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RURAL WATER SUPPLY AND SANITATION:

A FRAMEWORK FOR IMPROVING INVESTMENTS

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PREFACE

The International Drinking Water Supply and Sanitation Decade is now more than half over. Although the Decade has had some notable achievements, its original quantitative goals are unlikely to be met. This is particularly true of coverage in the rural areas. The number of people in rural areas without adequate water and sanitation services continues to grow and will be larger at the end of the Decade than at the beginning. It is not simply a question of inadequate amounts being invested; in many countries difficulties are encountered in spending the funds presently allocated. More importantly it is the limited success of existing investments in meeting their objectives. In many cases, because of lack of maintenance and poor operations, systems are going out of business faster than new ones are being built.

Why this disappointing record? What can be done about it? Answering these questions is the major objective of this paper. An examination of the problems indicates that there is a need to change the way in which resources in this sector are allocated and utilized. Too many untested assumptions have been made about both the costs and benefits of these investments. These assumptions in turn have led to programs of investment that are not replicable at the required scale and furthermore are unworkable even at present inadequate levels.

The framework of analysis proposed in paper suggests new approaches to rural water supply. Some of the ideas and hypotheses presented in this paper need to be developed further; some of the proposals need to be tested in the field; others require further research. The framework presented is, however, an alternative with great promise. It leads to a set of policy recommendations and practical guidance that offer a way out of the present unsatisfactory situation.

Before the approaches in this paper can be implemented, many people at the technical and political level in both developed and developing countries will have to be convinced of their validity. The authors recognize that this will be no easy task. Many opinions will be voiced, and many discussions need to be held. Some will find the paper overly technical or analytical; we believe this is a difficult subject requiring detailed technical analysis. It is hoped that by a combination of analysis and experience, presenting this paper will serve to sharpen the focus of those involved in improving the delivery of services to the rural populations of the developing world.

In order to encourage early discussion and to benefit from collegial review, the paper is being circulated for comment in its present draft form. Although it concludes with a set of recommendations for the World Bank, it should be emphasized that these are the conclusions of the authors. It is hoped that a draft of this nature will give an opportunity to all interested parties to participate in the process of developing a set of workable and acceptable strategies for improving the quality of life of some of the most disadvantaged populations in the world. Comments are not only welcome but essential to arriving at the necessary degree of consensus for policy and action.

# EXECUTIVE SUMMARY

Improvements in rural water supply and sanitation services are priority investments in most developing countries. Few public services have had as much popular appeal among both aid donors and national leaders as has had rural water supply, particularly during the International Drinking Water Supply and Sanitation Decade (1981-1990). Yet a review of the experience shows that few countries have programs that are replicable on the scale required to reach a significant fraction of their rural populations within a reasonable time frame.

After some three decades of effort and investment, the pace of progress has remained slower than some expected. More and more countries and aid institutions have begun to ask how future efforts can be made more effective. The purpose of this paper is to contribute to this re-examination of the issues and problems.

## ISSUES AND PROBLEMS

Can the rural poor pay for services? It has generally been assumed that much of the rural population is too poor to pay for adequate water supply and sanitation services. The available evidence suggests otherwise. Although there are undoubtedly some rural areas in some countries where poverty is so extreme that resources are not available for improving services, this is far from being the general case. A review of the global situation reveals that most rural areas can afford to pay for improved services, provided appropriate technologies and delivery mechanisms are used. People in rural areas already are spending large amounts of time and energy in collecting water; the issue is, can it be done at a lower cost?

Are there significant health benefits? Most rural water supply and sanitation projects have been justified on the basis of assumed improvements in health. However, the available evidence suggests that the effect on health is not always as sure or as direct as has often been expected. Water supply and sanitation services appear to be necessary but not sufficient conditions for reducing morbidity and mortality. The complex chain through which disease is transmitted does not lend itself to simple solutions. Human behavior and interactions with the environment are as important in determining overall health status as availability of clean water. Prevailing levels of literacy, female education, and income also can be significant factors. Given these other considerations, it is by no means clear that water supply and sanitation investments will by themselves improve health. Fortunately, however, most investments in rural water supply can be justified on grounds other than achieving improvements in health.

Can the public sector provide the services that are needed? The provision of rural water supply and sanitation services in many countries has been considered the responsibility of the central government. But the performance of governments in this sector has often been marked by inefficiency, high costs, and failure to deliver services. An examination of the possible alternatives suggests that the private sector should play a larger role than is currently the case.

To what extent can strengthening institutions help project performance? In the search to explain the problems of past projects, institutional weaknesses are frequently cited. Undoubtedly institutional deficiencies are a major problem, but it is not easy to separate that issue from the weakness of institutions in general in developing countries. Many of the changes required will come only as part of the general process of development. More important is the need to focus on what can be done within the limits imposed by existing institutional constraints. A re-examination of this issue is required to see if the institutional constraints can be overcome by changing the framework of incentives and policies within which institutions operate and evolve.

To what extent can more appropriate technologies help? There are many examples of overly capital-intensive and complicated technologies being used in situations where their maintenance and operation is beyond the capacity of the state and the local community. The Bank in cooperation with the United Nations Development Programme and other bilateral donors has conducted extensive research on this point. Appropriate technologies do exist and are available to be used in developing countries. They will not be used, however, unless countries adopt appropriate incentives for their use. Extensive subsidies, in particular, have discouraged the development of more efficient and lower cost options.

## SUPPLY AND DEMAND

Many of the failures in developing rural water and sanitation systems can be traced to the lack of an adequate analytical framework for making decisions on who gets what services and at what prices. The key elements of any analytical framework are knowledge of what consumers want and what they are prepared to pay for (demand), the costs of producing these services under a variety of conditions and technologies (supply), and the benefits that are derived either to society or individuals from the consumption of these services.

Demand. Rural settlements could not exist without access to water. Most investments are made to improve the existing level of service. Determining demand thus becomes a question of determining how much individuals (or society) are willing to pay for additional or more convenient quantities of water. Most of the direct benefits of improved water services are the result of savings in time and effort required to obtain a given (or greater) quantity of water. Therefore, some valuation of this time and effort is essential.

Direct observations can be made of how consumers trade off time and effort against additional increments of water. Information from urban fringe areas where markets for water exist and from rural areas where it is possible to observe the trade off between distance, a proxy for time and effort, and the quantities of water consumed, all provide valuable data for estimating the approximate shape of the demand curve. These estimates suggest that at low levels of consumption the quantity demanded is insensitive to changes in prices (inelastic) while at higher consumption levels it becomes more sensitive to price changes (elastic). Using available information it is possible to make rough estimates of the demand relationships, which, with appropriate sensitivity tests, can serve as a basis for estimating willingness to pay.

The value to be placed on time is obviously the most sensitive of the parameters required. If time is worth little, investments in improving services will be more difficult to justify, since the main benefit is the saving of time--time that households can devote to purposes other than hauling water. The empirical evidence does not support the view that time is of little value to rural households. For the most part, they appear to value the time used in hauling water no differently than the time used in other activities. In many contexts, the value of time can plausibly be assumed to reflect local average wage rates.

While it is possible to be reasonably confident of the estimates for the demand for water, this is not the case for sanitation services. The best evidence available suggests that the key factors in the demand for improved waste disposal methods are comfort, convenience, and privacy. In sparsely populated areas, demand for sanitation facilities is likely to be much weaker than in denser communities.

Supply. The literature on the cost of rural water supply generally has not stressed one of the most important costs, the cost of hauling water from where it is supplied (eg. the pump) to where it is used (the house). The head-loading of water is an expensive process and, even in very low-wage economies, can result in high unit prices.

The most significant other variables that determine cost are source costs or physical conditions (for example, depth of the water table), density of settlement, size of settlement, and the income level of the inhabitants. Although each situation must be analyzed and evaluated on its own merits, the following conclusions from estimates prepared for a wide range of diverse hypothetical village situations are likely to be broadly applicable:

1) Whenever wages are above US$0.25 per hour, or per capita incomes above $250 per year, the lowest cost system will often involve the piping of water.

2) Whenever the size of the village is over 1,000 persons, the economy of scale inherent in piped systems will make them the dominant choice.

3) Whenever electricity is available, the electric pump combined with some minimal distribution system will be best.

4) Whenever the source cost or the cost of the borehole increases, if any investment is justified, it is likely to include a piped distribution system.

5) Whenever average queue times go above two minutes, an additional handpump or further investments in a distribution system are likely to be justified.

6) Whenever densities go above sixty to seventy persons per hectare, investments in improving the distribution system are likely to lower total costs.

BENEFIT-COST ANALYSIS

By combining the information on the demand for water with the estimates of costs of improving services, it is possible to develop criteria and procedures for choosing among alternative water service improvements. Because water supply projects involve both a choice among alternative technologies (handpumps vs standpipes vs yard taps) and a level of water service with any given technology, a two-stage choice criterion must be used. The techniques used in calculating benefits are the usual techniques of benefit-cost analysis.

In order to estimate benefits, it is important to know the existing situation in terms of village size, density, income, present source of water, and the cost of capital. By setting up a "typical" village situation and by varying the parameters on both the supply and demand side, it is possible to come up with a set of generalizations regarding the net benefits (benefits minus costs), as follows:

1) As distance to alternate water sources falls, net benefits of a handpump project rise but, if these benefits are positive, the best number of handpumps is not changed.

2) As density changes, net benefits of handpumps change in the same direction but by a much smaller proportion and the best number of handpumps remains unchanged.

3) A given percentage fall in the discount rate results in a slightly smaller percentage fall in the best number of persons per handpump.

4) A given percentage change in the value of time may result in a comparable percentage change in the best number of handpumps or persons per handpump.

5) Over a significant range of costs, a given percentage fall in well-drilling cost results in an approximately comparable percentage fall in the best standard for persons per handpump.

6) As the value of time exceeds $0.35 per hour (falls below $0.25 per hour) net benefits of yard taps (handpumps) tend to be larger.

7) The smaller the village, the greater the comparative advantage of handpumps, particularly when population falls below 400 persons.

8) As well costs (or source costs) rise, the relative net benefit of yard taps rises at a decreasing rate but, for well costs above $8,000, it is difficult to justify any water project in small villages.

## POLICY IMPLICATIONS AND INVESTMENT STRATEGIES

The policy framework. The design and implementation of replicable programs for rural water and sanitation requires three essential policy elements:

1) Cost Recovery. Without a high level of cost recovery it is unlikely that programs will be either financially or administratively replicable on the scale required to get the job done. The evidence suggests there is both a willingness and ability to pay for improved services in most rural areas.

2) Consumer Participation. Assessing consumer preferences is one of the most neglected aspects of rural water systems and features prominently in the reasons for project failure. Unless consumers participate actively in the selection of service levels and in decisions associated with the how and why of cost recovery they will not accept ownership.

3) Financing and Pricing. Few communities have the required capital for investments in water improvements without recourse to borrowing. Improving this access to funds is an obvious first step. One alternative is the creation of a revolving fund at the local or national level. Another is the use of financial intermediaries. Although existing in various forms in many countries, credit institutions have little if any experience in financing these services. The development of such intermediaries does have a number of advantages, including

the community ownership of the assets and the encouragement of small private firms providing investment and maintenance services. An acceptable level of cost recovery will require decisions on what prices to charge to whom and for what services. While the ultimate decision rests with the local or community decision makers, there are a number of guidelines that can be helpful. In order to maximize the economic benefits, it makes sense to charge marginal costs. This may be inadequate in the case of handpumps, where no rationing exists and where placing a charge on incremental use sufficient to cover the financial costs may cause people to return to traditional sources. To avoid this situation, the solution is to charge villagers throughout the village a lump sum fee not related to consumption, which should be agreed upon in advance of the project. The main point, though, is that communities must be encouraged to explore and develop systems that are acceptable to the local population.

4) Public and Private Supply of Services. In most countries rural water supply is largely the responsibility of a government department or monopoly. Alternative supply mechanisms should be encouraged that place greater reliance on the private sector.

5) Institutional Development. Most institutions working in this sector are weak because the policy framework is weak. Given a more supportive policy framework, what would be the role and structure of the institutions within it? It is doubtful that a

case can be made for a specialized institution, given the scattered nature of the rural population. Rather, using existing private and public institutions with established rural networks is probably the best route. The issue is the extent to which such institutions require specialized expertise to evaluate the technical and economic feasibility of proposals they receive. There is, however, no single answer to this question. Promoting a vigorous private sector to complement the work of public agencies is one of the more important institutional objectives. The development of small private firms has been hindered by the provision of these services through public organizations using approaches more suited for large-scale public works than for small, isolated civil works. Reversing this trend will be difficult, but not impossible. Financial assistance to small firms, either through equity or loan capital, may be required, together with training and technical assistance. Institutions providing information and governance need considerable strengthening as well. Information on hydrology, geology, rainfall, etc., is seriously lacking in all countries. Record keeping is poor or non-existent.

6) Private Voluntary Organizations. The assistance of these organizations in promoting and developing rural water and sanitation programs could be of considerable value--provided there is an appropriate framework for their participation. At the moment, when most countries lack a carefully thought out

pricing and cost recovery policy, there is a danger that disparate strategies of numerous domestic and international organizations will encourage unrealistic expectations.

7) Nonhousehold Use of Water. Improving access to water in rural areas can be expected to lead to its greater use in other productive activities, agriculture being an obvious example. In such cases, the benefits might be understated by not taking into account possible increases in agricultural output. This has implications on the cost side as well; if a significant amount of the water is to be used for agricultural purposes, then the design of the system will have to provide for these circumstances, and increases in capacity may be justified. Estimating these influences on demand and supply will require observation and quantification of the effect of improved supply on agricultural production in those villages with water projects.

8) Sanitation. Investments in sanitation services do not appear to be of high priority for rural areas with low population densities. The public sector through education and other means can have some limited impact on this demand but should concentrate its direct investment on more densely populated areas where there is likely to be a higher payoff in terms of improvements in the environment.

9) Training and Technical Assistance. It is important that training and technical assistance programs be designed within a framework that requires the maximum use of incentives and a minimum of administrative rules. The spreading of the knowledge of appropriate technologies, workable policy frameworks, and regulatory systems should all have high priority. The World Bank, in cooperation with the United Nations Development Programme and bilateral donors, has been actively engaged in providing such assistance.

10) Research and Development. Further research is required to expand the knowledge of economic, social, institutional, and technological issues related to improving the delivery of water and sanitation services in rural areas. In particular, better estimates of the factors determining the demand for services would be of great assistance in designing projects. A better understanding of the complex interrelationships between water, health, and sanitation services could improve the cost effectiveness of delivering services in each one of these activities.

## A ROLE FOR THE BANK

The level of investment required to provide adequate water and sanitation services to currently underserved rural peoples in developing countries far exceeds what the World Bank can make available. The Bank can, however, play an important role by assisting countries in using available resources more efficiently by redefining objectives, and by developing acceptable and workable strategies.

The Bank should be active only in those countries that are prepared to work towards the development of replicable programs. This is likely to be a difficult process, requiring staff-intensive effort over a prolonged period of time. One-shot projects that provide for a few handpumps per village cannot realistically be expected to achieve the type of institutional and policy adjustments needed to operate more efficiently in the sector.

In addition to working with the borrowing countries, the Bank will have to engage in an intensive dialogue with other investors, particularly the bilateral agencies. As long as these institutions are prepared to provide funds without requiring an appropriate policy framework, it will be difficult for the Bank to provide any support in this sector.

## POLICY RECOMMENDATIONS

The Bank should adopt the following principles and goals:

1) the Bank should move away from the direct financing of rural water supply systems constructed by government departments and instead focus on the use of financial intermediaries that would provide loan funds to communities.

2) The Bank should consider financing small and medium sized, locally based enterprises that would be able to construct and maintain rural water systems.

3) The cornerstone of any Bank involvement in this sector should be a goal of full cost recovery in its rural water and sanitation projects. In order to achieve this goal, the Bank should be prepared to accept some continuing level of subsidy in the short run in order to introduce the structural and policy reforms that would achieve higher levels of cost recovery over the longer term.

4) The benefit-cost framework developed in this paper should be tested and developed to assist in the design of more efficient interventions in rural water supply.

5) Efforts should be undertaken to estimate the time and labor savings from investments, and only when these are sufficient should projects be undertaken.

6) Benefits from improved health should be noted where possible, but they should not be relied on as the primary means of justifying projects.

7) Bank financing of rural water and sanitation services in the form of sub-components of rural development projects should be continued in those cases where an adequate policy framework exists, or when the project can assist in the development of such a framework.

8) Investments in rural sanitation services should be limited in low-density rural areas to a few experimental programs that would test different approaches/technologies/combinations of services and evaluate and compare their performance.

9) Encouragement should be given to efforts that attempt to shift the demand for sanitation services through general educational programs and those directed at specific behavioral practices affecting health and hygiene.

10) Research on the issues surrounding the estimates of demand and the methods for cost-benefit analysis of water supply and sanitation projects should be undertaken.

11) To complement the Bank's considerable investment in research in engineering and technological issues, additional work should be done on low-cost distributions systems, the development of lower cost drilling techniques, and the use of alternative energy resources.

# I. INTRODUCTION AND BACKGROUND

Rural populations throughout the developing world continue to be without adequate access to safe, convenient water and appropriate sanitation facilities. Governments and international agencies have invested billions of dollars in recent decades trying to improve conditions, with particular emphasis during the current International Drinking Water Supply and Sanitation Decade (1981-1990). While considerable advances have been made, the results overall have not met the expectations either of rural dwellers or of investors. More and more countries and aid institutions are concluding that something must be done to accelerate progress in the future.

This paper addresses that issue. A fundamental reorientation of policies and investment strategies is proposed, with the ultimate aim of helping rural dwellers, governments and donor agencies achieve their water supply and sanitation objectives sooner and more effectively and efficiently than would be possible if past approaches were continued.

The findings and conclusions are based on an extensive review of investment project reports, the published literature, and discussions with water and sanitation experts at the World Bank and elsewhere. The investment projects examined cover a range of water supply systems, excreta disposal facilities, and some related health education programs, financed by the World Bank, the U.S. Agency for International Development, the Inter-American Development Bank, other multilateral and bilateral agencies, and the developing countries themselves.

This chapter first describes the context within which the concern about present strategies has emerged. It then points out -- and challenges -- some common assumptions underlying current approaches.

THE CONTEXT

In 1985, an estimated 65% of the rural population in the developing world is still without access to a safe and convenient source of water. An estimated 75% still has no satisfactory means of excreta waste disposal. This is true despite an estimated US$45 billion invested in water supply and sanitation projects over recent decades, from all sources combined.

Much of that sum has been contributed by the governments of developing countries themselves. World Health Organization (WHO) figures show that during 1971-75 alone, the developing countries, excluding China, invested an estimated US$3 billion per year (in 1973 dollars) in water supply and sanitation. By 1979, that amount had risen to over US$6 billion per year (in 1979 dollars) of which external assistance amounted to a little less than 10%.1/

The World Bank began lending in the water sector in 1961 but did not begin activities in rural areas until the early 1970s. Until 1974, Bank lending amounted to less than US$1 million a year, mostly through small components in agriculture, rural development, and water supply projects. By 1979, this cumulative figure had reached nearly US$180 million. Through 1984, the Bank's first 10 years of rural water supply and sanitation lending had amounted to a total of nearly US$530 million.2/

In the late 1970s, as governments, bilateral and multilateral institutions, and the non-government organizations tallied the results of two decades of investment, they began to recognize that most programs had fallen

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1/ "Development and International Economic Cooperation; International Drinking Water Supply and Sanitation Decade: Present situation and prospects," United Nations General Assembly, September 18, 1980.

2/ "U.S. Strategy Needed for Water Supply Assistance to Developing Countries," U.S. General Accounting Office, August 25, 1981.

far short of their intended objectives. In-depth studies in Latin America revealed that the problems encountered there some 50 years ago--typical today throughout the Third World--have not been overcome, despite a considerably longer involvement in rural water supply and sanitation investments than in the other regions. In all regions, rural water supply and sanitation investments have often failed to provide affordable, acceptable services or to deliver all of the expected health benefits to a population that remains by and large poor and in fragile health.

In one country, only three-quarters of the 29.3 million cubic meter production capacity of a rural water system was recently being used, with only two-thirds of the population that had been scheduled for service getting it and half of them receiving water only three or fewer days per week. In another country, the central authorities decided to serve a particular area with a communal diesel-pumped system. After the entire system was constructed, the villagers would not use or pay for the fuel to operate the pumps. They preferred the taste of the water from their usual source at a more convenient location. In another country, as many as 80% of the handpumps were not functioning at any one time, since no provision had been made for maintenance or repair. When the pumps broke down, the villagers returned to their traditional -- and unhealthy -- water sources. In still another country, authorities installed some 2000 latrines in rural villages at no cost to the users, with the aim of reducing the high incidence of excreta-related disease. Two years later project personnel discovered that most of the households were using the latrines as storage closets. In country after country systems are going out of operation almost as fast as they are being built. Such failures make the international aid community understandably wary about continuing to lend money for programs that not only have little to recommend them in terms of returns for the dollar but also simply do not work.

Even projects deemed successful have not been replicable on the scale required to reduce or eliminate the debilitating effects of an unsanitary environment and, ultimately, to raise the productive capacity of the rural poor throughout the developing world. The costs of this dismal performance are clearly high, with scarce resources being used inefficiently. In regions such as rural Africa where increases in agricultural productivity are key to economic development targets, the consequences of a continued erosion of the productive potential of the people are especially severe.

Meanwhile, continued rapid population growth exacerbates the challenges. Despite high rates of rural/urban migration throughout the Third World, its rural population is estimated to be increasing at an average 2% per annum, adding some 30-35 million new rural inhabitants each year, who require arable land and supporting services. In the case of Africa, even more rapid rates of population growth make the task ahead all the more difficult. In Nigeria, which currently accounts for approximately 22% of the sub-Saharan population, the rural population is expected to increase at about 2.5% per annum from 1985-2000, which could add anywhere from 30-35 million people by that date. Today an estimated 55 million rural dwellers in Nigeria lack a safe water supply and adequate excreta disposal facilities, and those figures could rise to 81 million and 91 million respectively, unless a major breakthrough is made in project coverage. In Kenya, in 1980, some 95% of its rural population, estimated at 14 million, was without access to safe water supplies; growing at an estimated high rate of 3-4% per annum, this number will nearly double by the year 2000. By the end of the International Drinking Water and Sanitation Decade (1990), it is estimated that some two billion or more people will lack adequate water supply and sanitation services, this in addition to the backlog of the millions slated for improvement but as yet to be served as of this date midway into the Decade. (See Table 1.1)

Table 1.1

## RURAL WATER SUPPLY AND SANITATION AT A GLANCE

Just exactly how many people are receiving what services in the rural areas is difficult to estimate. There are no common definitions, for example, on what constitutes "adequate" services or what is meant by "access". Few countries keep up-to-date information on what is happening in their rural areas. The figures in Table 1.1, drawn from a sample of 15 countries representing about 75 percent of the rural populations of the world, should be seen as more illustrative of the situation than as "hard" facts. Several trends should be noted. With the exception of a few African economies, rural incomes are or will be in the near future at levels above US$250 per capita — an income level where piped water systems tend to become affordable. Also with the exception of Africa, rural population growth rates are beginning to take a downturn. Access to electricity that dramatically lowers water costs is, again with the exception of Africa, improving rapidly in most of the world (e.g. in India it is estimated that nearly 80 percent of the rural population will have access to electricity by the year 2000). There are no reasonable figures on "access" to "adequate" sanitary services.

Table 1.1

## RURAL WATER SUPPLY AND SANITATION AT A GLANCE

| Region Country | Rural/ Population 1980 (millions) a/ | Rural/ Population 2000 (millions) a/ | Net Rural Growth Rate b/ (%) | 1980 Access to Elec.*c/ (%) | 1980 Access to Safe Waterd/ (%) | Est. Per Cap. Rural GNP 1980 (US$) | Est. Per Cap. Rural GNP 2000 e/ (US$) |
|---|---|---|---|---|---|---|---|
| **East Africa** | | | | | | | |
| Kenya | 14.4 | 28.4 | + 3.4 | 6 * | 4 | 400 | 700 |
| Malawi | 5.4 | 9.2 | + 2.7 | — | 29 | 200 | 200 |
| Ethiopia | 27.4 | 41.9 | + 2.0 | 9 * | 2 | 100 | 100 |
| **West Africa** | | | | | | | |
| Nigeria | 64.1 | 107.9 | + 2.6 | 7 * | 25 | 300 | [illegible] |
| Burkina Faso | 5.7 | 9.2 | + 2.3 | 3 | 23 | 200 | 20[illegible] |
| **Mediterranean** | | | | | | | |
| Egypt | 22.8 | 29.5 | + 1.7 | 23 | 50 | 600 | 1,[illegible] |
| Tunisia | 3.0 | 3.1 | + 0.2 | 31 | 25 | 1,300 | 2,300 |
| **Latin America** | | | | | | | |
| Brazil | 39.4 | 31.1 | - 1.3 | 43 | 57 | 2,000 | 3,8[illegible] |
| Mexico | 23.1 | 24.7 | + 0.4 | 3.4(?) | 51 | 2,000 | 3,6[illegible] |
| **East Asia & Pacific** | | | | | | | |
| Philippines | 30.3 | 38.1 | + 1.1 | — | 33 | 500 | 1,000 |
| China | 799.1 | 922.0 | + 0.7 | 50 | NA | 200 | 300 |
| Indonesia | 117.4 | 129.9 | + 0.5 | 8 | 18 | 400 | 600 |
| **South Asia** | | | | | | | |
| India | 527.5 | 632.4 | + 0.9 | 14 * | 20 | 200 | 400 |
| Bangladesh | 80.1 | 117.1 | + 1.8 | — | 55 | 100 | 300 |
| Pakistan | 60.2 | 87.2 | + 1.8 | 33 | 17 | 300 | 600 |

* indicates estimate for both urban and rural areas

Sources:

a/ UN Estimates and Projections of Urban, Rural and City Populations, 1982 assessment, UN Population Division.

b/ Ibid.

c/ IBRD, Energy Department, July 1984.

d/ IBRD, Social Indicators Data Sheet, June 1984.

e/ IBRD, Water Supply and Urban Development Department, July 1984; GNP estimates are based on best available data and are designed primarily to give an order of magnitude for comparisons among regions.

SOME COMMON ASSUMPTIONS

Why have past approaches not been more successful? Finding some answers requires first distinguishing the common assumptions underlying investment strategies and country policies.

Most investments have assumed two crucial propositions. One is that rural households are unable or unwilling to pay for improved services, given their incomes and resources. The other is that water supply and sanitation improvements will have significant health benefits for the population affected and through those benefits will generally enhance their overall well-being.

