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THE TRANSFER OF TECHNOLOGY TO WATER SUPPLY, SANITATION AND WASTE DISPOSAL SYSTEMS IN DEVELOPING COUNTRIES

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THE TRANSFER OF TECHNOLOGY TO WATER SUPPLY, SANITATION, AND WASTE DISPOSAL SYSTEMS IN DEVELOPING COUNTRIES

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A State of the Art for Provisions of Services in Developing Countries

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PREFACE

The services of Urban Resources Consultants, Inc. (URC) were engaged by the Agency for International Development to perform a literature survey that would result in a state-of-the-art report on water supply and sanitation technologies. The literature search was to identify technology currently in use to provide water and sanitation facilities and services, and would evaluate the need for possible technology modification before application in developing countries. The goal was to make maximum and appropriate use of workable technologies in order that poor people could have greater access to these services and benefits.

The URC study resulted in GUIDELINES FOR DEVELOPMENT OF WATER/SANITATION COMPONENTS OF URBAN FRINGE AND RURAL VILLAGE PROJECTS and a companion report, PATENTS, PROPRIETARY PROCESSES AND METHODS SPECIFIC TO WATER SUPPLY, WASTE DISPOSAL AND SANITATION. They have been published as a separate document.

As a part of the study an in-depth literature survey of customs, practices, problems of technology transfer, and other factors surrounding water supply, sanitation, and waste disposal processes and systems in developing countries was completed. The major results of that survey have been summarized in Section II of the GUIDELINES cited above. However, the URC team of health and sanitation specialists, who prepared the study, felt that the more detailed findings, which necessarily had to be omitted from that volume, were both practical and realistic.

That information is the content of this report. It is intended to assist decision makers and health and sanitation specialists as they consider the social, economic, cultural, and environmental aspects that can enhance or hinder the transfer of water supply, sanitation, and waste disposal technologies to developing countries.

The introductory section contains a statement about the current worldwide situation in water supply, sanitation, and waste disposal, considers its relation to health and disease, and summarizes the results of a two-year state-of-the-art study of low-cost technology options for water supply and waste disposal in developing countries. Section II reviews current prevailing customs and practices in water supply systems and in human waste disposal systems in developing countries. The transfer of technology or, more specifically, planning a village water supply program is presented in detail in Section III. Some of the problems of transferring technology are considered in Section IV. A list of conclusions is presented in the final section of the report.

The sections contained in this report provide related tables on recommended dimensions for different types of wells; recommended construction standards, preconditions, and input-output complementary relationships for water supply systems; characteristics of disposal systems; and various models for organizing and administering water and sanitation projects.

Appended to the report are World Bank guidelines for evaluating technology options, excerpts from a Guatemala case study, and a substantial list of references.

ACKNOWLEDGMENTS

This report is the result of a study sponsored by the Office of Urban Development, Bureau for Development Support, Agency for International Development. URC is grateful to Dr. William R. Miner, Director, and Dr. John W. Dickey, Urban and Regional Planning Advisor, of that Office, who initiated and supported the study.

The content of this report does not necessarily reflect the opinions or policies of URC.

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SECTION I

INTRODUCTION

While technologies to provide safe water and sanitation for people in developing countries are well known and various options are available, there are few feasible options. The geographic and climatic constraints invariably limit the location choice; constraints of financial, institutional, public health, social and environmental nature exist either singly or in combination.

The effects of a combination of constraints eventually make themselves felt in the communities. For example, after the first years of the implementation of the Indian Village Water Program in many areas up to 80% of the handpumps were reported out of order. The causes were manifold. [1]

All countries in the world have some form of commitment to provide the population with safe and adequate water. There is little evidence to show that the same recognition is being accorded to basic sanitation. Excreta disposal facilities are rarely provided as complementary measures for health and economic development. Few countries have policies, strategies and plans for coordinated development of drinking-water supplies with other water sectors. [2]

The current situation indicates the urgent need and importance of an increased effort in the improvement of water supply and sanitation. Worldwide in 1975, approximately 1100 million people or 80% of the rural population did not have reasonable access to a safe water supply. Furthermore, 23% of the urban population, frequently the poorest and underserved, were also without adequate water.[3]

Sanitation and waste disposal improvements lag even further behind water supply. In rural areas only one person in seven has adequate excreta disposal or household convenience. In 1975 an estimated 150 million people (25%) in urban areas were not served by any sanitary system whatsoever, while in rural areas 1200 million (85%) lacked sanitary facilities.[4]

Due to the rapid and unplanned growth of cities in the developing world, the situation will continue to deteriorate. Unless attention is directed to urban fringe areas, the health situation will become hazardous. To date, however, the major thrust of activities has not been in either rural or urban fringe areas.

There is increasing awareness that even the current education of professionals is often unsuited and unrelated to the current needs. Insufficient attention is paid to training in aspects of planning and management, and the relationships between water supply, sanitation, health and socioeconomic development. Few opportunities have been created to sensitize the professionals to people's values or social patterns. There is often little desire or incentive for professionals to work within the rural areas.[5]

During the five-year period, 1971-1975, countries made investments totalling some $9000 million for urban water supply, $3400 million for urban sewage disposal, $2250 million for rural water supply and $450 million for rural sanitation. It is estimated that roughly 75% of the investments were made from internal resources.[6]

During this period investments resulted in an overall worldwide increase of only 9% more people having access to adequate water supply and 6% more people having access to some form of excreta disposal.[7]

The worldwide analysis for water supply and sanitation,[8] clearly shows that policies and plans generally have a bias in favor of urban areas, frequently at the expense of the underserved rural and urban fringe areas. Often health administrators do not accord priority for rural water supply and sanitation, even when the most urgent health problems are related to these health interventions.

The need for an adequate source of water is a major need for sustaining life. The provision of safe, sufficient and accessible quantities of drinking-water is also a basic health measure. Water has an important role in personal hygiene, increasing food production, in diversifying to more nutritious foods, in cleaning, and even in carrying wastes. Water is also needed for development, since the widely diverse uses of water can considerably enhance the quality of life. In many societies, water also has a symbolic value and is of religious significance. Finally, water is a resource that has a recreational and aesthetic value that contributes to a feeling of well-being.

Without water, sanitation is almost impossible. Indeed the quality of life is affected by the many dimensions of sanitation. The proper disposal of human excreta is another element of sanitation. Other aspects include: personal hygiene, the collection and disposal of solid wastes, wastewater disposal, food sanitation, vector control, and household cleanliness. Water use linked with sanitation opens a range of alternatives for improving the quality of life of the vast majority of those in the developing world. Easily accessible water supply and sanitation are essential for primary health care, and for their impact on many other essential elements related to improvement of the quality of life.

A review of case studies and other experiences confirms that many of the problems associated with technology for water supply and sanitation are conditioned by a range of interacting factors. These and other experiences show that technology is not just "hardware";[9] the "software"[10] of technology is of equal importance. In general the social, cultural, political, economic and environmental elements, "software" and "hardware," are behind many of the past failures and standout as the major obstacles to rapid progress.

Approaches to the end user also need to be made in order to encourage the proper use of facilities. No matter how sophisticated the facilities for water supply and sanitation may be, they cannot have the desired effect of improving the quality of life unless used in a hygienic manner. Increasing attention is being given by UNICEF to (1) technologies for water supply and sanitation, (2) national self-reliance in terms of local manufacture of equipment, their operation and maintenance, and (3) development of skills.[11]

Nongovernmental organizations have supported this view and have been in the forefront in recognizing the need to deveiop locally sustainable and appropriate technologies and the use of local resources for water supply and sanitation technologies.

The Relationship of Health and Disease to Water and Sanitation

Poor sanitation and the lack of a safe and sufficient water supply have been well established as contributing to disease. Eighty percent of all illness in the countries in the Third World is linked to water. Typhoid and cholera outbreaks occur in conjunction with dirty water. Water breeding insects carry malaria, filariasis, yellow fever, and sleeping sickness and affect huge numbers of people. An estimated 400 million people (or twice the population of western Europe) are affected at any one time by gastroenteritis; over 200 million people (equal to the entire population in the United States of America) suffer from schistosomiasis.

Children are the most vulnerable to these diseases. In the developing countries diarrhea is the major cause of sickness and death among children. During 1975, for children aged less than five years, there were approximately 500 million episodes of diarrhea in Africa, Asia and Latin America.[12] Gastroenteritis and diarrhea are the major causes of death in Colombia in the under-15 age group. Similarly in Bangladesh children between one and ten years of age have the highest diarrhea and cholera attack rates. Their conditions are further complicated by malnutrition. In the Philippines, gastroenteritis is still the third ranking cause of mortality.

The main hindrance to latrine programs in the Philippines is reported to be the people's reluctance to accept changes in living habits and the attitude that sanitation is the least of their problems. Bangladesh children are primarily given surface water to drink rather than better quality tubewell water because of the belief that tubewell water causes chills. Children are also unlikely to be instructed or supervised concerning the choice of container.[13] As 25% of children die before the age of five years in Bangladesh, water and sanitation education should primarily be focused on the mothers and children. However, there are few documented cases of comprehensive education activities that have been implemented in conjunction with and specifically related to the problems of water and sanitation improvement. The provision of facilities for the supply of safe water and the proper disposal of human waste must be accompanied by effective health education programs if the greatest impact is to be made on disease problems.

The Findings of a Recent Study

In 1976, the World Bank in collaboration with the International Development Center, launched a two-year study to identify appropriate water supply and waste disposal technologies for the rural and urban poor of developing countries.[14] The study

focused on low-cost, socially and environmentally acceptable technologies. Outputs of the study, Low-Cost Technology Options for Sanitation, included a state-of-the-art review; an annotated bibliography on the technical aspects of collection, treatment, reuse, and disposal of human wastes in developing countries;[15] and guidelines and instructional materials for use by decision-makers in development agencies, consulting engineering organizations and universities.[16] Prototype projects are being developed and implemented in coordination with Bank project offices, the United Nations Development Program (UNDP), and the World Health Organization (WHO). Some of the results of the World Bank research project which are relevant to the current USAID project are summarized below.

Waste Disposal

The authors' overview of the conditions and problems of waste disposal facing developing countries shows that the situation is extremely different and more severe than that faced by the Western countries in the 1850's.[17] For example, the population explosion in developing countries presents a waste disposal problem of a much larger scale than that encountered by present day developed countries. At the time that the decision was made to adopt underground sewers, London had slightly over 2 million inhabitants. All the other cities at the time they initiated sewer construction (Hamburg, Paris, and New York) had less than 1 million inhabitants. In contrast, most of the primary cities in Asia that currently do not have sewers have a population surpassing 5 million. In addition to the population explosion, other pressures influencing the scope of the problem within developing countries are:

- A lack of natural resources such as clean water;
- Climatic conditions which create ideal conditions for survival of greater numbers and in greater varieties of pathogens;
- The extent to which the population is malnourished, which increases the risk of infection;
- The fact that in less developed countries, the use of night soil for fertilizer is a real need. (Agriculture is necessary for survival; chemical fertilizers are too expensive for the average farmer.)

Considering the combined effect of these pressures, the authors believe it is unlikely that the systems that were appropriate for the smaller populations of the resource-wealthy industrialized countries of northern Europe in the 19th century will be successful in solving the waste disposal problems of developing countries.[18]

These constraints provided the basis for evaluating various technologies in the United States and other developed nations for their transferability--that is, if they were acceptable economically and culturally--to underdeveloped nations, especially in the rural and impoverished areas. The technologies had to meet the criteria of (1) acting positively to reduce disease and contamination of the water supply, (2) being culturally acceptable and (3) not invoking any economic hardships. The study addressed the following areas:

1. Options for Human Waste Disposal in Developing Countries: pit latrines, vaults, septic tanks, aqua privies, composting privies, night soil collection, night soil treatment, grey water.

2. Techniques for Reusing Human Wastes: fertilization, irrigation, aquaculture, algae production, aquatic weeds, biogas.

3. Waste-Disposal/Reuse Options for Cities and Towns: waterborne options, water saving, the cartage options, the on-site options, economic comparisons.

The significant characteristics of three classes of systems, waterborne, cartage, and on-site, were summarized. (See Table 3.) The authors stressed that these characteristics often vary from country to country, and noted that each system was described in simple terms and design formulae in Small Excreta Disposal Systems, a publication updated in 1978 by the Ross Institute of Tropical Hygiene of the London School of Hygiene and Tropical Medicine.[19] A discussion and guidelines for the selection of an appropriate technology for waste disposal can be found in the World Bank document "Appropriate Sanitation Alternatives: A Technical and Economic Appraisal."[20] These guidelines provide a basis for assessing a technology's technical, economic, public health, and socio-cultural aspects.

The consensus from the study provided a number of caveats to the premise that United States technology can be transferred abroad. The authors' observed:

1. It is not surprising that the data bases do not provide a large amount of reference on nonconventional wastewater technologies. Most data bases are, after all, enterprises that reflect the information requirements of their clientele, which are universities, engineering firms, and government agencies in North America and Europe. As a result more than 99% of the published literature on wastewater is of no practical value to the urban and rural poor in the developing countries.[21]

2. The literature on "on-site collection and treatment" tends to focus on the septic tank, which is prevalent in the United States, but inappropriate to a developing country for cost reasons. On the other hand, the easily adaptable pit latrine has been ignored since the the 1930's. Hence two areas in need of additional research are:

   a. How the operation of the pit latrine could be improved to overcome problems of flies, smell, and uncleanliness; and

   b. How the non-technical aspects of rural latrine programs contribute to their success or failure when adapted to the urban environment.

3. The literature on collection and off-site treatment tends to focus on sewage treatment for developed countries, while ignoring the

fact that sewerage serves such a small fraction of the population in developing countries. Stabilization ponds are more relevant to the developing countries circumstances. Truck collection, although widely used, lacks documentation of operating data. Similarly, little data was found on various cart and night soil systems that are widely used in developing countries and play a significant role in existing urban waste disposal.

4. The reuse of treated sewage and sludges in irrigation and aquaculture is well documented in western literature; however, the use of night soil in fertilization and fish culture as widely practiced in developing countries is virtually ignored.[22]

The study indicated that a series of cultural, ecological, economic, and traditional differences could serve as barriers to the transfer of domestic technology of sewage treatment and water treatment to underdeveloped countries. In general, the technology review found that the differences in climate, socioeconomic conditions, and the scale of the problem make it difficult to apply technological data from an industrial country directly to conditions in a developing country, even when the data was of a "scientific nature."[23] Furthermore:

> "Wastewater research, even when it is going on in a developing country, in many cases follows Western models and turns its back on local traditions and practices. The result is that very little is known about what is actually going on. Any attempt to upgrade or improve the existing situation. . .will have to be based on sound understanding of existing resources, limitations, and possibilities."[24]

Water Supply

A companion publication to the Small Excreta Disposal Systems bulletin, entitled Small Water Supplies, is available from the Ross Institute.[25] The most comprehensive work on rural water supply, which takes into account all the relevant literature on problems associated with planning, administration, and evaluation is Village Water Supply: Economics and Policy in the Developing World, by Robert J. Saunders and Jeremy J. Warford.[26]

SECTION II

CURRENT PREVAILING CUSTOMS AND PRACTICES

In planning water supply and excreta disposal programs, administrators and planners may draw upon data from several operating systems. Most researchers agree that for maximum health benefits to be achieved, for both urban squatter settlements and rural villages, the installation of an improved water supply should be complemented with health education to improve water use practices and excreta disposal facilities. McGarry stated that, "Water supply, proper excreta disposal and hygiene improvements to health must be viewed together as components of a 'sanitation package' to be implemented simultaneously."[27] Particularly in rural areas where a convenient water supply is more often the primary need, and excreta disposal facilities are only dimly perceived as needed, water supply and sanitation activities should be integrated into rural health care activities. Although the coordination of water supply and excreta disposal activities is necessary for planning both urban and rural programs, the constraints on planning are more stringent for excreta disposal in urban areas and for water supply in rural areas.

The most critical constraints for urban and rural areas appear to be folklore and custom surrounding water supplies and waste disposal. The remainder of this chapter will be devoted to examining the current prevailing customs in several underdeveloped countries for both utilization of water supplies and human waste disposal. This will provide a perspective from which to propose a set of preliminary ideas of transfer of technology.

Water Supply Systems

Water Sources

Current water supply is determined from the source of water, its accessibility and its purity. Under this topic are outlined the two main types of water sources, surface and ground water. The remainder of this section will describe in detail how clean water is obtained from them.

The water source must be able to supply enough safe, clean water for the community. The purification of unsafe water under rural conditions can be expensive and requires some trained supervision if it is to be reliable. It is much better to consider a source that provides naturally pure water, and then to protect it from pollution. If the existing source used by the community is polluted, it may still be possible to improve it sufficiently to make it suitable as a new supply.

When water falls as rain, it runs off to streams or is absorbed into the ground. Water in streams and rivers is called surface water; water flowing underground or emerging at springs is called ground water.

Rain water collection as the only source of water is only suitable for countries with reliable rainfall all the year round and where other sources of water are not available.

Ground water is usually quite pure because it is filtered as it flows through the ground. However, there are notable exceptions. For example, when ground water is less than 3 meters deep, it may be subjected to surface contamination. In some kinds of rock, particularly limestone, water passing through cracks and fissures is not filtered and contamination may travel over long distances.

A spring is a manifestation of ground water which flows out at surface level. Spring water needs protection from pollution by harmful bacteria introduced from the areas surrounding. As for wells, springs must be properly located and constructed if they are to be made an acceptable source of safe drinking water.

Methods of Water Collection

Rain Water

Rain water is collected from roofs made of tiles, slates or sheeting (galvanized iron, aluminum or asbestos). Bituminous surfaces such as roofing felt make the water unpleasant to taste but do not necessarily render it unsafe to drink. However, when pools of water form where the guttering sags, breeding places for mosquitoes often occur. Furthermore, dust, dead leaves, bird droppings and other contaminants may fall on the roof during dry periods, and be washed down by the first rain into the collecting vessel. Where rain water is collected for drinking purposes, it is advisable to waste the first water which runs off the roof.

Springs

Spring water usually flows from a 'water bearing layer' of sand or gravel, and comes to the surface because a layer of material such as clay or rock (an 'impervious layer') prevents it from flowing downwards. The best places where springs can be found are the slopes of hillsides and/or river valleys. Green vegetation at a certain point in a dry area may also indicate a spring.

Real spring water is usually pure, but it can become polluted if it stands in an open pool, flows over the ground or is penetrated with surface water uphill. Collecting spring water is usually done using a retainer of brick, masonry or concrete, so that the water flows directly into a pipe without ever being open to outside pollution.

