah & Al Bireh	165.36	154.8	640	3362	347	Yes	269
Mazari' an Nubani (Bani Zeid ash S	Ramallah & Al Bireh	166	161.77	520	2299	239	Yes	184
Qaddura Camp	Ramallah & Al Bireh	169.6	144.35	850	1427	5447	Yes	114
Qarawat Bani Zeid (Bani Zeid al gh	Ramallah & Al Bireh	162.3	162.42	340	2535	497	Yes	203
Rammun	Ramallah & Al Bireh	178.43	148.9	750	2941	98	Yes	235
Rantis	Ramallah & Al Bireh	151.89	159.6	255	2650	226	Yes	212
Ras Karkar	Ramallah & Al Bireh	159.9	150.05	500	1739	295	Yes	139
Saffa	Ramallah & Al Bireh	155.88	145.85	350	3702	451	Yes	296
Shabtin	Ramallah & Al Bireh	154.92	153.35	260	800	181	Yes	64
Shuqba	Ramallah & Al Bireh	153.72	154.9	305	3971	287	Yes	318
Silwad Camp	Ramallah & Al Bireh	174.87	152.82	850	388	12931	Yes	31
Surda	Ramallah & Al Bireh	169.36	149.65	830	1303	349	Yes	104
Umm Safa	Ramallah & Al Bireh	165.65	157.3	620	660	162	Yes	53
Yabrud	Ramallah & Al Bireh	173.25	153.43	790	631	252	Yes	50
Bruqin	Salfit	159.54	164.43	390	3397	189	No	163
Deir Ballut	Salfit	152.55	163.48	280	3425	86	Yes	211
Deir Istiya	Salfit	163.31	170.9	440	3582	105	Yes	221
Farkha	Salfit	164.63	164	750	1425	251	Yes	88
Haris	Salfit	163.35	168.92	480	2850	2850	Yes	176
Iskaka	Salfit	171.3	167.88	700	1021	192	Yes	63
Khirbet Qeis	Salfit	166.92	163.22	410	235	69	Yes	14
Kifl Haris	Salfit	165.04	169.48	600	3008	251	Yes	185
Marda	Salfit	168.48	169.05	440	2058	228	Yes	127
Mas-ha	Salfit	154.9	168.38	290	1842	154	Yes	113
Qarawat Bani Hassan	Salfit	159.79	170.25	380	3454	356	Yes	213
Qira	Salfit	166.35	169.92	690	963	160	Yes	59