Taken together, these assumptions have led planners to justify water supply and sanitation projects as necessary for general health and welfare rather than in terms of standard benefit-cost criteria. In World Bank projects, for example, it has been common to dispense with the calculation of an economic rate of return on the grounds both that no method exists for calculating the benefits and that they are largely nonquantifiable health improvements. Such thinking is evident in the following report about a project in Nigeria:

> "Formal analysis of the economic return on the rural water supply program would not be meaningful because of the practical impossibility of quantifying and then internalizing the different forms of benefits into an indicator like the rate of return. Further, a substantial but uncertain amount of benefits will be qualitative, due to an improvement in the safety of water supply."3/

3/ Staff Appraisal Report, Nigeria, Sokoto Agricultural Development Project, (3304-UNI), May 24, 1982, page 47.

In addition, policies and investment strategies have tended to encourage a large role for the public sector as a dominant or monopoly supplier. This has led to the politicization of the decision-making process in project design, high levels of subsidies, and close linkages to health delivery services. The resulting top-down or paternalistic delivery systems have not been able to sustain the cooperation of the user populations.

Two further assumptions also have typically been made, as explanations have been sought for the disappointing performance of past investments. One is that the source of the problem is institutional weakness. The other is that inappropriate technology choice alone is responsible.

Because painful experience has demonstrated that the reality is often not precisely what all these assumptions suggest, it is important to examine them more closely.

Are the rural poor able and willing to pay for water supply and sanitation improvements? Although data on rural incomes and, hence, ability to pay are scarce, few disagree that rural populations are much poorer than their urban counterparts and that rural incomes are denominated primarily in kind. Some developing countries justify their policies in rural water supply or sanitation on this basis. Saunders and Warford note that "the general lack of any hard evidence on ability (and willingness) to pay has resulted in the politically expedient assumption, which has been made in most developing countries, that the rural population cannot pay the full cost of water".4/

4/ Robert J. Saunders and Jeremy J. Warford, Village Water Supply: Economics and Policy in The Developing World, page 190.

Moreover, many governments presume that water is a merit good -- a basic necessity for survival -- that, therefore, should be provided free to its poorest citizens.

However, cash income is far more prevalent in rural villages than is often recognized. A household survey conducted in one of the least developed and most remote areas of Mali provided evidence that rural dwellers have considerable sources of cash income from nonagricultural activities; the percentage of total income from cash-earning activities ranged from 43% to as high as 50%. Furthermore, high expenditures absolutely and proportionately on social activities (community projects, celebrations, gifts) and durables and loans to others provided a strong indicator of ability to pay at least some amount toward water supply improvements; these expenditures ranged from 28% to 45% of total household income in the areas surveyed.5/ In other countries, too, cash or a barter equivalent is frequently available. The village producing only nontradeables has become virtually a vanishing breed. Valued consumer items such as radios and motorbikes are no longer rare sights even in remote areas.

The issue thus appears to be not whether rural populations can reasonably contribute from their household income but how large an amount. Whether they will be willing to contribute is another matter. There must be a felt need for improved services, and the population also must understand that it will have to pay for them. In a CCCE-financed water project, also in rural Mali (Mali Aqui Viva), villagers themselves offered to finance all or part of the construction of wells, some of which were equipped with solar pumps.

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5/ Three Studies on Cost Recovery in Social Sector Projects, CPD Discussion Paper No. 1983-88 Nancy Birdsall, Francoise Orivel (Consultant), Martha Ainsworth, and Punham.

Sometimes communities prefer a more costly service than initially provided, if they value the higher quality enough. A U.S. Agency for International Development project in Thailand found this out the hard way:

> "The Thai piped water project with 250 systems serving 600 communities had been a failure when it supplied water only through communal taps. By 1972, three years after the completion of the project, only one-quarter of the systems were working. In 1979, at the time of the evaluation, over 80 percent of these systems were operating and self-sufficient. The change resulted from the conversion from communal facilities to individual metered connections. The private connections provided more convenient sources of supply than had the water from existing community shallow wells".6/

It is a common rule of thumb in designing rural water supply and sanitation interventions that households can pay 2-3% of their income for an improved water source. This assumption has led to design alternatives that, in the main, have produced too little water and at locations too inconvenient to adequately serve all the intended users. Villagers consequently often abandon the clean water source and return to contaminated streams and other more conveniently located sources. And as a practical matter, whether they use the water or not, villagers frequently end up not paying anything for the service.

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6/ USAID, Community Water Supply in Developing Countries: Lessons from Experience, AID Program Evaluation Report No. 7, September 1982, page 17.

One of the basic hypotheses underlying the alternative framework presented in this paper is that a majority of the rural population can contribute to water supply and sanitation improvements, and, indeed must do so if these projects are to be replicable on a large scale. The data and analysis presented in later chapters suggest, in fact, that rural populations in most instances are actually paying the equivalent of a relatively large sum in terms of time and effort for hauling water. Translated into dollar figures, rural households are probably paying as much as 5% of their income -- and this for only small quantities of often contaminated water. This means that the poorest of the poor are paying far more for water service than most other people in the world and getting less for the investment. (By comparison, for example, while the cost of using water from a handpump in an isolated area in the Third World can be the equivalent of about US$4.00 per cubic meter, the cost of water in Washington, D.C. is about 30 cents.)

Do rural water supply and sanitation projects bring significant health benefits? Efforts to demonstrate that the introduction of clean water and excreta disposal facilities results in improved health have so far led to more questions than conclusive evidence. Part of the problem is that health benefits are extremely difficult to estimate directly because of the impossibility of isolating and separately quantifying the myriad of inter-related factors that contribute to the spread of diseases. Also, to the extent that health benefits can be measured, they seem to result from interventions beyond just water supply and sanitation improvements.

A comparative study between Sri Lanka and Guatemala of the decrease in mortality, for example, shows that health improvements are related to general advances in the standard of living, greater literacy, and to a mix of health services, rather than to just a specific intervention, in this case malaria control.7/ A recent evaluation of a USAID provincial water project in the Philippines similarly found no clear proof of a substantial, positive project impact on health status during the project period. Of the water-related variables studied, there was no significant direct association between the source of water and health, when socio-economic variables were controlled for. Among other important conclusions of the study, education in proper water handling and storage practices, along with provision of better sanitary facilities, was found to be necessary before health improves. The Philippines study also suggests an additional complicating issue: that the higher the income level, the more successful the health education programs associated with the introduction of improvements to water supply and sanitation.8/ This conclusion confirms experience elsewhere of the difficulty of convincing an illiterate population of the connection between the germ theory of disease and benefits to health. A World Health Organization-published review of evidence on alternative methods to control diarrhea, which examined some 67 studies from 28 countries that measured health impact, came to another significant conclusion. The authors found, inter alia, that although some reductions in diarrheal morbidity and mortality rates can be expected from investments in water supply and sanitation, the inclusion of a hygiene education component to a project may further enhance the health impact.9/

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7/ S.A. Meegame, "Malaria Eradication and Its Effects on Mortality Levels", Population Studies, Vol 21, No. 3, November 1967, page 237.

8/ International Statistical Programs Center, U.S. Department of Commerce, Evaluation of the Provincial Water Project in the Philippines, Final Report, June 1984.

9/ Interventions for the Control of Diarrhoeal Diseases among Young Children: Improving Water Supplies and Excreta Disposal Facilities, S.A. Esrey, R.G. Feachem, J.M. Hughes. WHO Bulletin 60, No. 4 (1985).

Understanding the etiology of the numerous categories of water- and excreta-related diseases helps to clarify why simply improving the quality of the water supply has so little preventive effect. These diseases can be variously classified as to their route of transmission, and almost none comes exclusively from drinking water. A number of infections such as cholera and typhoid are transmitted mainly through drinking water, but water quality is not the only critical factor, as is often assumed. Contamination through transportation and storage in the home environment and poor personal hygiene are also important. For other types of diseases, such as scabies, conjunctivitis, and ascariasis, the quantity of water used is more crucial than quality, since the disease-causing agents can be washed away or diluted to noninfective levels by using more water. It is estimated that 30-40 liters per person per day -- about twice as much as that available to the average Third World Resident -- are required to allow adequate washing for good personal hygiene. Another group of diseases, such as yellow fever, malaria, and African sleeping sickness, is transmitted through the bite of insects that breed in water. For these diseases, the critical factor is whether the water supply is protected or far enough away from living quarters. Still other diseases, such as various forms of gastroenteritis, depend on the ingestion of fecal matter in food. Prevention requires stopping defecation near agricultural areas and curbing non-hygienic interpersonal contact. Finally, certain diseases, such as schistosomiasis and guinea worm, are transmitted through contact with pathogenic organisms in an aquatic environment. Of all these diseases, only guinea worm is transmitted exclusively by drinking contaminated water.10/

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10/ Saunders and Warford, op. cit., include a trenchant discussion of this, and a table, categorizing all these diseases, pp. 31-35.

This perspective on disease transmission suggests that intervening at only one part of the transmission cycle will have relatively little, if any, effect on health. The spread of cholera, for example, can be drastically curtailed by a protected water supply, but only with the elimination also of transmission through interpersonal contacts, bed clothing, and eating utensils. Improved quality and quantity of water may consequently have limited impact in the absence of hygiene education designed to change well-entrenched social and cultural habits and traditions. Thus, water supply and sanitation appear to be necessary but not sufficient conditions for health improvement.11/

All this would indicate that although recent investments in water supply and sanitation have been significant in monetary terms, they may not have achieved sufficient population coverage to make a difference or, equally important, addressed the right mix of social and environmental factors. Much more analysis is clearly required to determine the cost effectiveness of health-related investments, when looking at these investments purely from the point of view of their effect on health. Investments in water supply and sanitation services constitute only two in an array of potential investments that must be made to reduce morbidity and mortality. In the rural context, some skepticism has already been expressed as to their effectiveness:

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11/ One theory holds that a certain threshold of socioeconomic development must be reached before water supply and sanitation investments can be successful. See H. I. Shuval, et. al., Effect of Investments in Water Supply and Sanitation on Health Status: A Threshold-Saturation Theory, Bulletin of the World Health Organization, 59 (2), 243-248 (1981).

"Briefly our conclusions are that no measurable reduction in water-related disease has resulted so far from [improving] village water supplies. It is possible that benefits might result were other health measures to be implemented together with water supply improvements. But we suspect that they would in that case result in the first instance from those other measures, rather than any improvements to the water supply".12/

Fortunately, most investments in rural water supplies can be justified on grounds other than achieving improvements in health -- as Chapters II, III, and IV show.

Can the public sector provide adequate rural water supply and sanitation service? Central governments in the developing world traditionally have played a major role among the providers of rural water supply and sanitation services. The private sector has not had the opportunity to develop and market these services, and governments with few exceptions have functioned as monopoly providers. This appeared to be the best way to reach the largest number of people, and international aid institutions for the most part have not interfered.

The conventional wisdom has been that public monopolies are best because there are economies of scale in water systems. But this presumption was based on experience with urban water systems, and most rural systems do not exhibit the same economies of scale. The evidence suggests, in fact, that government monopolies have been high-cost suppliers and that there may be considerable diseconomies of scale. In the United States, for example, public monopolies and large privately owned systems exist side by side with over 10,000 independent systems.

Public monopolies have often been inefficient. Many programs that are rooted in high levels of public subsidy tend to breed excessive administrative costs. Public funds are scarce funds and the need to ration them leads to centralized bureaucracies that assume a life of their own.

Another problem associated with the dominance of the public sector is an ignorance of, or lack of exposure to, consumer preferences -- leading to little or no community participation in a project. When rural communities contribute little or nothing of their funds, time, or other resources to a water supply or sanitation project, it is not theirs. Their sense of ownership in the whole undertaking and interest in maintaining the system in operational condition are likely to be limited. The result is often failure, as this USAID report states:

> "The evidence shows that when communities value a system, the system tends to be successful. Systems that were built to fulfill AID's perceived need to provide only better quality water were not valued and did not survive."13/

Inadequate provision for community involvement frequently leads to systems poorly matched to users' desires and ultimately to underused or abandoned facilities. In extreme cases, countries have systems going out of service as rapidly as they are being installed.

The implicit costs of underutilization or abandonment can be substantial. Suppose, for example, that a country has 20,000 rural water supply systems, representing an average investment of US$25,000 each. If only

12/ Overseas Development Administration, Manual for the Appraisal of Rural Water Supplies, HMSO, 1985, page 89.

13/ USAID, Community Water Supply in Developing Countries: Lessons from Experience. AID Program Evaluation Report No. 7, September 1982, p. 25.

60% of systems are functioning, then 8,000 are out of operation at any given time. Should an improved maintenance system result in the proper and continuous functioning of 4,000 of these, this would be equivalent to a capital investment of US$100 million. And by averting that investment, valuable foreign exchange is saved.

In addition to all these problems, some countries, notably the poorest, are simply not able at present -- given their severely limited budgets and managerial weaknesses -- to assume the responsibility of bringing water supply and sanitation services to widely scattered rural populations. As a result, large numbers of rural dwellers simply get no service at all.

The alternative is to encourage the public sector to share with the private sector some of the responsibility for water supply and sanitation. Obviously, any change of this sort would have to occur gradually and systematically, and in some places the government would have to maintain its involvement for some time to come until the appropriate firms could be found, financed, and promoted. But the ultimate goal would be for the public sector to serve in the role mainly of regulator, educator, and promoter, and the private sector, in that of provider.

To what extent can strengthening institutions help project performance? In the search for answers to the problems of past projects, it is often argued that stepped-up "institutional development" is needed. But institutional development is not likely to resolve the many and varied problems in rural water supply in the absence of a more fundamental change -- i.e., a shift from exclusive reliance on the government to a partnership between the public and private sectors.

Water supply and sanitation institutions presently suffer from the same broad spectrum of structural and policy weaknesses as do most other institutions in developing countries: inadequate financial and human resources, poor management, too much or too little staff of a particular category, overcentralization or too much decentralization, inadequate incentives for good performance, lack of sensitivity to consumer needs, etc. While improvements in institutional performance are always possible and desirable, the institutions responsible for rural water supply and sanitation services cannot be expected to achieve levels of efficiency much beyond those found in the public sector in general. Thus, institutional development is unlikely to be sufficient by itself to resolve all of the problems of past investments completely, except perhaps over the very long term.

The major challenge is to develop institutions that are highly responsive to localized needs, yet at the same time are capable of effectively using scarce and usually centralized resources. Many countries have experimented with a variety of institutional forms, from large centralized institutions or government ministries to private voluntary agencies. More often than not, diverse institutions exist side by side, sometimes under the sponsorship of different external donors.

Modest reforms will seldom be enough. A more far-reaching examination of the issues is usually required, focusing on what services are delivered, how they are delivered, to whom they are delivered, and who ultimately pays. But even projects that have hoped for fundamental change have met with obstacles. For example, where overcentralization has been identified as a weakness, efforts to decentralize have proven difficult in practice, given that the services traditionally require large amounts of public resources and the allocation of resources is inevitably made in a centralized and usually political way -- precisely the way in which rural populations have the least influence and representation. Another example is the many attempts that have been made to design better maintenance systems. In theory, maintenance that is more dependent on local efforts appears to be a step in the right direction. In practice, local communities have been reluctant to accept responsibility for infrastructure over which they have had little say in its design and construction.

Institutional improvements are vitally needed, but because truly effective improvements typically evolve slowly, other steps are essential too. This is the heart of the issue. All too often problems have been approached by choosing the institutional structure that will work for a particular delivery system rather than selecting the delivery system that will work given the limitations of the existing institutional framework.

To what extent can more appropriate technologies help project performance? When water supply and sanitation improvements were first undertaken, not enough emphasis was given to simple systems, such as gravity ones fed by springs. Pumping systems were too sophisticated and complicated; early handpumps designed for single family use broke down when subjected to heavy, intense village use. In some countries, maintenance workers from the centralized depot handling maintenance often reached villages requiring assistance only when fuel was available for transport. Latrines and other low-cost sanitation techniques were not coupled with adequate village education, fell into disrepair, or were simply abandoned. By the late 1970s, donor agencies were reporting that even handpumps, widely hailed as one of the simplest means of supplying drinking water to rural and urban fringe areas where groundwater was reasonably available, had failure rates of over 70% in some projects.

While the poor choice of technologies has undoubtedly contributed significantly to the failure of many projects, it is not the sole cause. The poor performance and short working life of the handpumps, for example, can be traced to problems with their design, their selection for particular environments, the availability of replacement parts, the quality of their manufacture, and their misuse, overuse, and care. But perhaps the more fundamental question is why were the wrong technologies chosen and what were the incentives that led to the wrong choices? Is the issue that the appropriate technologies do not exist, or is it that they have not been used or adapted properly to meet local needs?

There is little doubt that appropriate technologies do, indeed, exist. Techniques of water delivery and the sanitary disposal of human wastes are centuries old. What has changed is the introduction of modern materials and methods (e.g., plastic pipes and remote-sensing techniques and improved geophysical techniques for groundwater location and development) that have lowered the per capita costs of providing services. But these improvements have not been employed on a wide enough scale to filter down to low-income, rural area groups. Part of the reason is that in low-income rural areas limited and fragmented markets give entrepreneurs little incentive to promote the modern, more efficient techniques. The virtual monopoly power that public institutions often exercise over service provision also removes market incentives. Furthermore, the consumers of the service -- who presumably know most about what would or would not work best in their environment -- rarely participate in decisions about appropriate technology. Instead, external donors far removed from the site often make these decisions.14/

14/ Feacham, Richard G., David J. Bradley, Hemda Garelick, and D. Duncan Mara, Sanitation and Disease: Health Aspects of Excreta and Wastewater Management, John Wiley & Sons, New York, 1983.

In response to these difficulties, the World Bank, and the United Nations Development Programme, with the support of a number of bilateral aid agencies, have undertaken a large-scale research and demonstration effort ($17.9 million to date) to develop, test, and introduce more workable handpump and sanitation technologies in the developing world. Handpumps that can be operated and maintained at the village level are an example, as are improved dry-pit and pour-flush latrines. Perhaps more important than the technologies themselves has been the careful evaluation of how they are used and under what circumstances they can be introduced successfully on a large scale with financially sustainable strategies. (See Box 1.1)

While continuing research and demonstration work into more appropriate technologies is desirable, that alone will not resolve the problem of how (or if) these technologies will be applied on a global scale. Improving handpumps, for example, will do little to lower the cost of delivering water supplies to rural communities if boreholes continue to be drilled in costly and inefficient ways and are not properly developed and protected. A better latrine will be of little use if the consumer does not see the need for this investment and make use of the facility. Unless appropriate incentives are provided for the implementation of improved technologies, their application will be limited.

Box 1.1

## THE WORLD BANK/UNDP WATER DECADE PROGRAM: RESEARCH AND DEVELOPMENT OF LOW-COST TECHNOLOGIES

During the past six years, the World Bank and United Nations Development Programme (UNDP) have cooperated in a special global program to develop, field test, and demonstrate the effectiveness of low-cost technologies for providing safe drinking water and basic sanitation to low-income groups in urban and rural areas of developing countries. The program presently includes four major components: testing and development of rural water supply handpumps, development of low-cost sanitation investment projects, research and development on integrated resource recovery, and an information and training network for water and waste management. In FY85 the prograam was conducting activities in 38 countries with a budget of about $6.0 million, with financial support provided by the UNDP, one multilateral and seven bilateral agencies, and the Bank itself.

### Testing and Development of Rural Water Supply Handpumps

Through extensive laboratory and field testing of different handpumps, this project is attempting to identify those that are most efficient, reliable and cost-effective for the varying requirements of rural water supply systems throughout the world. Laboratory tests have been conducted on 23 pump types and field trials on 70 different types in 17 countries. The project is also supporting research and development on handpumps that can be maintained and repaired at the community level or by a low-cost decentralized mobile maintenance system. During 1986, the findings of the handpump testing will be published as guidelines for selection of handpumps for rural water supply projects and local manufacturing. Thereafter project activities will give greater emphasis to the promotion of and assistance to local manufacture and to the application of the findings to and promotion of large-scale rural water supply investment projects.

Development of Low-Cost Sanitation Investment Projects

The project has been highly successful in disseminating knowledge and gaining increased acceptance of on-site sanitation options as technical alternatives to costly conventional sewerage. It is presently conducting activities in 16 countries and financial support through a network of country sanitation projects and advisory posts, with a headquarters team providing the overall management, intellectual leadership and technical backstopping. The project has assisted governments in designing and implementing pilot demonstration projects both urban and rural; preparing large-scale feasibility studies; formulating sector policies and programs; and training sector staff. The project has also sponsored and supervised research to refine low-cost sanitation technologies and human waste management systems. Recently, the project has been placing greater emphasis on the development of large-scale investment projects and on the vital institutional and delivery systems to implement large-scale on-site sanitation schemes.

Research and Development In Integrated Resource Recovery

The resource recovery project has been analyzing and demonstrating basic technological, environmental, and institutional practices and potentials of waste recycling in developing countries. The project has produced a series of reports on resource recovery practices and is preparing studies of waste management and recycling in metropolitan areas of nine countries. Among the most important topics are: solid waste recycling, biogas production, remanufacturing of durable products from discarded materials, the use of effluents in aquaculture, and the health aspects of effluent irrigation. In the future, the project will deal with the economic and institutional feasibility of the most promising waste recycling technologies and prepare case studies in a number of metropolitan areas such as Colombo, Mexico City, Dakar, and Jakarta to evaluate the potential for recycling and large-scale recycling investment projects.

International Training Network for Water and Waste Management

The World Bank has recently completed the production of a comprehensive set of information and training materials on the full range of appropriate technologies. It is now launching a training network of developing country institutions to disseminate knowledge of these technologies and promote their use. The network is more fully described in Chapter V.

## CONCLUSIONS

Commonly held assumptions about the ability and willingness of the rural poor to pay for water supply and sanitation improvements, the potential health benefits associated with them, the ability of the public sector to provide them, institutional inadequacies, and inappropriate technologies have had enormous influence on current policies and investment strategies. All of these concerns have some validity, but a close examination of each one of them suggests that the fundamental issue is the way investment decisions are made.

Tackling that more basic problem requires a totally new conceptual framework for designing and developing water supply and sanitation programs. Clues for what that fresh approach should contain were already beginning to surface as the evaluations of past investments emerged in the late 1970s. Experiments in the Sahel, for instance, showed that communities could and would help decide on the location of their wells, help build them, and contribute to their recurrent costs. Niger, Burkina Faso, Mali, Senegal and the Ivory Coast financed similar pilot operations, with the assistance of the multilateral and bilateral donors and private and public voluntary agencies. These experiences, though isolated, contain the seeds of a sound development strategy. Gradually small but important inroads have begun to be made in a sector development philosophy that once appeared irrevocably linked to the notion that water should be delivered free to a population too poor to contribute and seemingly incapable of making decisions on the type of service it wanted. The lesson is being learned that community participation in decisions about rural projects, particularly in water supply, encourages more rational use and better maintenance, not to mention a higher direct return on investment.

This paper seeks to further advance that thinking. It develops a conceptual framework that can help improve the identification, design, implementation, and maintenance of investments in rural water supply. The framework stresses quantifiable economic benefits in terms of time and labor savings and provides a methodology for utilizing a benefit-cost approach. The issues of appropriate technology and the effectiveness of delivery mechanisms are addressed as well. The paper is directed primarily at borrowers and lenders in the water and agricultural/rural development sectors. But it is hoped that the recommendations will reach a wide audience and will be catalytic in mobilizing the range of donors involved in the sector to coordinate and cooperate in a concerted effort to extend the benefits of improved services to larger numbers of people.

Although all regions were included in the analysis, sub-Saharan Africa and parts of South Asia received primary emphasis. It is in these two regions where the numbers of unserved rural inhabitants are currently -- and are projected to be -- the largest and where financial and trained manpower resources are the most severely constrained. Nonetheless, the framework presented here can be adapted to all the regions, and indeed, is expected to serve as a guide to rationalize Bank participation across the regions.

The discussion of the conceptual framework in the next three chapters applies only to rural water supply and not to sanitation services, and sanitation will not be discussed again until later, in the context of policy recommendations. Sanitation issues differ in certain key respects from water supply issues. The demand for sanitation services in rural areas appears to come from an interest in privacy and convenience. In urban fringe areas and in densely populated rural villages, new sanitation facilities have been introduced with good results, as in the case of improved latrines in rural

Zimbabwe and pour-flush toilets in peri-urban and urban areas of India and Pakistan. There are, by contrast, few documented successes in the low-density, scattered villages where open space allows both convenience and privacy. Given the importance of this density issue, the priority that sanitation investments should receive will depend on the characteristics of each setting.

## II. MEASURING THE BENEFITS

Once the past record of water supply investments is understood in the way outlined in the preceding chapter, it is clear that the criteria on which investment choices are based need to be reconsidered. This and the next two chapters propose a set of criteria and a method for applying them that differ substantially from previous practice but adhere closely to procedures widely recommended for other types of investments that countries make routinely.

The approach suggested is a form of benefit-cost analysis.1/ Although benefit-cost calculations have been presumed in the past to be infeasible for water supply investments, that assessment rests on some of the common assumptions called into question above. Once the prevailing misconceptions about those assumptions are cleared away (e.g., once it is recognized that rural populations are able and willing to pay at least some amount toward improved water supply), then the obstacles to performing benefit-cost analysis are no longer so formidable.

This chapter discusses how the benefits of water supply improvements can be evaluated -- in the past the primary stumbling block to benefit-cost analysis. The cost side is examined in Chapter III. Chapter IV brings

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1/ On the general arguments why societies are best off basing resource allocation choices on benefit-cost criteria, see Little, I. M. D. and J. A. Mirrlees, Project Appraisal and Planning for Developing Countries, New York, Basic Books, 1974 or L. Squire and H. G. van der Tak, Economic Analysis of Projects, The Johns Hopkins University Press, 1975.

benefits and costs together. The practical benefit-cost analysis developed in these chapters will help in planning what sorts of improvements -- if any -- should be undertaken in the quantity and quality of existing water supply services, given both the preferences of the population and the resources available for building, operation, and maintenance.

OVERVIEW OF THE APPROACH

The most important benefit of rural water supply improvements from the perspective of the people affected is generally the fact that water is brought closer to where they live. Typical investments provide a central well where formerly there was only a water hole outside the village center; or multiple neighborhood standpipes where formerly there was only a single central well; or a yardtap outside each house where formerly there were only standpipes serving a group of houses. The result in general is a reduction in the time and effort people have to spend hauling water.