River Intakes

In some areas, water is collected directly from a river or stream by some kind of 'intake' structure. These catchment areas usually require extensive planning, engineering,

and structural considerations to prevent the infusion of pollution, and to minimize treatment. The farther upstream the intake area is, the less pollution is usually encountered. If an upland stream is to be used, it is important to keep cattle away from the intake works and preferably off the catchment area altogether. In Africa, big game can be a problem. It is advisable that the intake or watershed area should be fenced to exclude livestock and grassed to prevent erosion. Treatment, discussed in a later section, will always be required to insure safety when surface sources are used. [28]

Wells

1. Well Location

Wells should be located as far as reasonably possible from known or possible sources of contamination. Minimum recommended distances where the soils are consolidated and quite impervious should never be less than soft.

There are five main methods which are employed to extract ground water. See Tables 1 and 2. In rough order of preference these are: (1) driven tube well, (2) bored tube well, (3) jetted tube well, (4) hand-dug well, and (5) bore hole. These methods will be described in subsequent sections.

2. Driven Wells

A driven well is made by pushing a pointed strainer called a 'well point' into the ground. A well point is a specially made metal tube with a point at the lower end, and holes or slits in the sides through which water can filter. These holes are made in special ways, to prevent them from becoming clogged with soil.

As a well point is driven further into the ground, lengths of steel pipe are added to the top. Sometimes a well point can be pushed into the ground by twisting it, or by pumping water down the pipe ("jetting"). More usually, it is driven by hitting the top of the pipe with a heavy weight.

Driven wells require a pump to raise the water from the ground to surface. Most well points are only 30 to 50mm in diameter. Most pumps have a mechanism known as the 'cylinder' which is inserted down the well, and is usually at least 50mm diameter. These wells can be sunk deeper than those using suction pumps. Pumps with the cylinder at the top of the well ('suction pumps') are only suitable for wells less than 8 meters deep.

3. Bored Tube Wells

Tube wells can be bored by using hand tools. Several boring tools, and connecting rods to make the handle longer are needed as the hole gets deeper. The rods are made from ordinary 25mm diameter steel pipe.

The first section of the hole is normally bored with a hand auger. As it is pushed down and turned into the hole, the soil collects between the two flaps, and is lifted to the surface when the flaps bend inward to hold the soil as the auger is lifted. If the soil

TABLE 1*

PRACTICAL DEPTHS, USUAL DIAMETERS, AND SUITABLE GEOLOGIC FORMATIONS FOR THE DIFFERENT TYPES OF WELLS

TYPE OF WELL	DEPTH	DIAMETER	GEOLOGIC FORMATION
Dug	0 to 50 feet	3 to 20 feet	Suitable: Clay, silt, sand, gravel, cemented gravel, boulders, soft sandstone, and soft, fractured limestone. Unsuitable: Dense igneous rock
Bored	0 to 100 feet	2 to 30 inches	Suitable: Clay, silt, sand, gravel, boulders less than well diameter, soft sandstone, and soft, fractured limestone. Unsuitable: Dense igneous rock

TABLE 1 - Continued

PRACTICAL DEPTHS, USUAL DIAMETERS, AND SUITABLE GEOLOGIC FORMATIONS FOR THE DIFFERENT TYPES OF WELLS

TYPE OF WELL	DEPTH	DIAMETER	GEOLOGIC FORMATION
Driven	0 to 50 feet	1¼ to 2 inches	Suitable: Clay, silt, sand, fine gravel, and sandstone in thin layers. Unsuitable: Cemented gravel, boulders, limestone, and dense igneous rock.
Drilled: Cable tool	0 to 1,000 feet	4 to 18 inches	Suitable: Clay, silt, sand, gravel, cemented gravel, boulders (in firm bedding), sandstone, limestone, and dense igneous rock.

TABLE 1 - Continued

PRACTICAL DEPTHS, USUAL DIAMETERS, AND SUITABLE GEOLOGIC FORMATIONS FOR THE DIFFERENT TYPES OF WELLS

TYPE OF WELL	DEPTH	DIAMETER	GEOLOGIC FORMATION
Rotary	0 to 1,000 feet	4 to 24 inches	Suitable: Clay, silt, sand, gravel, cemented gravel, boulders (difficult), sandstone, limestone, and dense igneous rock.
Jetted	0 to 100 feet	4 to 12 inches	Suitable: Clay, silt, sand, ¼-inch pea gravel. Unsuitable: Cemented gravel, boulders, sandstone, limestone and dense igneous rock.

* Table 1 was adapted from Public Health Service Publication No. 24, "Manual of Individual Water Supply Systems." (Revised 1962).

TABLE 2**

RECOMMENDED STANDARDS FOR CONSTRUCTION OF WELLS
IN DIFFERENT WATER-BEARING FORMATIONS AND OVERBURDEN FORMATIONS

Water-Bearing Formation and Overburden	Oversized Drillhole for Grout		Well Diameter		Minimum Casing Length or Depth	Liner Diameter (if req.)	Miscellaneous Requirements
	Diameter	Depth	Cased Portion	Uncased Portion			
Sand or gravel with an overburden of:							
Unconsolidated caving material sand or sand and gravel.	None req.	None	2" min.; 5" or more pref.	Does not apply	20 ft. min., but 5 ft. below pumping level	2" min.	Well screen may be needed for sandfree water; min. diameter 2"
Clay, hardpan, shale, or similar material to a depth of more than 20 ft.	Casing size plus 4"	Minimum 20 ft.	ditto	ditto	5 ft. below pumping level	ditto	Well screen may be required. Fill annular space around casing with cement grout.

TABLE 2 - Continued

RECOMMENDED STANDARDS FOR CONSTRUCTION OF WELLS
IN DIFFERENT WATER-BEARING FORMATIONS AND OVERBURDEN FORMATIONS

Water-Bearing Formation and Overburden	Oversized Drillhole for Grout		Well Diameter		Minimum Casing Length or Depth	Liner Diameter (if req.)	Miscellaneous Requirements
	Diameter	Depth	Cased Portion	Uncased Portion			
Sand or gravel with an overburden of:							
Clay, hardpan, shale, or similar material containing layers of sand or gravel within 15 feet of ground surface.	Casing size plus 4"	Minimum 20 ft.	2" min.; 5" or more pref.	Does not apply	5 ft. below pumping level	2" min.	Well screen may be required. Fill annular space around casing with cement grout.
Creviced or fractured rock such as limestone, basalt lava, granite or quartzite.	ditto	Through rock formation	4"min.	ditto	5 ft. below over-burden of rock	ditto	ditto

TABLE 2 - Continued

RECOMMENDED STANDARDS FOR CONSTRUCTION OF WELLS
IN DIFFERENT WATER-BEARING FORMATIONS AND OVERBURDEN FORMATIONS

Water-Bearing Formation and Overburden	Oversized Drillhole for Grout		Well Diameter		Minimum Casing Length or Depth	Liner Diameter (if req.)	Miscellaneous Requirements
	Diameter	Depth	Cased Portion	Uncased Portion			
Creviced, shattered, or otherwise fractured limestone, basalt lava, granite, quartzite, or similar rock with an overburden of:							
Unconsolidated caving material, chiefly sand or sand and gravel to a depth of 40 feet or more and extending at least 2,000 feet in all directions from the well site.	None req.	None	6" min.	6" pref.	Though caving overburden	4" min.	Seat casing firmly in rock.

TABLE 2 - Continued

RECOMMENDED STANDARDS FOR CONSTRUCTION OF WELLS
IN DIFFERENT WATER-BEARING FORMATIONS AND OVERBURDEN FORMATIONS

Water-Bearing Formation and Overburden	Oversized Drillhole for Grout		Well Diameter		Minimum Casing Length or Depth	Liner Diameter (if req.)	Miscellaneous Requirements
	Diameter	Depth	Cased Portion	Uncased Portion			
Creviced, shattered, or otherwise fractured limestone, basalt lava, granite, quartzite, or similar rock with an overburden of:							
Clay, hardpan, shale or similar material to a depth of 40 feet or more and extending at least 2,000 feet in all directions.	Casing size plus 4"	Minimum 20 ft.	6" min.	6" pref.	Though overburden	4" min.	Seat casing firmly in rock. Fill annular space around casing with grout.

TABLE 2 - Continued

RECOMMENDED STANDARDS FOR CONSTRUCTION OF WELLS
IN DIFFERENT WATER-BEARING FORMATIONS AND OVERBURDEN FORMATIONS

Water-Bearing Formation and Overburden	Oversized Drillhole for Grout		Well Diameter		Minimum Casing Length or Depth	Liner Diameter (if req.)	Miscellaneous Requirements
	Diameter	Depth	Cased Portion	Uncased Portion			
Creviced, shattered, or otherwise fractured limestone, basalt lava, granite, quartzite, or similar rock with an overburden of:							
Unconsolidated materials to a depth of less than 40 feet and extending at least 2,000 feet in all directions.	Casing size plus 4"	Minimum 40 ft.	6" min.	6" pref.	40 ft. minimum	4" min.	Seat casing firmly in rock. Fill annular space around casing with grout.

TABLE 2 - Continued

RECOMMENDED STANDARDS FOR CONSTRUCTION OF WELLS
IN DIFFERENT WATER-BEARING FORMATIONS AND OVERBURDEN FORMATIONS

Water-Bearing Formation and Overburden	Oversized Drillhole for Grout		Well Diameter		Minimum Casing Length or Depth	Liner Diameter (if req.)	Miscellaneous Requirements
	Diameter	Depth	Cased Portion	Uncased Portion			
Sandstone with an overburden of:							
Any material except creviced rock to a depth of 25 feet or more.	Casing size plus 4"	15 ft. into firm sandstone or to 30 ft. whichever is greater	4" min.	4" pref.	Same as oversized drillhole or greater	2" min.	Seat casing firmly in sandstone. Fill annular space around casing with grout. Well screen may be required for sand-free water.
Mixed deposits, mainly sand and gravel, to a depth of 25 feet or more.	None req.	None	ditto	ditto	Though overburden into firm sandstone	ditto	Seat casing firmly in sandstone. Well screen may be required.

TABLE 2 - Continued

RECOMMENDED STANDARDS FOR CONSTRUCTION OF WELLS
IN DIFFERENT WATER-BEARING FORMATIONS AND OVERBURDEN FORMATIONS

Water-Bearing Formation and Overburden	Oversized Drillhole for Grout		Well Diameter		Minimum Casing Length or Depth	Liner Diameter (if req.)	Miscellaneous Requirements
	Diameter	Depth	Cased Portion	Uncased Portion			
Sandstone with an overburden of:							
Clay, hardpan, or shale to a depth of 25 feet or more.	Casing size plus 4"	Minimum 20 feet	4" min.	4" pref.	Though overburden into sandstone	2" min.	Seat casing firmly in sandstone. Well screen may be required. Fill annular space around casing with cement grout.
Creviced rock at variable depth.	ditto	15 ft. or more into firm sandstone	6" min.	6" pref.	15 ft. into firm sandstone	4" min.	Fill annular space around casing with cement grout. Well screen may be required.

** Table 2 was adapted from Public Health Service Publication, "Recommended State Legislation and Regulations...Water Well Construction and Pump Installation Act and Regulations...", July 1965.

is hard or stony, a heavy iron tool on the end of the connecting rods is used to break up the rock or soil. Then the auger is used to remove the broken soil and rock. The auger is brought up to the surface and emptied frequently, to prevent it from becoming stuck at the bottom of the hole. When water is reached, loose soil is excavated either with a spiral or fan auger.

In many soils, especially below the water table, the sides of the hole tend to fall in. A casing is then required. This basically is a strong pipe (normaly made of steel or plastic [PVC]) the same size as the hole. Each length of casing is about 7 meters, and held by at least two strong steel cables so that it can be pulled out when the well is complete. The casing is pushed down as the hole is bored deeper, usually with the connecting rods of the auger. The hole is generally bored at least 7 meters below the water table.

4. Jet Tube Wells

The simplest method of jetting is known as the 'sludger' method, and needs no pump. It is only useful in fine loose soils, such as sands and silts, and is difficult when the water level is more than ten meters deep. It is most appropriate for delta areas where the soil is suitable and ground water is near the surface.

First, a hole about a meter deep is dug by hand and filled with water. Then a piece of steel pipe, about 50mm diameter and 4m long, is inserted vertically into the hole. A pipe coupling, sharpened at the end with a file, is fixed to the bottom to help the pipe cut its way into the soil. A scaffolding of wood or bamboo is built beside the hole, with a lever attached to it. One end of the lever is tied to the pipe by a chain, so that by operating the lever the pipe can be lifted up and down in the hole. An operator sitting on the scaffolding uses his hand as a valve. As the pipe rises he holds his hand firmly over the end, but lets go each time the pipe is allowed to fall. Repeating this up-and-down process pumps water up the pipe, bringing some of the soil with it. The pipe slowly sinks into the ground. As it sinks, further lengths of steel or threaded PVC pipe are added at the top.

The hole is kept full of water. If the soil is very permeable and the water table is deep, it may be difficult to keep the hole full. In some areas, it is the practice to add a little cow dung to the water to seal the soil and slow down the rate at which the water seeps in. It is believed that cow dung will not be dangerous to health as long as the well is properly disinfected on completion. When the hole is complete, the pipe is pulled out, carefully keeping the hole full of water, and a slotted tube inserted as for a bored tube well.

The other jetting methods all require special equipment. Water is pumped down the pipe, and this with a twisting action on the pipe helps it to sink. This requires a pump, and a special swivel connection so that the pipe can be twisted without disconnecting it from the pump. The pipe is hung from a tripod by a pulley to keep it vertical. Usually, a special fitting is attached to the bottom of the jetting pipe.

5. Hand-Dug Wells

Digging a well by hand has been found to be a dangerous business and it is used more often to improve an existing polluted well than to dig a new one. An existing well may be polluted by any of the following means:

- Surface water. If the ground surface water around the well has sunk, surface water may be washed straight down the hole.

- Spilt water. If there is no headwall, or if people stand on the headwall to draw from the well, water which has splashed against their feet may fall back into the well and spread guinea worm and other diseases.

- Seepage water from the surface. Unless the well lining is waterproof for the top 3 meters in clay soils, and preferably for the top 6 meters in sand or gravel, water may seep through.

- The vessel used for drawing water. However often vessels may be rinsed out by users, some pollution of the well may occur.

- Polluted ground water. Wells located too close to pit latrines, soakaways or refuse dumps may be contaminated by pathogens.

- Rubbish thrown down the well. This may be caused by children playing near the well.

6. Boreholes

A drilling rig is required to drill a borehole. A drilling rig is a large machine usually mounted on a truck. This is a very expensive operation. Further, the rig may not be able to reach certain areas.

There are two kinds of rig. The simplest is a percussion rig, which drills the hole by repeatedly dropping a heavy weight into the hole. The other type, a rotary rig, drills by rotating a sharp bit in the hole. Rotary rigs are much faster and can drill harder rock, but they are much more expensive.

Raising and Transporting Water

A very large array of methods are available for lifting water. Unfortunately, many of them are not suitable for small water supplies. Many methods cannot lift water a sufficient height. Others expose the water to the risk of pollution. The cost factor excludes several being too expensive to install and operate. The cheapest and simplest methods can easily be made and repaired with local materials. The major disadvantages are (1) they are less durable, and (2) usually require more maintenance by the local community.

Buckets

The simplest method of raising water is a bucket on the end of a rope. It is virtually impossible to prevent water from being contaminated when open wells with buckets are used. They are not recommended.

Hand Pumps

Hand pumps work more efficiently than buckets and utilize human energy. Of more importance they can be designed and installed to prevent entry of contamination. Most hand pumps work by moving a piston up and down in a cylinder, rather like a bicycle pump. This cylinder is normally at the bottom of the well, and the piston is connected to the surface by a steel pump rod. In a 'suction pump' the cylinder is built into the top of the pump body. Most hand pumps are not used for lifting water from a depth of over 60 meters.

Suction pumps will only function in wells where the water level is less than 8 meters deep.

Another kind of hand pump, the Mono pump, uses a corkscrew mechanism in the bottom of the well and appears more reliable than other types of pumps. The disadvantages are (1) it cannot be used in wells of less than 90mm diameter, (2) it is more expensive, (3) it is more difficult to repair than most other hand pumps.

Wind Powered Pumps

The advantage of wind power is that wind is free. However, a windmill is necessary to use wind power, and windmills are usually rather expensive. Homemade windmills can be made cheaply, but they are not usually strong enough to last very long under village conditions. Like a hand pump most windmills drive a piston in a cylinder.

In order for wind pumps to be effective, enough wind must blow regularly to give a reliable supply of pumped water. Wells pumped by wind power should be equipped with hand pumping arrangements to permit supply of water when there is no wind. Storage tanks big enough to hold several days' supply of water will prove desirable to minimize periods when hand pumping may be required.

Hydraulic Rams and Solar Pumps

Two other types of pumps use naturally occurring sources of energy. A hydraulic ram uses the energy of a rapid flow of a large volume of water to pump a small proportion of that volume. It therefore requires a much larger flow of water (usually 10 to 100 times) than the amount necessary for the community's needs alone. Rams require careful adjustment. Unless carefully designed, homemade hydraulic rams are often shaken apart by vibration.

Solar pumps are suitable for arid areas. Several have been installed in rural areas of West Africa by a French company. Although they may pump as much as 6 liters per second, they require sophisticated technology and are not easy to repair. Rams are cheap. Solar units are expensive.

Diesel and Electric Pumps

Most pumps can be run either by diesel or by electric motors. Electric motors need less maintenance and are usually more reliable than diesel engines. Therefore, where a reliable supply of electricity is available, electric motors are preferable.

Water Storage

In general there are two types of storage reservoirs: large, unprotected reservoirs such as dams (whose purpose is to store water through dry periods of the year) and tanks (for storing water ready for consumption). Tanks, because of their cost, are usually much smaller, and normally hold only one day's supply of water.

A reservoir of quite large capacity can be built cheaply by building an earth dam across a suitable ravine or erosion gully. However, dams can be very dangerous. First, if the water overflows, dams can be washed away in minutes, releasing huge quantities of water onto the area downstream. Secondly, the reservoir may provide a breeding site for mosquitoes and other vectors of disease. There are other drawbacks. Some reservoirs formed by damming streams become filled with silt in only a year or two. Others never fill up--e.g., the ground below them is to porous, the water evaporates as fast as the flow into the dam.