Community Name	District Name	X (Km)	Y (Km)	Elevation (m)	Population mid 2004[a]	Density (P/Km2)	Community with water network	Commun wastewater pr (m3/d)
Rafat	Salfit	154.21	164.95	300	1874	187	Yes	115
Sarta	Salfit	158.75	167.8	360	2428	435	Yes	150
Yasuf	Salfit	172.65	168.45	650	1638	205	Yes	101
'Ein el Beida	Tubas	197.87	198.66	315	1007	7045	Yes	74
Al Farisiya	Tubas	198.25	194.3	-160	199	4735	No	12
Al Hadidiya	Tubas	197.4	183	25	170	4059	No	10
Al Malih	Tubas	195.23	192.85	51	192	4274	No	12
Ath Thaghra	Tubas	187.03	193.23	300	240	30050	No	14
Bardala	Tubas	195.51	199.22	50	1471	4596	Yes	108
Kardala	Tubas	196.83	198.43	-90	154	5313	Yes	11
Ras al Far'a	Tubas	182.4	189.65	250	653	15558	No	39
Tayasir	Tubas	187.5	194.4	300	2235	96	No	107
Wadi al Far'a	Tubas	182.37	188.08	165	2183	12768	No	131
'Akkaba	Tulkarm	157.82	205.98	130	246	2588	No	15
'Izbat Shufa	Tulkarm	154.15	188.27	99	930	7380	Yes	96
Al Hafasa	Tulkarm	157.25	188.67	99	152	7594	No	9
Al Jarushiya	Tulkarm	154.71	194.75	110	856	3943	No	51
An Nazla al Gharbiya	Tulkarm	157.87	200.8	120	835	360	No	40
An Nazla al Wusta	Tulkarm	159.08	201.65	150	391	259	Yes	40
An Nazla ash Sharqiya	Tulkarm	160.3	201.9	220	1554	321	Yes	160
Ar Ras	Tulkarm	156.15	184.28	280	478	85	Yes	49
Baqa ash Sharqiya	Tulkarm	156.88	201.7	100	3860	1018	No	185
Far'un	Tulkarm	152.55	188.16	150	3009	474	Yes	311
Iktaba	Tulkarm	155.2	192.57	170	1863	2934	Yes	192
Kafa	Tulkarm	154.44	188.77	150	329	5305	No	20
Kafr 'Abbush	Tulkarm	158.15	181.1	320	1404	285	Yes	145
Kafr al Labad	Tulkarm	160.43	189.25	320	3802	258	Yes	392
Kafr Jammal	Tulkarm	154.43	181.25	210	2409	271	Yes	249
Kafr Rumman	Tulkarm	162.1	191.45	300	820	209	Yes	85
Kafr Sur	Tulkarm	156.28	183.45	280	1182	126	Yes	122
Kafr Zibad	Tulkarm	157	181.3	195	1232	174	Yes	127
Khirbet at Tayyah	Tulkarm	154.2	189.65	145	329	58	No	16
Khirbet Jubara	Tulkarm	154.3	186.13	100	308	3713	No	18
Kur	Tulkarm	159.38	182.45	370	306	36	No	15
Masqufet al Hajj Mas'ud (Al Masqufa)	Tulkarm	155.73	193.6	180	200	2941	No	12
Nazlat 'Isa	Tulkarm	155.67	202.25	80	2360	1276	Yes	244
Nazlat Abu Nar	Tulkarm	157.34	201.44	100	185	246	No	9
Ramin	Tulkarm	164.34	188.17	340	1981	223	Yes	204
Saffarin	Tulkarm	160.67	185.33	350	978	101	No	47
Seida	Tulkarm	161.32	198.92	350	2902	574	No	139
Shufa	Tulkarm	157.9	187.2	330	1182	101	Yes	122
Zeita	Tulkarm	155.06	199.06	100	2965	1913	Yes	306

[a] Small rural communities population numbers are projected from the population numbers for the mid-year 2001.

[b] Wastewater production is estimated to be 80% of water consumption (based on data from Table 3.1) in case of water networks availability, and a water consumption of 60 l/c/d is assumed in case of villages with no water networks available.

Appendix II: Palestinian Standards for Treated Domestic Wastewater/ PS 742

Table A II.1: Standard Conditions for Treated Domestic Wastewater as Maximum Value Except Otherwise Indicated DRAFT - Palestinian Standards for Treated Domestic Wastewater/ PS 742