For the vast majority of rural dwellers, carrying water is still time-consuming and heavy work. Often they must travel considerable distances to reach traditional water sources. In parts of Mozambique, for example, women used to spend three to four hours a day hauling water, and sixteen hours working in total, until new wells were installed. The time savings resulting from the new wells averaged 1.75 hours per day, or approximately 50 percent of the former water hauling time.2/

There is evidence that rural households value such time savings and are willing to contribute some of their own resources, in cash and in kind, toward supporting improvement efforts that bring water closer to them. (This

2/ UNICEF and the National Directorate of Water Resources, Water and Sanitation Workshop of the Mueda Plateau, People's Republic of Mozambique, November 1982.

evidence is discussed below under "Time is Money".) Consequently, estimates of the benefits of rural water investments must include the value to the beneficiaries of the time saved.

The value of time saved is more difficult to estimate than quantities like the amount of water a household consumes or the cash price charged for a commodity. Nevertheless, sufficient data usually exist or can be collected to infer with confidence that the value of time saved for a particular population is within a certain range, where the lower end of the range is greater than zero and the upper end usually is equal to or less than the local average wage rate. Information on the tradeoffs people make when getting water can be helpful in determining this range: When do they pay others to haul water for them? How much do they pay? When they haul their own, how does the amount they take vary with the distance they must travel? Information on wage rates (e.g., for water vendors, for household servants, and for the local labor market generally) and on who in the household does the hauling (women? children?) can also be useful. Household survey techniques are improving rapidly, too, for inferring people's valuation of time from observation of their daily activities or from responses to questions about their preferences among contingent alternatives.

Once the approximate order of magnitude of the value of the time saved has been determined, an estimate of the overall benefit of this savings to the population affected can be obtained using a well-known procedure that is described in Box 2.1. The essence of the procedure is to estimate the benefit from the viewpoint of how much the beneficiaries would be willing to pay to keep the time savings they gain.

Suppose, for example, that a particular project is expected to reduce average water hauling time by 45 minutes and that, considering the value of this time savings to the households affected, the implied decrease in the price they pay is from 0.4 to 0.2 cents per liter. Suppose also that following this time reduction, the quantity of water consumed is expected to increase from 100 to 150 liters per household per day.

The benefit of this investment for a single household, estimated by performing the simple calculations required by the formula in Box 2.1, is $0.25 per day. This is 5.0% of income for a household with a gross annual income of $1,800, a not atypical figure for rural communities in poorer countries. If the $0.25 per day is an average for the households in a 100-household village, the overall benefit is $9,000 annually.[3/]

This approach to benefit estimation, while emphasizing time savings, does not ignore the fact that bringing water closer to people also saves them the physical exertion involved in water hauling. Exertion expends body energy, which is a limited resource just as time is. Insofar as rural dwellers are willing to pay to avoid the exertion in water hauling, that preference will be fully reflected in the value they assign to the time savings. The estimated value of time saved is thus not just for any time saved but for a certain kind of time -- water hauling time.

The approach also does not completely ignore certain other benefits of water supply projects, specifically, improved taste, clarity, and odor, and better reliability of supply. Insofar as the population affected attaches importance to any of these considerations, households will adjust the value of the time savings accordingly -- as they do for the exertion factor. A small

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3/ Strictly speaking, this is the net benefit, in that users' costs have been netted from gross benefits.

Box 2.1

## THE WILLINGNESS-TO-PAY METHOD OF ESTIMATING BENEFITS

The relationship between price per liter, P, and daily water consumption in liters, Q, on the part of an individual may be summarized by a demand curve such as that shown in Figure 2.1 below. Assume that the household initially purchases $Q_1$ liters of water daily from vendors at a price of $P_1$ for a total daily expenditure of $P_1 \times Q_1 = E_1$. Assume further that the water service improvement provides water through yard taps at price $P_2$. From the demand curve, an individual now consumes $Q_2$ liters of water daily at a total cost of $P_2 \times Q_2 = E_2$. The person benefits in two ways. First, there is a saving of $(P_1 - P_2)Q_1 = s$ dollars per day on the initial daily water consumption, $Q_1$. This is equal to the rectangular area in Figure 2.1 labled "s". Second, the person consumes $Q_2 - Q_1$ additional liters of water. The value that an individual places on this incremental water consumption exceeds the price of each liter, $P_2$, by an amount equal to the shaded area labeled "S". Thus the total increase in welfare of the individual experiencing the fall in price from $P_1$ to $P_2$ is measured by the entire shaded area. This is the basis for the consumer's surplus or willingness-to-pay measure, which is the measure of economic benefit used here, as exemplified in the following formula:

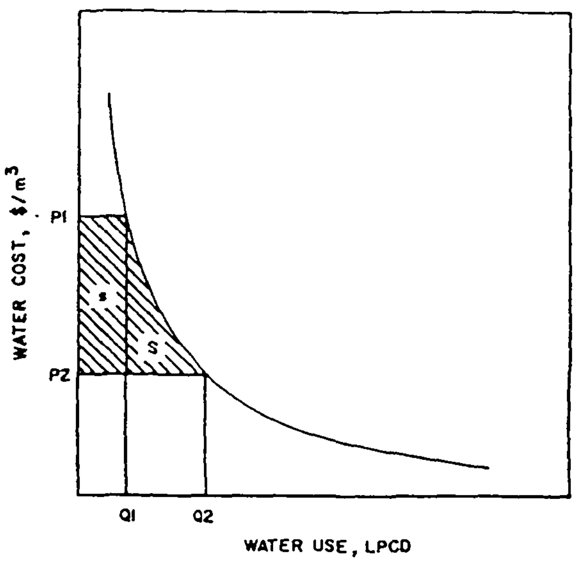
$$B \approx (P_2-P_1)\ Q_1 + {}^1/_2\ (P_2-P_1)\ (Q_2-Q_1)$$

Of course, the shaded area in Figure 2.1 measures willingness-to-pay per person per day because it is based on a daily water demand curve. However, this benefit measure is annualized easily by multiplying by 365 days per year. Benefit and cost measures are compared by computing them as annualized flows, rather than as discounted present values (DPV), as is often the case in benefit-cost analysis. Both approaches produce equivalent results.

FIGURE 2.1

WATER DEMAND AND WILLINGNESS-TO-PAY FOR A REDUCTION

IN THE PRICE OF WATER FROM $P_1$ TO $P_2$



time savings may be worth a lot to households if they will concomitantly get a more reliable source. In situations where the expected improvements in taste, clarity, odor, or reliability would be so important as to overshadow the time savings, an amended estimation procedure, giving more emphasis to those dimensions explicitly, would be needed. However, such cases are likely to be the exception rather than the rule for the vast numbers of rural communities where the potential for substantial time savings has yet to be realized.

If households believe they will receive health benefits from an improvement project in addition to the other benefits already mentioned, then the above remarks about taste, etc. apply as well for health effects. That is, the perceived health benefits will, to some degree, be captured in the value that households place on the time saved; but if health effects dominate other benefits, then the approach outlined here would need to be substantially amended. There is no indication that rural populations expect health gains. Given the lack of conclusive quantitative evidence that past projects have produced any, this is not surprising.

Thus far, the discussion has focused on benefits from the perspective of the beneficiaries. For benefit-cost analysis, benefits should be calculated from the perspective of society as a whole. The two perspectives yield different results only if there are some additional benefits beyond those that accrue to the beneficiaries directly. In practice, for the rural water supply sector, there would be significant additional benefits of this sort only if there were appreciable health-related "externalities" -- i.e., if when some people got better water, others benefited through reduced disease transmission. However, the existence of substantial, health-related externalities is extremely improbable, given the evidence. Thus, the approach proposed here, which excludes any consideration of externalities, is likely to give at least a reasonably good approximation of the total benefits of a water supply investment. In rare cases where additional benefits such as externalities do need to be incorporated, it is still best to proceed this way as a first step; amendments can then be made later to reflect any further information available.

The discussion thus far also has assumed that the only "cost" that users incur to get water is the time and effort they spend on it. No cash price -- or charge paid to the supplier per unit of water taken -- has been included. This in fact is common; water from a central village well or neighborhood standpipe is available without a fee (although households may pay indirectly through a tax). In some cases, though, there is a charge. Where so, the present approach can easily be adapted to incorporate the joint effects of time savings and fee charges.

## TIME IS MONEY

It follows from the above that if rural households care little about the time and effort required to get water, and thus are not willing to pay much to avoid lengthy trips and long waits, then the benefits from water supply improvements will be minor. If, on the other hand, households value the time highly, then the benefits will be substantial.

How much in fact is known about the value that rural dwellers place on water hauling time? Though the available evidence has many limitations, a careful review of it suggests that water hauling is by no means looked upon lightly: rural households appear to be willing to pay sums that are substantial enough to cover the costs of the low-cost technologies now being recommended widely for rural conditions.

Some of that evidence is from places where water is sold by vendors. When households use vendors, they reveal their willingness to pay every time they make a purchase. Studies of vendor use find the expected inverse relationship between price and the amount of water consumed. Antoniou, for instance, examined vendor sales in poor urban fringe areas in the Sudan where vendors compete with kiosks. At the kiosks, water is dispensed for little or no charge, but there is often a queue and, hence, a wait. Vendors were able to charge four times or more as much as kiosks. Vendor prices increased with distance from the kiosk, showing that households will pay more as the alternative of fetching water themselves becomes more burdensome.4/ White, Bradley, and White report findings from low-income areas where water use is metered. They conclude that the quantity consumed is negatively related to the cost per liter.5/

Where vendors, metering, or other user-charge arrangements do not exist, it is still possible to infer something about willingness to pay from observed relationships between the amount of water consumed and the distance it must be hauled. If rural households were not willing to pay for water (i.e., attached little value from saving time and effort in water hauling), then one would expect to find no particular relationship between the amount consumed and distance. But, in fact, people consume less water the farther they are from the source. When water is brought right outside their house, through installation of yardtaps, consumption may triple relative to when they have to travel to central village standpipes.

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4/ Antoniou, James, "Sudan: Khartoum-El Obeid Water Supply Project Urban Poverty Review," World Bank, October 1979.

5/ White, Gilbert, David J. Bradley, and Anne V. White, Drawers of Water: Domestic Water Use in East Africa, University of Chicago Press, Chicago, 1972.

Traditionally, most water hauling is done by women and children. The notion that their time in this work is of little or no value to the household is clearly inconsistent with recent research results on that subject. Women and children have other work to do -- household work, infant tending, labor in the fields; in some societies they are the primary agricultural workers. Furthermore, there is no support for the view that water hauling time is enjoyed as social time, as is evident in this study of Lesotho practices:

> "We found no evidence in Lesotho for the common supposition that the opportunity for gossip, while waiting for water at the tap, has a positive social value. For example, when one village tap flowed only very slowly due to blockage of the pipes, the women preferred to make an arduous uphill walk of several hundred meters to another tap, rather than wait a couple of minutes for their buckets to fill."6/

So water hauling time has value. But how much value? Some data suggest that people value water hauling time at close to the local rural wage rate. For example, households with incomes above the wage rate are often observed to pay others -- servants or vendors -- to haul water. Those below the wage rate haul their own. If water hauling time were valued at less than the wage rate, more of the poorer households would pay others to do the work for them. If it were valued at more than the wage rate, more of the richer households would haul their own.

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6/ ODA, Manual for the Appraisal of Rural Water Supplies, op.cit. p.93.

Also, both Antoniou 7/ and Zaroff and Okun 8/ found vendor earnings in the $2 to $3 per day range. This compares favorably to rural wages in the areas they studied but lags slightly behind the wages that might be expected in the urban fringe zones. Antoniou reports that in some areas where periodic dry seasons create a temporary demand for vendors, these vendors are drawn from rural areas to work in the urban fringe. The close links between rural and urban labor markets have been extensively documented.9/

Other data imply that water hauling time may be valued at less than the wage rate. The extensive literature on the value of time for developed countries demonstrates that it varies from 30% to 100% of the after-tax wage, depending on what activity is considered. For rather pleasant activities, the value of time may be a modest fraction of after-tax wages. But Deacon and Sonstelie recently found that the value of time spent waiting in gasoline lines was equal to after-tax wages. This was true even for persons not currently employed.10/

The issue of what else people would do with the time they spend hauling water is obviously important. A study in Mozambique found that women used a large percentage of the time saved for leisure, child-care, and other household activities:

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7/ op. cit.

8/ Zaroff, Barbara and Daniel A. Okun, "Water Vending in Developing Countries", Aqua, No. 5 (1984), pp. 289-295.

9/ Friedrich Kahnert, "Improving Urban Employment and Labor Productivity", World Bank, February 1985.

10/ Robert T. Deacon and Jon Sonstelie, "Rationing by Waiting and the Value of Time: Results from a Natural Experiment", Journal of Political Economy, 1985, Vol. 93, No. 4.

"... the time saved for the women of Namaua, an average of 106 minutes per day or almost two hours, permits an increase in their free time of 48 minutes per day - almost half of the time saved. It should be noted that a considerable part of the time spent resting by the women is passed in the company of their children ... the majority of the remaining time was spent on other household chores ... [principally] ... those of cleaning and of preparing food.[11/]

In the end, analyses that require information on the value of water hauling time will have to use the best information available for each project environment and then check the sensitivity of the results to changes in the assumptions. In many cases, as will be illustrated below, investments are justified even when the value-of-time assumptions are varied over a broad range -- including down to very modest levels for the implicit price of time.

ESTIMATING DEMAND

In carrying out the benefit estimation procedure outlined in Box 2.1, a projection must be made of the effect of a water supply investment on the quantity of water consumed. This effect depends on the characteristics of household demand for water -- that is, on how much water households want, given its price (time for hauling), among other factors.

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11/ UNICEF, *op. cit.*.

In this section, one possible method for estimating demand for water is described. The method is kept as simple as possible. While other, conceptually more complete and analytically more sophisticated formulations have been proposed in the past, they have not proved significantly more effective than simple procedures, which obviously are easier to apply operationally. The parameter values used here to demonstrate the workings of the demand estimation method are meant to be illustrative of the type of information needed and of the approximate magnitudes likely to be appropriate. For most applications, alternative figures, specific to the local conditions and context, should be assembled where possible.

Water services have a multi-dimensional nature. For simplicity, the discussion will focus on the quantity supplied by a water system. Water quality (taste, biological purity, etc.) and the reliability of the service (frequency of breakdown, down time, hours of operation, etc.) complicate the analysis, but do not alter the basic conclusions.

The starting point for the analysis is a demand equation whose general form is:

$$Q = f(Y, P, N) \qquad (1)$$

where Q is the quantity consumed in liters per household per day (lphd) for a household which has a <u>real</u> daily income of Y dollars, N is persons per household, and P is the <u>real</u> price of water in dollars per liter, where this price includes the value of the time and effort as well as any money that must be spent to acquire a liter of water for use at the residence of the householder.

Although water use and income are expressed on a daily basis, they should be thought of as long-term relationships extending over at least a year. Water consumption responds primarily to long-term income and does not fluctuate with weekly or monthly income receipts. However, there are considerable short-term variations in water consumption responding to the variations in price. For example, in the harvest season, the high value of time raises the cost of water and may result in water use below the long-term average. Thus it is convenient to think of water consumption as being determined in the long run by permanent income and the long-run trend of price, and in the short run by variations in the price about the trend.

For the illustrative examples developed in this paper, equation (1) is assumed to have the specific form:

$$Q = 0.025\ Y/P \qquad (2)$$

The available evidence suggests that this formulation is a conservative assumption in the sense that it biases the analysis against finding the conclusions drawn below.

For example, equation (2) implies that the fraction of household income spent on water is 2.5%. (This follows from multiplying both sides of the equation by P.) The data on this point suggest that the actual figure in many countries is above 2.5% -- and sometimes in the range of 5% (See Box 2.2). Using a higher estimate than 2.5% would strengthen the case below.

BOX 2.2

## PERCENT OF INCOME SPENT ON WATER

Saunders and Warford note that according to "a frequently used rule-of-thumb", a rural near-subsistence family "should never have to spend more than about 5 percent of its income for water. This 5 percent of income figure is usually more than most urban dwellers pay for the water they consume from the public system".

Table 2.1 presents very tentative estimates of the percent of household income spent for water in twelve selected cities in developing countries. According to these estimates, the lowest income group pays about 5 percent of household income in Sao Paulo and Lima and more than 5 percent in Addis Ababa, Manila, and Nairobi. In the remaining seven cities the figure is less than 5 percent.[13/]

13/ Saunders and Warford, Village Water Supply, pp. 187-188.

Table 2.1

ESTIMATED MONTHLY WATER CHARGES AS A PERCENTAGE

OF ESTIMATED MONTHLY INCOME, BY INCOME GROUP, TWELVE SELECTED CITIES

| City | Income Group (and consumption category by liters) Lowest 20 % (7,000) | Second 20% (15,000) | Third 20% (27,000) | Fourth 20% (36,000) | Upper 20% (40,000) |
|---|---|---|---|---|---|
| Addis Ababa (1972) | 3.70 | 7.89 | 7.70 | 6.17 | 2.46 |
| Bogota (1971) | 0.67 | 0.70 | 1.04 | 0.83 | 1.51 |
| Bangkok (1972) | 0.49 | 1.12 | 2.19 | 2.02 | 0.86 |
| Cartagena (1971) | 0.97 | 0.84 | 1.23 | 1.25 | 0.62 |
| Kingston (1971) | 1.76 | 3.04 | 6.05 | 3.75 | 0.31 |
| Lima (1971) | 4.96 | 2.34 | 1.25 | 1.41 | 0.56 |
| Manila (1970) | 9.27 | 1.67 | 1.65 | 1.50 | 0.72 |
| Mexico City (1970) | 0.41 | 0.33 | 0.38 | 0.29 | 0.17 |
| Nairobi (1970) | 6.80 | 5.51 | 6.00 | 3.93 | 1.88 |
| Sao Paulo (1970) | 4.71 | 2.28 | 3.35 | 2.85 | 0.90 |
| Seoul (1972) | 0.36 | 0.32 | 0.55 | 0.61 | 0.49 |

Note: Water charges are estimated from tariff schedules and estimated water consumption figures for households in the individual cities. Income is the estimated monthly income of households.

Source: Computed by Kenneth Hubbell from survey data.

Ideally, the specific form of the demand equation that is chosen for practical applications should be based on formal econometric studies. Although few such studies exist for rural settings, an analysis of survey data assembled by Zaroff and Okun on consumption from water vendors offers some helpful insights.14/ Both income and price of water were found to have statistically significant effects on water consumption. The exponents of income and price, both near 0.65, were not significantly different from one -- the value assumed in equation (2). Overall, the results imply that equation (2) is not an implausible starting place for the simple analysis that follows.

Price P in equation (2) depends on the time required to haul water and the value of that time to the household. That is,

$$P = WT \qquad (3)$$

where T is the hauling time per unit of water, counting travel and waiting time, and W is the value of that time. Equation (3) assumes there is no cash

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14/ Zaroff and Okun, *op. cit.* Using the Zaroff and Okun data, the following equation was estimated:

$$\log(\text{quantity}) = \underset{(2.6)}{-0.73} + \underset{(0.38)}{0.65} \log(\text{income}) - \underset{(0.25)}{0.64} \log(\text{price})$$

Taking the antilog of this equation, one gets:

$$Q = 0.54\ Y^{0.65}/P^{0.64}$$

The estimated coefficients of income and price are both statistically significantly different from zero and they are of almost exactly equal magnitude and opposite in sign. Neither estimated coefficient is significantly different from one. One would expect the estimated coefficients to be biased downward in this equation because of the particular measurement errors encountered in estimating income and price of water. The estimated equation has a good fit, with a F statistic of 9.3 and a coefficient of determination of 0.73.

price for water, only a time cost. As noted earlier, this is not atypical for rural water supply systems. In cases where a cash price does exist, equation (3) could easily be amended to include a cash fee.

W will be assumed here for simplicity to equal the average wage rate of the household. In situations where there is evidence that the value of water hauling time is some other figure, that could be used instead. For example, a fraction of the wage could be used instead of the full amount.

The household's wage W obviously affects its income Y. If the household does 7,500 hours of work annually and has no unearned income, then:

$$Y = 7{,}500\ W \tag{4}$$

A total of 7,500 hours, spread across 365 days, is about 2.57 hours daily per person in a household of eight members.

The water hauling time T is made up of three components: i) the time spent walking to and from the water source, ii) the time spent waiting to fill one's containers, and iii) the time spent filling the containers. T is given by the following equation where d is the round-trip travel distance to the source in kilometers, s is the walking rate in kilometers per hour, q is the queue time per trip in hours, v is the volume carried per trip in liters, and r is the delivery rate at the source in liters per hour:

$$T = (d/s + q + v/r)\ y/v = (d/s + q + v/r)/v \tag{5}$$

Using equations (2) through (4) as rough approximations, it is possible to estimate the amount of water consumed by a person on the basis of information on the amount of time it takes to collect water. This is a first, essential step in estimating the benefits of water investments, because most of the benefits come from the increase in quantity of water consumed as the result of a lowering in price or collection time. Substituting the expressions of Y and P from equations (3) and (4) into equation (2) results in the following demand function:

$$Q = 0.065/T \qquad (6)$$

A number of general observations can be drawn from the demand equations (2) and (6) generated above:

1) Water demand increases with income for households that do not collect their own water. Households with incomes above the average wage rate will pay others to haul all or a part of their water and thus increase the quantity consumed to the point where it remains a constant fraction of income.

2) Water demand is independent of income for households that must collect their own water because increases in income result in proportional increases in costs.

3) Households would be willing to pay vendors for the services of transporting water, and their willingness to pay would increase with income and distance from the water point because the cost of collecting water increases with income and distance from water.

The specific consumption levels predicted by using these equations are in the range of water use generally observed in rural and urban fringe areas. For example, equation (5) implies that a household of 8 living 100 meters from the water point would consume approximately 15 liters per capita per day, while a household living just 10 meters from the water point would consume approximately 30 liters per capita per day. If the household were 1,000 meters away, consumption would fall to 8 liters per capita per day.

Clearly there is a demand for water in rural villages that gives rise to a willingness to pay for improved water services. The demand curve and value of water hauling time developed here are illustrative of the sorts of relationships that can be used to assess the benefits of water supply improvement projects. The next chapter will discuss a method for calculating the costs.

# III. ASSESSING THE COSTS

The cost of supplying water in rural areas can vary considerably, depending on the technology selected, the environment, maintenance regimens, and other factors. Nevertheless, certain strategies are clearly more costly than others in a wide range of circumstances. In this chapter, a procedure for analyzing costs is developed that can help planners assess their alternatives more effectively. The procedure is demonstrated through an illustrative cost comparison of a few generic alternatives spanning the spectrum of options appropriate for most rural villages. The results of the analysis suggest a number of general hypotheses, or rules of thumb, that can help guide future investment choices.

## DATA SOURCES AND DEFINITIONS

The costs used here are based on engineering estimates and actual cost experience. In general, they assume "best practice". The cost estimates for the source cost of water from a well system are based, for example, on the assumption that appropriate well-drilling equipment is available and is used. Obviously it is possible (and is borne out by experience in many parts of the world) that the combination of inappropriate construction management and technology can lead to substantial increases in costs.

The analysis includes all costs per unit of volume delivered to the point of consumption. The conveyance of water, whether in a bucket or a pipe, is part of the cost of water at the point of consumption. This permits some of what have been considered "qualitative" dimensions to be reduced to the costs of the resources used up in providing the service. The cost of water services produced by a handpump, for example, can be equivalent to that of services from a yard tap if sufficient labor is engaged in hauling water.

Total costs consist of the sum of annual capital charges, operating costs, and maintenance costs. Various assumptions (detailed in Annex A) have been used regarding useful life of equipment, opportunity cost of capital, etc. These assumptions are based on what appear to be typical situations, and their effects on the conclusions reached are checked through the use of sensitivity analysis. This is particularly true of the value of time, which turns out to be a cost of critical importance in rural water supply systems.

For the yard tap, an important additional cost is the capital cost of water distribution piping. Clearly, these costs will vary with the total population and the population density in the area served. Two special sources of information on the costs of household distribution systems of the type contemplated here were used to formulate cost estimates. The first is a method developed by Yezer, which uses the output of an engineering model of distribution system costs developed by Donald Lauria.1/ The total capital cost of a piped distribution system is expressed as a function of the area served, the total population, the number of outlets, the estimated total water consumption by that population, a daily peaking factor, and available

1/ Yezer, Anthony M.J., "An Economic Analysis of Alternative Water Distribution Systems: Public Standpipes vs. House Connections," World Bank, 1984.

headloss. If this piping cost function is applied to a prototype community of 10 hectares, with 1,000 total population, daily water consumption of 100 liters per capita, and a peaking factor of 2, total capital cost is estimated at $38,000 or $38 (1984 U.S. dollars) per capita.

The second source of information on capital costs of the piped distribution system is an econometric model in which a capital cost function was estimated using actual data on the capital cost of recent projects in Asia and Africa funded by the World Bank.2/ Taking these projects as a whole, the mean capital cost per capita was $42, with a variance of $21. A capital cost function was estimated in which capital cost was related to the same basic variables used in the economic model above and, as expected, cost was related to population served, density of population, and total water consumption. There was also considerable variation in cost by country. If the characteristics of the prototype village discussed below are substituted into the estimated cost function, the predicted capital cost per capita for the

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2/ The costs of 32 recent water distribution projects in Paraguay, Niger, Somalia, India, Tanzania, and Sri Lanka were used as the data source in estimating a distribution system cost function. The mean cost per capita was $43. The estimated cost function with total cost per capita regressed on project characteristics such as density of households per hectare (DENSITY), area served in hectares (AREA), population served in thousands of persons (POP), water supply capacity in liters per capita day (LCPAP), and percentage of households connected (CONNECT). The specific equation estimated, along with associated standard errors in ( ), is:

COST/CAP=25.5-0.33 DENSITY - 0.005 AREA - 0.6 CONNECT + 0.5 LCPAP
- 0.06 POP (0.30) (0.0015) (0.18) (0.21)
(0.04)

The F (5.26)=3.4, which is quite significant. The coefficients indicate that projects covering big areas and serving large populations have lower costs. Greater water consumption per capita results in larger costs per capita. These results are generally consistent with those estimated, based on an engineering model of water supply.

"average" country is $35 (in 1984 U.S. dollars), which is quite close to the $38 (in 1984 U.S. dollars) figure obtained from the model based on engineering costs. Thus, both sources of estimates of capital cost per capita produce consistent estimates of capital costs of piped water distribution systems.

## ILLUSTRATIVE COST COMPARISONS

The cost comparisons presented in this section are based on an analysis of three alternative technology options for a prototype village. The three options are: a system of handpumps only, representative of typical point sources where water must be headloaded to the point of use; a yard tap system, where water is available with little or no haul and queue time; and a standpipe system, which lies somewhere between the other two in terms of what it delivers. There are obviously many other alternatives that are variations -- an electric pump, for example, can be substituted for a handpump. But the analytic procedure remains the same regardless of the types or number of alternatives considered.