Water Treatment

Storage and Sedimentation

The simplest method of treatment is storage in a covered tank. Water stored for several days will be less likely to contain schistosome larvae, and will likely contain considerably fewer bacteria. The quality of water is improved in a large tank by sedimentation, that process by which silt and other solid material sink slowly to the bottom of the tank. While sedimentation does not remove many of the harmful organisms from polluted water, it helps to make silty water clearer. This is particularly useful if the water is to be filtered, since silty water clogs filters in a short time. In order to produce completely clear water, a specially designed tank must be used and chemicals added to the water to help the sedimentation process.

In any storage tank, the inlet is located above the top water level, while the outlet is about 100mm above the bottom. However, if the inlet and outlet pipes are too close together, some of the water may flow straight by a 'short-circuit' route directly from the inlet to the outlet, while most of the water remains still in the tank.

Filtration

Many impurities can be removed from water by filtering the water. If correctly operated at least 90% of the bacteria and viruses in water as well as some other sources of disease such as cysts, ova and schistosome larvae can be removed by some filters. Sand is the most convenient material for filtering water, but other materials such as burnt rice husks are used.

While various prefabricated filter plants using 'rapid' sand filters or 'pressure' filters are available, they are generally too complicated for operation in small communities. The slow sand filter is not only the simplest to operate it is the most effective in removing bacteria. The operation requires little skill but it does need regular attention.

A slow sand filter consists basically of a large tank containing a bed of sand. The water filters down through the sand bed to a set of drains connected to an outlet well. The filter does not work by a simple straining process. The sand grains in the top layers of the bed become coated with a sticky deposit in which bacteria and microscopic plants multiply. These form a very fine straining mat in the topmost few millimeters, as well as killing most other microorganisms which pass through.

If the water being treated is reasonably clear, a slow sand filter may run for weeks or even months without cleaning. If the water going into the filter is very dirty, it is often cleared up by sedimentation. However, if the sediment in the water is too fine, it does not settle fast enough for sedimentation to work. If the water is still dirty after this initial filtering special chemicals must be added to complete the sedimentation. An alternative would be to add another filter (filled with coarse sand or coconut fiber) before the slow sand filter.

When a slow sand filter requires cleaning, the flow through the filter will slowly drop to the point where it is not enough for the community's need. It is easily cleaned by raking off the top 20mm of sand from the surface of the sand bed and discarding it. When the sand bed becomes less than 600mm thick, more sand is replaced.

Disinfection

Insuring safe water requires constant vigilance. Chlorine can kill bacteria, schistosome larvae, some viruses and, in very high doses, amoebic cysts. Larger water supplies are usually disinfected by adding chlorine, but it is often an unreliable process when used in smaller communities. There is little danger to health from excessive dosing, but if too much chlorine is added, the unpleasant taste may drive people to use more heavily polluted water instead. The main problem, however, is that, unless the chlorinator is filled every week or two, the chlorine will run out. Then there is no easy way of knowing that the water is no longer safe.

Large communities obtain chlorine in pure gas or liquid form in large pressure bottles. For small water supplies, it is obtained from liquid laundry bleach or bleaching powder. This is easier to obtain than bottled chlorine, but the chlorine rapidly loses its strength when exposed to the atmosphere or to sunlight. Even carefully stored in sealed containers in a cool, dark place, chlorine loses half its strength in about a year. A stronger disinfectant, High Test Hypochlorite (HTH) solution or powder, contains about 70% available chlorine. This is slightly more stable than bleach, but should also be stored in sealed containers in a cool, dark place.

Filtration before chlorination is highly desirable since the dirt in the water will absorb the chlorine. Chlorine requires at least an hour to act. When chlorine is being added to a water supply, the amount of chlorine in the water is regularly checked because the amount required will vary, depending on the level of pollution. While, simple chlorinators, which dispense a chlorine solution at a constant rate, can be bought or made with materials available in most developing countries, they are difficult to adjust correctly. Regular attention is necessary to ensure they run reliably.

Aeration

Aeration is sometimes used to remove chemical impurities in water. In a few areas, heavy concentration of iron and manganese give ground water an unpleasant taste, and give a brownish color to clothes washed in it. In other areas various chemicals in the water, while not necessarily harmful, may give an unpleasant taste. Sedimentation and filtration can help to partially remove these impurities. However, if they do not remove a sufficient quantity, people will be annoyed and even stop using the water. When other processes do not succeed, these chemical impurities can sometimes be removed by aeration. Aeration oxidizes the iron and manganese into a fine dark sediment which is easily removed.

An aeration unit consists of four cylinders, placed on top of one another. The top three cylinders each have a mesh or sieve in the base, and ventilation slots in the side. The top two each have a layer of stones 150mm deep, and the third has a 50mm layer of stones covered with 300mm of coarse sand. The unit stands on a solid brick concrete platform.

Water can be pumped in from a hand pump and is sprayed over the stones at the top. It runs down and is collected in the bottom cylinder where it can be withdrawn through a tap at the bottom. The water is exposed to the air as it trickles down through the stones. The sediment is deposited on the sand which requires replacement once a month.

Salt and Fluoride

Salty water can be purified by various methods, but they are so expensive that they are only practicable in special cases or for limited amounts of water. It is almost always better to obtain another salt-free source of water. When ground water is salty as in some flat areas near the sea, there is sometimes fresh water lower down. If so, a deep tube well or borehole may be sunk to reach the fresh water below.

Similar considerations apply to water containing flouride in concentrations over 4 parts per million. This cannot be tasted in water, but in the long term can damage the teeth and bones of those who drink it. It is mainly found in ground water in areas of flat dry scrubland. When another fluoride-free water source cannot be found, flouride is removed by the Naldonda technique, i.e., the addition of lime and alum, followed by sedimentation.

Human Waste Disposal Systems

Characteristics

The characteristics of prevailing methods of human waste disposal as practiced in a sampling of underdeveloped countries are as follows:

- They represent ingrained cultural habits and practices which extend from the cradle to the grave. Altering these customs will be an extremely formidable task.

- They represent probably the worst single source of health problems to the population and are the source of diseases not generally known to the developed countries. By nuturing disease bacteria and providing a rich medium for carriers (flies, mosquitoes, rats, etc.), they affect not only the rural poor, but to some extent, the total population of the country.

- They are characteristic of the agricultural economics of the country in that they represent a principal source of fertilizer for crops.

- Finally, despite the disease problem they are characteristic of the level of funds the country is willing to commit to improving the water and sewer capabilities. Even in a relatively affluent country these may not be high priority items. Should priority be placed upon these projects, then a great deal of importance will accompany the transfer of technology related to both human waste disposal and water treatment.

Cultural Practices

It is extremely difficult to achieve changes in human waste disposal practices. They are part of the basic behavioral pattern of a community and are not readily modified. Many western cultures cannot comprehend the defecation practices of other areas, particularly in parts of Asia. Similarly, many villagers, used to promiscuous defecation in the bush around the village, are reluctant to adopt the use of a latrine-even though latrines are considered primitive by western standards.

It is necessary to understand existing defecation practices and beliefs in order to develop any sanitation program in close cooperation with community leaders. Human waste disposal in rural areas is far more complex socially than it is technically and it may not be appropriate to assign total responsibility for rural sanitation programs to engineers alone. A rural sanitation program requires a team combining engineers, community workers and health personnel.

Elements of the System

The overall process of collecting and disposing of human wastes in underdeveloped areas generally consist of six stages: deposition, collection, transportation, treatment, disposal and reuse. The following sub-sections describe the elements used for each stage and what they do.

Deposition

In developing countries, the most common practice of disposing human waste is promiscuous and spontaneous use of open fields or foliaged areas, slop buckets, or other facilities that happen to be at hand at the moment. When available, the various latrine devices consist of a squatting slab or a water seal device, flushed either by hand or by a cistern.

Collection

After deposition, human waste is normally collected in a pit, tank or bucket. When excreta are kept in one place for a period of time, various bacteria feed on them and cause them to decompose slowly. This process is usually called 'digestion'. In most systems, it takes place underwater. If not underwater, it is usually called 'composting'. For composting to work well, some organic waste such as food leftovers or ashes are added to the excreta. Depending on the amount of air available, different bacteria will multiply and digest excreta; the digestion can be aerobic (with air) or anaerobic (without air). Roughly speaking, aerobic digestion is faster, hotter and more complete. This is less easy to arrange, at least after the initial stages when any available oxygen is quickly used. Following are the advantages and disadvantages of present collection methods:

1. Pit Latrines

   Pit latrines are the commonest and most simple sanitation system. They are almost universally applicable in rural areas and are widely used in urban areas, although often not ideal. In a pit latrine, the excreta are collected in a hole in the ground, generally located directly beneath a squatting slab, and usually dug by hand. When the pit is two-thirds full, it is filled in with earth and a new pit is dug nearby.

   Excreta can be composted in a pit. A composting pit latrine uses two pits, side by side. The excreta in one pit are digested while the other is being used. This composted excreta are then dug out for use as fertilizer.

   Pit latrines are the cheapest system possible and the system most appropriate for self-help programs in which individual householders are responsible for their own sanitation. Certain basic problems exist for pit latrines.

   (a) They cannot be built where there is not enough space to dig and re-dig sufficient pits to receive the excreta of the whole community. In general, pit latrines should be located to allow some separation from the house. As population and housing density increase, problems with lack of space for latrines and pits also increase. However, history shows that many large cities have continued to use pit latrines in spite of the congestion and frequent complaints over odors.

   (b) Where the ground water level is high, the construction of pits can become difficult. They tend to collapse in the wet season.

   (c) Pit latrine construction also becomes both difficult and expensive in rocky ground. The temptation in rocky ground has been to build very small pits, which quickly become filled so that more pits are required. Further, pits dug in loose and unconsolidated soils will collapse.

   (d) The placing of wastes in pits will always present the danger of polluting water sources--particularly wells located nearby. This

has occurred where pit latrines have been built within 30 feet of a well or other drinking water source and have been located uphill from the water source. The danger of pollution is increased if the pit base is below the water table or if the soil contains fissures and cracks. The danger is even greater when large volumes of water are extracted from the well.

Thus, pit latrines are simple and low cost. They can provide a safe means for the disposal of human body waste. Like all methods of disposal, problems exist if poor location, poor construction, or poor maintenance occur.

2. Aqua Privies

An aqua privy is a water-filled tank located directly underneath the point of defecation. It is basically a septic tank directly beneath a latrine. Its advantages over a separate septic tank are that it uses less water and less land, and it does not require solids to be flushed along a pipe and so is less liable to blockage.

The human waste falls directly down a tube or a chute into the water-filled tank. The tank allows the solid material to settle and form a 'sludge' to be digested anaerobically at the bottom, while the liquid 'effluent' flows out through an outlet pipe. The tank has to be kept full of water, to provide a water seal against odors. The effluent from an aqua privy usually flows to a soakaway but it may also be fed into a sewerage system. The sludge which accumulates in the tank must be periodically removed.

Aqua privies require less water and are usually cheaper than any other system with the same standard of protection from smells, flies and disease transmission. The commonest cause of failure of a basic aqua privy is failure to pour into it a couple of buckets of water a day to maintain a seal. It has been found that where public taps are combined with individual aqua privies, householders are very reluctant to carry water from the tap to pour down the privy unless water is required for anal cleansing. It is for this reason that the self-topping aqua privy was devised. Water used in the same block for washing purposes drains into the aqua privy tank, to ensure a sufficient flow of water to maintain a seal. It has proven successful in some areas, but had disappointing results in others such as Zambia due to the blockage of the sewers.

No refuse of any kind can be placed in an aqua privy because it causes premature filling of the tank and failure of the privy. For this reason, aqua privies have worked much better in parts of the world where water is used for anal cleansing (as in Muslim countries) than where sticks, stones or heavy paper may be used (as in parts of Africa). The use of water for anal cleansing has the effect of eliminating the need for paper, etc., of keeping the squatting slab and chute clean and of providing the necessary water to flush through the tank and maintain the seal. Aqua privy vaults have to be routinely cleaned if the system is to function.

3. Septic Tanks

The septic tank is a widely used collection device usually in high or medium income areas. It is a water-tight settling tank normally located underground, away from the house or toilet. Wastes are carried to it by water flushing down a sewer. Septic tanks normally take all wastewater from the dwellings they serve.

A septic tank does not dispose of wastes; it only helps to separate the solid matter and to digest it anaerobically, in the same way as an aqua privy tank. The liquid effluent flowing out of the tank remains to be disposed of, normally by soakaways. The sludge must be periodically removed.

Septic tanks can be used for populations of over 300 but they are most commonly found on individual dwellings. In the tropical cities of the world, houses in relatively high-income, low-density areas not having a sewerage system frequently employ individual septic tank systems. The septic tank often takes all wastewater from the house and thus needs a substantial soakaway. This need for adequate soakage makes the system unworkable in high density areas. The toilet may be of the cistern-flushed or the pour-flushed variety although the cistern-flush is more usual. Clearly, a plentiful supply of piped water is required for a cistern-flushed system and this requires a larger and more expensive tank and soakaway.[29]

4. Cesspools (Leaching Pits)

A cesspool is a covered chamber receiving all wastewaters from a dwelling or dwellings. It is a pit, curbed with open jointed brick or blocks. Emptying may be required depending on the soil and the loading placed on the pit. Cesspools are cheap but may involve high operation costs if the soil is unable to absorb all of the water.

5. Night Soil System

Many households in Japan, Taiwan and other countries store their excreta, plus the small amounts of water used for pour flushing and anal cleansing, in sealed vaults under or beside the house. These vaults are emptied about once every two weeks by various means. This system has relatively high operating costs but may have relatively low initial costs. It is suitable for high density urban areas where access by cleaning units is possible and suitable areas and means exist to dispose of the collected waste.

6. Buckets (Conservancy System)

One of the oldest and generally least hygienic systems is the bucket latrine. A squatting slab or seat is placed immediately above a bucket which is filled within a few days by the excreta of an average family. The bucket is positioned adjacent to an outside wall and is accessible from the street or lane. A sweeper will call regularly--preferably everyday but more typically once or twice a week--and will empty the bucket.

The act of emptying the bucket into the barrow or cart typically involves spillage and the area becomes a center for fly breeding and cockroaches. The same occurs at the depot where the carts are emptied for transportation in trucks or for treatment, composting or agriculture.

In general, all cartage systems which require removal of the night soil by hand from one vessel (e.g., the bucket) to another (e.g., the cart) are extremely unhygienic and offensive. Motorized systems employing vacuum trucks, on the other hand, can be perfectly hygienic and aesthetically acceptable and are used in some modern and wealthy communities. They are more expensive, however.

A bucket system can work under situations of tight institutional control if all operations are closely supervised. It should be regarded as a temporary measure (suitable for camps, for instance) while more permanent installations are being constructed. However, it may prove to be the only feasible solution for high density slum and squatter settlements.

7. Multrums

The 'multrum' dry composting toilet is a technology for the continuous composting of a mixture of human wastes and refuse. It was developed in Sweden and has not yet proved its worth in the tropics or among low-income communities. Multrums have undergone extensive trials in Botswana and Tanzania and the results of these field tests have yet to be evaluated and published. Cost and operational problems will probably restrict use of such units to only a few special situations.

Transportation

It should first be noted that there is no point in having a transportation system unless there is a treatment or disposal system of some kind. Transportation systems are of two types, piped and carted. Waste material is either piped in a flow of water through a sewerage system or is carted without added water.

A sewerage system is a network of large diameter pipes laid at fairly steep grades along which wastewater containing human wastes (called sewage) flows. It is the system found in most communities in Europe and North America and in certain high-income communities elsewhere. Sewerage systems are expensive because they involve laying large pipes in trenches. Unless the lay of the land is unusually favorable, they also involve pumping stations. The design of sewage systems is a complex, but relatively routine exercise for qualified sanitary engineers and is described in many standard texts on the subject. Large quantities of water are needed to move solid wastes along a sewer pipe, so that a cistern flush is normally necessary. For this reason, a pour flush system is not feasible since it uses only enough water to flush excreta a few meters along a straight pipe. However, where only liquid wastes are to be transported, as in the case of the effluent from an aqua privy or septic tank, a cheaper form of sewerage is possible. Because there are no large solids, smaller diameter pipes may be laid at flatter grades at a considerable cost savings.

A cartage system is one in which human wastes are transported by human or mechanical means. In this system no water is used for flushing. Human feces and urine transported in this manner are often called night soil and are sometimes reused for agriculture fertilizer or in fish ponds.

At its simplest, a cartage system is a person with buckets, often carried on a yoke, which are filled from bucket latrines. The next stage up is a hand-pushed cart or a donkey drawn cart. Beyond this, various forms of motorized cartage are possible including the vacuum truck system, which in conjunction with individual vaults, is widely used in the Far East. Motorized cartage is also used in commerical waste disposal systems in this country, serving "port-a-john" installations. Motorized cartage of flushed, chemically treated waste is used in airport flight servicing facilities and in Amtrak's amfleet coaches.

Treatment

Ponds may be used for the treatment of sewage or night soil and can be constructed for a small community (such as a village or a school) or for a large city. Ponds allow treatment through natural biological and physical processes and require no mechanical parts or equipment. They are cheap and easy to construct and their operation and maintenance is more akin to gardening than to engineering. Their rate of operation increases with the rise in ambient temperature, so that they are particularly well suited to tropical climates.

For small systems, three ponds in series are appropriate. The wastes flow by gravity from one pond to the next. The first pond would be a facultative pond (combining both aerobic and anaerobic processes) while the subsequent ponds would be maturation ponds which provide aerobic treatment and greatly reduce the numbers of pathogenic microorganisms in the sewage.

Ponds receive sewage from (1) a conventional sewage system, (2) settled sewage from an aqua privy or septic tank, or (3) night soil which is carted to them and sluiced into them down a ramp. In this last case, water must be added to the ponds to maintain water levels.

Anaerobic digestion may be used to treat night soil. Gas known as 'biogas' and consisting mainly of methane is produced, and may be used as a source of energy as described in the subsection on Reuse. The digested sludge or 'slurry' may be used as an agricultural fertilizer.

Compost treatment is another alternative for night soil treatment in combination with solid waste disposal. Mixed with organic wastes and refuse composting takes place in piles or in pits, and not underwater. If the compost is frequently turned, to allow air into it, it will not produce offensive odors. Temperatures of 50 degrees to 60 degrees Centigrade are needed and efficient composting will take 1-4 months. This combination of time and temperature will cause most pathogens to be destroyed and will produce an inoffensive material suitable for agricultural use.