	Maximum Allowable Level (mg/l)						
Quality Parameter mg/l Except Otherwise Indicated	Vegetables Eaten Cooked	Trees, Industrial Products & Seeds	Discharge to Wadis & Water Bodies	Aquifer Recharge	Fish(2) Husbandry	Landscape Lawns & Parks	Fodder (1) Irrigation
BOD5(3)	150	150	50	50	-	50	250
COD	500	500	200	200	-	200	700
DO	>2	>2	>2	>2	>5	>2	>1
TSS	200	200	50	50	25	50	250
Ph	9-Jun	9-Jun	9-Jun	9-Jun	6.5-9	9-Jun	9-Jun
Color (PCU)(4)	-	-	75	75	-	75	-
FOG	8	8	8	nil	8	8	12
Phenols	0.002	0.002	0.002	0.002	0.001	0.002	0.002
Industrial Detergents (MB	50	50	25	15	0.2	15	50
NO3-N	50	50	25	25	-	25	50
NH4-N	-	-	15	15	0.5	50	-
T-N	100	100	50	50	-	100	-
PO4-P	-	-	15	15	-	15	-
Cl	350	350	350	350	-	350	350
SO4	1000	1000	1000	1000	-	1000	1000
CO3	6	6	6	6	-	6	6
HCO3	520	520	520	520	-	520	520
Na	230	230	230	230	-	230	230
Mg	60	60	60	60	-	60	60
Ca	400	400	400	400	-	400	400
SAR	9	9	9	9	-	12	9
Residual Cl2(5)	0.5	-	-	-	-	0.5	-
Al	5	5	5	1	-	5	5
As	0.1	0.1	0.05	0.05	0.05	0.1	0.1
Be	0.1	0.1	0.1	0.1	1.1	0.1	0.1
TDS	2000	2000	2000	1500	2000	2000	2000
Cu	0.2	0.2	0.2	0.2	0.04	0.2	0.2
F	1	1	1	1	1.5	1	1
Fe	5	5	2	1	0.5	5	5
Li	2.5	5	1	1	-	3	5
Mn	0.2	0.2	0.2	0.2	1	0.2	0.2
Ni	0.2	0.2	0.2	0.2	0.4	0.2	0.2
Pb	5	5	0.1	0.1	0.15	0.1	5
Se	0.02	0.02	0.02	0.02	0.05	0.02	0.02
Cd	0.01	0.01	0.01	0.01	0.015	0.01	0.01
Zn	2	2	15	15	0.6	2	2
CN	0.1	0.1	0.1	0.1	0.005	0.1	0.1
Cr	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Hg	0.001	0.001	0.001	0.001	0.00005	0.001	0.001

Table AII.1: Standard Conditions for Treated Domestic Wastewater as Maximum Value Except Otherwise Indicated DRAFT - Palestinian Standards for Treated Domestic Wastewater/ PS 742

Maximum Allowable Level (mg/l)							
Quality Parameter mg/l Except Otherwise Indicated	Vegetables Eaten Cooked	Trees, Industrial Products & Seeds	Discharge to Wadis & Water Bodies	Aquifer Recharge	Fish(2) Husbandry	Landscape Lawns & Parks	Fodder (1) Irrigation
V	0.1	0.1	0.1	0.1	-	0.1	0.1
Co	0.05	0.05	0.05	0.05	-	0.05	0.05
B	1	1	2	1	-	3	3
Mo	0.01	0.01	0.01	0.01	-	0.01	0.01
TFCC (MPN/100ml)(6)	1000	-	1000	1000	10000	200	
Pathogens	-	-	-	-	100000(9)	nil	
Amoebae & Gardia (Cyst/	<1	-	-	-	-	nil	
Nematodes (Egg/L) (8)	<1	-	<1	-	-	<1	<1

(-): Not Determined.

(1): Values of trace and heavy metals were estimated depending on water consumption rate for irrigation at 1000 CM/Dunum/year

(2): Depends on Fish type, pH, TDS, and Temperature

(3): BOD is meant by filtered (soluble) in natural treatment and not filtered in mechanical treatment.

(4): Color is measured as Platinum/Cobalt Unit

(5): Contact time not less than 30 minutes

(6): Number with most probability per 100 ml

(7): Cyst per liter

(8): Means Escaris, Anclostoma, and Tnkiorex and measured as No. of eggs per liter

(9): Salmonella per 100 ml

APPENDIX III: Contaminated springs in the West Bank for the year (2000)

Table A III.1 Point name, locality, governate, nitrate concentration of contaminated springs in the West Bank, (PWA, 2003)