By systematically varying other key variables including the characteristics of the village, it is possible to determine what factors contribute significantly to differences in the costs of the three options. The principal variables examined for the present analysis were: the total population of the village; population density; the cost of drilling and finishing a productive well; the value of time for persons carrying water; and the length of time spent waiting to fill the water containers. The initial values assumed for the variables included are summarized in Table 3.1. Further details are elaborated in Annex A.

TABLE 3.1

## STANDARD VALUES OF VILLAGE CHARACTERISTICS AND ECONOMIC CONDITIONS USED IN PROTOTYPE WATER PROJECT COMPUTATIONS

| Demographic Characteristics of the Village | Standard Value |
|---|---|
| Total Population (number of persons) | 400 |
| Persons Per Household | 8 |
| Total Households | 50 |
| Persons Per Hectare | 200 |
| Households Per Hectare | 25 |
| **Village Water Use And Collection** | |
| Meters To Alternative Water Source | 500 |
| Liters Of Water Carried Per Trip | 20 |
| Minutes To Queue And Fill Water Container | 2 |
| Velocity Of Carrying Water (meters/minute) | 100 |
| Water Demand Equation (liters/household day) | Q=0.0255 Y/P |
| Daily Water Use From Yard Taps (liters/capita) | 100 |
| Peaking Factor (maximum/average hourly use) | 3 |
| **Economic Conditions** | |
| Village Wage Rate (\$/hour) | \$0.25 |
| Discount Rate | 10.0% |
| Electric Power Cost (\$/kw hour)1/ | \$0.10 |

1/ The yard tap and standpipe designs are assumed to use electric pumps.

Water System Cost And Performance Conditions

| | |
|---|---|
| Numbers of Wells | 2 |
| Cost Per Well Drilled | $2000.00 |
| Water Lift (meters) | 20 |
| Available Headloss (meters) | 5 |
| Storage Volume/Output Ratio | 0.33 |
| Useful Life Of Mechanical Equipment (years) | 10 |
| Useful Life Of Non-mechanical Equipment (years) | 20 |
| Water Delivery Rate (liters/minute) | |
| Handpumps | 10 |
| Standpipes | 15 |
| Maximum Daily Output (liters) | |
| Handpumps | 7,200 |
| Standpipes | 10,800 |
| Annual O&M, Mechanical Equipment (% Capital Cost) | 10% |
| Annual O&M, Non-mechanical Equipment (% Capital Cost) | 3% |

Starting with these initial assumptions describing a "typical" situation, Figure 3.1 compares the costs of the three options as reflected in cost curves relating consumption in liters per capita day (lpcd) to cost in dollars per cubic meter ($/m3). In these estimates, the value of time is assumed to be zero, so that the effect of introducing more realistic assumptions about value of time can be highlighted below.

The shape of the curves in Figure 3.1 follows predictable patterns. All show declining costs but over different ranges. The economies of scale for handpumps are reached at low volumes, while those of the yard tap or piped distribution systems show declining costs over a fairly wide range. The general shape of these curves is maintained over a wide range of variations in the cost assumptions.

When the value of time is varied from zero to as high as $0.50 per hour (equivalent to a per capita annual income af about $500), the cost of the handpump and standpipe systems increases. The cost of the yard tap system remains unchanged because there is no travel and waiting time for yard taps. Figure 3.2 compares the handpump and yard tap systems. The effect of successively higher figures for the value of time is substantial. At $0.25 per hour, the cost per cubic meter is about four times the result when the value of time is zero. Overall, water from a handpump system can cost up to US$4.00 per cubic meter compared to a range of between US$2.00 (at 20 lpcd) and US$.50 (at 75 or more lpcd) for a piped distribution system. (As a point of comparison the cost of water in Washington, D.C., as mentioned earlier, is approximately US$0.30 per cubic meter.)

The findings suggest that when the value of time is less than 10 cents per hour, a system of handpumps is likely to prove the most efficient and lowest cost form of water supply. If the value of time is 50 cents or

FIGURE 3.1

CAPITAL PLUS O&M COSTS

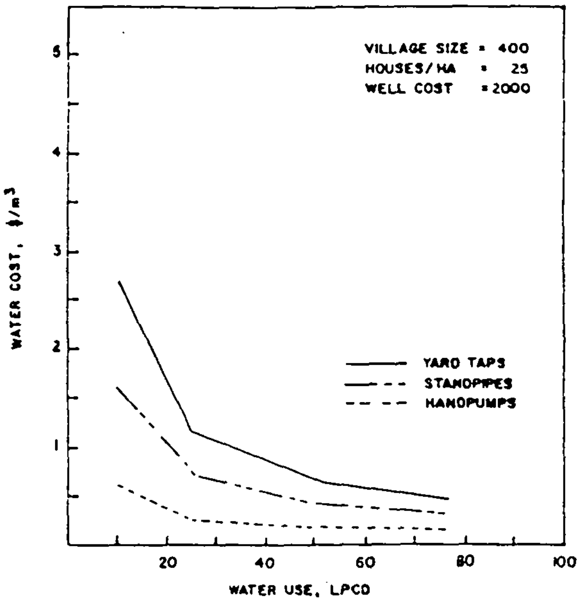
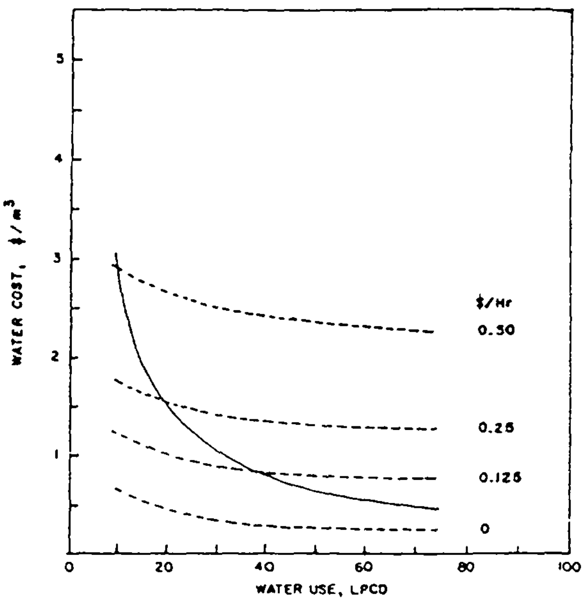


FIGURE 3.2

EFFECT OF THE VALUE OF TIME ON THE COST OF WATER



over, the piped distribution of water is almost always the lowest cost system. If it is between 10 cents and 50 cents per hour, the choice of technology will depend on the quantity demanded, or how much the community is prepared to pay for water.

Further calculations with varying sets of assumptions show that the standpipe system is never the lowest cost alternative. Therefore the remainder of the discussion here focuses on comparisons between the handpump and yard tap systems. A standpipe system combines the capital costs associated with a distribution system and the labor costs associated with headloading of water. Fewer standpipe systems around the world would probably be justified if these haul costs were routinely included in the analysis of proposed investments.

So far, population has been kept constant at 400 people, a relatively small village for some parts of the world. Figure 3.3 shows the effect of varying population size. In these estimates, density is the same in all cases. Thus the comparison is between a small village occupying a certain area with a larger village occupying a correspondingly larger area.

The handpump shows limited economies associated with rising population and area. For the yard tap system, most of the economies of scale of a piped distribution system are reached at fairly low levels of population, approximately 500 persons or 2.5 hectares. It should be noted, however, that it is the level of consumption, regardless of village size, that is more important in determining the ultimate cost.

In figure 3.4, population is again held constant (at 400), but now density is varied. Density affects both the piped distribution costs of the yard tap system and the haul distances of the handpump system. For both systems, most of the effect of density on costs is reached at a density of about 10 households per hectare. Below this level, density is an important factor in determining the choice of system to be used. Once densities reach 10 households per hectare, they become largely irrelevant as a factor in the choice of technology. As density increases, area decreases so that population is const nt.

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FIGURE 3.3

EFFECT OF POPULATION ON THE COST OF WATER

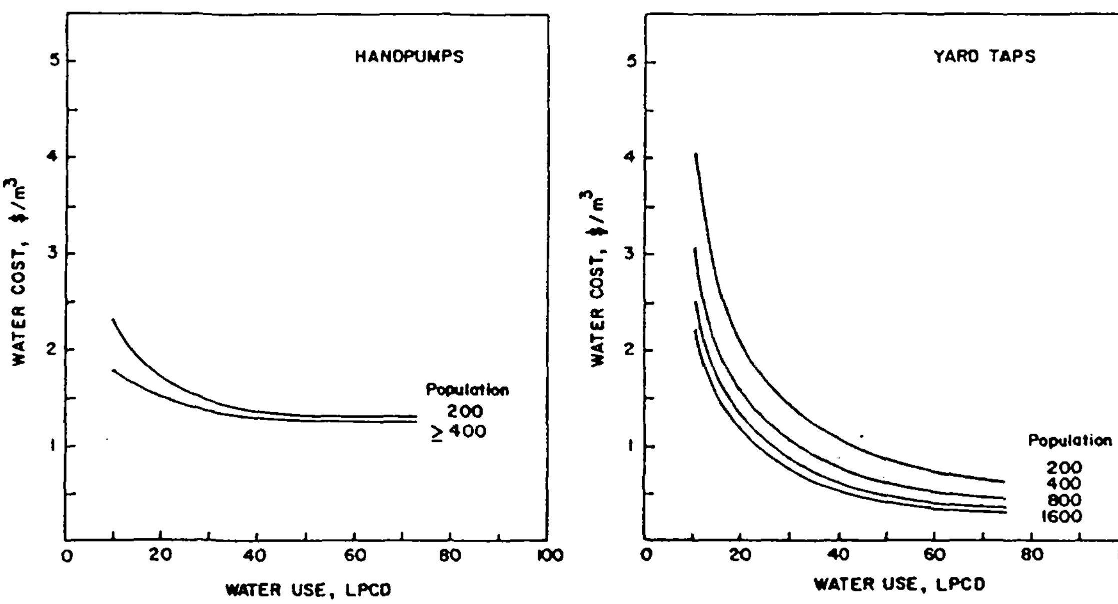
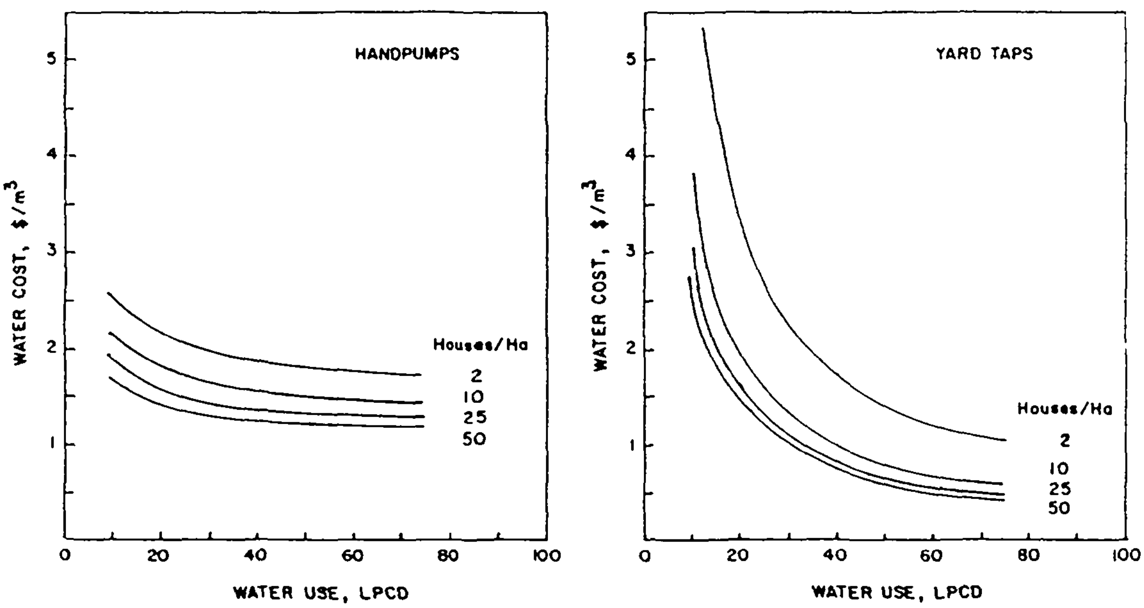


FIGURE 3.4

EFFECT OF HOUSING DENSITY ON THE COST OF WATER



Varying the cost of well drilling (Figure 3.5) has relatively little impact on the total cost of the two systems, contrary to what some of the literature on the subject has implied in the past. At a typical consumption rate of 20 lpcd from handpumps, when the drilling cost per well increases from $1,000 to $8,000, the cost of water increases from about $1.00 to $1.75 per cubic meter, or less than double. This is because the haul cost (at $0.25 per hour) represents some 75% of total costs. In the case of the yard tap system, an eightfold increase in the drilling cost leads to less than a one-third increase in total costs (at a level of consumption of 75 lpcd).1/

The effect of travel distance (Figure 3.6) is obvious. If a householder lives next to the pump so that the distance travelled is close to zero, the cost of water is about 50 cents per cubic meter; if he lives 500 meters away, the cost of water increases by a factor of eight to $4.00 per cubic meter. In the case of queue times, the results are not so obvious. They indicate that even relatively modest increases in queue times can have a dramatic impact on the cost of water. A two-minute queue time at a wage rate of US$0.25 per hour can double the price of water. A ten-minute queue can increase it fivefold. This would explain why, in many African situations, observers have noted that people would walk considerable distances to traditional sources to avoid a fifteen-minute or more queue at a handpump. It also suggests that in those urban situations where long lines form at water points, expanding services would have a very high rate of return. Further empirical study of the maximum output capacity of handpumps would be useful in modeling such high demand cases.

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1/ The effect of drilling cost increases on total cost is similar for the two systems in these calculations because both are assumed to require two wells for this size village. For larger villages, the number of wells needed for handpump service would rise far faster than for yard taps, and hence the effect of drilling cost would be greater.

FIGURE 3.5

EFFECT OF WELL COST ON THE COST OF WATER

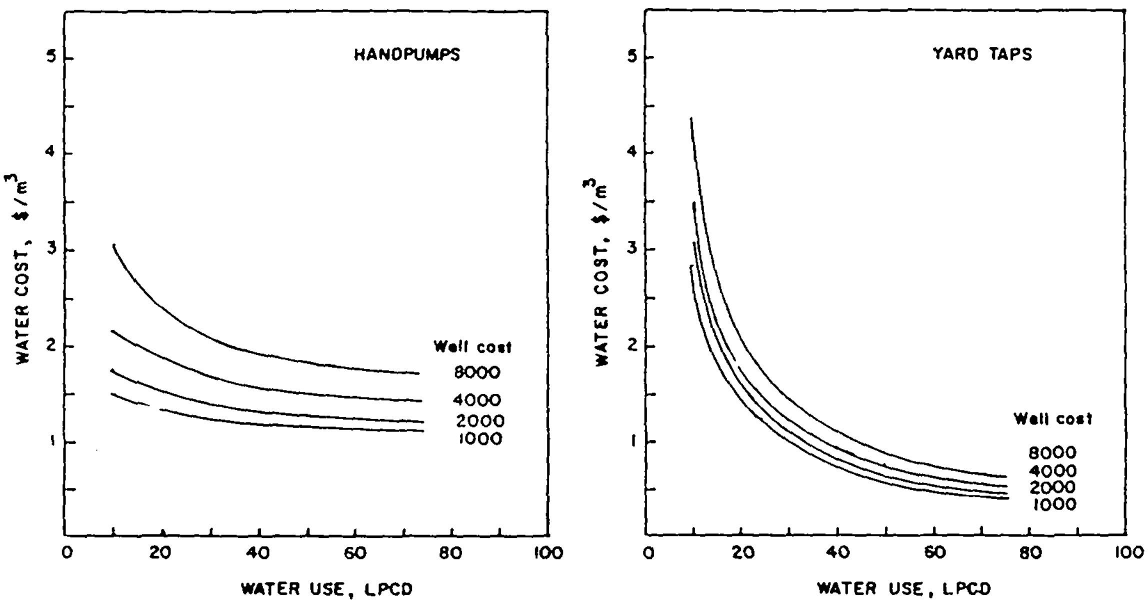
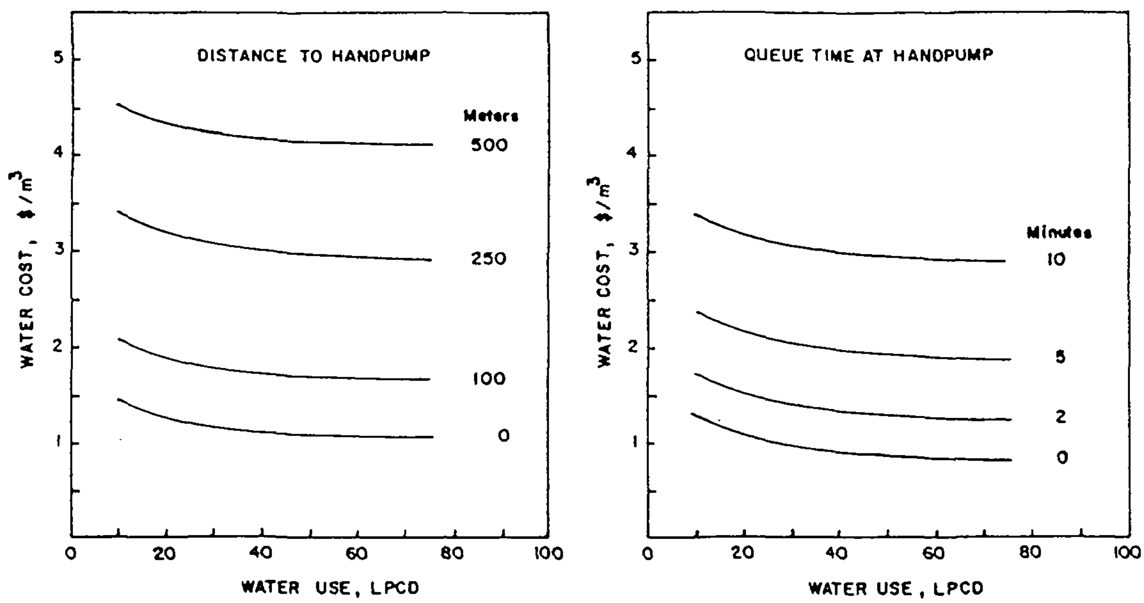


FIGURE 3.6

EFFECT OF TRAVEL DISTANCE AND QUEUE TIME ON THE COST OF WATER



In the above results, assumptions have been varied one at a time. In order to get a better idea of how these parameters interact with each other, various combinations of the more important parameters can also be compared.

In Figure 3.7, the effect of jointly varying village size, density, and value of time is shown. The curve represents the points at which handpumps and yard taps are equal in cost at a consumption level of 75 lpcd. Anywhere to the left of the curve, the handpump yields the lowest cost; to the right, the combinations of density and income would indicate that yard taps would be the lowest cost alternative. For communities where (i) density is 60 persons per hectare, (ii) population exceeds 400, and (iii) the value of time exceeds $0.125, the yard tap system is best. At lower levels of consumption than assumed here -- for example, 20 lpcd -- the curve for the handpump would be somewhat larger.

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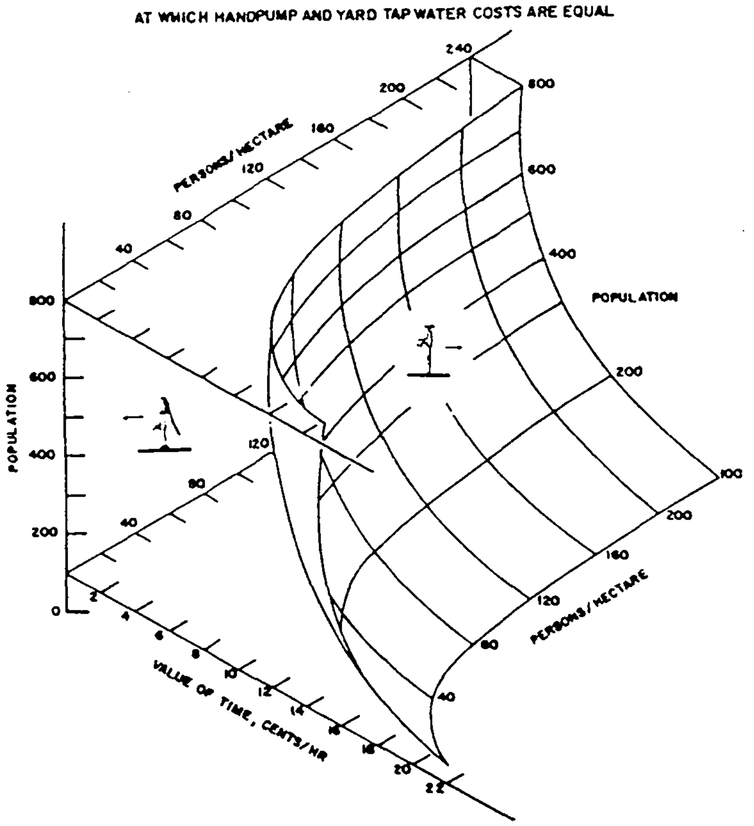
FIGURE 3.7

COMBINATIONS OF VILLAGE POPULATION, HOUSING DENSITY, AND VALUE OF TIME AT WHICH HANDPUMP AND YARD TAP WATER COSTS ARE EQUAL




The curved surface corresponds to the combinations of population, housing density, and value of time at which the cost of water ($/m$^3$) from handpumps and yard taps are equal. Points inside the curved surface indicate that handpumps provide water at a lower cost than yard taps, and conversely points outside the the curved surface indicate that yard taps provide water at a lower cost than handpumps.

SUMMARY OF THE RESULTS

One central observation that emerges from this study of costs is that man -- or more accurately, woman -- is an inefficient carrier of water. The headloading of water is an expensive process and, even in very low-wage economies, can result in a high implicit price for water. The rural poor of Africa and Asia are paying prices for water that are many times higher than what is being paid by their urban counterparts in both the developing and developed world. This is not to say that all headloading can be eliminated; some will continue to be necessary in many parts of the world where incomes and densities are too low to justify piped distribution systems. It does suggest, however, that there is much scope for reducing costs by concentrating on minimizing haul distances and wait times. Whether this is to be done through investments in pipes or improvements in the spacing of point sources will depend on the specifics of each situation.

While each situation must be analyzed and evaluated on its own merits, there are a number of sound conclusions that follow from the above analysis that could form the basis for some rules-of-thumb:

1) Whenever wages are above US$0.25 per hour or per capita incomes above $250 year, it is likely that the lowest cost system will involve the piping of water.

2) Whenever the size of the village is over 1,000 persons, the economy of scale inherent in piped systems is likely to dominate the investment choices.

3) Whenever electricity is available, the electric pump combined with some minimal distribution system will be the dominant choice.

4) Whenever the source cost or the cost of the borehole increases, the easier it is to justify a distribution system.

5) Whenever average queue times go above two minutes, an additional handpump or further investments in a distribution system are likely to be justified.

6) Whenever densities go above ten households per hectare, investments in improving the distribution system are likely to lower total costs.

# IV. BENEFIT-COST ANALYSIS

Once the steps outlined in preceding chapters have been completed to quantify the benefits and costs of proposed water supply investments in comparable terms, it is possible to apply standard benefit-cost analysis. This chapter demonstrates how that analysis can be carried out using well-established techniques within the context of the special characteristics of the water supply sector. After some general remarks about the approach, an illustrative application for a prototype village is presented.

## A TWO-STAGE PROCESS

A two-stage process is required for making decisions about rural water supply investments. In the first stage, it is necessary to determine, for a given type of water service system--handpump, standpipe, or yard tap--the best level of project size or cost. In the second stage, the benefit/cost criterion may be used to choose among the three alternative technologies. The final choice will depend on village characteristics that may influence benefits or costs. However, it is important that project analysis consider these two stages in the order presented here. The best version of each respective design must be selected first in order to make a sound choice among technologies. Comparing the welfare of a village served by a system with too many handpumps, for example, with that of a village served by the correct number of yard taps would tend to bias choice in favor of the yard tap.

The First Stage. In the case, first, of handpumps, the first stage is relatively straightforward. Based on village characteristics, particularly drilling costs, discount rate, and pump installation and maintenance costs, it is possible to use the analysis of costs developed in Chapter III to generate the total cost implications of supplying, one, two, three, or more handpumps in the village. Given the demand equation introduced in Chapter II and information on village income, density, population, and distance to current water sources, an expression for total benefits based on willingness-to-pay may be developed (see Annex B for a technical exposition of these techniques).

Figure 4.1 shows hypothetical total cost and total benefit functions for a particular village. Note that total cost increases at a more or less constant rate as handpumps are added while total benefit increases at a decreasing rate. A net benefit curve is also plotted in Figure 4.1. Net benefit is total benefit less total cost and is the vertical distance between the curves in Figure 4.1. Clearly, if three handpumps are installed in the village, net benefit is maximized at n3 = b3 - c3. The alternatives of installing 2 or 4 handpumps result in net benefit levels of n2 and n4, respectively, but neither of these alternatives produces as large a surplus of benefits over costs as n3. Therefore the best handpump design for the village is 3 pumps and the best net benefit available with handpump technology is n3.1/

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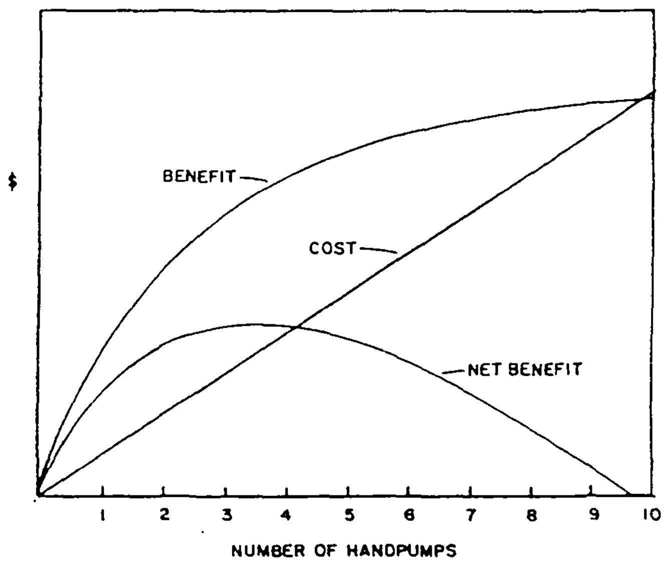
1/ Analysis of a standpipe system in this type of village would also generate a set of curves similar to those in Figure 4.1. The peak of the net benefit curve would suggest the best number of standpipes, perhaps 4, for the village and a resulting maximum net benefit figure, which may be noted N4. Choice between the handpump and standpipe technologies, the second level of choice to be performed using the benefit/cost criterion, is simply based on the size of n3 for handpumps and N4 for standpipes. The technology generating the largest net benefit is the technology that should be implemented.