Conventional Sewage Treatment - Sewage can be treated by trickling filters, activated sludge and chemical methods. Most are costly and require trained personnel for operation and maintenance.

Disposal

There are various methods of getting rid of human wastes. Some of these are linked to reuse systems and will be discussed in the subsection on Reuse.

Trench burying is the disposal of untreated night soil by burying it in trenches at least 0.6 meters deep. Night soil is placed in them to a depth of not more than 0.3 meters, covered with tamped earth to make a small mound of earth over the trench, and then left for at least two years. The chief advantage of the method is simplicity, although good supervision is required to ensure that the trenches are not filled too full of night soil. The disadvantages include the cost of land required, the possible contamination of ground water for supplies and the depredations of domestic or wild animals. Some simple form of reuse such as composting will often be preferable to this.

Soakaways are mostly used to dispose of waterborne wastes on a small scale. A soakaway is basically a pit, lined with stones or a tiled trench through which water can seep. It simply allows the wastewater to filter into the ground and disperse. The size of a soakaway, and the area of land it requires, will be determined mainly by the volume of wastewater produced. The site of a soakaway must be carefully chosen to avoid the pollution of water supplies.

Discharge to a stream, river, lake or sea is another method of disposal of waterborne wastes not connected to a reuse system. The key factors affecting the design of a discharge are (1) the quality and quantity of the sewage, (2) the quality and the quantity of the water into which it is being discharged, i.e., "the receiving water," and (3) the other purposes for which the water may be used. In developing countries where many untreated streams are used as sources of domestic water, there is a danger of pollution by fecal pathogens. The design of a discharge system should be left to competent sanitary engineers, and is described in several standard texts on wastewater engineering and water pollution control.

Reuse

Western cultures in recent years have not regarded human waste as a natural resource because of public health problems associated with reuse and because of unfavorable economics. However, in certain oriental countries human wastes have been considered a valuable natural resource and employed for agricultural purposes. There are essentially three different systems for reuse: biogas production, agriculture and aquaculture. The exact nature of a particular reuse system depends extensively on local conditions.

Biogas, or methane, can be generated from sewage sludge or night soil mixed with animal wastes. The night soil technique is most commonly found in China and India. In India a biogas plant can combine a family's excreta with the dung from three or four cattle to provide the fuel needs for cooking and lighting for a family of five people. As the influent waste is diluted and fed into the digester, the effluent or spent slurry is released and channelled away for use as fertilizer. A biogas plant requires careful control and is only appropriate where good operation and maintenance facilities can be guaranteed.

Conventional sewage treatment plants in many industrialized countries have produced gas from digestion of sewage sludge, and operate most of their equipment by use of the gas.

Agricultural reuse of both night soil and sewage provides enrichment to the soil. The direct application of night soil as an agricultural fertilizer has been practiced for centuries in many parts of the world, but this practice involves very substantial health hazards to agricultural workers and to the consumers of the crops grown, and is not recommended for vegetable crops. Night soil should preferably be either anaerobically digested, or composted with organic refuse and vegetable matter, before application to the land.

Similarly, waterborne should first be treated in waste stabilization ponds and the pond effluent used for irrigation. It is preferable from a public health viewpoint to use sewage effluent to irrigate crops such as trees or cattle fodder rather than crops intended directly for human consumption. It is especially inadvisable to use either night soil or sewage effluent to fertilize fruit, vegetables or any crop which may be eaten uncooked.

Aquaculture is a more recent reuse of wastes. Ponds containing human wastes are rich in aquatic life provided they remain in an aerobic condition. In particular, they support large blooms of algae. These conditions are perfect for the growth of certain types of fish, especially carp and tilapia. Fish productivities of 2-3 tons per hectare per year can be achieved in ponds enriched with excreta. Ducks will also thrive, in conjunction with fish, in such ponds.

It is possible to feed fish ponds with a certain amount of night soil brought in carts from a nearby community, or to locate latrines over ponds for the direct entry of excreta, or even better, to grow fish in maturation ponds of waste stabilization, which are treating waterborne wastes. All those arrangements are commonly employed today, particularly in South East Asia.

The fish harvested may be used to produce high-protein meal for pig or poultry farming but are usually sold for domestic consumption. However, if the fish are for human consumption it is important that they are well cooked. Otherwise, the contaminated fish may act as the main transmission route for a variety of pathogens, most notably the oriental liver fluke (Clonorchis sinensis).

TABLE 3

A SUMMARY OF THE SIGNIFICANT CHARACTERISTICS OF THE THREE CLASSES OF DISPOSAL SYSTEMS

	WATERBORNE	CARTAGE	ONSITE
Capital Cost	High	High/low	Low
Operating Cost	Low	High	Low
Offshore Cost Component	High	High/low	Nil
Water Consumption	High	Low/nil	Low/nil
Optimal Density	High density (high rise)	High density (low rise)	High and low density (low rise)
Adaptability to Incremental Implementation	Nil	High	High
Adaptability to Self-Help	Nil	Low	High
Reuse Potential	High	High	High/low

SOURCE: Witold Rybczynski, Chongrak Polprasert, and Michael McGarry, Low Cost Technology Options for Sanitation: A State-of-the-Art Review and Annotated Bibliography, Ottawa, Ontario, IDRC, 1978, p. 37.

SECTION III

THE TRANSFER OF TECHNOLOGY: PLANNING A VILLAGE WATER SUPPLY PROGRAM

In planning projects in rural areas, the guidelines summarized below are considered the most useful in the literature. They were developed by Feachem, et al. and were published in Water, Health, and Development: An Interdisciplinary Evaluation.[30] Many of the recommendations put forth by Feachem, et al., in retrospect, were incorporated in a program in Latin America. A useful case study of that program is "The Introduction of Potable Water and Latrines: A Case Study of Two Rural Communities in Guatemala," by Patricia K. Buckles.[31]

Three useful documents in planning projects in urban areas are World Bank products: "Appropriate Sanitation Alternatives: A Technical and Economic Appraisal," "Sanitation Program Planning, A Field Manual," and the "Country Guidelines" which is used in collecting field data to evaluate various technology options. A copy of the "Guidelines" is attached as Appendix A of this report.

Planning A Village Water Supply Program

Feachem, et al., have mapped out the "Chain of Decision-Making"[32] whereby a village water supply program should be planned. Observing that water and waste disposal projects are already being implemented, they state that program planning must begin with evaluation. What benefits are being achieved and what benefits may be achieved must be determined in order that specific economic or social goals can be built into the program.

Once evaluation has determined the possible benefits or goals, required complementary measures can be coordinated to achieve the optimum cost benefits. Then, the local institutions already existing or which could be established for management of the water supplies, including local, "self-help" inputs must be considered. The above, together with factors such as construction cost and availability of materials and water sources will dictate the range of most appropriate technologies to be used. The circumstances of each village will determine the most suitable choice of technology. Next, the strategy for selection of villages to be supplied must be devised. Finally, the government's administrative structure and procedures should be designed to suit all of the above "constraints." Appraisal, disbursement, and monitoring should be adapted to the program design. Each of these points on the "Decision Chain" will be examined in detail below. All of the material that follows is excerpted verbatim from the text and should be properly credited to the authors, Richard Feachem, et al., White, et al.

Goals and Benefits

Table 4 sets out a scheme of potential benefits which would result from different improvements designed into a water supply project. Potential benefits are broadly classed as: time savings to the households, health improvements, redeployment of labor to productive activities, agricultural improvement, and economic diversification.

While improvement in the quality, quantity, availability, and reliability of water cannot be achieved to the maximum extent in every community, the proper selection of improvements appropriate to a particular case requires an examination of the potential benefits from a water supply. It is necessary to assess the degree to which different improvements will realize different levels of benefit. In this way, the improvements with the most impact at a given cost can be determined and the anticipated cost-effectiveness of alternative schemes can be compared. For example, accessibility yields the immediate benefit of time savings, and if associated with greater water use, may improve health. Greater quantities of water, if used, may bring about improvements in hygiene and hence in health, with a conceivable spinoff in increased productivity. On the other hand, unforeseen factors may cause an improvement in water supply to have deleterious side affects. More reliable water supply can be associated with overgrazing and desertification in some arid places, and a leaky piped supply, while making water more accessible, may provide a focus for transmission of waterborne disease, or provide a new site for mosquito breeding in the dry season. The extent to which a particular benefit can be gained will depend greatly on the prevailing economic and environmental circumstances. For instance, where labor is not a constraining factor of agriculture production, labor release will be of little benefit to agriculture.

Complementary Inputs

Table 5 lists some of the necessary preconditions or complementary inputs which should be taken into account if particular benefits sought from a rural water supply program are to be realized. Once benefits are decided upon, projects can be designed with the specific benefits or goals in mind. The cost-effectiveness of a design can be assessed and compared with that of rival designs by weighing the cost against the anticipated benefits. Then, national and regional planning and resource allocation can proceed within the rational framework of attempting to achieve the defined goals.

In general, the design goal of rural water supply improvements should be to reduce the cost of water to the rural poor, where the cost of water to the individual is made up, as suggested by White, et al. (1972), of the sum of:

(1) Any cash payment made to the water authority to the standpipe owner, to the water carrier or vendor, etc.

(2) The value of the time and energy expended in collecting water where the individual lacks water supplied to the dwelling.

(3) The cost of sickness related to the use of polluted water, to the use of insufficient water or to diseases acquired in the course of water collection.

TABLE 4

RELATIONSHIPS BETWEEN WATER SUPPLY IMPROVEMENTS AND POTENTIAL BENEFITS

BENEFITS	ACCESSIBILITY	QUANTITY	QUALITY	RELIABILITY
Time-saving	Saving on the water collection journey for each household	-	-	Saving during season when unreliable sources fail
Health Improvement	Water piped into homes may increase quantity used (see next column) and reduce exposure to water-based disease	Potential improvement in hygiene if additional water is used	Precludes one avenue of faecal-oral disease transmission	May avoid seasonal use of more polluted sources of water
Labour	Labour released by time-saving, and indirectly by health improvement	Indirect through health improvement	Indirect through health improvement	Seasonal time-saving

TABLE 4 - Continued

RELATIONSHIPS BETWEEN WATER SUPPLY IMPROVEMENTS AND POTENTIAL BENEFITS

BENEFITS	ACCESSIBILITY	QUANTITY	QUALITY	RELIABILTIY
Agricultural advance	Possible indirect benefit from labour release	Surplus or waste available for gardening	-	Seasonally significant in some cases
Economic diversity	A prerequisite, but not usually a major one	A prerequisite, but not usually a major one	-	Permits permanent settlement

SOURCE: Richard Feachem, et al., Water, Health and Development: An Interdisciplinary Evaluation, London: Tri-Med Books, Ltd, 1978, p. 210.

TABLE 5

PRECONDITIONS AND COMPLEMENTARY INPUTS FOR WATER SUPPLY BENEFITS

AIM OR BENEFIT	PRECONDITIONS OR COMPLEMENTARY INPUTS
Time-saving	New supply used in preference to old, and closer to dwellings than old; supply competently built and maintained
Health Improvement	Hygiene changed to take advantage of improved supply; new supply must not create new health hazards
Labour Redeployment	Economic opportunity in agriculture or industry
Agricultural Advance	Any benefits from domestic water supply alone are very small compared with those from new markets or new technology such as large-scale irrigation
Economic Diversity	Water must be one component in a growth point strategy, although growth points will normally be towns, not villages

SOURCE: Richard Feachem, et al., Water, Health and Development: An Interdisciplinary Evaluation, London: Tri-Med Books, Ltd, 1978, p. 212.

This approach of cost assessment facilitates the allocation of priorities by determining which communities currently bear the highest cost for water, and in which communities the greatest reduction of cost to the consumer by the expenditure of 'x' dollars per head on water supply improvements can be most effective. The two sets of communities may or may not be the same. The final allocation of government resources is always a political decision. Other factors, such as the willingness of the community to contribute to the cost of the system and community organizational ability may be included to evaluate and prioritize potential projects.

Local Institutions

If village water supplies are to work effectively, local participation is indispensable, particularly in the areas of maintenance and repair. Table 6 identifies some of the ways in which rural people can participate in the provision of water supplies. In reviewing these possibilities, the object is to find the best means of enabling small community water supply systems to be built cheaply and effectively, to serve the public at minimum cost and, most importantly, to be reliably maintained and operating efficiently. These requirements form the column headings of Table 6. By considering alternative forms of organization against these functional requirements, it is possible to compare strengths and weaknesses in the management of rural water supplies. The most suitable system for village level management of water supplies will depend on many factors and vary from country to country. In some, there will be an existing village organization which can easily be adapted to the extra tasks required. In others, particular systems will be inappropriate because of a tendency to engender village factionalism, because they do not concur with the government's overall policies for village development, or other reasons.

The choice of the most appropriate overall system for village level management of water supplies is only a first step. A government must also give some careful consideration to the detailed operation of village level institutions, in order to provide clear guidance to the villages. A good example is the need for the government to draw up a model constitution for village water committees, which would assist community workers and villagers to establish an institution in which: (1) the basic pitfall has been foreseen and (2) a good chance of successful operation is forecast. For instance, the constitution would help to establish exactly which individuals would be responsible for each practical task, such as repairing a water supply or keeping a minute book. The constitution would also define to whom they should be responsible, subject to which sanctions, and what government support they could expect in carrying out their task.

Once the government's policy on village level organization has been determined, it must be advertised as widely as possible. In the absence of a clear government policy, made known to all concerned, it is inevitable that destructive conflicts will arise between the various forces competing for power, prestige and influence in most rural communities. Proclamation of such a policy is unlikely to suffice on its own, to prevent such conflicts, or to harness them to productive ends. Nonetheless, an official policy document would be an invaluable tool in the hands of the government or party officials who have the thankless tasks of arbitrating, adjudicating, administering, advising and encouraging. These officials, in turn, must be able to call on their superiors for advice, encouragement and material support in the execution of the policy. A government must be prepared to make a real political and material commitment to the policy it promulgates. Delegation of

TABLE 6

VARIATIONS OF VILLAGE LEVEL ORGANIZATION

TYPES OF ORGANIZATION	KEY REQUIREMENTS				COST	
	Construction	Maintenance	Access	Motivation of Manager	To Authority	To User
Water authority with water rate	Direct employment or contract: construction may be efficient, but expensive	Routine maintenance possible	Open to the public by right	Bureaucratic	High cost, but offset against the prospect of recurrent income	User faces recurrent charges that will be substantial in the case of small supplies
Water authority with some management delegated to local individual or committee	Community participation in fund raising and in construction can be organized	Some local maintenance or 'firstaid' repair can be institutionalized, but responsibility rests with water authority	Open to the public by right	Local managers receive some kind of reward	Initial cost may be reduced but recurrent costs must be met	User pays thru participation, thereafter only indirectly thru taxation

TABLE 6 - Continued

VARIATIONS OF VILLAGE LEVEL ORGANIZATION

TYPES OF ORGANIZATION	KEY REQUIREMENTS				COST	
	Construction	Maintenance	Access	Motivation of Manager	To Authority	To User
Private supply or institution supply with access to public	Private; no administrative involvement	Private; no administrative involvement	Access by payment (per container or per month)	Interests of owner/user plus possible profit in some cases	Some subsidy may be necessary to secure standards and to secure access for the public	Commercial fee unless there is private or public subsidy
Water users' association	Association constructs with some technical assistance	Association responsible for maintenance	Access to members only	Corporate interests of members plus token share of dues		
Very local authority or commune	Water supplies constructed as a communal facility	A routine activity for a work team or department	By right of community membership	Water Management one of several functions	Grants and supervision costs	Costs met out of local tax or in a commune; production profits

SOURCE: Ricahrd Feachem, et al., Water, Health and Development: An Interdisciplinary Evaluation, London: Tri-Med Books, Ltd., 1978, p. 226.

certain tasks to village-level institutions does not remove the necessity of providing the support these institutions require to carry them out effectively. Broadly, this will first consist of supervision, advice and guidance on the running of the institutions themselves and of help when organizational or political problems are encountered, and secondly, of assistance with those technical tasks which the villagers are unable to carry out unaided.

The Technology

Options

The chief desirable attributes for a particular type of water supply will generally be: (1) the reliability of its continuous operation, (2) its ability to supply adequate quantities of safe and acceptable water as near as possible to the user, and (3) a cost which bears some reasonable relationship to the available resources and the social or economic benefits which are anticipated. In practice, more than one technology will meet the chosen goals under any given conditions, although some may do so better than others. In order to formulate the decision as to the choice of technology, it is necessary to compile as long a list as possible of the available types of rural water supply. Ideas from this list may be derived from supply systems built in the past in the same country or abroad, or from handbooks on the subject. This list may then be cut down to manageable size by elimination of those types of supplies which cannot bestow the design benefits of the program. Before eliminating each type, it should be considered whether any modification is possible which might enable the system to operate effectively.

An important characteristic of each type of supply is the amount of required maintenance. Generally, the more maintenance a system needs, the less reliable it will be in the long term. It is worthwhile to enumerate maintenance tasks required for each type of supply options–such as lubricating a bearing, or changing a washer, etc. Also, indicate the frequency with which each task must be done. The type of water supply and the level of technology employed will determine the amount of maintenance work required. The type of work may determine the extent to which it can be delegated to the villagers. Re-laying of pipes exposed by erosion, for example, is a task villagers can organize and carry out themselves, whereas servicing a pump may require equipment beyond their means.

Each possible type of water supply should then be considered in the context of the administrative and institutional framework within which it would be built and maintained. It is important that responsibility for each maintenance task be clearly allocated. Decisions must be made to determine the extent in cash and labor of any self-help contributions to construction and maintenance, that the rural communities would be expected to make and to determine which present or proposed local institutions would manage these contributions, and what powers they would have. Decisions are also required at this stage about the government's contribution to construction and maintenance, and the administrative structure through which it is to be directed. In other words, it must be decided who is to pay for, build, own, control, and maintain and repair a village water supply.

Similarly, decisions must be made about the technical design of each proposed type of supply. Each feature which is likely to have any major effect on cost, on maintenance

requirements or on the ability of the supply to provide the design benefits, should be identified, at least in outline form. For instance, it should be decided at this stage whether each particular type of water supply is to include water treatment facilities, and of what kind. The type of water point--standpipe or public washhouse--and the number of them to be provided in a typical village should be chosen at this stage. These decisions usually require research in the field. The design of a water supply requires knowledge of existing water use patterns--of daily water use per head and of daily and hourly peak factors--and how the introduction of the supply may change these. Also, it is important to ascertain how close the supply must be to each household if the villagers are to use it in preference to their traditional sources of water. It is also necessary to know typical pumping needs and lengths of trunk mains. A survey of existing water supplies will help to show which types are more reliable in practice, and why.