Spring Number	Point Name	Locality	Governate	Parameter	Value mg/l
1	Al 'Alaq	Abu Shukheidim	Ramallah	NO3	60
2	Al 'Amud	Husan	Behtlehem	NO3	98
3	Al Balad	Beit Imrin	Nablus	NO3	45
4	Al Balad	Iraq burin	Nablus	NO3	105
5	Al Balad	Burin	Nablus	NO3	70
6	Al Balad	Al-Fandaqumiya	Jenin	NO3	149
7	Al Balad	Nahhalin	Behtlehem	NO3	51
8	Al Balad	Yasuf	Salfit	NO3	47
9	Al Hammam	Bir Zeit	Ramallah	NO3	88
10	Al Hawuz	Al-Fandaqumiya	Jenin	NO3	154
11	Al Magharah	Wadi Fukin	Behtlehem	NO3	53
12	Al Qur'an	'Ein el Beida	Tubas	NO3	50
13	Al Sharqiyyah	Jaba'	Jenin	NO3	52
14	Al Skhunah	Husan	Behtlehem	NO3	100
15	Battir	Battir	Behtlehem	NO3	49
16	Beit Al Ma'	Nablus	Nablus	NO3	46
17	Blaibel	Bardala	Tubas	NO3	51
18	Flaiflah	Bir Zeit	Ramallah	NO3	77
19	Fukin Al Balad	Wadi Fukin	Behtlehem	NO3	49
20	Haskah	Halhul	Hebron	NO3	51
21	'Imran No. 1	Dura	Hebron	NO3	53
22	Irtas	Artas	Behtlehem	NO3	53
23	'Itan	Artas	Behtlehem	NO3	85
24	Jurish	Jurish	Ramallah	NO3	445
25	Kanar Al Gharbiyyah	Dura	Hebron	NO3	45
26	Sa'ir	Sa'ir	Hebron	NO3	100
27	Saleh	Artas	Behtlehem	NO3	99
28	Shraish	Nablus	Nablus	NO3	48
29	Therweh	Halhul	Hebron	NO3	94
30	Unqor	Dura	Hebron	NO3	96

Table A.III.2 Point name, locality, governate, nitrate concentration of contaminated wells in the West Bank, (PWA, 2003)

Well number	Point Name	Locality	Governate	Parameter	Value mg/l
1	'Abdallah Ghnaim	Qalqilya	Qalqilia	NO3	46
2	'Abdallah Muhammad 'Abed Al	Qalqilya	Qalqilia	NO3	52

Well number	Point Name	Locality	Governate	Parameter	Value mg/l
	Rahman				
3	'Abed Al Kareem Zaid	Tinnik	Jenin	NO3	51
4	'Abed Al Majeed Qasem	Deir al Ghusun	Tulkarm	NO3	51
5	'Abed Al Raheem As'ad Jada'	Habla	Qalqilia	NO3	49
6	'Abed Al Raheem As'ad Jada'	Habla	Qalqilia	NO3	51
7	'Abed Al Raheem Hasan	Qalqilya	Qalqilia	NO3	49
8	Ahmad 'Abed Al Raheem	Kafr Dan	Jenin	NO3	103
9	Ahmad Abu Khadeejah	Qalqilya	Qalqilia	NO3	45
10	Ahmad Qasem Abu Kharrub	Habla	Qalqilia	NO3	52
11	Ahmad Qasem Abu Kharrub	Habla	Qalqilia	NO3	53
12	Ahmad Shanti & Partners	Ras Al-Far'a	Tubas	NO3	70
13	Al Fawwar - Hebron Municipality No. 3	Al Fawwar Camp	Hebron	NO3	94
14	Al Fawwar - Hebron Municipality No.1c(2)	Al Fawwar Camp	Hebron	NO3	53
15	'Ali Abu Khader	Qalqilya	Qalqilia	NO3	48
16	'Ali Hasan Abu Salman	'Izbat Abu Salman	Qalqilia	NO3	46
17	'Ali Najeeb 'Ashur	Qalqilya	Qalqilia	NO3	48
18	Ameen Ahmad Yusef	Qabatiya	Jenin	NO3	70
19	'Anabta Municipality	'Anabta	Tulkarm	NO3	96
20	Arab Project	Jericho (Ariha)	Jericho	NO3	48
21	Arab Project	Jericho (Ariha)	Jericho	NO3	48
22	'Arrana Local Council	'Arrana	Jenin	NO3	63
23	'Azzun Village Council	Azzun	Qalqilia	NO3	45
24	Basel Husaini	Jericho (Ariha)	Jericho	NO3	47
25	Deir Sharaf No. 3	Deir Sharaf	Nablus	NO3	50
26	Fathiyyah Faheem Jarrar	Kafr Dan	Jenin	NO3	73