FIGURE 4.1

Choosing the Optimal Number of Handpumps
for a Village



Consider next the yard tap technology. In this case, the "best" number of yard taps is already implied by the technology to be one yard tap per household. There may be minor design questions about location of the tap inside or adjacent to the house but the number of taps in a village with N households is N. Of course, the benefits of a yard tap could be constrained by installing meters and charging a high price for the water and/or intentionally interrupting water service. However, such actions could never pass a benefit-cost test; or, put another way, net benefit for yard taps will be maximized at a definite level of service provision with each identical household connected. Experience indicates that water consumption under such circumstances will equal or exceed 100 liters per capita per day and costs of supply must be based on such a figure. Net benefit for yard taps is then calculated as a single figure at one level of service provision.

The Second Stage. The second-stage choice among the alternative technologies is based on a comparison of total net benefit, given the particular characteristics of the village in question. While the determination of the exact shape of the total benefit and cost functions involves considerable technical inquiry, the second-stage selection of a best water service improvement project, including both project size and technology, involves fairly straightforward considerations of net benefit maximization.

The maximization of net benefit is equivalent to choice based on the equality of marginal benefit with marginal cost. The final solution chosen by selecting the project size for each technology of water service production that maximizes net benefit in the first stage and then by choosing the technology with the largest net benefit in the second stage, results in a solution in which marginal benefit equals marginal cost. Note that the benefit-cost criterion is not equivalent to choice based on maximization of the internal rate of return (IRR). Internal rate of return maximization is not appropriate when projects are alternatives, i.e., when only one water system is installed in each village. This is stated clearly by Little and Mirrlees in the following illustration:

"Suppose that the enterprise has to choose between, say, a small factory and a large one. Now it is possible that the small factory would give a higher yield but the smaller PV (present discounted value of revenues over cost). In this case, the firm should, of course, borrow more and build the larger factory, for it is the PV that it wants to maximize. The point is that the IRR, being number, gives no indication of size. Sometimes it is best to make a large investment with a low yield rather than a small one with a higher yield. Why not make both investments, the reader may well ask? But that would not be possible if the large and small factories were mutually incompatible--and each was evaluated on the assumption that the other would not be built. Other examples of mutual incompatibility arise when comparing the same factory this year and next year; or a large and small dam on the same river; or any number of schemes for settling the same agricultural region. In all these cases, the IRR may give the wrong answer. It is necessary to stress this. Only very recently a famous firm of consultants told us that they had been instructed by the IBRD to maximize the internal rate of return when designing an irrigation scheme; no doubt there was some misunderstanding. Thus the IRR can be safely used only if there is no incompatibility."2/

2/ Little, and Mirrlees, op. cit., pp.13-14.

Clearly handpumps and yard taps are generally "incompatible" projects under the Little-Mirrlees criterion. The number and location of wells as well as mechanical equipment used for these technologies are not consistent. Standpipe technology may be compatible with yard taps and careful evaluation of the standpipe alternative might consider this issue. It could be argued that the choice among one, two, three, or more handpumps is not a choice among "incompatibles" and that the Little-Mirrlees caution does not apply. However, the optimal location of handpumps would change depending on how many were planned for installation in a village and the costs of returning to a village to drill a second, third, etc. well would be significant so that these alternatives may be incompatible. Also, by finding the handpump project that maximizes net benefit, it is possible to make the best case for choice of handpump technology in the second stage comparison with yard taps where alternatives are obviously incompatible and the Little-Mirrlees warning about internal rates of return applies. The net benefit criterion will be used here following the accepted procedure in benefit-cost analysis, as illustrated by the colorful passage from Little and Mirlees.

Some important considerations should be kept in mind when applying benefit-cost analysis to water service project investment in the manner suggested here. These potential problems are noted below along with the steps taken in the analysis to deal with them:

1) Any of the parameters used to characterize the prototype villages may be changing over the 20-year economic life of the water service project. This is particularly true of the population size and income or wage variables. In many villages

being evaluated for water service projects, important variables such as population or income may be changing rapidly. To the extent that such changes are taking place, the water service project should be evaluated, based on both the current and the expected future characteristics of the village.

2) It may not be possible for the agency responsible for financing water service projects to borrow funds at a uniform interest rate. In the case of such a "capital shortage" problem, there may be large numbers of projects that would generate positive net benefits but cannot be undertaken promptly. Indeed, it may be many years before all projects with significant net benefits can be undertaken. In such circumstances, the net benefit calculation should be performed with a higher cost of capital or discount rate because there are obviously extra limits on capital availability facing the agency. Alternatively, the analysis might be performed for several years' worth of projects at once to determine optimal project design and then a scheduling routine adopted to maximize the present discounted value of net benefits. A similar analysis would hold for foreign currency limitations on agency projects. In such cases, costs of inputs that must be imported should be increased to reflect the limitations imposed on the use of foreign currency for water projects. This issue will be discussed later.

3) There may be limitations on the availablity of certain essential equipment, particularly well-drilling rigs. The approach taken to resolving this problem is in the general spirit of that proposed for the "capital shortage" case above. The cost of well drilling should be increased in order to reflect the scarcity of equipment for producing wells. In addition, the time period covered by the analysis could be increased to cover several years.

4) Income redistribution through the water service project is not given explicit attention. If there is a special concern to transfer income or better improved water services to the lowest income groups, then extra weight could be given to net benefits generated in lower income villages. In principle, this creates no technical problems, but it may be difficult to achieve agreement on how heavily to discount net benefits in higher income villages. Also, the amount of income redistribution involved in water service projects is determined by the method of finance. Clearly, if there is public provision with no charge to the village, the redistribution may be large. However, the use of the willingness-to-pay criterion implies that villages could be charged for the improved water services. If such charges are implemented, the redistribution associated with the project will be small.

5) Benefits from water service projects may be underestimated by individual willingness-to-pay because the villagers fail to consider many health benefits. Some of these health benefits accrue to the water user and others to the general community if morbidity rates fall. As noted above, these extra benefits are not considered here and far more research would be needed to quantify them.

The subsequent section includes samples of benefit-cost analysis in which village characteristics, discount rates, and well costs are varied and the implications of changes in these variables for water project choice are developed. Most attention is given to factors that have proven to be most important in influencing net benefits of particular projects.

## BENEFIT-COST ANALYSIS OF WATER PROJECTS FOR A PROTOTYPE VILLAGE

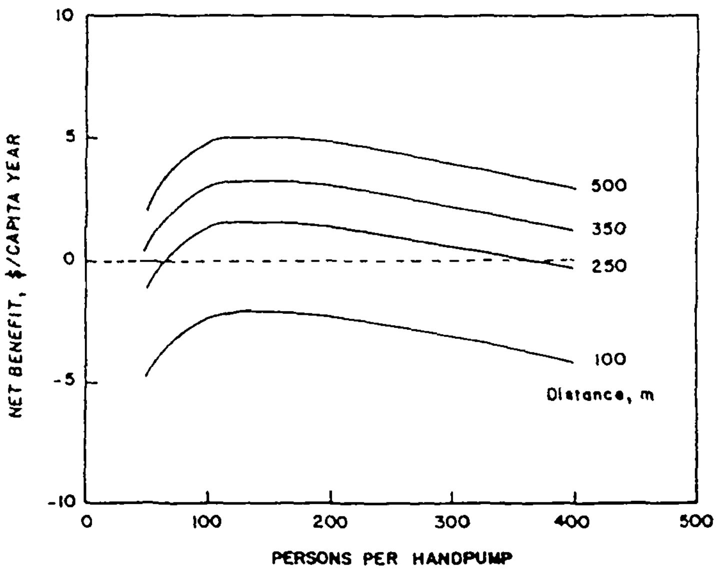
The application of benefit-cost analysis techniques presented in general form above to specific choices of water projects is illustrated here using the prototype rural village discussed in Chapter III. Because the choice process involves a two-stage analysis, the illustration will also begin with an analysis of the choice of the best project size, given a choice of water service technology. The discussion concentrates on the choice of the best number of handpumps because standpipe choice follows similar rules and the cost analysis performed above generally gives a cost advantage to the handpump. There is no need for a first-stage analysis of yard taps because the best project size is defined as one outlet per household or, in some cases, groups of households. The second-stage choice of appropriate technology, based on optimization of project size in the first stage, is then performed. In addition to the results for a specific prototype village, the effects of changes in village characteristics and/or economic conditions confronting the water service planner are analyzed by allowing key parameters to vary one or two at a time. Effects on both choice of best project size in the first stage and on choice of appropriate technology in the second stage are illustrated. Based on these results, a series of generalizations about the effects on project size and technology of changing village characteristics and economic conditions are developed. These generalizations should have a wide range of applicability in water project planning.

The standard values of rural village characteristics, general economic conditions, and water supply cost parameters that are used in the prototype analysis of water service projects are given in the previous chapter in Table 3.1.

The first stage analysis of the best number of handpumps to install in the prototype village proceeds by computing total benefit and subtracting from it total cost for various numbers of handpumps installed in the prototype village. The net benefit associated with different numbers of pumps may then be compared as in Figure 4.1 and the best number of handpumps is easily found at the maximum of net benefit. The results of this net benefit calculation for a prototype village are displayed in Figure 4.2 below by the curve labeled 500, which reflects the standard value of 500 meters to an alternative water source. The net benefit criterion implies that the best number of handpumps for the prototype village is achieved if 3 are installed and that the optimal ratio of persons per handpump would be 135. At this best ratio of 135 persons per handpump, net benefit is $2,000 per year or $5 per capita per year. Installation of either 2 or 4 handpumps produces slightly lowered benefits. Note that the net benefit curve is well above 0 for all levels of handpump

FIGURE 4.2

Effect of Number of Handpumps and of Distance To an Alternate Water Source on Net Benefits



service shown on the "500" curve. Any number of handpumps, from 1 to 4, would generate positive net benefits but the best project size for comparison with alternative technologies is 3 handpumps.

Figure 4.2 also shows the effect of changing distance to alternative water on the net benefits of handpumps and on the best number of pumps. The curves labeled 350, 250, and 100 show how the net benefit curve falls vertically as distance to alternative water falls from its initial value of 500 meters to 350 meters, 250 meters, or 100 meters. Given that the curve falls vertically with decreasing distance to alternative water, the best number of handpumps is always 3 until distance reaches 100 meters. Then net benefit is always below 0 so that the best number of handpumps would be 0, and the benefit-cost criterion implies that no water project should be undertaken in the village. The effect of distance to alternative water on net benefit arises because the willingness-to-pay for handpumps depends on how much the distance to water falls as a result of the water project. This benefit falls if alternative water sources are close to the village. Thus, a **first generalization** from the analysis is that **as distance to alternate water sources falls, net benefits of a handpump project rise, but, if these benefits are positive, the best number of handpumps is not changed.**

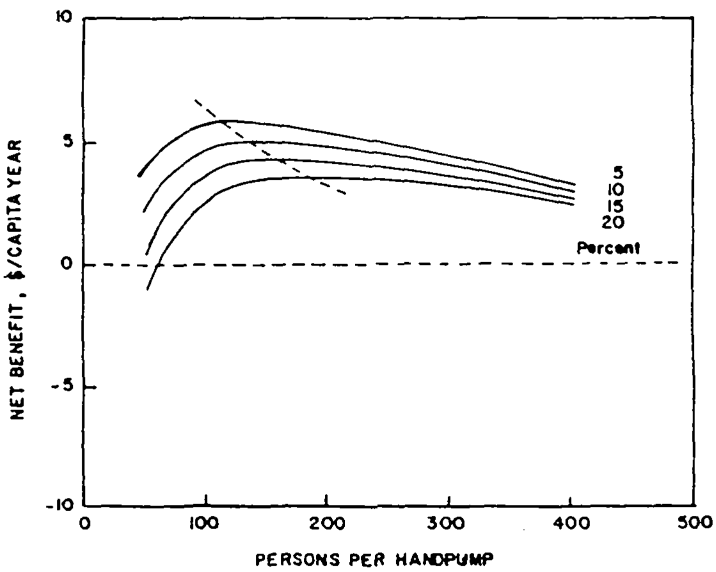
Another important variable affecting the net benefits from handpump projects is the density of the village in households per hectare. The prototype has a density of 25 households per hectare. If the net benefit curve is plotted for higher densities, which result if the area is lowered and population held constant, the resting pattern of net benefits curves is similar to that shown in Figure 4.2. Changing density leaves the shape of net benefit unchanged. Doubling density from the standard level raises net benefits by about 10% and cutting density in half lowers net benefit by about

10% also. Density must fall to 2 households per hectare, or by more than 90% of its standard value, in order for net benefit to fall by 50%. As density falls, average distance to a handpump rises and the advantage of the handppump over existing water sources falls. This suggests a **second generalization: as density changes, net benefits of handpumps change in the same direction but by a much smaller proportion, and the best number of handpumps remains unchanged.**

Figure 4.3 shows the relationship between net benefit and number of handpumps for a range of values of the discount rate. As noted above, capital scarcity for water projects may justify use of a discount rate in excess of the 10% real interest rate used as the standard value. The range of values selected for analysis in Figure 4.3 begins at 5% and extends through 20%. Given that increasing the discount rate increases costs without changing benefits, we would expect it to lower net benefits and perhaps to lower the best number of handpumps. Both these effects are found in Figure 4.3. The best number of handpumps rises from 2 or 1 per 200 population with a discount rate of 20% to 3 or 1 per 135 population with a discount rate of 10% to 4 or 1 per 100 population with a discount rate of 5%. This suggests our **third generalization: a given percentage fall in the discount rate results in a slightly smaller percentage fall in the best number of persons per handpump.** Obviously this percentage relationship is based, in part, on all the standard values used in the prototype case, but the general principle of a strong positive relationship between percentage changes in the discount rate and the best number of persons per handpump should hold across a variety of project situations.

FIGURE 4.3

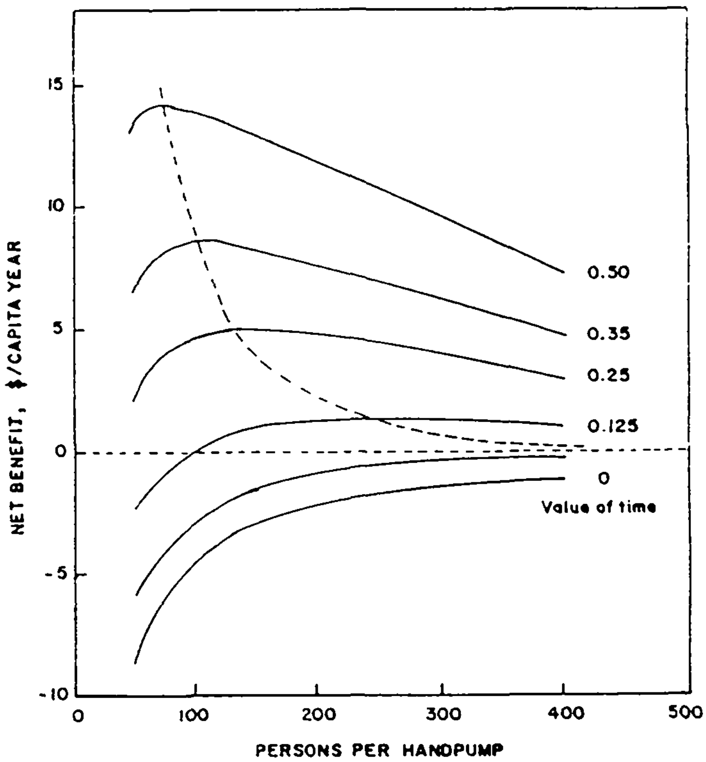
Effect of Changing the Discount Rate
on the Net Benefit and Best Number
of Handpumps



The value of time as measured by the wage rate is a very important determinant of the benefits from water service improvement projects. This point is demonstrated dramatically for handpump project design in Figure 4.4, where net benefits of alternative numbers of handpumps are traced for values of times ranging from a high value of $0.50 per hour through the standard value of $0.25 per hour down to 0. If the value of time is 0, improved access to water does not lower the cost of water and hence generates no benefits. Thus net benefit for the 0 value case is always negative and rises toward 0 only because installation of fewer handpumps lowers cost. Similarly, a value of time of $0.05 per hour generates so few benefits that net benefit is always negative and no handpump project can be justified. In contrast, if time spent collecting water is valued at $0.50 per hour, net benefit is always positive and it peaks at best project with 5 handpumps in the village or 1 handpump for every 80 persons. A 50% fall in the value of time to $0.25 results in a rise in persons per handpump to 125, a rise of approximately 50%. Thus, a **fourth generalization** that holds approximately over the range of values of time considered here: **A given percentage change in the value of time may result in a comparable percentage change in the best number of handpumps or persons per handpump.**

FIGURE 4.4

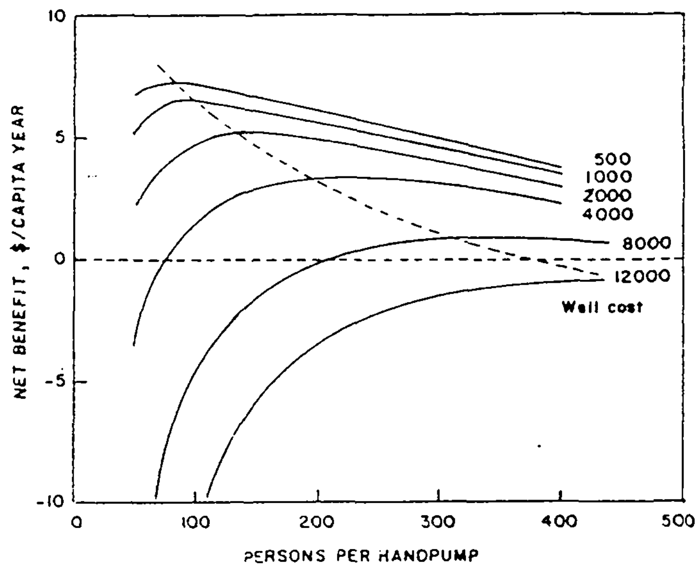
Effect of Changing the Value of Time on the Net Benefit and Best Number of Handpumps




The capital cost of drilling wells, which is based in large part on the geology of the village, including depth to water, has an important effect on the cost of handpumps. Figure 4.5 shows how variation in the cost per well from its standard value of $2,000 can dramatically affect the level and peak of the net benefit curve. For high well costs, above $10,000, net benefit is always negative and no project can be justified. If well cost is $8,000, 1 well can be justified in the prototype village or a general standard of 1 well per 320 persons. Halving well cost to $4,000 causes the best persons per well ratio to fall by almost 50% also, to 200.

FIGURE 4.5

Effect of Changing Well-Drilling Cost
on the Net Benefit and Best Number
of Handpumps




Overall, the results in Figure 4.5 suggest a fifth generalization: **over a significant range of costs, a given percentage fall in well-drilling cost results in an approximately comparable percentage fall in the best standard for persons per handpump.**

The results presented here for handpumps would have comparable counterparts for standpipes. Changes in distance to available water, discount rate, value of time, and well-drilling cost affect net benefits from standpipes and from handpumps similarly. These variables were presented and analyzed here because they were found, of all variables for which standard values were assumed, to have the most dramatic effects on the net benefit curves. Thus, the most important influences on project design have been illustrated in Figures 4.2-4.5.

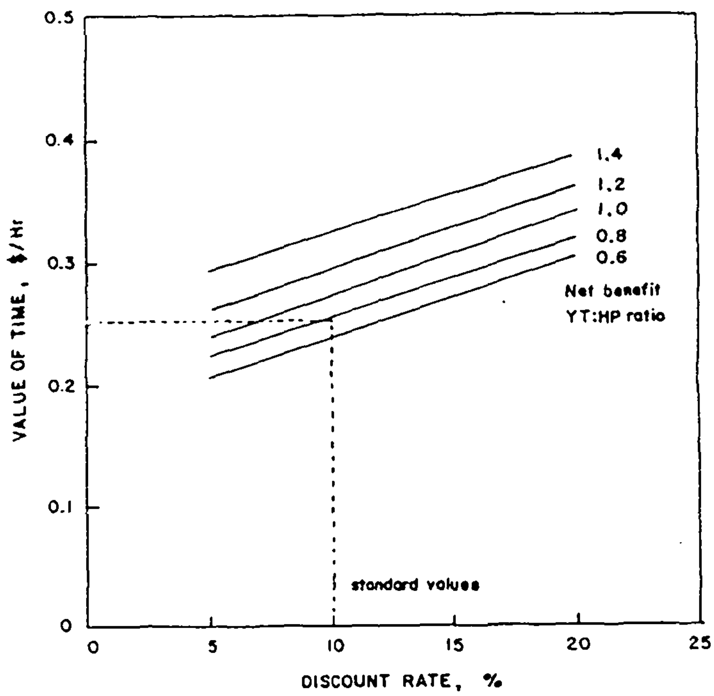
It is also possible to generate results for net benefits and best numbers of handpumps for villages in which two or more standard values differ from those used for the prototype village. In general, the effects of varying two variables at once can be judged by examining the separate results of changing the variables in the Figures 4.2-4.5. For example, if both the value of time and the cost of well drilling are increased above their standard values, the effects of both variables on net benefit and best number of handpumps tend to cancel, leaving choice unchanged from the standard case. If, however, value of time fell and drilling cost rose, there would be a dramatic fall in net benefit and in the best number of handpumps.

The second stage of the choice process involves selection among technologies. The discussion concentrates on handpumps vs yard taps because analysis has found these systems to be most competitive. In each case, net benefit of handpumps is based on the assumption that the best number are installed, and net benefit of yard taps is calculated with one tap per household or groups of households. Under the benefit-cost criterion, one is indifferent between the two technologies when their net benefits are equal, or the net benefit ratio is equal to one. If the net benefit ratio is expressed as net benefits of yard taps divided by net benefits of handpumps, then net benefit ratios above one imply selection of yard taps, and ratios below one favor handpumps.

Figure 4.6 shows the relationship among value of time, discount rate, and net benefit ratio for the prototype village. Each curve in the figure shows combinations of value of time and discount rate that leave the net benefit ratio fixed at some constant value. For example, the curve labeled 1.0 shows combinations of value of time and discount rate for which net benefits of the two technologies are equal. Given that raising the value of time tends to raise benefits of yard taps faster than the benefits of handpumps and raising the discount rate raises costs of yard taps faster, the constant net benefit ratio curves have a positive slope. For the values used in the initial prototype village, $0.25 for the value of time per hour and 10% discount rate, the net benefit ratio is 0.8, as indicated by the X falling on the 0.8 curve at 10%, 0.25. Thus, the standard values for the prototype village generate net benefits for yard taps that are only 80% as large as those for handpumps. However, small increases in the value of time, from $0.25 to $0.29, raise the net benefit ratio to 1.2, favoring the yard tap by 20%. Figure 4.6 illustrates the extreme sensitivity of the choice of technology to the income levels in the village. The vertical distance between the curves reflecting net benefit ratios of 0.6 and 1.4 is only $0.09 per hour. Obviously an important element of water project planning should be the determination of income levels in the villages being studied for potential water projects. The five net benefit ratio curves divide the figure into various regions of choice. For ratios greater than 1.4 or less than 0.6, there is a very strong presumption that technology should be yard taps or handpumps, respectively. For ratios between 0.8 and 1.2, the potential loss from choice of the wrong technology is not very large. Finally, for ratios greater than 1.2 but less than 1.4 or less than 0.8 but greater than 0.6, choice of the technology having smaller net benefit is unfortunate but perhaps not very seriously flawed.

FIGURE 4.6

Effect of Changing Value of Time and
Discount Rate on the Ratio of Net
Benefits of Yard Taps To Those of
Handpumps

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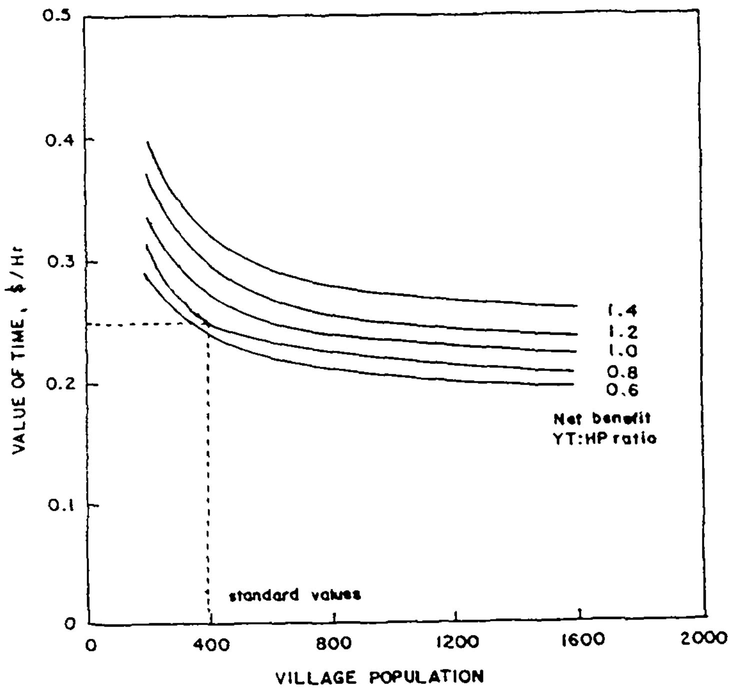
The dramatic results in Figure 4.6 suggest **generalization six:** as **the value of time exceeds $0.35 per hour (falls below $0.25 per hour) net benefits of yard taps (handpumps) tend to be larger.**

Figure 4.7 adds to the insights of Figure 4.6 by showing the effect of village size, holding density constant, on the net benefit ratio. As both population and area are increased together, net benefits of yard taps tend to increase far faster than those of handpumps, so that the curves of constant net benefit slope downward.