Costs

Estimates should then be made of the construction costs of each major component of each type of supply. The components would then be items such as trunk main, storage tanks, and distribution system; and their costs would be expressed as costs per head or cost per kilometer per head. The most influential factor will be the population of the community served by each supply. Therefore, it will probably be most convenient to estimate the cost of each component for a variety of populations, and plot the graph of cost per head against population served. Several graphs may be plotted to examine the variation of the costs between geographical graphs and should suggest advantages of one type of component over another. The costs of components can then be combined to give costs of complete water supplies of each type under typical conditions. These total costs may be plotted against the population of the community served. Where local institutions and the terrain permit, it may be worthwhile to consider the possibility of serving several communities from one supply and a secondary graph of cost per head may be plotted against the total population served.

Choice

The formulation of the choice of technology by listing the available range of options involves careful study and consideration of every aspect of the execution of the program. Once the range of choices have been formulated, it is relatively easy to see which type of water supply is more appropriate to local conditions. In formulating costs, some factors should be kept in mind. Cheapness of construction is not the only criterion to be used in choosing the most appropriate technology for village water supply. The cost of maintenance may be equally important. Also, simple financial costs may not truly reflect the true cost to a country's economy, where foreign exchange is scarce and unemployed labor is plentiful. Cost is only one side of the cost-benefit account. The ability of the type of water supply to bestow the design benefits determines the other side. A judgment is required concerning the relative importance of these benefits, and their cost.

For example, handpump supplies may be cheaper than gravity-fed spring supplies, but they may not bring water quite as close to a typical household. Handpumps would reduce the time saved in water collection and may not be as reliable in practice as gravity supplies. Choosing the most suitable technology by weighing the costs and benefits of each should permit priority to be given to those communities where the greatest benefit can stem from the construction of water supplies at the least cost.

Village Selection

After the choice of technology, the next link in the chain of decisions is to determine the policy for selection of villages to receive water supplies. Together with the choice of technology, it is these guidelines which will determine the physical form of the village water supply program. Like the choice of technology, they too should depend on the goals of the program and the feasibility and cost of attaining them for different communities. With clear goals, the need to coordinate water supply construction with complementary measures such as the provision of clinics will become apparent. The goals may also include the desire to serve target populations. The necessity of selecting communities where adequate maintenance arrangements are feasible could lead to the rejection of communities where no community contribution to maintenance would be forthcoming. The cost of providing the service is also important.

All factors affecting village selection may not coincide. For example, communities with particularly high incidence of water-related disease and those with enthusiasm for self-help will not necessarily be the same or the cheapest in which to build systems. The different factors must be weighed and a decision made on how much importance to attach to each.

There are advantages in expressing selection criteria in the form of easily ascertained facts about each village, such as the village's population, the presence of a clinic or a school, and the distance from its present source of water and from the source proposed for the improved supply. These are chosen to give an approximate measure of the relative cost of each proposed scheme, and of the anticipated design benefits. It enables the selection to be made by local staff without technical assistance and it would make the criteria comprehensible to the villagers. Once they have been agreed upon, the policy and procedures for selecting communities to receive supplies must be made widely known. The final decision for inclusion should probably rest with the villagers after cost and technical feasibility has been determined. The village decision can be expressed in a written agreement signed by community heads of household committing contributions of labor, materials and operation and maintenance fees.

Administration

The responsibility of organizing water supplies could be given to any one of several different agencies. For example, a branch of the central government or the local government could be made responsible; or a private company or a private contractor; or the responsibility might be delegated to the village administrators. In all cases, there is a need at the central government level for a clear delineation of administrative responsibility for rural water supply, preferably with the functions of construction and maintenance consolidated under a single agency. The Ministry of Health should at least be brought into the planning process to identify priority health needs, since it is best able to mount any health education program that is required as a complementary input. It may be best to give the Ministry of Health the overall responsibility for rural water supplies, since water supply is an important part of a rural health care program, and the Ministry of Health will be particularly well suited to administer maintenance where it has a health auxiliary in every village.

The administration of rural and urban supplies under a single department may not be advisable, however, unless the rural supplies are catering to large communities. The technology most appropriate to rural supplies is generally different from that required for large urban water supply systems, and there is a danger that urban standards may be incorrectly applied to rural communities. Where this does not arise, for example, when the rural supplies serve large settlements, there would still be other problems of incompatibility. Urban and rural supplies are managed by different institutions, and financed in different ways. Urban supplies are generally intended to be self-financing, subsidizing their public standpipes from water rates paid by the large consumers, and are often run by quasi-governmental agencies whose construction activity is funded by loans. Rural water supplies, on the other hand, usually have a negligible financial return, and so are generally run by government departments often financed by donor aid.

A number of different agencies can develop water supply programs. But structurally, the main contrast is between a self-help approach and a direct administration approach. Tables 7 and 8 contrast the two approaches, and Table 9 describes a recommended compromise model. In the compromise model, the government's planning prerogative is exercised at central level along with the necessary programming and funding activities. At the same time, village level organization and participation is encouraged. The key element in the approach is a carefully formulated policy, expressed in clearly stipulated project selection criteria for local level planning and implementation. The function of the central office would be to establish which benefits might be expected to follow from water supply development schemes and to identify geographical areas or categories of villages which are to be given priority. Local level planning and implementation procedures then follow these guidelines. The compromise has consequences for the nature of self-help in villages. Villages would not be invited en masse to participate in a scheme; only those that meet project selection criteria would be approached. Also, villages would not be asked to identify their own requirements. Rather, they would be approached by the authorities with various project proposals depending on their circumstances.

In this approach, much depends on the effectiveness of the district level office. A fairly sophisticated and controlled set of procedures would be required to incorporate the project selection criteria laid down from above, to contain the endeavors of the various villages, and to work out a carefully scheduled program. District level staff would also have to be skillful at encouraging, educating, and advising the villagers on organizational matters, and at settling any disputes. Finding staff of an adequate caliber to manage this may be one of the principal constraints on the self-help approach, but with planning, much of the necessary administration can be reduced to routine procedures. The crucial coordinating role of the local office cannot be avoided if any element of participation is to be allowed. Appendix B describes a project in Guatemala incorporating most if not all of the elements described in this model.

Summary

For maximum health benefits to be achieved, for both urban squatter settlements and rural villages, the installation of an improved water supply should be complemented with health education to improve water use practices and excreta disposal facilities. In coordinating water supply and excreta disposal activities, the most critical constraints

TABLE 7

A DIRECT ADMINISTRATION MODEL

ACTIVITY	CENTRAL AUTHORITY	BRANCH OFFICE* DISTRICT OR REGION	COMMUNITY
Establish priorities	Decide project selection criteria	Modify selection criteria to suit local conditions	
Plan	Obtain information, allocate resources to regions	Interpret government priorities, select projects	
Fund	Collect revenue and disburse central grants and donor funds	Collect water rates, prepare project memoranda	Pay rates individually
Implement	Provide central technical advisory unit, purchase materials	Employ labour and organize construction	
Maintain	Provide maintenance funds	Employ maintenance staff	

* The branch office is not strictly essential to this model and most of its functions may be absorbed by the central authority.

SOURCE: Richard Feachem, et al., Water, Health and Development: An Interdisciplinary Evaluation, London: Tri-Med Books, Ltd., 1978, pp. 247, 249.

TABLE 8

THE SELF-HELP MODEL

ACTIVITY	CENTRAL AUTHORITY	BRANCH OFFICE* DISTRICT OR REGION	COMMUNITY
Establish priorities	Allow priority for self-help		Choose 'felt-need'
Plan	Prepare project plans incrementally (muddle through)	Encourage and examine applications from communities for assistance	Establish local organization
Fund	Disburse central grants and donor funds	Collect self-help contributions, prepare project memoranda	Raise funds and make labour available
Implement	Provide central technical advisory unit, purchase materials	Provide technical supervision	Contribute labour under supervision or hire local contractor
Maintain	Provide maintenance funds (often neglected)	Employ maintenance staff (often neglected)	Provide occasional labour of services of a volunteer, alert branch office when necessary

* A well staffed and well supported branch office is absolutely essential to this model.

SOURCE: Richard Feachem, et al., Water, Health and Development: An Interdisciplinary Evaluation, London: Tri-Med Books, Ltd., 1978, pp. 247, 249.

TABLE 9

A COMPROMISE MODEL; CONTROLLED SELF-HELP

ACTIVITY	CENTRAL AUTHORITY	BRANCH OFFICE* DISTRICT OR REGION	COMMUNITY
Establish priorities	Decide upon project selection criteria		
Plan	Obtain information, allocate resources to regions on priority grounds	Select suitable villages and invite them to apply for specifid projects	Organize, ut only proceed wl en invited
Fund	Disburse grants and donor funds	Collect self-help contributions, prepare project memoranda	Raise specific funds and labour on an agreed basis
Implement	Provide central technical advisory unit, purchase materials	Provide technical supervision	Contribute labour or pay for work as arranged
Maintain	Provide maintenance funds	Employ maintenance staff	Provide occasional labour or services of a volunteer, alert branch office when necessary

* A well staffed and well supported branch office is absolutely essential to this model.

SOURCE: Richard Feachem, et al., Water, Health and Development: An Interdisciplinary Evaluation, London: Tri-Med Books, Ltd., 1978, p. 251.

appear to be folklore and custom. Waste disposal practices are part of the basic behavioral pattern of a community and are not readily modified. It is necessary to understand existing defecation practices and beliefs in order to develop any sanitation program in close cooperation with community leaders.

The overall process of collecting and disposing of human wastes in underdeveloped areas generally consists of six stages: deposition, collection, transportation, treatment, disposal and reuse. Current water supply is determined from the source of water, its accessibility and its purity and it must be able to supply enough safe, clean water for the community. Rain water collection as the only source of water is only suitable for countries with reliable rainfall all the year round and where other sources of water are not available. Ground water is usually quite pure because it is filtered as it flows through the ground.

Wells should be located above and as far as reasonably possible from known or possible sources of contamination. There are five main methods which are employed to extract ground water. These are (1) driven tube well, (2) bored tube well, (3) jetted tube well, (4) hand-dug well, and (5) borehole.

The simplest method of water treatment is storage in a covered tank. Water stored for several days will be less likely to contain schistosome larvae, and will likely contain considerably fewer bacteria. Many impurities can be removed from water by filtering the water. Filtering can remove 90% of the bacteria and viruses in water as well as cysts, ova and schistosome larvae. Large water supplies are usually disinfected by adding chlorine. Insuring safe water requires constant vigilance.

In general there are two types of storage reservoirs: large, unprotected dams and tanks. Dams can be built cheaply but can be very dangerous. If they burst, they release large quantities of water down stream. They may also provide a breeding site for mosquitoes and other vectors of disease.

In planning pilot projects in urban areas, planners should consult "Appropriate Sanitation Alternatives: A Technical and Economic Appraisal" and "Sanitation Program Planning, A Field Manual." Both documents are outputs of the World Bank Research Project. In general, the design goal of rural water supply improvements should be to reduce the cost of water to the rural poor. Cost assessment facilitates the allocation of priorities by determining which communities currently bear the highest cost for water. The final allocation of government resources is always a political decision, but if village water supplies are to work effectively, local participation is indispensable, particularly in the areas of maintenance and repair.

The choice of the most appropriate overall system for village level management of water supplies is only a first step. A government must also give some careful thought to the detailed operation of village institutions in order to provide clear guidance to the villages. Once the government's policy on village organization has been determined, it must be advertised as widely as possible. A government must be prepared to make a real political commitment to the policy it promulgates. This will consist of supervision, advice and guidance on the operation of water and waste treatment programs. In addition, emphasis should be placed on villagers' participation, such as education and training with regard to maintenance and use of water and sanitation systems.

In order to formulate the decision as to the choice of technology necessary, a list should be compiled of possible available types of rural water technology. Each type of water and sanitation technology should then be considered in the context of the administrative and institutional framework within which a system would be built and maintained. Similarily, decisions must be made about the technical design of each proposed type of equipment. Estimates should then be made of the construction costs of each major component of the project.

The formulation of the choice of technology by listing the available range of options involves careful study and awareness of every aspect of the execution of the program. After the choice of technologies, the next link in the chain of decisions is to determine the policy for selection of villages to receive water supplies. These are chosen to give an approximate measure of the relative cost of each proposed project and of the anticipated design benefits.

The responsibility of organizing water and sanitation programs could be given to any one of several different agencies, but the administration of rural and urban supplies under a single department may not be advisable, unless the rural agencies are catering to larger communities. A number of agencies can develop water supply programs. But structurally, the main contrast is between a self-help and a direct administration approach. The key element in a compromise model of these two approaches is a carefully formulated policy, expressed in clearly stipulated project selection criteria for local level planning and implementation.

SECTION IV

PROBLEMS OF TECHNOLOGY TRANSFER

The National Research Council has identified that a major hazard to the health and well-being of most people in developing countries is the horde of infectious agents in their environment. Most of these infections reach the people, directly or indirectly, via contaminated water or because not enough water is available for household and personal hygiene. More than half the world's population has no reliable and safe water supply; 70 to 80 percent has no sewage disposal. Furthermore, women and children spend hours hauling water from distant sources, using time that might otherwise be spent on more productive activities. An overall problem is the growing competition among many essential uses for scarce water resources.

Despite the availability of engineering capability in developing countries and substantial international interest, progress has been slow in providing adequate supplies of safe water to village households and to many metropolitan areas of developing countries. More effective systems are needed for assessing available water supplies, conserving their use, and influencing their distribution and methods of use. The selection of appropriate water system technologies by developing countries--systems that can be maintained and operated effectively with local resources--would stretch scarce capital, allowing more water systems to be constructed and successfully operated.

Adequate convenient supplies of safe water and sanitary facilities are essential to improving the quality of life whether in rural villages or urban squatter settlements of developing countries. Safe water prevents contact with debilitating, often fatal, water-related diseases like cholera, typhoid, enteric infections, hepatitis, schistosomiasis, and malaria. Hygienic conditions in the home help limit the spread of skin infections, lice, mites, and trachoma. Convenient supplies of water (not necessarily from costly in-house connections but from simple courtyard standpipes) reduce the daily burden of women and children who would be, instead of hauling water, spending their time on productive activities such as producing food or attending school.

Cities and towns use far more water than rural areas. This larger use of water alters the primary problem from one of providing a reliable supply of water in rural areas to one of pollution by sewage flows in metropolitan areas. Improved disposal of wastes and wastewater, an integral aspect of water systems, limits the transmission of water-related diseases such as hookworm, roundworm, and others. Such systems need not be sophisticated, but appropriate to the needs and resource levels of the community and household.

The impact of infectious diseases due to poor sanitation and to improper sewage disposal and water treatment in developing countries is enormous. Infectious diseases fall into three categories with respect to the knowledge and resources needed to deal with them. Cholera, diarrhea, and typhoid, among others, are a category of diseases which are exacerbated by malnutrition, large and poorly spaced families, and unsanitary living conditions. Here innovation in medical technology is less important than social change and progress in providing pure and ample water. An important need is for more social science research on involving communities in new forms of health-related activities and developing more effective delivery systems for preventive health information.

Governmental Options

Because the responsible government agency is concerned with the water supply of the urban and rural poor, it is obliged to take a position on each of the options outlined in Diagram 1. These are diagrammed as connected with each other and proceeding in a fixed time sequence. The choice may begin with a commitment to a maximum capital expenditure, with a political declaration of the type of service to be provided, or with any other option. It finally must embrace decision at each of the other points.

The particular government must decide whether it wishes to encourage or discourage occupation of an area which has been developed as a shantytown or which is in imminent danger of conversion in that direction. If it wishes to discourage use of the site it may:

1. Destroy the settlement, or

2. Ignore the situation and let the population shift for itself, taking the public health and social costs as they accrue, and generally permitting further development to take place.

If it wishes to encourage eventual use of the site but does not wish to actively promote immediate development it may:

3. Seek to reduce health hazards by a combination of community and public health education to alert people as to the hazards and the closing of contaminated sources; or

4. Plan for later improvement by designing appropriate transmission lines, specifying ground layout, and undertaking community education looking to the organization of self-help or other groups to work for improvement in the community.

In these instances it does not at the time undertake new works, although it may provide for later service of the area by including estimates of the needed supply for the development of new water supply facilities. The term "community education" is used here to mean any organized activity to inform the people as to risks and opportunities for action and to assist them in taking independent or group action. A similar problem arises in old slums which have never received adequate water supplies. There, the possibility of abandoning the area is slim, and the choice is among ways of serving the continuing population.