Well number	Point Name	Locality	Governate	Parameter	Value mg/l
27	Fu'ad Abed Al Hadi	Jenin	Jenin	NO3	80
28	Fu'ad Abu Al Rub	Qabatiya	Jenin	NO3	60
29	Ghaleb 'Ahed	Deir Ghazala	Jenin	NO3	71
30	Habla Village Council	Habla	Qalqilia	NO3	52
31	Haj Adeeb Hassan	Qabatiya	Jenin	NO3	95
32	Hasan Al Haj Hasan	Qalqilya	Qalqilia	NO3	46
33	Haseeb I'mus	'Attil	Tulkarm	NO3	53
34	Ibraheem Muhammad 'Othman	Jericho (Ariha)	Jericho	NO3	49
35	I'qab Fraij & Partners	Tulkarm	Tulkarm	NO3	49
36	Jamal Qasem 'Abed Al Hadi	Al Jalama	Jenin	NO3	54
37	Jameel 'Awartani	'Anabta	Tulkarm	NO3	58
38	Jawdat Sha'sha'ah	Jericho (Ariha)	Jericho	NO3	48
39	Jawdat Sha'sha'ah	Jericho (Ariha)	Jericho	NO3	85
40	Kamel Al Salem	Falamya	Qalqilia	NO3	50
41	Kamel I'raiqat No.2	Jericho (Ariha)	Jericho	NO3	71
42	Muhammad Al Haj Yaseen	Al Jalama	Jenin	NO3	59
43	Muhammad 'Ali 'Abdallah	Ras Al-Far'a	Nablus	NO3	101
44	Muhammad 'Aref	Jenin	Jenin	NO3	98
45	Muhammad Qaddurah & Partners	Habla	Qalqilia	NO3	51
46	Muhammad Yaseen Abu Al Rub	Qabatiya	Jenin	NO3	63
47	Muneer Hasan Saleh	Kafr Dan	Jenin	NO3	60
48	Musa Nassar Hater	Jericho (Ariha)	Jericho	NO3	60
49	Mustafa Abu Khayzaran	Ras Al-Far'a	Tubas	NO3	52
50	Mustafa Nazzal & Partners	Qalqilya	Qalqilia	NO3	52
51	Nash'at Al Masri	Furush Beit Dajan	Jericho	NO3	114
52	Qalqilya Municipality	Qalqilya	Qalqilia	NO3	52
53	Rafeeq 'Abaed Al Razeq	Qalqilya	Qalqilia	NO3	47
54	Rafeeq Al Zu'bi	Bardala	Tubas	NO3	45
55	Rafeeq Hamdallah	Iktaba	Tulkarm	NO3	55
56	Rasheed Samarah & Tahseen Shadeed	'Al Ilar	Tulkarm	NO3	49
57	Reda Abu Khader	Qalqilya	Qalqilia	NO3	45

Well number	Point Name	Locality	Governate	Parameter	Value mg/l
58	Sa'eed Ibraheem Hashshash	Jenin	Jenin	NO3	110
59	Saleem Abu Farhah	Al Jalama	Jenin	NO3	63
60	Saleem 'Udah & Partners	Habla	Qalqilia	NO3	51
61	Saleh Yaseen Hamdan	'Attil	Tulkarm	NO3	52
62	Sbeeru Hanhan & Rantisi	Jericho (Ariha)	Jericho	NO3	78
63	Sulayman Saleh	Ras Al-Far'a	Tubas	NO3	56
64	Taleb Makki	Jericho (Ariha)	Jericho	NO3	50
65	Tubas Water Project	Ras Al-Far'a	Tubas	NO3	64
66	Tulkarm Municipality	Tulkarm	Tulkarm	NO3	52
67	Tulkarm Municipality	Tulkarm	Tulkarm	NO3	57
68	Tulkarm Municipality	Tulkarm	Tulkarm	NO3	49
69	'Uthman Al Tabeeb	Qalqilya	Qalqilia	NO3	46
70	Zuhdi Hashwah	Jericho (Ariha)	Jericho	NO3	70