FIGURE 4.7

Effect of Changing Village Population and Area and Value of Time on the Ratio of Net Benefit of Yard Taps To Those of Handpumps




For the standard values of the prototype village, shown by the X at value of time $0.25 per hour and population equal 400 while area equals 2 hectares, the net benefit ratio is 0.8, favoring handpumps as noted in Figure 4.6. However, if village size doubles to 800 persons and 4 hectares, the net benefit ratio rises above 1. Conversely, for villages smaller than the prototype, the net benefit ratio is quite low unless wages exceed $0.30 per hour. This reflects the rising cost per capita of yard tap systems when population is very small and leads to a **seventh generalization: falling**

**village population generally raises the comparative advantage of handpumps, particularly when population falls below 400 persons.**

The effect of variation in well cost is added in Figure 4.8 While increasing well-drilling cost raises costs for both yard taps and handpumps, the cost increase is generally relatively larger for

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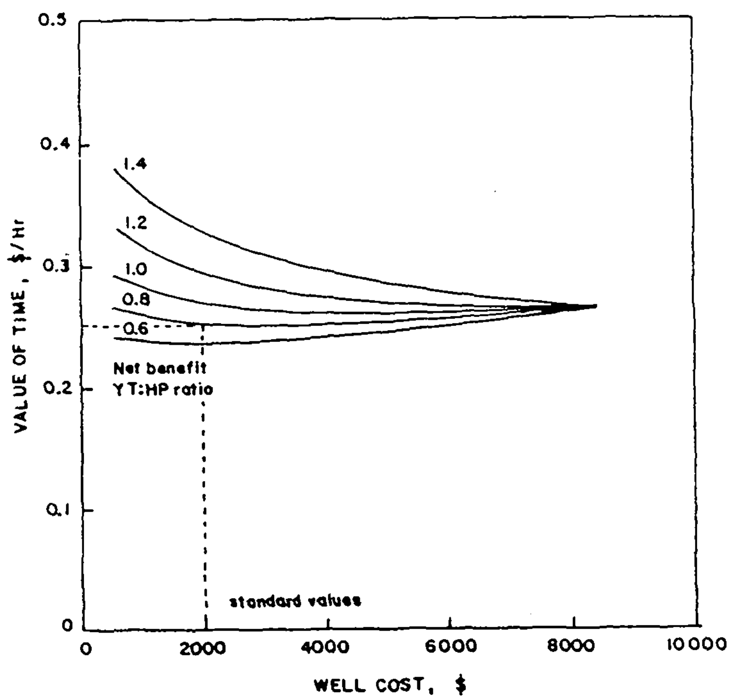
FIGURE 4.8

Effect of Changing Well-Drilling Cost
and Value of Time on the Ratio of
Net Benefit of Yard Taps To Those
of Handpumps



handpumps, so that the constant cost lines generally have a negative slope, as shown. The slope flattens and increases well cost above $6,000 because at this cost level, only 1 well is being drilled. This can be seen in Figure 4.5, and it leads to an **eighth generalization: as well cost rises, the relative net benefit of yard taps rises at a decreasing rate but, for well costs above $8,000, it is difficult to justify any water project in villages similar to the standard prototype used here.** With well costs above $8,000, the value of time must be above $0.25 per hour, population must exceed 400 and/or distance to alternative water must be great to generate significant positive net benefits using either handpump or yard tap technology.

The results presented in Figures 4.2-4.8 and the generalizations based upon them are drawn from many computational experiments with the model of water project choice developed for this paper (technical details discussed in Annex A). While changing values of the other variables listed in Table 3.1 certainly had an effect on net benefits, the most dramatic effects, and hence those most relevant for project planning, have been illustated in this section.

## CONCLUSIONS

Key Variables for Modelling. The eight generalizations developed above provide a general summary of the results of the benefit-cost analysis of water project analysis for rural villages. The application of the benefit-cost technique is made possible because a formal model of village water supply cost and willingness-to-pay was developed and used for computer simulation experiments that calculated net benefits of different water service levels.

Information required about the characteristics of a village in order to substitute it for the prototype village and perform the analysis is modest. Thus the model is designed to provide an operational guide to project planning.

One important result of the modelling effort is the separation of those variables that are very important in influencing the final choice under the benefit-cost criterion from those that are not. Data collection for project planning and future research should focus on further refining the variables identified as most important to the choice process. These key planning variables are listed below in decreasing order of importance, with a brief discussion of their role and measurement problems:

1) Value of water-hauling time. This is the key to justification of any water service improvement because benefits arise by making water available at shorter distances from the user. Figure 4.4 shows that the best number of handpumps varies dramatically with the value of time spent hauling water, and Figures 4.6-4.8 all show that the choice between handpumps or yard taps is very sensitive to variations in value of hauling time, with handpumps tending to prevail at values of $0.25 or less and yard taps for time values above $0.35 per hour. This result holds for almost all reasonable values of other variables, provided village size exceeds 300 persons and water service is not already optimal. Further research into the measurement of value of time spent in various activities (field work, leisure, child care, hauling water, etc.) in rural villages, using techniques of indirect measurement developed

for benefit-cost work, and of the waiting time or queueing problem at handpumps and standpipes, should be given high priority.

2) Availability of alternate water. The proximity of alternate water sources is crucial and easily measured. There is another research issue of importance here that should command high priority, i.e., the form of the demand for water equation. While not formally incorporated in the simulations presented, the form of the demand for water equation is clearly important because it influences the way in which the value of time and availability of alternate water are translated into a measure of net benefit.

3) Discount rate. The appropriate discount rate for capital projects is always an issue in benefit-cost analysis. There are several technical procedures that may be used to arrive at the appropriate discount rate in cases where the water provider has little control over total budget. In addition, the discount rate is linked to cost recovery strategy because the need to use external funding sources depends on the cost, net of revenues recovered.

4) Village population and density. The analysis demonstrates that it is important to have informaton on both the total population and the land area of the village, so that an estimate of

density can be constructed. This is particularly true when population is under 400 and density under 50 persons per hectare.

5) Cost and availability of electric power or diesel fuel. The yard tap systems all require a source of power. Within reasonable limits, the cost per unit energy of the power has little effect on the analysis, but its availability is important.

This is the relatively short list of factors that the analysis has isolated for special consideration before incorporating the benefit-cost decision criterion developed here in water project selection.

The benefit-cost approach to water project choice may be made operational by compiling tables of results, such as those presented in this chapter, showing project design that maximizes net benefit for villages with differing combinations of the key variables noted above. A planner equipped with such a set of tables and a modest data collection budget could easily look up the appropriate project design dictated by various village characteristics. In many regions, vast numbers of villages would tend to have similar characteristics and the choice outcome, once known for one village, would hold for many.

Benefit-Cost Analysis in Practice. Actual application of the benefit-cost criterion, using the results of a formal model, often raises a number of questions about the likely difference in final outcome for project choice compared to less formal systems. Also, there is concern about the compatibility of the final resource allocation with political and social constraints that may confront the planner. These issues are considered below in the form of a question-and-answer dialogue:

1) How can political realities be considered? This is easily done. Consider the case in which practical politics requires that 40% of the water project funds be allocated to projects in region X. This is taken as a constraint in implementing the benefit-cost criterion. Projects in region X and in the rest of the country are ranked separately in terms of net benefit and funded in each area, beginning with the highest net benefit case. At least 40% of the funding is used in region X. The difference between the net benefit of the last project undertaken in region X and that in the rest of the country can be cited by the planner as a measure of the marginal cost of the political constraint. Thus political and social constraints can be imposed on the benefit-cost analysis and the net benefit approach makes apparent the social cost of those limitations.

2) Does the benefit-cost criterion tend to give priority to projects in higher income and larger villages where net benefit is larger? It is true that such villages generate the greatest net benefit and hence have the greatest possibility for cost recovery. Indeed, private sector projects are often undertaken in those places where income and population are large enough. Cost recovery is usually important if large numbers of projects are to be undertaken and if projects are to be properly maintained.

3) Does the benefit-cost criterion ignore income distribution goals that may be achieved through location of water projects in poor villages? There are two problems with this statement. First, there is little income redistribution associated with water projects that practice cost recovery. Only when systems are provided for free is there a large redistribution. Giveaway approaches are not necessary if net benefits are large. Second, income distribution considerations can be built into the benefit-cost criterion easily by weighing net benefit inversely to village income. This will naturally bias project selection toward poor villages. The benefit-cost approach forces planners to be explicit about income redistribution choices.

4) Are not concepts such as value of time and discount rate impossible to measure? It is true that this discussion calls for additional research on measurement of value of time. However, there is a substantial literature showing that in water-hauling, and in many other domestic tasks, villagers behave as if they valued time in proportion to their market wage or earnings/hours or weeks of work. For example, in a recent study of World Bank self-help housing, Jiminez found that earnings/week was a most powerful factor in explaining whether households constructed their own housing or hired others to do the work. It is likely that simple rules-of-thumb can be developed for relating wages and value of time to readily observed living conditions in the village. Similarly,

discount rates can be observed from local lending practices or from the experience of simple institutions such as local credit unions.

5) What is wrong with spreading water projects around so that there is one handpump in every village before the addition of a second handpump is contemplated? There are four problems with this approach, which certainly violates the benefit-cost criterion. First, projects would undoubtedly be constructed even when net benefit is negative. Second, this approach would make it very difficult to achieve significant cost recovery because in some areas net benefit would be small and in others only a fraction of demand would be met and villagers would resent being charged for a handpump with a long queue. Third, the operating life of these handpumps might be very short because some villages would be unwilling to pay and in others the system would be vandalized by frustrated users who found a single pump totally inadequate to meet demand. Such fighting in the queue and damage are well documented in discussions of project problems. Fourth, it is very expensive to return year after year to the same village to add increments to the water service system. In some cases, the design of a small system is not consistent with that of a higher level of water services.

The idea of giving every village one or two handpumps before giving any village a yard tap system is in general contrast with the way in which all resources are allocated either by the market mechanism or in planned economies. Larger groups of population with higher income get larger facilities. For example, if a company has the choice in a given year of opening 50 small department stores in the 50 towns of a province or opening 5 large department stores in the 5 largest towns, it will often choose to open the 5 large stores in the first year. With the significant profits generated by the year's operations, it will expand to the next 5 largest towns in year 2 and so on down the line, as long as town willingness-to-pay is large enough to support an additional store. The benefit-cost choice criterion implemented here extends this type of reasoning to water service investment decisions.

6) <u>What is wrong with choosing between handpumps and yard taps based on maximizing the internal rate of return (IRR)</u>? As Little and Mirrlees have noted, maximization of the IRR produces the wrong result--usually in the form of project sizes that are too small--when projects are alternatives. This certainly applies to water projects. Given the shape of the total benefit and cost curves shown in Figure 4.1, net benefit increases at a decreasing rate. Application of the IRR criterion would result in choosing a strategy close to that discussed under point 5, putting 1 handpump in almost every village with net benefits greater than 0 and then going back again and again adding facilities incrementally until finally yard taps are installed in villages with greater net benefit.

Note that ~~the firm locating department stores in the example~~ above would also reject the implication of the IRR criterion that each town get a small store.

7) <u>What happens if the villages with the highest net benefits are at opposite ends of the country?</u> There are significant transportation costs for drilling equipment and it is desirable that a drilling campaign not have very long distances between villages. Some trade-off between ordering projects according to net benefit and minimizing transportation costs between villages is in order and can be achieved by comparing net benefit differences with transportation costs.

# V. POLICY IMPLICATIONS

The preceeding chapters' conclusions have important implications for country policies and investment strategies, particularly regarding:

- cost recovery, subsidies, pricing, and financing, and
- public and private sector roles.

Formulation and implementation of improved approaches will require governments and international institutions to focus also on other related issues concerning:

- nonhousehold use of water,
- requirements for training and technical assistance, and
- requirements for research and development.

This chapter, in addition to discussing these points, says more as well about sanitation.

Throughout, a key issue is replicability. To be replicable, a program must be financially sustainable, not just at the demonstration site but also on a large scale. Programs fail to be replicable when they are too costly (e.g., if overly expensive technologies have been employed), when insufficient funding is available to cover the costs (e.g., from user payments or subsidies), or when the design is not flexible enough (e.g, unable to adapt to different or changing consumer needs). Investments in programs that are replicable are more likely to result in service for significant numbers of the rural poor in a reasonable period of time. Replicability therefore should be a primary goal in any policy change.

## COST RECOVERY, CONSUMER PARTICIPATION, PRICING, AND FINANCING

Cost Recovery. One of the most critical implications of what has been said thus far is that country policies and investment strategies should aim for a higher level of cost recovery than has been sought in the past. Unless users -- the ultimate beneficiaries -- of water investments bear a larger share of the costs, expanded coverage and adequate service are unlikely to be financially sustainable on a large scale. Higher cost recovery, by helping to generate more revenue, increases the likelihood that a program will be replicable. Relying mostly on government subsidies is simply unrealistic in the majority of cases. The amounts required are too large, and competing needs for these scarce resources are too great, to permit other than token programs -- which result in little more than token improvements.

If rural populations were unable or unwilling to contribute more financially than they do now, if the only technologies available were beyond their means, or if substantial health benefits might be lost, then greater recovery from users might not always be advisable. But preceding chapters have shown that these possibilities are remote in most cases.

There are also two important further reasons for having users pay a larger share of the costs. One concerns the issue of consumer participation while the other has to do with efficiency in the allocation and use of resources.

Consumer Participation. Active community participation means that communities and individuals take a central role in the selection of service levels and in decisions about the how and why of cost recovery. Participation generally is more successful when the community takes over full responsibility than when higher level public agencies attempt to assess consumer preferences through surveys or meetings. In theory such efforts to establish intensive interactions between the public supplier and the community should work and there are in fact examples of this having been done on a small scale, with the involvement of voluntary organizations. In practice, however, these types of programs are difficult to maintain over any but a short time frame and at any scale. They are expensive in terms of human skills and require considerable organizational efforts.

Mismatches between what users want and what planners supply have other ill effects besides user dissatisfaction: they waste a nation's resources--materials, labor, time, and foreign exchange vitally needed for other purposes. Over- or under-designed systems and poorly maintained or mismanaged services consume excessive resources relative to the benefits they produce. If more appropriate solutions were found, more resources could be freed up to devote either to extending services into underserved areas or to accelerating development through other sectors.

Pricing. How should increased cost recovery be accomplished? What charges should be levied, and how should they be collected? In urban areas, where incomes are higher and consumption levels greater, the most effective means of cost recovery has been through metered connections, where the user is charged on the basis of volume used. This mechanism is not likely to be feasible in most rural areas, first, because the costs of metering are excessive in relation to the benefits received and, second, because many services will have less than individual connections.

One obvious option is a periodic per-family or per-capita payment applied to the entire community. This approach, however, has the potentially serious drawback of charging all residents the same, regardless of how much water they use. Consequently, conservation of water would not be encouraged. In villages where supplies are limited, unrestrained use by one family may be at the expense of the rest. These occurrences are by no means uncommon, and can cause much tension in small communities.

In cases where water has to be rationed, the form of rationing can provide an opportunity for levying appropriate charges; sufficient social pressures may exist to discourage the antisocial use of water. In some cases explicit rationing measures, such as each family being allowed to fill only a limited number of containers of a certain size, even from yard taps are possible. In other cases, people can be charged as they draw water from the taps.

Another traditional rationing device is to limit the number of water points, that is, to raise the price by requiring people to walk further. However, this approach, as pointed out in Chapter IV, can be self-defeating: the major benefits from most projects arise from reducing these distances.

Communities should be encouraged to explore and develop systems that they find acceptable. The role of the financial intermediary -- discussed in the following section -- or supplying agency should be to ensure that a workable scheme is in place and to insist that it be adequate to meet the financial obligations of the community.

Ultimately, the decision on how water is to be priced and how financial charges are to be recovered must be a local or community decision. There are, however, guidelines that can assist in the process. In order to maximize the economic benefits, it makes sense to charge marginal costs. But in the case of a handpump system where no rationing exists (i.e., no queues), such charges may be insufficient to cover total costs. Placing a charge on incremental use sufficient to cover the financial costs may cause people to return to traditional sources. If eliminating use of these traditional sources is desired, then the solution is to charge villagers throughout the village a lump sum fee not related to consumption; this charge could vary with income or persons per household and should be agreed upon in advance of the project. A similar problem may exist in the case of yard taps. Again, the appropriate pricing is an "all or nothing" pricing decision. The village must agree to this form of lump sum payment before a financial commitment is made to lend to the village in question.

Opportunities also exist for some degree of cross-subsidization in all programs. In Tunisia, for example, water is supplied by one public monopoly that is responsible for both rural and urban areas. Charges levied in urban areas are sufficient to provide large subsidies to the rural areas. The degree to which this can be done depends, of course, on the relative sizes of the urban and rural populations and the ability of the monopoly to extract funds from the urban populations. In most countries, the charges in urban areas are insufficient to cover their own costs, let alone subsidize rural areas. High charges in urban areas can create problems with respect to economic incentives: commercial and industrial users, who usually account for a large portion of total revenues, can change their production patterns or resort to less economically efficient sources. In the Tunisian example the availability of funds for rural areas has meant a lessening of discipline on costs, with water being supplied to some villages almost regardless of costs.

Financing. For the relatively large capital costs of constructing improved water supply and sanitation services, few communities have sufficient resources readily available locally. Massive subsidies from domestic public funds or external assistance have generally been used in the past to meet these costs. However, in some situations a preferable alternative, more in keeping with the user-bear-the-cost principle, is for the community to borrow the funds.

At present, borrowing funds is difficult in rural areas. Capital markets tend to be relatively underdeveloped and subject to many distortions and controls (although the wide prevalence of informal markets operated by moneylenders would attest to the ineffectiveness of many of these controls). Improving the access of rural communities to loan sources should therefore be undertaken first before expecting water investments to be accomplished mainly through borrowing.

One possibility is to establish a revolving fund at the local or national level. Loans are made to communities for the financing of water services and, as repayments come in from the communities, they are used to finance projects elsewhere. One of the disadvantages of this type of fund is its special status; when established at the national level, it falls within and under the control of the Ministry of Finance. Funding usually comes from special, earmarked sources and, in a budget crunch, more often than not is diverted to cover central treasury shortfalls. Nonetheless, establishing a revolving fund with its attendant cost recovery practices and consumer participation can be an important first step in developing replicable water supply programs, the inherent weaknesses notwithstanding.

The use of financial intermediaries can avoid such pitfalls. Credit institutions exist in various forms in a number of countries. Few, however, have had much, if any, experience with the financing of rural water services and would require strengthening of their appraisal and loan management capacity. Despite the lead time involved in such strengthening, this route may well be the most promising for many countries, particularly given a number of attractive features. Instead of being "given" services, rural communities, furnished the access to financing and technical assistance to make correct decisions, would be actively involved in the process of deciding what they want, and what they are willing to pay. As stated elsewhere, this ownership of assets is critical to assuring maintenance of the system and the recovery of the costs.

The use of financial intermediaries has the added advantage of encouraging the development of small private firms capable of providing rural communities with investment and maintenance services. Once a village has obtained financing, it should have some discretion in selecting a supplier; a number already exist in many countries and with adequate incentives, including access to capital from the local investment firm, more could be created. It is estimated that between US$50,000 and US$100,000 would be adequate capitalization for most investment firms of this nature, even in the high-cost regions of the world. The existence of a large number of small firms -- probably a rare occurrence in many countries, but, again, a realistic objective within a longer term time horizon -- should lower costs. Furthermore, smaller firms are likely to be highly localized and thus available to provide regular and reliable maintenance services. They are also likely to have a greater degree of success in collecting fees for such services, when compared to the remoteness of centralized collection mechanisms.

It will not be easy to promote effective institutions of this type. Throughout rural areas, there are a variety of official credit institutions that are frequently only channels for subsidized public funds. Repayment records are poor, and the credibility of the cost recovery effort is minimal. One way of preventing some of these problems is to avoid any pre-allocation of credits and to keep repayment periods relatively short. In Bolivia, for example, where funds were made available only to communities that had undertaken to meet certain initial conditions, including cost recovery plans, the competition for the funds available encouraged improved performances on the part of the institution and the community. The initial capitalization of institutions of this type will vary considerably from country to country, but it is unlikely that the sums required would be any greater than the amounts already being spent on rural water services. More careful use of existing funds, combined with a vigorous program of cost recovery from those who are first in line, will go a long way toward breaking the present bottlenecks in providing services to the bulk of the rural population.

## PUBLIC AND PRIVATE SECTOR ROLES

Toward a New Partnership. In many developing countries, rural water supply is considered a public service and largely the prerogative of a central government department or monopoly. Alternative strategies need to be developed that foster large development of local-level and private sector involvement in the construction and maintenance of operations. A substantial role for formal public agencies will still be required -- to help regulate suppliers, educate users, and provide services where private suppliers will not or where supplier markets are not yet well-developed. But central governments should move away from trying to maintain a public monopoly on all aspects of water supply. Policy development will be a question seldom of public vs. private but rather of identifying the most appropriate partnerships. Experience has indicated that the public-private partnership can serve developing countries well, as the example of Kenya illustrates [See Box 5.1].

BOX 5.1

PRIVATE WATER SYSTEMS

"..The water systems in Kenya, built and run by private associations that were completely independent of the national ministry, were among the most reliable systems in the country. These were often designed and built without adequate professional and technical assistance. Although poor design often resulted in inadequate supply, members persisted in improving both the reliability and quantity of water furnished to users....The systems were built either without any government support or under the formal Harambee or self-help rules. All were built with the substantial involvement of the community which had specific intended uses for water from the system, often for dairy cattle or other agricultural activities. Systems were operated independently of the Kenya Ministry of Water Development. Private entrepreneurs repaired and replaced faulty components and redesigned parts of the system that were inadequate. Funds for operating the systems were assessed directly to members."1/

Institutional Development. Achieving the policy reforms recommended in preceding sections will require changes in the roles, structure, and capacities of many institutions, public and private. Chapter I noted that institutional development is no panacea. Still, given an improved policy framework, there is much that can and should be done to help institutions evolve so as to support policy objectives. Some combination of both private and public initiatives will be required. For example, governments can continue to be the owners and developers of schemes, but can turn to the

1/ USAID, Program Evaluation Report No. 7, op.cit. pp. 16-20.

private sector for a larger role in actual construction and maintenance. Even in those cases where the government both owns and builds the systems, there is still room for small firms to provide many of the related services.

Perhaps the most important institutional development that can take place is the promotion of a private sector able to provide a wide range of services, from construction to operation and maintenance. The objective is to encourage development of a large number of small firms that would tend to disperse geographically and thus establish a local base for the provision of operation and maintenance services, as well as, of course, promoting a more competitive environment for controlling costs.

In the past, the development of small private firms in this sector has been hindered by the provision of these services through public organizations using approaches more suited for large-scale public works than for small, isolated civil works. This has meant covering whole areas or regions and awarding large contracts to foreign suppliers, as is the case in Africa, which tends to use large-scale, capital-intensive techniques that may not be appropriate where capital is scarce and economies of scale are limited.

Changing the way in which business is done will assist in the development of small firms, but it may not be enough in some countries. Private capital may be reluctant to commit itself to the necessary investments because of the perception of high risks, both of the instability of public policy and the poor record of financial intermediaries. Thus, countries may have to undertake active programs of promotion. Financial assistance to small firms, either through equity or loan capital, may be required along with training and technical assistance. In some cases, foreign suppliers of materials and equipment may be interested in participating in equity or franchising arrangements with local capital. There are a large number of possibilities, including the use of private firms to undertake under contract some of the operation and maintenance functions for public institutions as, for example, in the Ivory Coast.

A set of public institutions that needs considerable strengthening is that engaged in providing information. General information on hydrology, geology, rainfall, etc., is seriously lacking in all countries. Records are poorly kept or not kept and are seldom available to those who require them. This lack of information can result in dramatic increases in the cost of water supplies. Where groundwater is the basic source, for example, the cost is almost directly proportional to the ratio of successful to unsuccessful boreholes and the rate of success is related to information about what is underground. Few governments have or enforce regulations regarding the keeping and filing of drill logs. In many cases there is a multiplicity of institutions involved with little coordination among them. Putting some order into this institutional chaos, along with more adequate levels of funding, would have a high pay-off in terms of lowering water costs.

In addition to promotion and the provision of information, there are the pure governance functions of public institutions, that is, the establishment and enforcement of the rules and regulations for those working in this sector. Again, it is typical to find a fair amount of institutional chaos. Ministries of Health, Rural Development, Public Works, Local Government, etc. all promulgate rules and regulations, often conflicting and often unenforceable. Efforts to build a more supportive regulatory framework must be an important part of any institutional development effort in the sector.

In some instances a case could be made for a separate institute (or part of a government ministry) to promote projects and provide technical assistance to both borrowers and lenders. The same institution, however, would not be the one to provide financing, since the combination of promotion, together with financial intermediation, runs the risk of loss of financial discipline and independence of judgment.

In many cases, the best approach is to utilize existing private and public institutions with established networks in the rural areas. But the long-term goal is for government to diminish its role as supplier and move into that of promoter, provider of information, and regulator.

Private Voluntary Organizations (PVOs). Private voluntary organizations have long been active in both rural water supply and sanitation. With a few exceptions these organizations have had as their focus the health of the rural populations, with improved water supply and sanitation seen as a means of achieving this end. The general approach used by these organizations has created a set of expectations that will be difficult to fulfill. Although some of these organizations have tried to collect limited funds to pay for operation and maintenance, for the most part these schemes have been highly subsidized. This has encouraged the view, both at the village level and at the level of national decision-making, that these services are properly treated as welfare or charitable good.

These organizations do have an all-important advantage in having close ties at the local level. Their assistance in promoting and developing both rural water and sanitation programs could be of greater value -- provided there is an appropriate framework for their participation. At the moment where most countries lack a carefully thought out pricing and cost recovery policy, the danger is that the involvement of both domestic and international PVOs will continue to encourage an unrealistic set of expectations.

NONHOUSEHOLD USE OF WATER

As water becomes more plentiful and available, it may be diverted for nonhousehold use in agriculture, industry, or commerce. Project design must take this into account, correcting for both demand (the increase in agricultural, commercial, or industrial use) and for costs (the increase in system capacity).

Experience has shown that rural villagers have often diverted water intended for drinking, cooking, and washing to irrigating crops for domestic use and sale. This is particularly true where water is made available in large quantities through the use of piped distribution systems. Villagers in Senegal and Nigeria, for example, were found to be illegally tapping a large percentage of their piped water for agriculture. And in a United Nations Development Programme (UNDP) project, villages of 100-250 people actually paid for water enough for two and three times as many people; they used the excess water to grow tobacco and cash crops, the proceeds of which helped pay for the excess water.

Increases in the amount of water available may also lead to its use for other commercial and industrial purposes. It is not unusual in many areas of the world to find as much as 30% to 40% of rural incomes coming from off-farm activity. The introduction of yard taps, for example, may encourage development of industries ranging from beverage to noodle factories and other forms of food processing.

Increased use for nonhousehold purposes may introduce costs other than installation and maintenance fees and recurrent charges. Higher levels of consumption for commercial and industrial purposes in some cases, for example, have increased the problem of waste water disposal and added considerably to the investments required. In other cases, the increased availability of water has encouraged the keeping of larger cattle herds, for which villagers have not been able to find sufficient grazing lands. In situations like this, problems will arise because of the difficulty in either defining property rights over water or in pricing (rationing) supplies in such a way as to reflect their real costs; this can cause a high level of social tension.