DIAGRAM 1

DECISIONS IN CHOICE OF WATER SUPPLY SERVICE FOR THE URBAN AND RURAL POOR

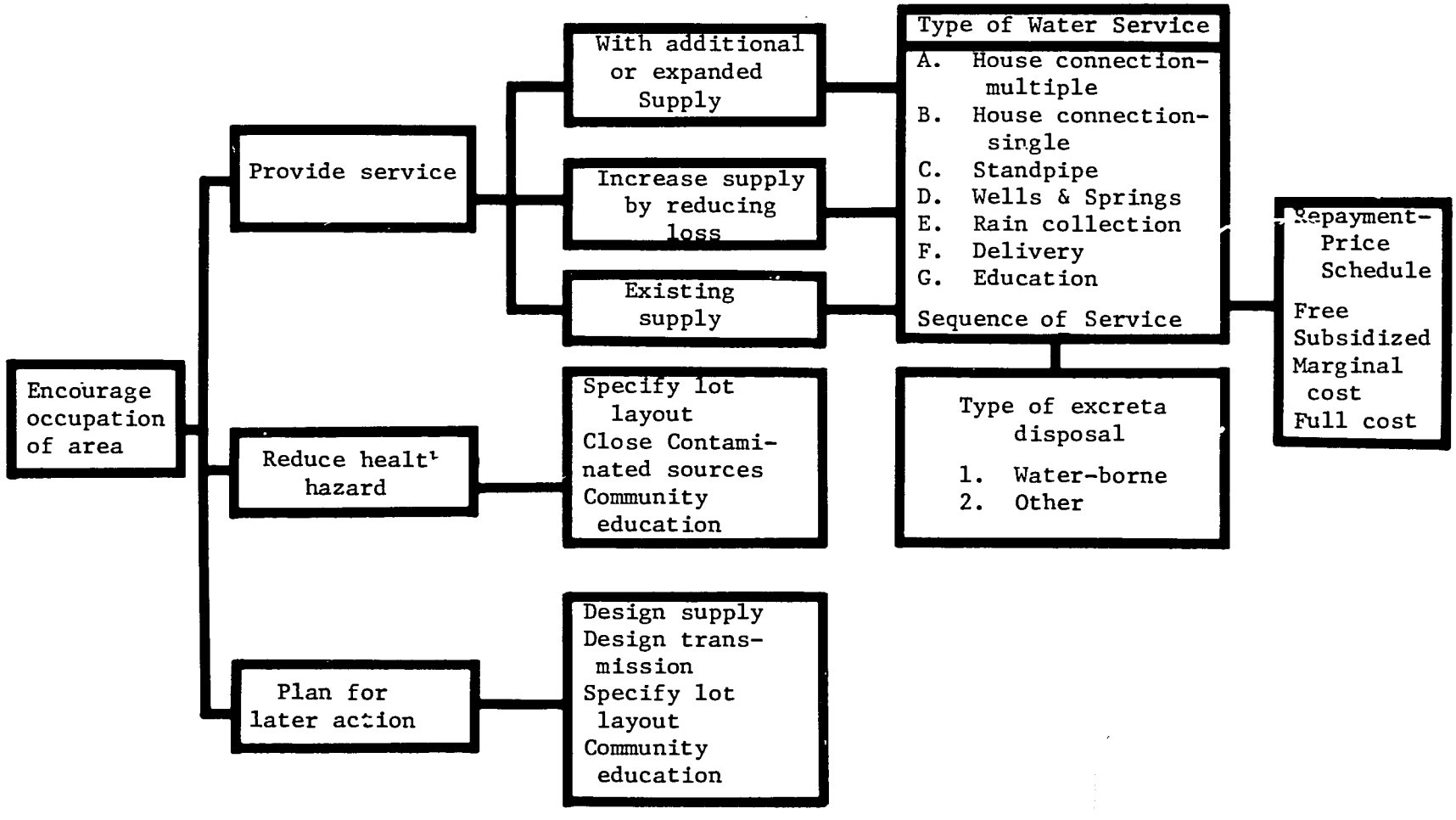
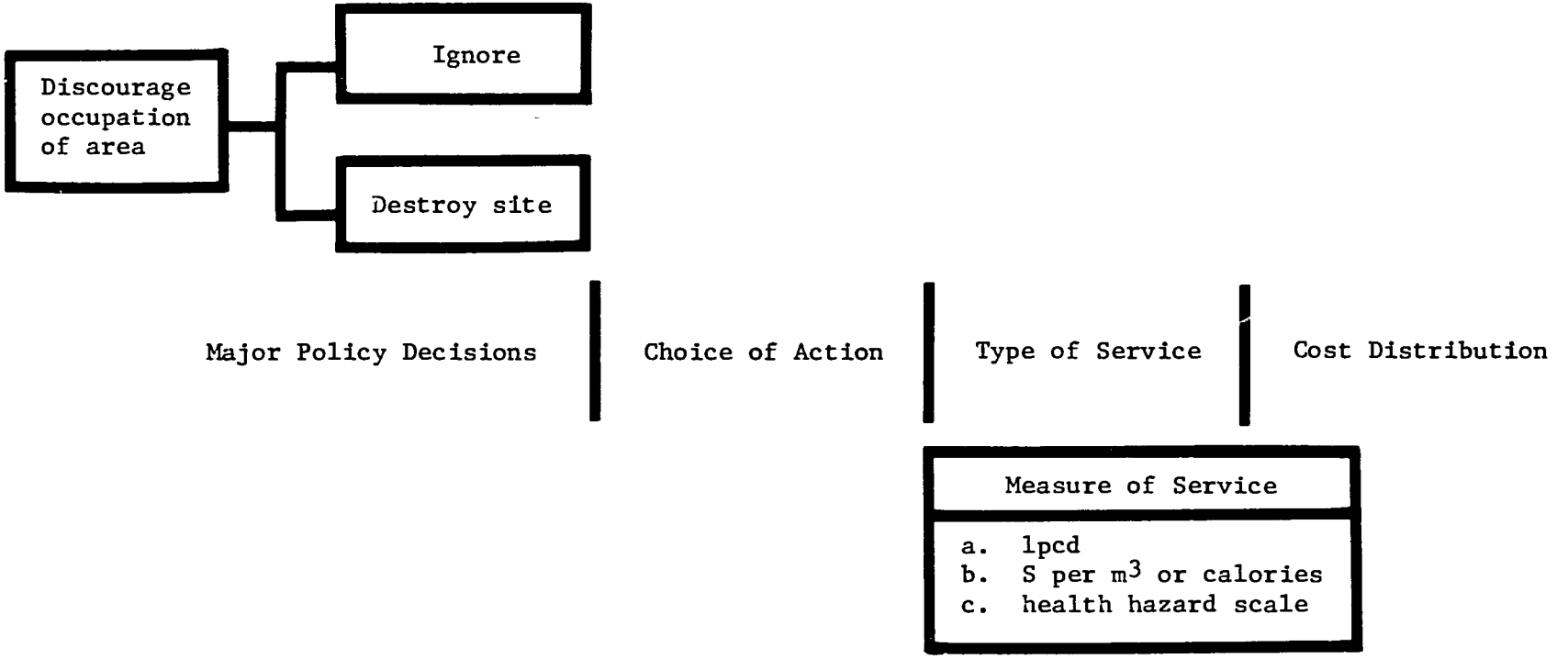


DIAGRAM 1 - Continued

DECISIONS IN CHOICE OF WATER SUPPLY SERVICE FOR THE URBAN AND RURAL POOR



If government decides to encourage immediate occupation of the shantytown or slum area it then has two options which will include later decisions. One is to serve the area on a holding basis, taking only those steps that will reduce health hazard or lay the groundwork for later service. The other is to go beyond the action and provide some kind of new service. In the latter case, the decision often depends on whether to extend or improve service within the limits of existing supply or to plan service requiring additional supply by loss reduction or from new sources. Loss reduction usually is the cheapest measure. In either case, the initial choice is among six types of service in various mixes and with various uses of community education.

The Population Served

Many cities display a rapid rate of change of location of the poor within their areas. The typical pattern is for new arrivals from small towns or the country to locate first in staging areas which have convenient access to jobs and where there are family ties. They later move to areas affording greater opportunity to establish households. Often, the second area is a disorganized shantytown in which the migrant is able to construct, frequently from the most rough materials, his own shelter and to add to it over the years. Thus, people with larger entrepreneurial skills locate in the shantytown peripheries and progressively invest in improvement of shelter. They tend to be innovative and to be open to new forms of organization. This goes on whether or not electricity and water is provided. These sectors of the urban poor may be quick to take on new technologies and responsibilities of direct benefit to them, and to take on progressively more complicated techniques.

Once established, the peripheral settlement is a highly flexible system of human adaptation. Because its inhabitants are varied in origin and have different levels of relationship to each other and to groups and individuals outside the settlement, they are unlikely to respond uniformly to any particular set of sanctions. They have a flexibility and independence which enables them, despite their kaleidoscope nature, to either cooperate with external institutions--or, perhaps more important for autonomy, to resist the encroachments of police, tax collector and other external agencies. The water enterprise can be a source of irritation or of stability. It is important that the local social system be responsible for administrating local improvements, such as standpipes or regulated private water vending. It is equally important that the responsibility not be placed upon any one group, say family networks, or other groupings, in such a way that it cannot readily be adapted to an evolving social environment.

Technical and Planning Considerations

In choosing among services, two fundamental considerations are the extent to which the facilities installed will be later upgraded, i.e., the provision of individual connections to an area served by standpipes, and whether the area will require early or later provision of sewage and waterborne excreta disposal. In seeking to explore the likely results of choosing among these alternatives, the following issues arise:

1. What is the target population in terms of present distribution and the extent to which provision will be made for future growth?

2. What is the range and phasing of alternative types of service which might be provided beyond the conventional, to the generally agreed ideal, service of providing a potable supply to individual house connections with multiple taps? What criteria are applied in choosing among these alternatives and providing for a phasing of transition from one to another over time?

3. What are the health benefits from (a) the several types of improvement at planned performance levels, and (b) the same improvements with degraded operation and maintenance in relation to standards of quality and reliability as suggested by WHO and as practiced in a variety of ways by countries and local authorities?

4. Is the balance optimal between source development and distribution system expansion and renovation?

5. What are the physical and financial thresholds beyond which it is essential to invest in sewage or other sullage or excreta disposal after water supply improvements are made?

6. What policies should be pursued with respect to pricing, repayment, and subsidy in financing the new works?

7. What institutional arrangements, including provision for public education and training for community organization, should be encouraged and supported in providing services deemed desirable or practicable?

8. What are the effects, if any, of each of the various types of services upon employment generation?

Clear answers to most of these questions are difficult because of the variety of local situations and because of the lack of information as to likely consequences of different modes of actions. It is important to identify points at which specific types of demonstration, experimentation, or research might have a significant effect upon the carrying out of the urban poor policy over the next decade or two.

The Role of Industrialization

Since the early 1970's, leaders of developing nations have been emphasizing the key role played by technology in industrial development and in related programs for generating employment and expanding trade. Previously, greater stress had been placed on increasing stocks of capital and physical infrastructure. This new emphasis on technology has a substantial basis. Technology--defined as the application of useful knowledge to felt needs--is an important determinant of economic growth in all major industrialized nations.

Growing interest in technology and industrialization coincides with the firmly held belief among many policymakers in developing nations that industrialization is a precondition of national economic well-being, adequate employment, and national autonomy. While it is possible to question the validity of such a generalization on analytical grounds (for example, in a developing country with strong comparative advantage in world markets for mineral or agricultural products), the belief itself is sufficiently rooted in the economic history of the presently industrialized countries as to stand beyond challenge. Hence, the logic that technology will foster industrialization, increase employment, and stimulate trade, leading to improved economic well-being has become a dominant theme.

In the broadest sense, the United States has usually maintained that its own long-range interests are best served by foreign assistance policies that strengthen the economies of all friendly nations. Through the Marshall Plan, the postwar reconstruction in Germany and Japan, President Truman's Point IV program, and successor foreign aid programs, the United States has sought to foster economic and social development abroad. As the world becomes more interdependent, the wisdom of these policies becomes more apparent.

With respect to developing countries, a generally accepted proposition is that, apart from considerations of basic equity and philanthropy, improved economic welfare will increase the probability that these nations will recognize that their interests are largely parallel to those of the United States. Alternatively, it is perceived that, if the developing nations were to remain hopelessly impoverished while the developed nations continued to prosper, resentments would build, and the results--economic, security, and other--would be inimical to the interests of all.

Capitalization

The conservation of human waste and its reuse into such products as biogas and fertilizer is in widespread practice in many areas. This is due to the inability to provide chemical or industrially-processed fertilizers as cheap energy.

The question of capital arises because economic conditions in developing nations differ in a number of respects from those of the industrialized nations. Typically, developing nations have larger ratios of unskilled to skilled labor than developed nations. Most developing nations also have a low rate of capital information, so that they are characteristically capital-poor when compared with industrialized nations. Thus unit labor costs in these nations are generally lower than those in industrialized nations, both in absolute terms and relative to capital costs.

These conditions have led many to espouse the need to develop and use labor-intensive and/or capital-saving technologies in developing countries. Such technologies are sometimes referred to as "appropriate technologies." Thus, the reuse of waste product falls into this category. We must therefore examine "appropriate technology" more closely to see how restrictive this might be in exporting technology.

Appropriate Technology

"Appropriate technology," as used in this chapter, means technology that is optimal for a particular situation in a particular developing nation, given the nation's economic

and social goals and conditions. For example, if a nation's overriding goal is to maximize national income, the technologies used should be those that are most efficient, given relative factor costs within the nation. If, on the other hand, national goals stress creating jobs over maximizing national income, more labor-intensive technologies might be chosen. Indeed, for many nations this would imply technologies that are capital saving and/or labor-intensive compared to corresponding technologies used by industrialized nations.

How to develop technologies that are "appropriate" to the goals of developing nations is the subject of wide controversy. It is unlikely that enterprises in developed nations will voluntarily invest substantial resources in the creation of new technologies designed primarily for use in small foreign markets. For this reason, new technologies suited to developing nations are most likely to be created by local business firms which would then have a stake in the outcome. Thus most of the initiatives which are primarily designed to enhance the capabilities of developing nations to create and use water treatment and waste disposal facilities would:

- Have to be easily replicable in developing nations without substantial capital investment;
- Be capable of removing poor or unsafe sanitation practices without causing upheavals in the agricultural communities.

Public Policy and the Private Sector

A recent study program involving the United States private sector noted that the major obstacle to technology transfer improvement is associated with the ability of the developing and underdeveloped countries to receive and exploit available technology.

A major conclusion of the study was that the private transfer of technology responded primarily to long-term incentives in the developed and developing countries. Development, adaptation, and transfer of technology in the private sector is extremely costly. The cost of this activity cannot be eluded or reduced and must be offset by incentives. Generally speaking, private industries were concerned with examining the prospect of profitable markets where technology can be transferred in a long-term involvement as opposed to a simple short-term sale of know-how. Overall, the companies stressed that no matter what kind of policies developed, there must be some kind of general compensation which will encourage the owners of private technology to make available or modify their technology according to the needs of the developing countries. This is particularly critical in the area of making available low-cost, yet effective means of supplying and purifying water, which may be naturally short supply.

The first question is who pays the bill? The development of science and technology and its adaptation and transfer to developing nations is always going to be a costly activity. This activity must be financed by someone whether it is the individual user, the owner of the technology, or different governments involved in the transfer process. The American public shows an increasing disenchantment with assistance programs for the Third World: Congress is mirroring their reservations over new major concessionary or assistance activities. Add to this the difficult competitive position of United States private

firms abroad, and the seriousness of this question is compounded. Neither public or private technology supporters are likely to provide new major resources.

Yet, it is important to realize that in an area of declining natural resources, mutual assistance is essential. The developing nations need America's advanced technology almost as critically as the United States needs their oil, tin, and rubber. Should the United States price up the cost of technology, developing nations can also price up the cost of a metric ton of tin ore--or a barrel of oil.

The scientific and technology infrastructures have varying degrees of capability throughout the Third World. In many of the developing countries, such as Korea and Brazil, there exists an extensive availability of laboratories, educational programs, and consulting services. However, in a majority of other developing and underdeveloped countries, the local capability to support industry is weak.

The need for United States transfer of technology to most developing countries is especially critical in the area of water supply and sewage. The majority of industrial units in developing countries do not have much understanding or capability to diagnose their water and sewage disposal technology needs or plan first steps to their technology importation and development. Dr. Carlos Varsavsky, an Argentine physicist associated with International Management and Technology, said in summary: "The gap that exists between the average developing country firm and what it should be to effectively plan and acquire technology is so great that almost any program that intends to promote technology must first begin by building an internal capability at the managerial level."

Summary

More than half the world has no reliable and safe water supply while 70 to 80 percent has no sewage disposal. Unfortunately, hordes of infectious agents create hazards to the health and well-being of most people in developing countries because of contaminated water or because not enough water is available for household and personal hygiene.

More effective systems are needed for assessing available water supplies, conserving their use, and influencing their distribution and methods of use. Without a doubt, adequate, convenient, and safe water supply and sanitary facilities are essential to improving the quality of life in both urban and rural settlements of developing countries.

Infectious diseases fall into three categories: cholera, diarrhea, and typhoid. Among others these are diseases which are exacerbated by malnutrition, large and poorly spaced families and unsanitary living conditions. Utilizing monitoring, planning and preventive techniques for such diseases a government must decide whether it wishes to encourage or discourage occupation of areas which have been developed or which is in imminent danger of being converted into shantytowns according to the degree of health hazard.

Many cities display a rapid rate of change of location of the poor. New arrivals from small towns or the country eventually acquire entrepreneurial skills and are innovative to the extent that they may be quick to take on new technologies and responsibilities and to take on progressively more complicated techniques. Governments should take advantage of this potential acceptability for increased technology to implement safer water supply systems and sanitary excreta disposal methodologies.

Technology--defined as the application of useful knowledge to felt needs--is an important determinant of economic growth. Hence, the logic that technology will foster industrialization, increase employment, and stimulate trade, and lead to improved economic well-being has become a dominant theme among developing nations. With respect to this view, the United States proposes that, apart from considerations of basic equity and philanthropy, improved economic welfare will better enable developing nations to recognize their own worth and goals. With acquired interests that are parallel to those of the United States, developing countries would then more likely look favorable on increased trade versus becoming bitter as a result of remaining hopelessly impoverished.

Because of larger ratios of unskilled to skilled labor and low rates of capital formation, unit labor costs are generally low in developing nations where compared to industrialized nations. These conditions have led many to espouse the need to develop and use labor-intensive/capital saving or "appropriate technologies" in developing countries. "Appropriate technology" means that it is optimal for a particular situation in a particular developing nation, given the nation's economic and social goals and conditions.

An increasingly critical question at this time is who pays the bill for the transfer of technology from the United States to developing countries? This activity must be financed by either individual user, the owner of the technology or different governments involved in the transfer process. Despite the contentions surrounding this question, it is important to realize that developing countries need America's technology in water supply, sanitary disposal systems, and in other areas almost as much as the United States needs their oil, tin, and rubber.

SECTION V

CONCLUSIONS

This report contains some of the more detailed findings from an in-depth literature survey of customs, practices, problems of technology transfer, and other factors surrounding water supply, sanitation, and waste disposal processes and systems in developing countries. It was felt that this information was both practical and realistic and would assist decision makers and technical specialists as they consider the application of technology to help meet the need for water supply, sanitation, and waste disposal systems.

The following conclusions, stated succinctly, are derived from this report:

1. Few developing countries have policies, strategies, and plans for coordinated control of safe drinking water with other water sectors. Population growth in these countries will only make the situation worse.

2. Those policies and plans that do exist generally exhibit a bias in favor of urban districts.

3. Eighty percent of illness in the Third World is directly or indirectly linked to the water supply. Such illnesses include: cholera, diarrhea, typhoid, malnutrition, and unsanitary living conditions.

4. The situation of water supply and excreta disposal is extremely different and more severe among developing nations today than that faced by western countries in the 1850's. Therefore, given a difference in climatic conditions, malnourishment, lack of natural resources, and population explosion, it is unlikely that systems appropriate for 19th century western nations will be successful in solving the waste disposal problems of Third World nations today.

5. The installation of improved water supply and sanitation disposal systems in developing countries must be accompanied by health education for new technologies to be most effective.

6. In coordinating water supply and excreta disposal activities, folklore and custom appear to be the most critical constraints.

7. The final allocation of government resources is always a political decision, but if village water supplies are to work effectively, local participation is indispensable, particularly in operation and maintenance.

8. A government must give careful consideration to the detailed operation of village institutions in order to provide clear economic, political, social and operative guidance to the villages in relation to implementing new sanitary technologies.

9. The responsibility of organizing water supplies could be given to any of several different agencies, but the administration of rural and urban supplies put under a single department by a government may not be advisable.

10. More effective systems are needed for assessing available water supplies, conserving their use, and influencing their distribution and methods of operations.

11. Economic conditions have led many to believe that there is a need to develop and use labor intensive/capital saving or "appropriate technologies" in transferring modern technology to developing countries.

12. Surveys of the literature reveal that a number of United States technologies can be directly transferred to developing countries without modification. In both water supply and waste disposal, appropriate administrative structures must be existent to assure proper maintenance and operation.

13. Technology transfer, to be effective, must include technical considerations as only one component of a larger system or package which takes into account the constraints imposed by the local cultural practices and beliefs and administrative requirements. Benefits and goals, especially, must be carefully delineated to provide a rational framework for comparing different technological options. Any investigation of "needs" must consider administrative and managerial requirements along with technical ones.

14. Host country objectives will vary. While community and/or village participation may not be needed to install water and waste facilities, without the participation of beneficiaries, proper use and maintenance is unlikely.

15. USAID is in a good position to build on what has already been accomplished in the field of water supply and waste disposal for the urban slum, urban fringe and rural areas of developing countries. Its unique field presence places the institution in a good position to gain the commitment of host country planners and administrators.

NOTES

1. Conference Room Document No. 1. JC22/UNICEF-WHO, 1979, page 5.

2. Ibid.

3. World Health Statistics Report, Volume 29, No. 10, 1976.

4. Ibid.

5. Hollensteiner, M. R. "People Power: Community Participation in Planning of Human Settlements," Les Carnets de l'Enfance/Assignment Children, Volume 40, No. 14, 1977.

6. Report on Community Water Supplies. WHO Report transmitted to the United Nations Water Conference (Issued as United Nations Document E/CONF. 70/14), page 22, Table 2.

7. World Health Statistics Report, Volume 29, No. 10, 1976.

8. Conference Room Document No. 1. JC22/UNICEF-WHO, 1979, page 16.

9. "Hardware" of appropriate technology as applied to water supply and sanitation implies a product tool, equipment, a process, technique, methodology of a system which has been successfully introduced, adapted and utilized.

10. "Software" consists of effective strategies and approaches such as organization, manpower, health, education and evaluation.

11. Conference Room Document No. 1.JC22/UNICEF-WHO, 1979, page 17.

12. Report of the United Nations Water Conference, Mar del Plata, March 14-15, 1979, New York, United Nations, 1977 (Document E/CONF.70/29), Resolution II.

13. Resolution 32/58.

14. Witold Rybczynski, Chongrak Polprasert, and Michael McGarry, Low-Cost Technology Options for Sanitation: A State of the Art Review and Annotated Bibliography, Ottawa, Ontario, IDRC, 1978.

15. Project Summary Description, "Appropriate Technology for Water Supply and Waste Disposal," Reference No. 671-46.

16. Witold Rybczynski, op. cit.

17. Ibid., page 11.

18. Witold Rybczynski, op. cit.

19. Richard Feachem and Sandy Cairncross, Small Excreta Disposal Systems, Bulletin No. 8, London: The Ross Institute of Tropical Hygiene, London School of Hygiene and Tropical Medicine, January 1978.

20. Charles Gunnerson; D. A. Julius, and J. M. Kalbermatten, "Appropriate Sanitation Alternatives: A Technical and Economic Appraisal," Public Utilities Report No. RES 5, The World Bank, Washington, D.C., 1978.

21. Witold Rybczynski, op. cit, page 41.

22. Ibid., page 44.

23. Ibid., page 45.

24. Ibid.

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26. Robert J. Saunders and Jeremy J. Warford, Village Water Supply, Baltimore: The Johns Hopkins University Press, 1976.

27. Michael G. McGarry, "Village Water, Health and a Potential Role for Primary Health Care," presented at the Fourth International Health Conference of the National Council for International Health, Washington, D.C., March 27-30, 1977.

28. "Soils and Septic Tanks," Public Works, compiled and edited by Walter Szykitka, Link Books, New York, 1979, pp. 704-707.

29. "Water Supply Sources for the Farmstead and Rural Homes." Public Works, compiled and edited by Walter Szykitka, Link Books, New York, 1974, page 703.

30. Richard Feachem, et al., Water, Health, and Development, London: Tri-Med Books, Ltd., 1978.

31. Patricia K. Buckles, "The Introduction of Potable Water and Latrines: A Case Study of Two Rural Communities in Guatemala," The World Bank, 1979.

32. Feachem, et al., op. cit, page 207.

APPENDIX A

WORLD BANK COUNTRY GUIDELINES

AN OUTLINE OF PRIORITY DATA COLLECTION STEPS AND ANALYSES FOR USE IN EVALUATING TECHNOLOGY OPTIONS

Objectives

The basic objectives of your research during the _____ month period beginning _____ 19___ are to collect the necessary information and perform a thorough evaluation of (a) the technical, and (b) the economic effectiveness of each technology studied and to recommend changes or further research, where appropriate, to improve one or both.

Research Design

In order to achieve these objectives the following general guidelines for the research design are presented. These will be refined and altered as necessary to suit country circumstances at the initiation meeting.

A. Priority Data Collection and Analyses

1. In conjunction with project management, select two to four communities in your country on the basis of the technologies represented, the information available, and any special demographic/geographic characteristics of interest.

2. For each community identify the existing collection, treatment, disposal and reuse technologies represented,* the total population served by each, and the volume of night soil, sewage, sullage, fertilizer, etc., handled by each technology. Seasonal variations and other deviations from average annual levels should be noted.

3. Provide a detailed description, with drawings and technical specifications where appropriate, of each technology represented in each community. These should include quantities and origin of construction materials (whether imported or domestically produced), labor requirements for construction (skilled and unskilled), both design and actual operating capacities, and a description of any problems associated with the construction, operation, community acceptance, etc. of each system. Where applicable, the environmental requirements and consequences of existing technologies should also be described and quantified insofar as possible.

In the following paragraphs, except where otherwise noted, a "technology" refers to a toilet, collection, disposal, or reuse component wherever system separation (technical and economic) is possible.

4. Collect detailed and comparable cost information on each technology studied including construction costs (both labor and capital components) incurred by households and by the community, the dimensions and lifetime of facilities, operating and maintenance costs (both labor and materials), and any income from user charges or sales for reuse. The attached Data Sheet for Technology Cost Comparison should serve as a guide. The year of information should always be specified and replacement rather than accounting cost of assets should be used wherever possible (e.g., if the collection system has 3 vacuum trucks purchased in 1970, 1973 and 1977, the 1977 unit cost should be used to value all 3 trucks). Compute total annual capita and per household cost of the collection, treatment, disposal and reuse components of each system, using estimated (and specified) opportunity cost of capital. Indicate which input information is relatively unreliable and how estimates of unobtainable data were made.

5. In countries where market prices are significantly distorted by import duties, interest rate ceilings, minimum wage legislation, undervalued foreign exchange, fertilizer subsidies, etc. an estimate must be made of the relevant "efficiency prices" and the cost calculations of Item 4 reworked. For additional guidelines on the method of estimation of efficiency prices see Economic Evaluation of Projects - Chapters 3 and 6-9.

6. Carry out socio-cultural survey of 3 households in each community (see Annex).

7. Collect health information for each community as described by health guidelines (see Annex).

8. List and describe areas of possible follow-up research and/or designs to improve the technical effectiveness, economic efficiency or social acceptability of the technologies studied and/or the quality of the information gathered.

B. Supplementary Information and Analyses

1. A description and economic costing of each community's water supply system including hydrological features, present production and consumption figures (total and per capita served) and construction, operating and maintenance costs (total and per capita served). When more than one service level is available (e.g., public standposts and house connections) they should be analyzed separately insofar as possible.

2. Where waste is reused (i.e., for fertilizer, irrigation water, fish culture, or biogas) a complete technical and economic analysis of the relevant agriculture, aquaculture, energy, etc. system should be included. This should include all relevant input costs and a valuation of the

outputs both at market prices and at opportunity cost (if different). Seasonal factors should be discussed and historical information on demand patterns collected, if possible, to aid in analyzing the relevant income and price factors which affect the tradeoff between waste by-products and chemical fertilizer, liquid petroleum gas, etc.

3. Describe both the institutional and informal processes of community decision making. Identify the primary actors and give examples of successes or failures of attempts at community involvement in setting public priorities and actual joint work projects.

4. Identify and describe any religious, cultural, institutional or attitudinal constraints on the choice of waste technologies.

5. Prepare conceptual designs of system improvements and preliminary cost estimates. You may also be asked to evaluate the potential local applicability of alternative technologies identified by project management.

Schedule

An initiation meeting with project management will be held at the outset of field work. Prior to this meeting you should identify candidate communities and be prepared to justify their selection according to the criteria discussed in A.1 above. Based on your information on the adequacy of the data and availability of secondary researchers, the specific scope and timing of the field research will be determined. A brief interim report will be due at the halfway point of your assignment (19) which should summarize your preliminary findings from Part A (1) - (8), highlight any information caps which prevent the completion of Part A, propose a plan of action for filling those gaps, and present a schedule for undertaking Part B. Depending upon your progress, a midterm review meeting with project management may be scheduled at that time. At the end of your assignment (19) a final report should be submitted which presents the findings of Parts A and B includes annexes detailing all supporting information.

DATA SHEET FOR TECHNOLOGY COST COMPARISON
(To Be Completed For Each Community With Year Of Information Indicated)

UNITS	BASIC TECHNICAL DATA
#	A. Total Population
#	B. Population Served by N.S. Collection
#	C. Population Served by Sewerage
#	D. Population Served by Septic Tanks
Description	E. Others-how served
persons/household	F. Average Household Size
persons/household	G. Population Density
lcd	H. Average Water Consumption
#	I. Population Served by Piped Water
lcd	J. Volume of Sewage
lcd	K. Volume of Nightsoil
times/month	L. Frequency of N.S. Collection
km	M. Average Length of N.S. trip
m^3/yr.	N. Total Volume N.S. Collected
m^3/yr.	O. Total Volume N.S. Treated
m^3/yr.	P. Total Volume Disposed Without Treatment
m^3/yr.	Q. Total Sold for Reuse
m^3/yr.	R. Total Given Free for Reuse

DATA SHEET FOR TECHNOLOGY COST COMPARISON - Continued
(To Be Completed For Each Community With Year Of Information Indicated)

UNITS	BASIC ECONOMIC DATA
$/yr.	A. Average Household Income
$/yr.	B. Average Unskilled Labor Income
$	C. Estimated Opportunity Cost of Capital
$/man-day	D. Estimated Efficiency Price of Unskilled Labor
$/man-day	E. Estimated Efficiency Price of Skilled Labor
local currency/$	F. Estimated Efficiency Price of Skilled Labor
local currency	G. Official Foreign Exchange Rate

UNITS	HOUSEHOLD (ON-SITE) COSTS
m^3	A. Average Vault Size
$	B. Labor for Construction
$	C. Materials for Construction
years	D. Life
$/year	E. Operating & Maintenance
$/year/HH	F. Annuitized Construction Cost (from b-d)

DATA SHEET FOR TECHNOLOGY COST COMPARISON - Continued
(To Be Completed For Each Community With Year Of Information Indicated)

UNITS	COLLECTION COSTS
#	A. Number of Laborers
$/man-day	B. Average Cost per Man-day
$	C. Total Labor Cost (a x b)
#	D. Number of Trucks
$	E. Cost per Truck
yr.	F. Lifetime of Truck
#	G. Number Carts or other Vehicles
$	H. Average Cost per Vehicle
yr.	I. Lifetime of Vehicles
$	J. Other Capital Costs
yr.	K. Lifetime of other Assets
$	L. Operating $ Maintenance Cost of Vehicles
$/yr.	M. Annuitized Capital Cost (from d-k)
$/yr.	N. Total Annual Costs (c+l+m)
#	O. Number of Households Served by Nightsoil Collection
m^3	P. Total Annual Volume of Nightsoil Collected
$/m	Q. Total Collection Cost/m^3 (n÷p)
$/yr/HH	R. Total Collection Cost/HH (n÷p)

DATA SHEET FOR TECHNOLOGY COST COMPARISON - Continued
(To Be Completed For Each Community With Year of Information Indicated)

UNITS	TREATMENT COSTS
$	A. Labor Construction Costs
$	B. Materials Construction Costs (structure and equipment)
yr.	C. Lifetime of Facility (structure and equipment)
$/yr.	D. Annuitized Capital Cost (from a-c)
#	E. Number of People Employed
$/yr.	F. Total Labor Cost
$/yr.	G. Other Operating and Maintenance Costs
m^3/yr.	H. Design Capacity of Plant
m^3/yr.	I. Actual Operating Capacity
$/yr.	J. Total Annual Treatment Cost (d+f+g)
$/yr.	K. Total Annual Treatment Cost/m3 (j÷l)
$/m3	L. Hypothetical Treatment Cost/m^3 (j÷l)
#	M. Families Whose N.S. is treated
$/HH/yr.	N. Treatment Cost/Household (j÷m)

UNITS	CHARGES AND REUSE
$/yr/HH	A. Annual Household Charges
3	B. Sales of Fertilizer
$/yr.	C. Revenue from Fertilizer Sales
m^3	D. Amount of Biogas Sales
$/yr.	E. Revenue from Biogas Sales

APPENDIX B
*GUATEMALA CASE STUDY**

Hardware

Mountain springs are tapped and PVC plastic pipe distributes the water to public taps serving groups of 3-5 houses or to private patio connections. The communities are offered a choice in level of service. Public taps are provided at no cost to the recipients for installation. The household members within each group of houses served decide the exact placement of the tap, which is situated no further than 150 meters from any one house (usually 60-100 meters). Those who opt for private patio connections pay for the additional costs of materials and labor to bring the water from the main line. The communities provide locally available materials such as rock, sand, and gravel, and each household contributes approximately 40 days of labor for construction. Households using public taps pay US $.25 per month for maintenance and those with private taps pay US $.35 per month. The money remains in a community fund supervised by the Village Water Committee organized to oversee project planning and implementation.

Software

There are as many as eight agencies with some role in rural water supply in Guatemala. One of them is the Community Development Agency, which operates under guidelines similar to the African community development agency described above (the matching funds principle and self-help). The program evaluated for this study, however, was created to introduce a new methodology for service delivery which would serve as a model for replication by other government agencies once it was proven in the field. Four institutions (USAID, CARE, The Guatemalan Ministry of Health, and Agua del Pueblo, a private voluntary technical assistance organization) established the program in 1975, in an innovative attempt to decentralize administration and to coordinate water supply activities with the activities of personnel in local health clinics. Since 1978, the Ministry of Health (MOH) has assumed full responsibility for the program. The program is distinguished from all other institutions working in rural water supply in Guatemala by the following program components:

A. Field Office

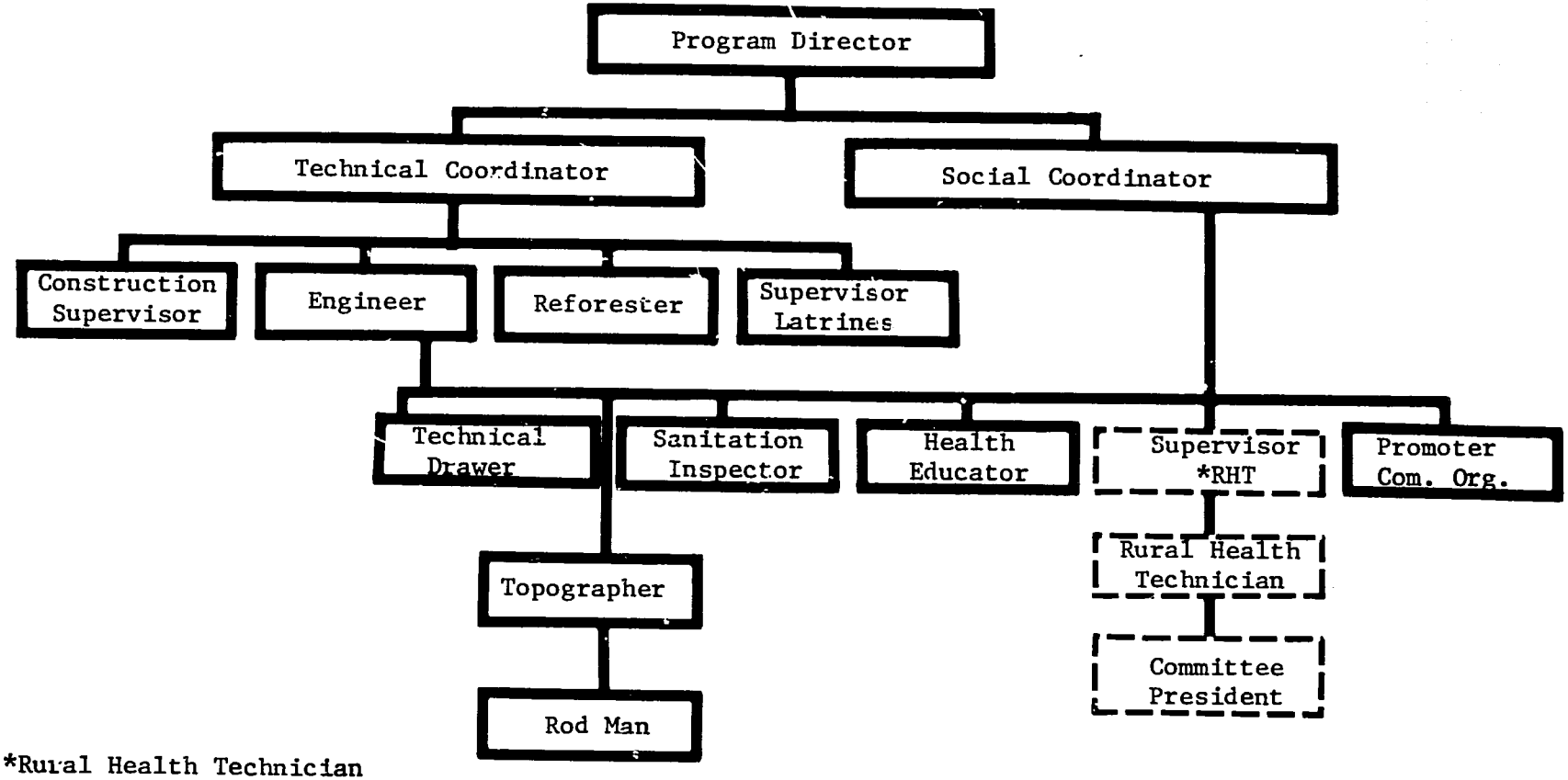
The establishment of a field office at the district level with the authority of project selection and development permits the interdisciplinary program team to respond immediately to community requests and any conflicts which may arise during project implementation. Diagram 1 describes the team's organization.