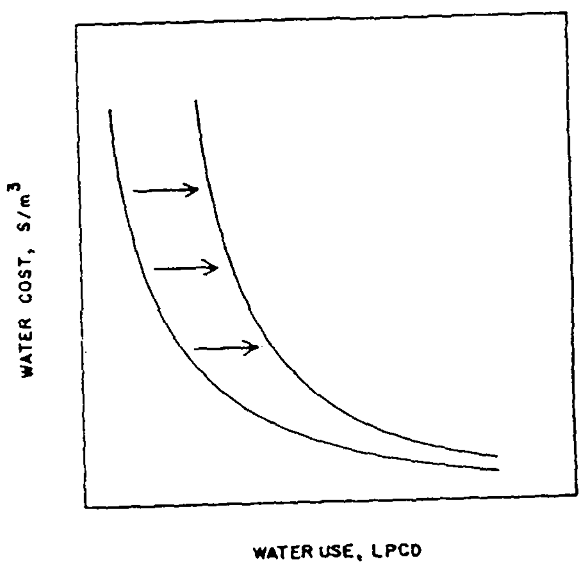
In order to estimate the possible impacts of these nonhousehold uses on demand and supply, it will be necessary to observe and quantify the impact of existing water supply projects. Assumptions will have to be made on whether new projects will have a similar impact in order to assess the correct level of investment and avoid social tension. The often dramatic decrease in prices or real costs of water that can result from these investments means that the shifts in demand may be considerable. (See Figure 5.1) These nonmarginal shifts are difficult to analyze because they require information about production functions and markets that is not readily available. Fortunately, the pace of implementation of most programs is sufficiently slow to permit adjustments to take place gradually in response to changing market requirements. But this does suggest that monitoring and evaluating the results of investments should be an ongoing part of any rural water supply program.

SANITATION SERVICES

As noted earlier, demand for sanitation services may often not be strong in sparsely populated areas. In such settings, the best route to improving sanitation may be by education and other means of persuasion, rather than by investing in new facilities.

FIGURE 5.1

Shift in Demand Curve as Water
Becomes Available



In contrast to urban areas where economies of scale require collective decisions, decisions about what is to be invested and how it is to be used in most rural areas are inevitably made at the household level. Investments are made on plot and usually for exclusive household use. Public or collective influence over these decisions is marginal at best. Even large subsidies for investment costs do not provide sufficient incentives if the use cost (in terms of time and effort) is high.

All of this suggests a more limited role for the public sector in improving rural sanitation services than has traditionally been the case. If a demand for improved services can be generated, low-cost technologies are within the capacity of the household's resources. The problem is on the demand rather than the supply side.

This also suggests, given the enormous size of the problem, that initial efforts be concentrated in those areas where there is potentially a high pay-off, both in terms of consumer willingness and possible health benefits. More densely populated rural villages and urban fringe areas deserve priority, since that is where the potential for disease transmission and desire for convenience and privacy are most pronounced. Here, the information on both the benefits of improved waste disposal and the methods for doing so are likely to receive a favorable response.

As in the case of water service, the replicability will depend greatly on the willingness to limit public subsidies, particularly for direct investments. The most effective use of scarce public funds is likely to be found in providing information that would improve household investment decisions.

Since the investments to be made by households are in small discrete units, the most efficient providers to construct the physical infrastructure are likely to be small contracting firms or craftsmen. In many instances, these could be the same firms providing water supply services. This is a common practice in both developed and developing countries. Many of the recommendations made above concerning the financing and other promotional efforts for water supply firms would apply to sanitation as well.

TRAINING AND TECHNICAL ASSISTANCE

Training and technical assistance are essential to the success of new rural water supply systems, but they must be closely linked to the way in which business is done. The amount of training and technical assistance required, particularly from external sources, is likely to be inversely proportional to the effective use of incentives within the system for supplying services. A system that relies heavily on the community to elucidate its demands and to obtain its own financing is less likely to need large numbers of trained social workers and other community motivators than a system that relies primarily on government initiatives. Small firms providing drilling and other services will have sufficient motivation to train their own workers. On the other hand, large public "campaigns" will require substantial training of both managerial and technical staff. In countries where trained manpower is scarce, greater reliance will have to be placed on setting in place the appropriate incentives, and less reliance will have to be placed on the use of trained public service personnel.

There are, however, a number of critical areas where even when appropriate incentives are used, technical assistance and training can be an important input. One is in the dissemination of information about low-cost technologies. Few people in the developing countries have this knowledge, and training in its application is critical. The Bank, UNDP, and other bilateral donors have indicated their strong support for this type of training and technical assistance through their contributions to the Training Network that has been established. This Network, of which the Bank is the coordinator, will provide training institutions in developing countries with materials and technical assistance designed to promote the use of lower cost and more appropriate technologies. (See Box 5.2)

BOX 5.2

THE TRAINING NETWORK

The International Training Network for Water and Waste Management was established at a meeting of bilateral and multilateral agencies convened by the World Bank in Bonn in October 1984. The principal aim of the Network is to disseminate knowledge and promote the use of low-cost water supply and sanitation technologies, where appropriate, in the planning and design of sector development strategies and projects.

The Training Network will ultimately consist of at least 15 developing country-institutions; full expansion is expected to be reached in about five years. The training and information dissemination programs of Network Centres will be supported by bilateral agencies. Development-oriented institutions in industrialized countries will also participate in the Network as "associated institutions" to provide technical support to Network Centres as needed in building up their training and research capacity. In 1985/86 Network Centres will be established in East and West Africa, South Asia and East Asia.

The World Bank has developed a comprehensive set of audio visual information and training materials necessary to teach successfully the purpose and application of low-cost technologies to selected audiences of the Network. The Network's audiences include: policy makers, practicing engineers, engineering students and their educators, project field staff and trainers of community development health, and other field workers. The materials cover not only technical aspects but, equally important, concepts of community participation and health education — all components of successful low-cost technology projects. The World Bank's Publications Department is reproducing and distributing these materials, which have been prepared in English but will be translated into French, Spanish and other languages.

The Coordination Unit for the Network is located in the Water Supply and Urban Development Department of the World Bank. The Bank and the United Nations Development Programme have provided initial financial support for the Unit. The Unit's Coordinator and staff are assisting developing country training institutions and bilateral and multilateral agencies in developing and expanding the Network. The Coordination Unit is also providing technical support and guidance to Network Centres as needed to formulate, implement and monitor their activities. The Unit also serves as liaison with World Bank Project staff and the Economic Development Institute in the planning and execution of Network activities.

Another area in which training and technical assistance are important is in the establishment of appropriate country policy frameworks. Most governments have seen their role in this sector as financiers, builders, and maintainers. Few are equipped to step back and take on the more demanding responsibilities of being promotors and regulators. To do so will require the development of new skills. The collection, analysis, and dissemination of information on water resources, for example, are poorly understood and badly done in most developing countries. Yet, this information is vital in any type of program to develop rural water supplies. If financial intermediaries are to be used effectively, their establishment and regulation will require some assistance in most countries. If large numbers of small firms are to be service providers, their promotion and regulation will require the establishment of new skills and new ways of doing business on the part of the public sector.

## RESEARCH AND DEVELOPMENT

There is no subsitute for more -- and more reliable -- data and information. The framework set out in this paper will require field testing, together with a program of research to provide the answers to the many questions raised. Particularly likely to have a high payoff are research and development on economic, social, institutional, and technological issues.

Economic Issues. The most obvious area for research is in developing a better understanding of the factors that determine demand for both water and sanitation services. The estimates of Chapters II and III are the best that can be done under existing circumstances, but leave a great deal to be desired. Better studies on the relationship between distance hauled and the amounts of water consumed, for example, would greatly strengthen the credibility of the numbers used. Better information on who in the family hauls what quantities of water for what purposes, including nonhousehold use, would help predict the outcome (benefits) of investments designed to reduce haul costs. More data on water markets in rural areas would increase the confidence with which income and wage data can be used. In the case of sanitation, almost nothing is known about the demand or the factors that determine that demand. It has been hypothesized that convenience and privacy are the major factors. But how much convenience? What is meant by convenience and privacy? Under what circumstances?

Social Issues. One of the most controversial and puzzling issues surrounds the links between water and sanitation investments and health. This paper has pointed out that the assumption of large health improvements is not necessary to justify water projects. On the other hand, the existence of better water supplies can enhance and may even be necessary to achieve any health benefits from investments in public health and education services. The links between water supply improvements and public health benefits need to be clarified, from the point of view not so much of justifying these improvements but rather of exploring how they can be used to enhance the benefits of direct investments in health and education services. Given the existence of some level of water service, how and in what form can hygiene education programs contribute to improvements in health? What are the circumstances under which benefits are achieved?

If adequate sanitation is to reach most rural areas, it will require a well-considered marketing strategy. Research needs to be done on the most effective ways of modifying human behavior in this regard. Waiting for general improvements in educational levels and rising incomes implies that such services will be a long time in coming to most rural areas.

Institutional Issues. There are a number of issues to be addressed under this heading. There are, for example, a large number of alternatives for cost recovery at the village level. Some villages have used head taxes in one form or other, some have used direct user charges, still others have used property or similar wealth taxes. In order to offer a range of possibilities, together with their strengths and weaknesses, it will be necessary to survey what has been done, how it has been done, and what has worked under what conditions. Access to this type of information would greatly assist institutions in giving guidance to villages and would improve the chances for a reasonable degree of cost recovery.

A key recommendation of this paper has been the use of small firms to supply water and sanitation services to rural communities. The promotion and development of these firms will be a relatively new activity in most countries. The experience of existing practices in both developed and developing countries needs to be documented and guidance provided to those countries seeking to emulate this approach. Financial institutions providing support need to have access to these data in order to develop their own guidelines.

If countries are to step back from the direct provision of services, they will need to develop a more appropriate regulatory framework, as well as to improve informational and technical assistance services. Today, few countries have anything like a supportive framework for these types of activities, and much will need to be done to develop them. Here, the experience of the developed countries could provide some guidance.

Technological Issues. Although a great deal of effort has gone into research on the technological issues, there is still much to be done. The development of better handpumps needs to be supplemented by improved technologies for locating and drilling boreholes. In many countries, it would appear that drilling technology is excessively capital intensive. A return to simpler, more labor-intensive technologies, where feasible, is a more efficient direction in which to move. Equipment of this nature is available, but its use and the necessary adaptations required for use in developing countries need to be explored.

From the analysis of Chapters II, III, and IV, it is clear that the gains from improved water supplies come from decreasing haul distances. The cost figures used in those chapters have assumed a fairly sophisticated system based on "standard" design specifications for raised storage and buried pipe. It is possible to reduce these costs by 30% to 50% by installing storage tanks that are raised only enough to provide adequate, but not necessarily ideal, flows to each residence and by burying pipe in shallow trenches, particularly along village pathways that are not subject to vehicular traffic. In many developing countries, it is possible to observe a great variety of "homemade" systems in place. These systems often minimize installation costs by using such things as above-ground plastic hose; although this is not generally recommended, such practices do show that nonoptimal designs can significantly improve access to water.

Costs can also be reduced by eliminating the central government's role in preparing detailed drawings of proposed systems in small villages where an experienced contractor is fully capable of installing a working system with minimal design drawings. The extent to which services are provided more efficiently by the private sector should be documented.

It will be increasingly important to monitor and evaluate the performance of alternative energy sources related to water supply in remote places. In the analysis of the costs and benefits of standpipe and yard tap systems, it has been assumed that power from an electric grid is available. However, in many countries the provision of adequate water supplies is limited by the unreliability or nonavailability of electric grid systems. To evaluate the increased cost of water due to either of these conditions, the source costs of pumping water by means of diesel, solar, and wind-powered pumps were estimated, where source costs included a pair of wells fitted with pumps, a storage tank, plus operation and maintenance. The basis of these calculations and a graphical presentation of the results are presented in the Annex A.

This analysis shows that at an electric power cost of 10 cents/kw hr, and a solar array life of 20 years, solar-powered pumps provide water at about twice the cost of electric grid systems (that is, 25 cents to 50 cents/m3 for solar versus 15 cents to 30 cents/m3 for grid supplies). However, if the real cost of electric power is higher, for example, if the price of electricity is 40 cents/m3 and the pumping lift is 20 meters or if the price of electricity is 75 cents per m3 and the pumping list is 20 meters or if the price of electricity is 75 cents per m3 and the pumping lift is 40 meters, the cost of water from solar-powered pumps is about the same as that of water from electric pumps run off a grid power supply. With the introduction of submersible well pumps powered by DC motors and the continuing drop in price of photovoltaic arrays, solar-pumped water supply systems for small communities are becoming increasingly attractive.

Although in most instances photovoltaic systems are not now competitive with pumps run off grid power supplies, these systems are quite attractive relative to either wind- or diesel-powered pumps. For example, at a fuel cost of $1.00 per liter, diesel-powered pumps provide water for about the same cost as solar-powered pumps, but relative to solar-powered pumping systems, diesel pumps are mechanically unreliable and must depend on fuel distribution systems that often have shortages resulting from state-imposed rationing systems. In the case of wind power, the cost of water delivered by windmills approaches that of solar pumps, at a daily average wind speed of about 4 meters per second (9 mph). It should be noted, however, that these costs are based on imported windmills and that costs could be substantially reduced by local manufacture. This would lower the break-even point between wind pumping and solar pumping to a wind speed of about 3 meters per second. In areas with consistent wind patterns, locally produced windmills could be a viable option.

As a point of comparison, the cost of pumping water by hand has also been evaluated. As the pumping lift increases, the cost of water from handpumps increases relative to the other pumping methods considered here. It should be noted, however, that this increased cost can be offset by the advantages offered by the potential for local manufacture and village-level repair of handpumps. Nonetheless, it is clear that as pumping depth increases, it becomes increasingly important to maintain water-delivery rates at as high a level as possible. This can be done either by installing pumps, such as those with flywheels, that allow a high-input power to be applied to them or by installing pumps that allow more than one pumping element to be inserted into a single well.

Whichever method of pumping proves to be most suitable in a given location, it is clear that locally based private installation and maintenance contractors working closely with local communities in many ways offer the key to widespread coverage of community water supply systems.

## CONCLUSION

The suggestions made here -- particularly those addressing the ability of the rural poor to pay for water supply, the changing role of the public sector, and the necessity of refocusing programs in sanitation and public health -- are admittedly controversial and will require careful and thorough implementation. A strong case can be made that a new approach to country strategy and investment policy is likely to provide more water for more people at less cost, and it is imperative to convey the reasoning behind these initiatives and their likely result, as well as to move toward implementing them.

# CHAPTER VI. A ROLE FOR THE BANK

## GENERAL OBJECTIVES

Limited resources and competing priorities preclude the World Bank from coming close to the level of investment required to deliver water and sanitation services to the rural population. The Bank can, however, play an important role in assisting countries in using available resources more efficiently by redefining objectives and by developing acceptable and workable strategies. In addition, the Bank can be catalytic in mobilizing other sources of financing. The previous chapters have developed an analytical framework that can serve as a starting point for this process.

World Bank assistance must be contingent on the recognition that whatever is done has to be replicable on the scale required to address the problem within a reasonable time frame. The Bank should be active only in those countries that are seriously prepared to work toward this objective. The definition of replicability and an understanding of what is meant by a reasonable time frame are clearly matters of judgment and will probably vary from country to country. Within the framework set out in this paper, replicability is not simply a financial concept; the administrative and political feasibility of proposed interventions must also be considered. A program requiring substantial administrative inputs or managerial talents, for example, is not likely to be replicable in most developing countries. Similarly, a program calling for substantial resource transfers from those in political power also is not likely to be successful.

The development of a suitable framework will be a slow and difficult process. Although there are "pockets" of potentially replicable operations in a handful of countries, no country has what could be termed an appropriate policy framework. Thus, the first and critical step will be the establishment of country dialogues with a view toward making measurable progress toward the overall goal of developing replicable operations to get the job done. Such an approach inevitably means a long-term and staff-intensive commitment on the part of the Bank to program development in specific countries. One-shot projects that provide for a few handpumps per village cannot realistically be expected to achieve the type of institutional and policy adjustments needed to operate more efficiently in the sector.

The choice of countries will, therefore, have to be judiciously made. Countries with a clear-cut willingness to make the necessary changes are obvious candidates. Without a political commitment to policy change, any effort is likely to be wasted. Given a willingness to take these difficult steps, priorities can be set on the basis of needs; these can be broadly defined in terms of income levels and the scale of the problem. Poor countries with large rural populations are an obvious first priority; Africa and southeast Asia fall within this category. In the other regions, the Bank's efforts should be selectively targeted to projects where participation can yield substantial and demonstrable policy improvements relative to the resources transferred.

It is not possible to predict the impact of these new directions on the demand for Bank financing. In the short run (the next three to five years), it is unlikely that there would be any significant shift. At the present moment, the volume of Bank lending for rural water supply and sanitation projects is small and sporadic. (See Table 6.1) During the all-

Table 6.1

WORLD BANK LENDING IN RURAL WATER SUPPLY AND SANITATION:
TOTAL LENDING AND PERCENTAGE OF PROJECT LENDING, 1974-84
(in millions of dollars)

| | RURAL WATER SUPPLY | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Project Component | | | | | |
| Year | Free-standing projects | Water and Sanit. | Agri-culture | Total lending to rural water supply | Total lending to urban water and sewerage | Total lending to water and sewerage sector | Total lending of IBRD and IDA |
| 1974 | 0.0 | 0.5 | 7.2 | 7.7 | 173.2 | 180.9 | 4,423.6 |
| 1975 | 0.0 | 1.5 | 22.7 | 24.2 | 143.6 | 167.8 | 5,945.9 |
| 1976 | 0.0 | 12.1 | 11.1 | 23.2 | 322.5 | 345.7 | 6,702.4 |
| 1977 | 0.0 | 3.6 | 28.9 | 32.5 | 297.1 | 329.6 | 7,086.8 |
| 1978 | 9.0 | 0.0 | 29.8 | 38.8 | 366.2 | 405.0 | 8,410.7 |
| 1979 | 20.0 | 19.6 | 11.9 | 51.5 | 979.2 | 1,030.7 | 10,010.5 |
| 1980 | 0.0 | 23.6 | 12.0 | 35.6 | 607.5 | 643.1 | 11,481.7 |
| 1981 | 11.8 | 27.3 | 34.7 | 73.8 | 495.4 | 569.2 | 12,291.0 |
| 1982 | 30.5 | 2.5 | 33.5 | 66.5 | 408.2 | 474.7 | 13,015.9 |
| 1983 | 46.1 | 8.6 | 28.4 | 83.1 | 747.5 | 830.6 | 14,447.0 |
| 1984 | 60.9 | 11.9 | 17.6 | 90.4 | 519.3 | 609.7 | 15,524.0 |
| Total | 178.3 | 111.2 | 237.8 | 527.3 | 5,059.7 | 5,587.0 | 109,339.5 |
| Cumulative percentage of total Bank lending | | | | 0.5% | 4.6% | 5.1% | 100.0% |
| Cumulative percentage of rural water supply investments as part of water sector and agriculture components | | | | 9.4% | 90.5% | 100.0% | |

important phase of country dialogue, a more important consideration will undoubtedly be the amount of staff resources the Bank is prepared to devote to both policy dialogue and project development. At a minimum, it is estimated that the development of suitable projects would require three times the average resources presently going into preparation of water supply and sanitation projects.

A further constraint on project and program development set out in this paper will be the willingness of other lenders to support these new initiatives. At present, relatively few of the bilateral and multilateral agencies, including national and international volunteer agencies, finance rural water and sanitation projects with cost recovery as a project objective. At best, cost recovery attempts are limited to operation and maintenance costs, although, in practice, even this limited objective is seldom achieved. Thus, as long as a commitment to cost recovery is the exception rather than the rule, it will be difficult for the Bank to engage in a constructive dialogue with its borrowers.

It will therefore be critical for the Bank to engage in a major effort to coordinate its rural water supply and sanitation strategy work with other funding agencies. The growing and collective frustration of both borrowers and lenders over the poor results of past efforts should aid in the willingness of all concerned to re-examine the issues. Here the Bank can be instrumental in explaining and testing the framework set out in this paper and in taking the lead in bringing the donors together to coordinate overall sector objectives; special attention will have to to paid to the evaluation of performance as well. The Bank's role as executing agency for UNDP and bilaterally financed research projects in low-cost water and sanitation has placed it at the center of a network of agencies in both developed and developing countries. This strategic position can serve as the springboard for a programmed series of discussions/seminars with all concerned.

POLICY RECOMMENDATIONS

Financing. As discussed above, the key to the successful implementation of any strategy is the transfer, over time, of the responsibility of service provision to local or community entities. A prime instrument for reaching this goal will be the support of financial intermediaries as a means to overcoming financing constraints. Most of the agencies engaged in promoting water and sanitation services have little experience in working with financial intermediaries of the type envisioned. The Bank, with its experience, is in a unique position to provide the support needed.

The encouragement of financial intermediaries as a vehicle for project financing will require the Bank to scale down and, over the long run, to withdraw from the financing of these services directly through investments in ministries of public works or rural development. In place of this, the Bank must be prepared to lend only if appropriate intermediaries are used. Clearly, this change will have to be introduced gradually. In most countries, well-entrenched interests encourage the present way of doing business, and considerable resistance will be encountered in efforts to change. Also, existing financial intermediaries are ill-equipped to undertake a new line of financing. This suggests a cautious, experimental approach, with the Bank continuing to finance some limited public works programs, but only on the condition that part of the loan be used to develop and strengthen intermediaries and to finance their programs. Certain regions or villages with an agreed level of population, income, or existing cooperative financing activity, for example, could be identified to receive financing through the mechanisms suggested above.

In addition to providing financing to communities to purchase water and sanitation services, the Bank should consider providing financial support to firms engaged in supplying these services. One way would be to encourage existing financial institutions such as the commercial banks to become more active in this area, by providing for a credit line component. Supporting guarantee funds or directing some portion of loan proceeds to existing financial intermediaries working in rural areas is another option. But perhaps more important than making loan funds available will be the development of programs to encourage the mobilization of both local and foreign private capital. The International Finance Corporation, for example, could be encouraged to provide equity or loan capital to programs designed to support the development of large numbers of small firms using franchise types of arrangements with foreign suppliers of equipment. In this way, foreign firms can be encouraged to provide the necessary technical assistance and training as well as some capital.

Cost Recovery. The cornerstone of any Bank involvement in this sector is a markedly improved record on cost recovery; without it, few countries will be able to afford other than token programs. Most countries are prepared to cover operation and maintenance costs, but few are committed to go beyond this amount. Even in this instance, however, the performance has not been satisfactory. Attitudes and beliefs in this area will be difficult to change. Nonetheless, the Bank will have to take a firm stand in principle and be prepared to be flexible in practice.

As a first step, it is recommended that the Bank articulate its goal of full cost recovery in its rural water and sanitation projects. In order to achieve this goal, the Bank should be prepared to accept some continuing level of subsidy in the short run in order to introduce the structural and policy reforms that would achieve higher levels of cost recovery over the longer term. Where high levels of subsidy exist, the amount of the subsidy--both implicit and explicit--should be quantified and a justification given. This justification should show what income groups are receiving the subsidy, the relationship between their income and the subsidy, the percentage of the unit cost of water represented by the subsidy, the total amount of the subsidy relative to public expenditures, the level of the subsidy relative to the needs of the populations not being serviced, etc. The objective is to require countries to move toward a more complete accounting of actual subsidies in the sector and then to formulate an explicit subsidy policy that can then be discussed in terms of need and effectiveness. The Bank should not be against subsidies _per se_ but should insist that, within a reasonable period of time, they meet the replicability criterion and be efficient in terms of its distribution and administration.

The benefit-cost decision rules generated in Chapters II, III, and IV can be useful here. Suppose, for example, that government policy is to allocate a major share of investment funds to rural water supply projects in region B; application of the decision rules, however, does not justify this politically motivated decision. Nonetheless, the projects in region B could be ranked according to their net benefits and then compared with a similar ranking of investment alternatives in region A, where it is clear that government can maximize benefits relative to costs. The project planner could then approach the decision maker with a concrete choice: by allocating investment to region A, government is losing net benefits, but, nonetheless, can choose from among the best alternatives in terms of the net benefits produced. The planner can further demonstrate that, by making this decision, government is foregoing X amount of benefits in region B, and that this represents the cost of the political decision.

Project Design and Preparation. The failure to reach more of the rural population at existing levels of investments is due largely to the absence of a suitable approach to project design. The framework of analysis presented in Chapters II, III, and IV sets out the minimum requirements to assess the benefits and costs of a proposed intervention, together with the steps needed to ensure that costs are minimized and services are affordable to both the beneficiaries and the country. As seen above, a minimal amount of information is required both to design effective interventions and to measure their benefits. Where information is not available or where it is subject to a wide range of interpretation (for example, the value of rural labor), some estimate is still required to make explicit the underlying assumptions and judgments used.

One issue that is likely to cause controversy is the evaluation of health benefits. The evidence suggests that water supply interventions by themselves are likely to yield minimal benefits—even if it were possible to quantify them. There are, however, many who will continue to insist on the importance of these benefits. The Bank should encourage project designers to be more explicit in linking specific investments to improvements in health through inclusion of health and hygiene education components and programs. In addition, there will be some cases where there are explicit links between the quality of the water and specific diseases. Excess fluorides in water, for example, are responsible for serious health problems in selected areas of

China. While recognizing these possibilities, the Bank should maintain the position that most high-priority projects will be amply justified in terms of the more quantifiable economic benefits.

Water and Sanitation Projects as Components of Rural Development Projects. Most of the Bank's financing of rural water and sanitation services has taken place in the form of sub-components of rural development projects. (See Table 6.1) As parts of these larger projects, they receive relatively low priority in terms of their design and institutional objectives. If improvements are to be achieved in project performance, it becomes pertinent to ask whether the Bank should continue to finance these services as part of rural development projects. Experience suggests the Bank should adopt a cautious approach: rural water and sanitation services should not be financed as part of multicomponent projects unless there is an adequate policy and institutional framework in place. Without such a framework there is little chance of achieving an adequate rate of return on the component.

There may be cases within such projects where it is possible to achieve substantial improvements in the policy and institutional framework. This would require more staff resources being devoted to these components than has generally been the case in the past. There also may be opportunities for experimenting with new ways of doing business within the context of the larger project. Financial intermediaries, for example, could be encouraged to expand their portfolios to include rural water systems.