B. Linkage

The program links together the activities of the Ministry of Health, the Township governments, and community committees. The Ministry of Health provides technical and administrative personnel for the program's offices; transport for materials and financial input by way of pipes, accessories, and latrines. Rural Health Technicians (TSRs) employed as extension agents by the Ministry of Health work at the

DIAGRAM 1

INTERDISCIPLINARY TEAM ORGANIZATION CHART
QUICHE DEPARTMENT CAPITAL



*Rural Health Technician

township level; they identify potential projects, investigate water sources, assess community enthusiasm, conduct house visits, take the census, register beneficiaries, and provide health education instruction. The township governments select and finance the skilled labor for projects in rural areas under their jurisdiction at an approximate cost of US $1,500 per system. Local Drinking Water Committee organize the non-skilled labor, supply local materials, and provide the leadership needed for maintenance, implementation, and planning.

C. Methodology

The Project Methodology enables communities to pass through a series of stages, i.e., Selection, Preparation, Design, Construction, Maintenance, and Evaluation, at their own rate (Diagram 2). Since a number of projects can be initiated and implemented simultaneously, the communities' participation in decision making and organization is not by-passed. A detailed description of the Project Methodology is located at the end of this report.

D. Early Feasibility Studies

To speak realistically, a project is not actively promoted before its technical and administrative feasibility has been determined. Technical and socio-cultural data are collected and analyzed at the earliest possible stage and before a high proportion of technical and human resources have been invested.

E. Community Involvement

Planning - The program only initiates a project upon community request, an ultimate inclusion is contingent upon the community's assessment of its capability of fulfilling participation requirements, i.e., provide voluntary labor, pay the monthly maintenance tariff, install latrines, and provide a warehouse for materials during construction. Eighty percent approval among households must be indicated on a petition.

Preparation - The community must select a Drinking Water Committee, which has the following responsibilities:

(1) Call and conduct meetings to inform community members about project status and to elicit cooperation;

(2) Organize the voluntary labor force and maintain records of individual labor contributions, as well as arrange for community 'helpers' to aid program personnel in activities such as drawing the plan, census taking, surveying, education, and evaluation.

(3) Petition township and departmental governments for legal authority to collect the maintenance fee and to obtain ownership rights for the land on which the storage tanks

DIAGRAM 2

"PROJECT IMPLEMENTATION SCHEME"

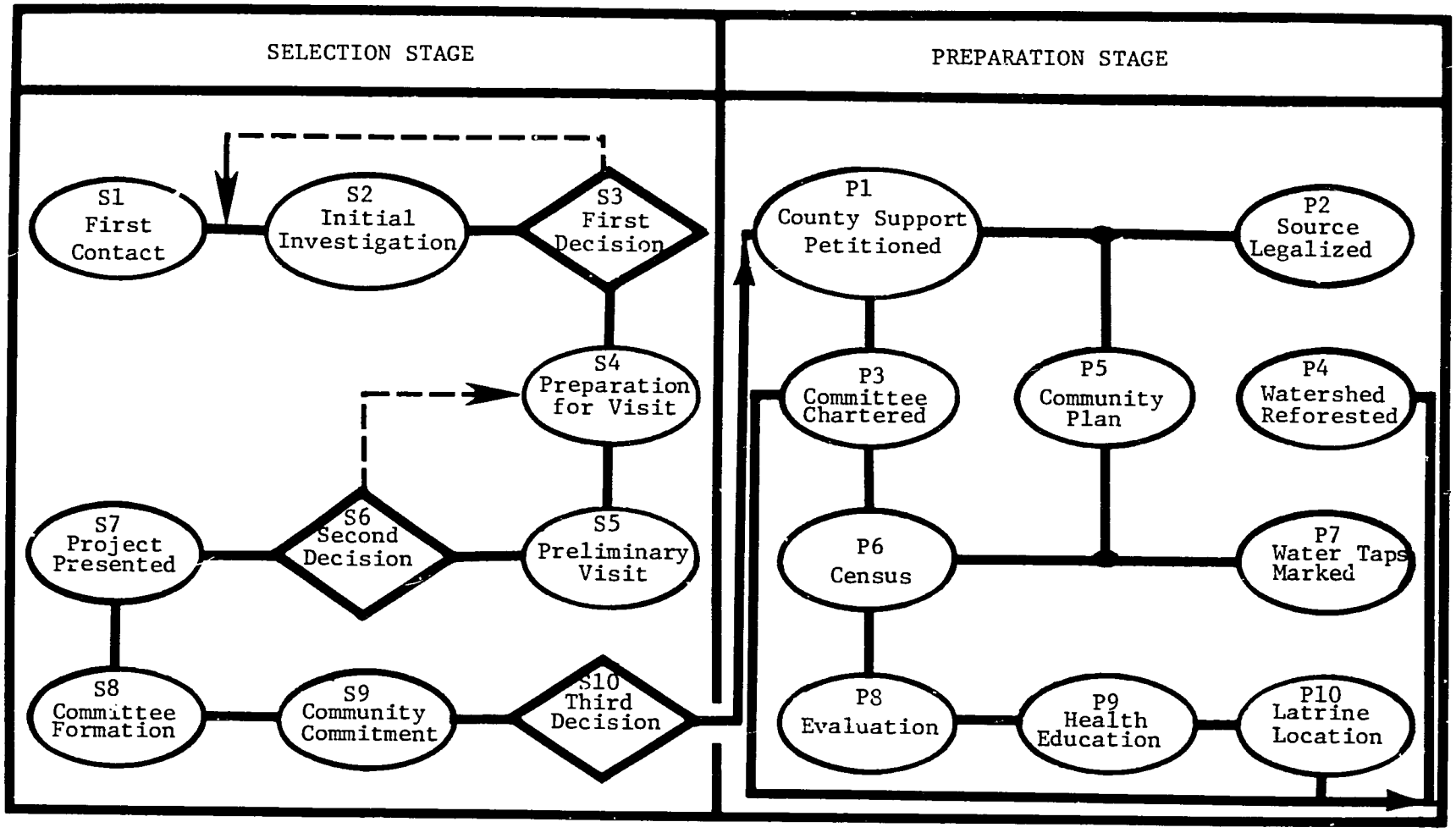
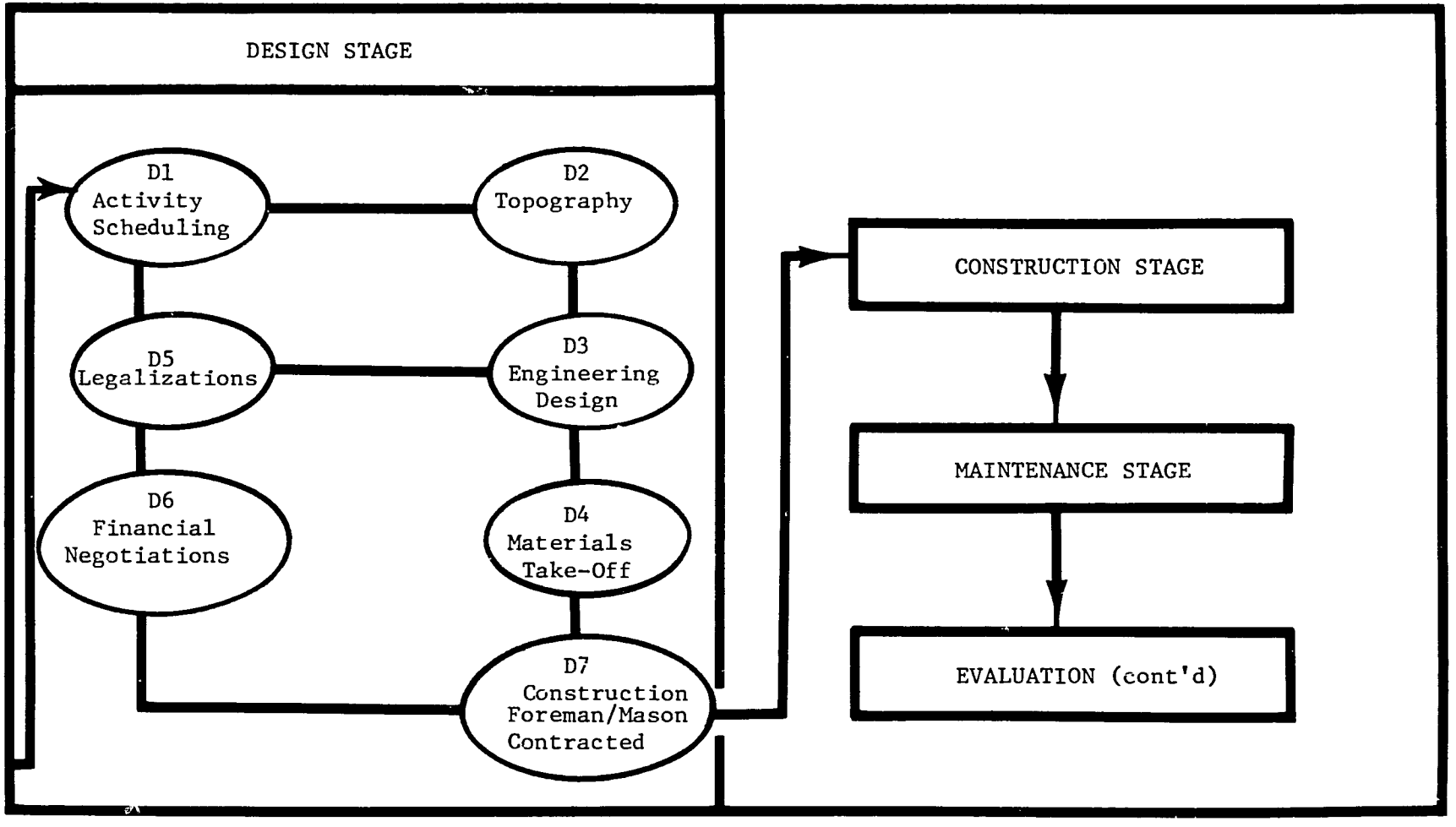


DIAGRAM 2 - Continued

"PROJECT IMPLEMENTATION SCHEME"



(3) and public taps are constructed, as well as for the land around the source (for reforestation) and on which pipes are passed.

(4) Select community members to be trained in system maintenance.

(5) Collect the maintenance fee, maintain records, and file periodic reports to the regional field office concerning the results of these activities.

Design - The community decides the level of service they can afford (public and/or patio connections). This decision is contingent upon the technical realities of the system, i.e., the percentage of patio connections the water source can accommodate over the design life of the system. The community also decides where the public taps are placed between the groups of 3 to 5 houses. A preliminary map of the area is drawn, and a member of the technical team and member of the social team accompany the villagers on a "site visit" through the community to place flags indicating the eventual positioning of the gaps. The committee reviews all placements. It invariably requires two or three trips to the community to finalize the positioning. Interchange between neighbors is a valuable output and decreases the possible rivalries emerging after system completion.

Construction - The community provides the volunteer unskilled labor to install the water system and latrines; they gather the locally-available construction materials such as rock, sand, wood, and gravel; and they transport materials from truck unloading sites to a warehouse they construct in the community.

Maintenance and Evaluation - The maintenance fee is collected by the Committee and remains in the community to be used both for maintenance and for other projects (after a minimum amount has been saved). Periodic visits by committee members to inspect latrines to ensure they are being properly used is encouraged.

PROJECT METHODOLOGY

RURAL POTABLE WATER SYSTEM AND LATRINE INSTALLATION

I. Selection Stage

- S1 - First Contact
- S2 - Initial Investigation
- S3 - First Decision
- S4 - Preparation for Visit
- S5 - Preliminary Visit
- S6 - Second Decision
- S7 - Project Presentation to Community
- S 8 - Potable Water Committee Formation
- S9 - Community Participation Commitment
- S10 - Third Decision

II. Preparation Stage

- P1 - Township Support Petitioned
- P2 - Water Source Right-of-Way
- P3 - Water Committee Chartered
- P4 - Reforestation of Watershed
- P5 - Community Plan Drawn
- P6 - Census Taken
- P7 - Water Taps Marked
- P8 - Evaluation Data Collected
- P9 - Health Education Begun
- P10 - Latrine Location

III. Design Stage

- D1 - Activity Scheduling
- D2 - Topography
- D3 - Engineering Design
- D4 - Materials Take-Off
- D5 - Legal Work Accomplished
- D6 - Financial Negotiations
- D7 - Construction Foreman/Mason Contracted by Township Government

IV. Construction Stage

- C1 - Construction Materials Delivered
- C2 - System Installation Begun

V. Maintenance Stage

M1 - System for Tariff Collection Established
M2 - Supervision of Tariff Collection System Extension and Repair

SELECTION STAGE

S1 - First Contact

a. Occurs in local office with a visit from interested parties, or

b. In the community through contact with the Rural Health Technician assigned to the District by the Ministry of Public Health.

S2 - Initial Investigation (accomplished by Rural Health Technician in community)

a. To find out if previous studies if any have been made.

b. Existing water sources and possible alternatives are measured.

c. Neighboring communities which could be included are noted.

d. Distance from the community to the source is noted.

S3 - First Decision (made by Program Team in Field Office)

a. The community's population size meets program prerequisites.

b. The water source is adequate for the 20-year projected population.

c. The source is close enough to the community to maintain costs within program norms.

S4 - Preparation for Visit (to community to benefit)

a. No program commitment is made yet.

b. Consciousness raising to the health need for clean water.

c. Explication of the program, including community participation prerequisites.

d. Establishment of best date for preliminary visit by Program Team.

S5 - Preliminary Visit (of Program Team to Community)

a. Technical Work: Altimetry readings, topographic sketch, flow measured, water quality tested.

b. Social Work: Detection of leaders, enthusiasm, social organization.

S6 - Second Decision (made by Program Team in Field Office)

a. Results of preliminary visit favorable: project accepted by program as feasible, community informed.

b. Not enough information obtained: decision postponed, community informed.

c. Problems detected: decision awaits problem resolution.

S7 - Project Presentation to Community (occurs at community meeting)

a. Community informed project is feasible and accepted by program pending community acceptance of program.

b. Questioning to determine if community members fully understand the contributions such as volunteer labor and monthly maintenance charge.

c. Assembly programmed for formation of a committee to serve as liaison between the community members and program team.

S8 - Potable Water Committee Formation

a. Assembly announced through house visits. Discussion of possible committee candidates encouraged.

b. Responsibilities of committee members explained at the assembly.

c. Election of the committee members.

d. Planning of the session to sign the community participation commitment.

S9 - Community Participation Commitment

a. Formal request drafted stating community agrees to its contributions.

b. Community heads of households sign request if in agreement.

S10 - Third Decision (made by community, reviewed by Program Team)

a. Accepted (80% or more heads of households signed request).

b. Awaiting signatures (less than 80% signed the formal request).

PREPARATION STAGE

P1 - Township Support Petitioned

To pay the salary of a skilled construction foreman/mason contracted by the township government in which the project is situated.

P2 - Water Source Right-of-Way

To legally establish the water source and surrounding terrain as public property.

P3 - Water Committee Chartered

In order to legally collect the maintenance fee and manage the maintenance fund in the community.

P4 - Reforestation of Watershed

a. To protect the watershed from serious soil erosion.

b. To achieve a soil structure through the development of an intricate network of root systems and surrounding flora, which acts as a natural filtration system in surface and sub-surface water flows.

c. To help control the overflow at the watershed during a heavy thundershower.

P5 - Community Plan

a. To aid in census taking.

b. To guide in the location of public taps.

P6 - Census Taken

To determine the exact number of inhabitants, water sources used, and the number of latrines needed.

P7 - Water Taps Marked

The members of each group of four houses make a group decision about the location of the public tap which will serve them. The tap is never located more than 150 meters from any one house.

P8 - Evaluation Data Collected

Base-line data collected to evaluate the impact of the education program and to determine water usage patterns for design purposes.

P9 - Health Education

a. To instruct on the proper location, maintenance, and use of the latrine.

b. To inform on the proper storage and handling of water in the home.

c. Basic hygiene habits made easier with greater water availability.

P10 - Latrine Location

Latrines are located to avoid drainage problems, and work is begun on their construction.

DESIGN STAGE

D1 - Activity Scheduling

Work must be programmed around seasonal work migration and climate changes.

D2 - Topography

A two-man team lives in the field until work is finished. First pass uses a transit and stadia and vertical angles are computed to calculate horizontal distances. The route is revised using a level and chain.

D3 - Engineering Design

a. Calculations from field notebook.

b. Line-profile drawing.

c. Preliminary engineering plan.

d. Topographic changes.

e. Final engineering design.

f. Drawing.

D4 - Materials Take-off

D5 - Legalizations

a. Right-of-way for the piping system.

b. Right-of-way for the public tap connections.

c. Right-of-way for the distribution tank.

d. Collection of payments for private tap connections.

e. Authorization to collect monthly maintenance fee.

D6 - Financial Negotiations

The contributions to be made by supporting financial institutions are determined.

D7 - Construction Foreman/Mason Contracted

Township government awards contract according to bids submitted to the corporate township government.

CONSTRUCTION STAGE

C1 - Construction Materials Delivered

Construction materials are delivered to the furthest point that they may be transported by vehicle. From this point the community members must transport them to a warehouse established in the community.

C2 - System Installation Begun

Community members form teams to work under the supervision of the construction foreman/mason.

MAINTENANCE STAGE

M1 - System for Tariff Collection Established

The social worker of the program team trains committee members in how to maintain records of the monthly maintenance fee collected from each

family. They are taught to distribute receipts for payment and how to report activities periodically to a supervisory agency.

M2 System Extension and Repair Supervision

Accomplished by a technician trained by the program team in the community.

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*Excerpted from World Bank study by Patricia K. Buckles.
See footnote 31.

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