Investments in Rural Sanitation Services. As indicated earlier, there would appear to be limited demand for this type of service in low-density, small, rural settlements. In any case, it is not clear that current levels of measurable benefits justify attaching a priority to their financing. This would seem to suggest that the Bank limit its funding of these services to a few experimental programs that would test different approaches, technologies, or combinations of services, and evaluate and compare their performance. In the peri-urban areas and in the larger rural settlements, there is both sufficient demand and greater likelihood of having some impact on health; under such circumstances packages of such services are warranted and should be considered for Bank financing.

In the less dense, more remote rural areas, the Bank could target limited financing to programs that aim to shift demand, i.e., to encourage the use of improved waste disposal systems. Both general educational programs and those directed at specific behavioral practices affecting health and hygiene are examples. In addition, financial aid and technical assistance could be used to encourage private suppliers to meet the limited demand for such services. Higher income families and those living at the center of higher density villages would be prepared to purchase greater convenience and privacy, provided acceptable techniques were available at a low enough price. The same firms contracted to build water systems could be encouraged to provide sanitary services as well. Although the limited use of these facilities would result in little or no impact on community health, increased familiarity with their construction and use could have a cumulative impact on health as incomes and densities increase.

Research and Development. At present the Bank is engaged in a highly productive program of research and development with the support of the United Nations Development Programme (UNDP) and most of the bilateral donors, as described in the first chapter in Box 1.1. This program has concentrated on developing technically feasible low-cost water supply and waste disposal systems. Most of the basic research is now coming to an end and increasingly the effort is focused on marketing and dissemination. The setting up of the training network, described in Chapter V in Box 5.2, is an important step in the active dissemination of the research findings. Even though this work is moving out of the basic research stage, it would be cost effective to use the capacity that has been developed to continue to do some limited research into the engineering and technological issues. In particular, some of the suggestions for further research discussed in Chapter V could be followed up on at relatively low costs. High priority should be given to further work on very low-cost distribution systems, the development of lower cost drilling techniques, and the use of alternative energy resources.

The Bank is in a unique position to follow up on some of the economic issues raised throughout this paper. No other agency or research institution has the capacity to do so. In particular, high priority needs to be given to the issues surrounding the estimates of demand and in improving the methods for cost-benefit analysis of both water supply and sanitation projects. A modest start has been made using the resources of the UNDP-funded program. Research is under way in rural Kenya to quantify more precisely the relationship between quantities of water consumed and the distance hauled. Additional information will be obtained on prices paid for water, who is doing the hauling, under what circumstances, and the relationship between income levels and water consumption. This work needs to be expanded to cover a greater variety of situations.

In addition the Bank can assist countries in developing appropriate country strategies. Through its financing of innovative projects using the type of institutions and financing methods suggested in this paper, the Bank would be in a good position to monitor and disseminate the results. By making sure, through its knowledge of overall investment priorities and constraints, that these programs are replicable, the Bank could provide an important service to both borrowers and lenders in this field.

One area where the Bank does not have any particular comparative advantage is in the research that will be required to better link water and sanitation investments with investments in public health. Other organizations such as WHO, UNESCO, and national health agencies should be encouraged to become more active in providing these links.

# BASIS OF COST ESTIMATES

In this annex the basis for the cost estimates used in the body of the report is outlined. In addition, a brief overview of the types and reliability of rural water supply systems and an expanded analysis of the cost of pumping water with alternative power sources is presented.

## Types of Water Sources

Water supplies are derived from three sources: surface water, groundwater, and rainwater. Surface water sources include rivers, streams, lakes, and irrigation canals; groundwaters are derived from springs and wells; and rainwater collection requires individual roof or impervious area catchments. The source of water largely determines its quality. Consequently, surface water, groundwater and rainwater often have quite different characteristics.

The quality of water can perhaps best be viewed in terms of the materials that are disssolved or suspended in it. Suspended solids include fine sands, silts, clays, detritus, algae and other microorganisms. These materials in general cause turbidity, which affects the aesthetic appeal of drinking water and in high concentrations impedes chlorination effectiveness. However, of greatest concern are pathogenic microorganisms: various bacteria, viruses, protozoans and their cysts, and the eggs and larvae of helminths. Surface waters are likely to be turbid and to contain pathogenic microorganisms; consequently, the potential of water-borne disease transmission always exists with them.

Due to the filtration action of the soil, groundwaters have low turbidity and are nearly always free of pathogens. However, close contact of percolating water with the soil often results in high levels of inorganic dissolved solids (salts). Therefore, groundwaters may taste so poor that consumers switch to a better tasting supply that very likely will be a surface water of poorer bacterial quality.

Rainwater, generally containing few human pathogens and little dissolved solids, on a quality basis, is an ideal source. However, rain can be relied on in few localities and construction materials for catchments can be expensive for individual households.

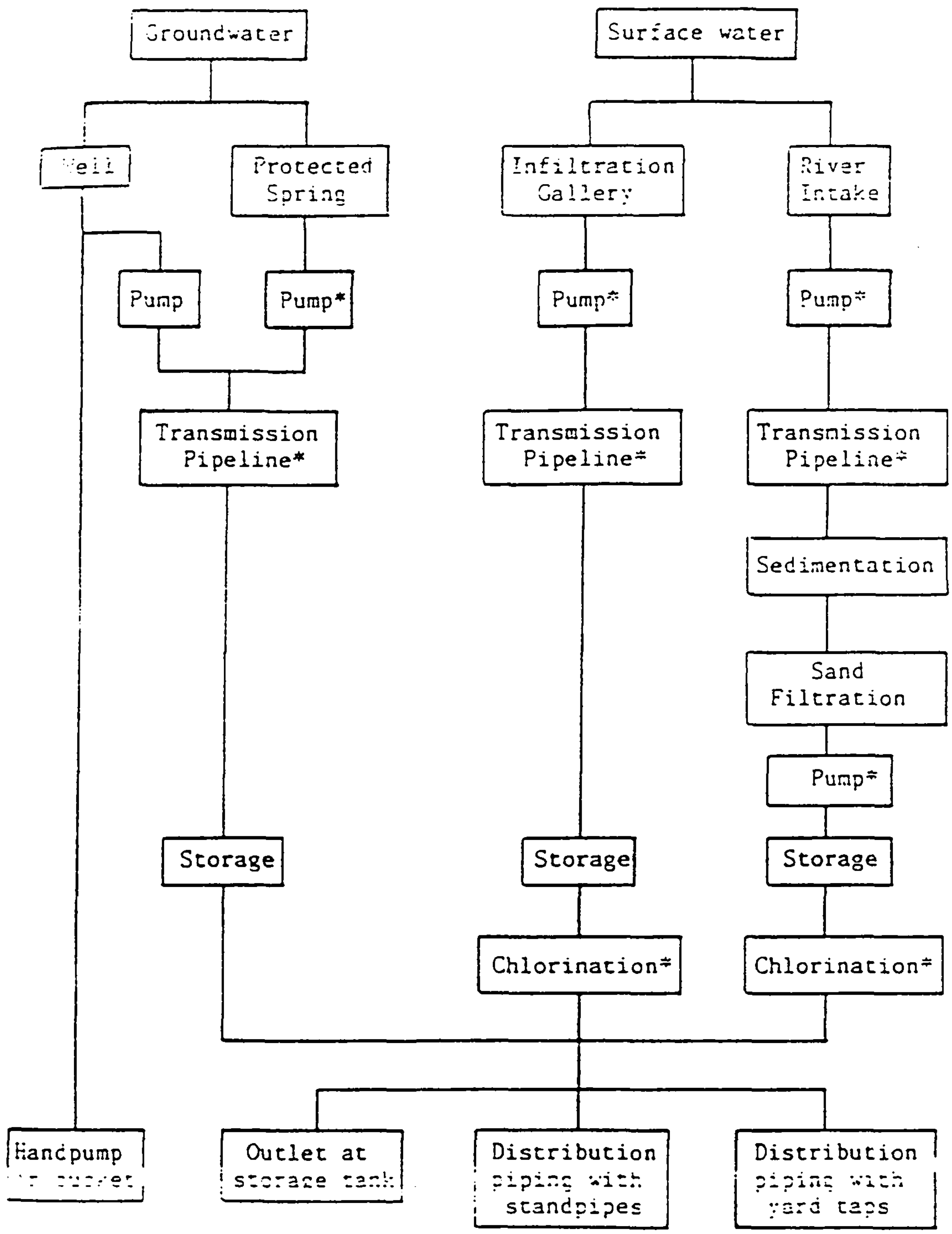
Types of Water Supply Systems

The quality of surface water and groundwater and their proximity to a community in terms of both distance and elevation principally determine the individual components of a water supply system. To provide an overview of the range of these systems, possible components of surface and groundwater systems are outlined in Figure A-1.

The simplest type of a water supply system is one in which water is taken as it is found at the source from a spring or surface water. The first step in the process of improving the supply should be protection of the source from potential contamination. For example, a spring might be enclosed in a box that is fitted with an overflow pipe. Surface waters might also be treated, the simplest form of treatment is probably a shallow hole dug in the sand of a river bank from which filtered water having less sediment and fewer impurities than the main stream may be obtained (White, Bradley and White, 1972). As suggested by this example, surface waters may also be treated by means of sand filtration; however, because even moderately turbid water can rapidly clog a

FIGURE A.1

TYPES OF WATER SUPPLY SYSTEMS




* Indicates component not necessarily required.
Pumps refer to motor driven pumps.

sand filter, water should pass through a settling tank prior to filtration. In addition, in order to meet World Health Organization bacteriological water quality guidelines (MPN of 3 coliform per 100 ml), surface waters must be disinfected (WHO, 1984). The need for continual attention to maintain such treatment processes and the requirement of an uninterrupted supply of chlorine result in almost inherent reliability problems with water treatment in rural communities.

In terms of bacterial quality, groundwater offers a more reliable water source. Traditionally, hand dug, wide diameter, open wells have been used to tap groundwater sources. Such open wells can be protected by providing a headwall designed such that neither surface water nor spillage enters the well. A concrete apron can also be provided and, if raised, gives still better protection. Covering the well and lifting water by means of a handpump or windlass provides excellent protection; however, access to the well may be reduced and the mechanical reliability of the pump becomes a factor. Thus, to some extent, a tradeoff must be made between reduced risk of contamination and increased risk of mechanical failures.

Groundwater sources can also be tapped by driven, jetted, bored, or drilled boreholes fitted with a pump that is powered by electricity, diesel, solar, wind, or manual energy. Whether boreholes or hand dug wells should be installed depends, among other things, upon their relative costs and whether the expected pumping rate will produce a drawdown greater than can be accommodated by a dug well.

Reliability of Water Supply Systems

Selection of a source of supply by an individual is largely based upon taste and turbidity of the water, relative distances to alternative sources, reliability of the supply, and local social factors (Whyte and Burton, 1977; Stein, 1977; Pacey, 1977). Water resource planners must consider each of these when developing a water supply system. Of particular importance is reliability (Cairncross and Feachem, 1977b). Ideally, mechanical failures should be rare and pumps easily repaired by local residents. In addition, some form of backup should be available to provide service when failures occur; fuel and disinfectant supplies, if required, should be uninterrupted; and the capacity of the system should be adequate to meet water use demand during wet and dry seasons as well as during dry weather years over the design period of the system.

A spring, having good quality water that comes naturally to the ground surface, requires no pumping or treatment and in terms of both microbiological quality and mechanical reliability, is the optimum water source (World Bank, 1976; Pickford, 1977), particularly if the spring is located above the community and water can be conveyed by gravity pipeline.

If a well is required or water must be conveyed uphill, a mechanical pump must be used, and reliability of the system decreases. If treatment to improve quality is also necessary, a reliable operator, spare parts, and an uninterrupted supply of chlorine must be available; as a result the reliability of the system further decreases. If the water source is highly polluted, even temporary failure could cause a severe outbreak of water borne disease. Consequently, it is preferable to find a source of good quality water and protect it, rather than take water from a doubtful source and treat it (Pickford, 1977; Cairncross and Feachem,1978). Accordingly groundwater is a good source of water because it offers the best and most reliable protection against contamination.

Because over 75 percent of the world's rural population has access to groundwater and because it is the preferred source for rural water supply, this strategy paper focuses on groundwater, and costs are based on boreholes that are fitted with mechanical pumps.

Components of Water Supply System

A community water supply system consists of a source works and a means of conveying water to the point of use. In this analysis, it is assumed that the source of water is groundwater that is of acceptable taste to users. Source costs consist of installation and maintenance of a borehole fitted with either a handpump or an electric pump, plus the cost of storage tanks if electric, diesel, solar or wind powered pumps are used. Conveyance to the point of use, in this case one's yard, is done by carrying the water or by pipeline. Because the cost of a water supply system is often evaluated only in terms of capital plus maintenance costs, the cost of handpump and standpipe systems typically includes only source and partial distribution costs, whereas the cost of yard tap systems includes both source development and conveyance to the point of use.

To make accurate judgments about the type of water supply system a community wants and will be willing to maintain, it is essential to compare costs of alternatives at the point of use, which in this analysis is assumed to be the home. Conveyance costs for yard tap systems are based on the capital plus maintenance costs of a piped distribution system with individual yard connections; conveyance costs for handpump and standpipe systems include the time required to collect water and an estimate of the value people place on their time.

A sensitivity analysis carried out on various site-specific factors that affect this total cost was made. The value of a number of these factors was varied sequentially over their typical ranges, while holding all other values constant. The standard values are shown in Table A.1 and the results of this analysis are presented in Chapter V.

Cost calculations are based on limited data from recorded projects, and project costs are highly dependent on local material and labor costs as well as construction efficiency. Therefore, price information presented here should not be used for estimation purposes. Nonetheless, the costs presented here are believed to be internally consistent and to be representive of good engineering and construction practices at reasonable materials costs, labor rates, and profit margins.

It should also be noted that excess capacity for future population growth was not included. The annual per capita cost of each system was based on the number of persons presently living in the community. This tends to reduce the economies of scale possible with standpipe and yard tap systems. However, in a similar vein, savings in handpump systems that could result from defraying installation of additional handpumps to a future date when they would be needed to serve an increased population were not considered, nor were similar savings that could be realized by first installing a handpump-based system and later upgrading this to a standpipe or yard tap system.

TABLE A-1

## STANDARD VALUES FOR COMPONENTS OF A WATER SUPPLY SYSTEM

| | Standard value |
|---|---|
| **Village characteristics** | |
| Village population, number of persons | 400 |
| Household size, number of persons | 8 |
| Housing density, persons/hectare | 200 |
| Housing density, households/hectare | 25 |
| Number of handpumps, persons/outlet | 200 1/ |
| Number of standpipes, persons/outlet | 100 |
| **Water use** | |
| Per capita use, liters/day (lpcd) | 10-75 |
| Peaking factor, max/ave hourly use | 3 |
| Available headloss, meters | 5 |
| Storage volume, V/Q | 0.33 |
| Water lift, meters | 20 |
| **Collection time** | |
| Volume carried per trip, liters | 20 |
| Round trip travel distance, meters | 200 |
| Queue time, minutes | 2 |
| Water delivery rate, liters/minute | |
| Handpumps | 10 |
| Standpipes | 15 |
| **Economic** | |
| Discount rate, percent | 10 |
| Useful life of mechanical equipment, yrs | 10 |
| Useful life of non-mechanical equipment, yrs | 20 |
| Value of time spent collecting water, $/hr | 0.25 |
| **Operations and Maintenance** | |
| Annual O&M for mechanical equipment, % cap cost | 10 |
| Annual O&M for non-mencanical equip, % cap cost | 3 |
| Electric power cost, $/kw hr | 0.10 |

---

1/ If pumped volume is greater than 5 m3/day
number of handpumps = integer of population + lpcd/5000

Handpump, standpipe, and yard tap systems were costed in terms of the following components:

Handpumps

Wells

Pumps

Operation and maintenance

Collection time

Standpipes

Wells

Pumps

Storage tank

Partial distribution piping

Standpipes and drain fields

Operation and maintenance

Collection time

Yard taps

Wells

Pumps

Storage tank

Distribution piping

House laterals

Yard taps and drain pits

Operation and maintenance

To determine the cost of supplying water, the annualized capital cost of each of the above components was estimated and added to the annual maintenance cost of each. To determine annualized capital costs, mechanical equipment was assumed to have a useful life of 10 years and non-mechanical equipment was assumed to have a useful life of 20 years; to account for mechanical equipment having only half the useful life of non-mechanical equipment, the present value of the replacement cost of mechanical equipment at year 10 was added to the initial capital cost of these components. The cost of water in terms of dollars per cubic meter was determined by dividing annual per capita costs by the volume used per person each year.

Wells. Because the cost of well drilling is highly dependent on the type of drilling equipment, the amount of expatriate labor, and construction efficiency, well construction costs are specified on a lump sum basis rather than by specifying a well depth and geologic conditions and then estimating the cost of the well. For example, in some drilling projects the construction cost per well has been more than $10,000, while other drilling projects using more suitable drilling equipment, minimum expatriate labor, and an efficient drilling program have constructed wells to equal depths in similar geologic strata that each cost less than $2,000.

In order to allow for a wide range of volumetric output capacities, the lump sum cost was applied to a well that would provide 15 m3 per day, and the cost of wells with larger capacities was assumed to increase above this base cost in proportion to the square root of the daily capacity. Thus well costs are given by the following equations where Q is the well capacity in m3/day:

$$\$ = \text{base cost} \qquad \text{if capacity} < 15 \text{ m3/day}$$

$$\$ = \text{base cost} * \sqrt{Q/4} \qquad \text{if capacity} > 15 \text{ m3/day}$$

To make systems roughly comparable in terms of reliability, a minimum of two wells per community was provided. In the case of electric pumps installed in a community with water use of over 30 m3/day, each well was required to provide half the total output.

Pumps. The cost of handpumps can vary from less than $100 for simple direct action, low-lift pumps to more than $2000 dollars for imported, heavy duty pumps. In this analysis, costs are based on commonly used community handpumps, typified by the India Mark II, which cost on the order of $600 when installed in a 20-meter borehole. Handpump costs were assumed to increase with the cost of the borehole and were incremented by $100 for every additional $2000 in well cost (e.g. $900/each for pumps fitted in a $8000 well). Electric pumps including discharge pipe, float controls, electric panel, and wiring were assumed to cost $1500 per unit and were also increased by $100 for every $2000 increase in well price.

Storage tanks. Storage tanks were sized to meet a peak daily demand of 3, where the peak demand is equal to the maximum divided by the average hourly flow. It was also assumed that electricity was available during the morning hours when most water typically is drawn and that it remained on for a minimum of 6 hours each day. Accordingly, the required storage volume was calculated to be 1/3 the total daily flow.

A major factor in the cost of storage tanks, particularly large ones, is whether they must be raised or the terrain is such that sufficient head can be obtained even though the tank is placed on the ground. In this analysis it has been assumed that tanks are raised to provide 10 meters of head in the distribution system. The cost of storage tanks was based on the following equation where V is the useful storage volume in m3:

$$\$ = 1500 * \sqrt{V} \quad \text{where } V = Q/3$$

Two alternatives to community storage have been considered: (i) individual household storage and (ii) minimal community storage, consisting simply of a constant head tank, where electricity is available throughout the day and pumps and wells were sized to meet daily peak demand. Household storage at $100 per household resulted in storage costs that were somewhat higher than community storage and, when storage was offset by increasing well capacity, the cost was essentially the same as that calculated for community storage.

Distribution piping. The required size, length, and corresponding installation cost of distribution piping was based on earlier work done for the World Bank by Donald Lauria, in which he evaluated several completed projects to obtain unit costs for pipe installation and required lengths of distribution piping for various numbers of outlets per hectare. He then expanded on these case studies to derive optimal pipe diameters as a function of community size, housing density, and water demand. The equation he developed for average pipe diameter (D) is given below where N is the number of outlets, P is the number of people, A is the area of the community in hectares, Q is the average daily use in liters per capita day (lpcd), Pk is the peaking factor, and H is available headloss in meters:

$$D = 2.7\ N^{-0.20}\ P^{0.23}\ A^{0.10}\ (QPk)^{0.38}\ H^{-0.23}$$

The length (L) of distribution piping is given by

$$L = 90\ N^{0.40}\ A^{0.40}$$

the length of house laterals is given by

$$L = 40\ (A/N)^{0.63}$$

and the the unit cost of piping is given by

$$\$/m = 6.35 + 0.133D + 0.0062D^{1.57}$$

For the range of village sizes and per capita water consumption used in this study, the installed cost of distribution piping was typically between $10 and $12 per meter.

Yard taps and standpipe outlets. When water is pumped by hand, water use typically averages between 15 and 25 liters per capita day; when it is piped to individual yards, consumption usually increases to between 50 and 100 liters per capita day. Because the water usage generated by yard taps often results in ponded water and muddy village pathways, proper design requires the provision of either surface drainage or a seepage pit at each outlet. The $100 per outlet cost used for yard taps includes the installed cost of both a tap and drainage pit. Similarly, drainage is needed for public standpipes and $500 was used as the installed cost of an outlet, splashpad, and drain field.

Collection. The cost of collecting water depends on the distance to the source, queue time, the delivery rate of the handpump, the amount of water a family uses each day, and the quantity of water carried per trip. The total amount of time required to collect water was calculated by means of the equation given below, which includes these factors. The cost of water collection was then determined by multiplying the collection time by the price at which people value their time. It should be noted, however, that no assumption has been made about how people value their time; rather throughout this analysis the value of people's time is approached in terms of a sensitivity analysis, that is, by evaluating the effect of a range of time values on the cost of water collection.

The collection time T is given by the following equation where d is the round trip travel distance, q is the queue time per trip in hours, v is the volume carried per trip in liters, and r is the delivery rate at the source in liters per hour:

$$T = (d/s + q + v/r)/v$$

The collection cost of water, in dollars per cubic meter is then given by the following equation where W is the value of time in dollars per hour:

$$\$/m3 = TW$$

Just as the required length of distribution piping is a function of housing density, so too is the distance a person must walk to collect water. If the assumption is made that paths in a community are laid out in a rectangular grid and outlets are evenly distributed throughout the community, then the average round trip travel distance is proportional to the square root of the area per outlet. Thus the round trip travel distance is given by the following equation where A is the size of the community in hectares and N is the number of outlets:

$$L = \sqrt{A10,000/N}$$

In order to put collection time in perspective, the following example is offered. If the distance to the water source is one kilometer, a family of 6 using 15 liters per capita day (lpcd) will spend about 2 1/2 hours each day collecting water. If the water source is brought into the village, the distance to the well will typically be between 50 and 100 meters; if there is a 2 minute queue each time a family member goes to the well, about 1 hour per day will be needed to collect water.

Maintenance. In this analysis, annual maintenance costs are based on the initial capital cost of the system, where the annual maintenance cost of mechanical equipment (pumps and outlet taps) was assumed to be equal to 10 percent of the initial capital cost of the mechanical components, and the annual maintenance cost of non-mechanical equipment (wells, storage tanks, and pipes) was assumed to be 3 percent of the initial capital cost. Maintenance costs are highly dependent on the type of maintenance system. For example, if centralized maintenance with mobile maintenance teams is undertaken in rural water supply, the cost of travel, labor, and overhead can result in costs that exceed by several times the cost of maintenance used in this analysis. Costs that are used here reflect levels that are obtainable if the system can be maintained by local residents with minimal centralized support.

The Cost of Water. A breakdown of the component costs of handpump, standpipe, and yard tap systems is presented in Table A.2. These costs correspond to the standard conditions outlined in Table A.1. Cost information is presented in terms of unit costs, total capital cost, and annual costs including both capital and maintenance costs. It should be noted that these costs do not include the cost of collecting water from handpumps and standpipes.

It can be seen that if no value is placed on the time a person spends conveying water and only capital costs are considered, handpumps can be provided in three times as many communities as standpipes, and in six times as many communities as yard taps; if both capital and maintenance costs are included, handpumps can be provided in twice as many communities as standpipes and four times as many communities as yard taps.

Water costs can also be viewed in terms of their cost in dollars per cubic meter. The cost of water based solely on capital costs is shown in the first figure in Chapter 2 and in the second figure in Chapter 2 the effect of the value of time on the total cost of water (source plus conveyance) is depicted.

Source Costs. As discussed previously, a water supply system can be considered in terms of source works plus conveyance to the point of use. Source works include the well, a pump, as well as a storage tank if water is not pumped by hand. In the body of the report, the cost of pumping water is based either on handpumps or electric submersible pumps connected to an electric grid system. In many rural areas electric grids are not available and other power sources must be considered. These include diesel, wind, and solar power. In addition, if handpumps are used, the height that water must be lifted and the power output a person can generate have a major effect on the cost of pumping water.

TABLE A-2

## COST OF WATER SUPPLY SYSTEMS

| | Unit Cost ($) | Total Capital Cost ($) | Annual Per Capita Cost ($) | Percent of Total |
|---|---|---|---|---|
| **HANDPUMPS** | | | | |
| Wells | 2,000 | 4,000 | 1.17 | 52 |
| Handpumps | 600 | 1,200 | 0.49 | 22 |
| O&M | - | - | 0.60 | 26 |
| Total | | 5,200 | 2.26 | |
| **STANDPIPES** | | | | |
| Wells | 2,000 | 4,000 | 1.17 | 17 |
| Electric pumps | 2,400 | 4,800 | 1.95 | 29 |
| Storage (4 m3) | 3,000 | 3,000 | 0.88 | 13 |
| Dist pipe 90.6 m/cap) | 20.40 | 4,800 | 1.42 | 21 |
| Standpipes | 500 | 2,000 | 0.81 | 12 |
| O&M | - | - | 0.38 | 6 |
| Electric power | - | - | 0.12 | 2 |
| Total | | 18,600 | 6.74 | |
| **YARD TAPS** | | | | |
| Wells | 2,000 | 4,000 | 1.17 | 10 |
| Electric pumps | 2,400 | 4,800 | 1.95 | 16 |
| Storage (10 m3) | 4,700 | 4,700 | 1.39 | 11 |
| Dist pipe (1.6 m/cap) | 18.40 | 12,000 | 3.52 | 29 |
| Lat pipe (0.7 m/cap) | 16.80 | 4,400 | 1.30 | 11 |
| Yard taps | 100 | 5,000 | 2.03 | 16 |
| O&M | - | - | 0.62 | 5 |
| Electric power | - | - | 0.30 | 2 |
| Total | | 34,900 | 12.29 | |

Village size = 400 persons
Population density = 200 persons per hectare
Costs in 1984 US dollars

In the analysis of source costs the following equations were used to estimate capital costs:

Handpump

$\$ = 600 + 8\ H$

where H = Pumping head (meters)

Electric submersible pump for grid, diesel, and solar pumping

$\$ = 275 + 25\ H + 75\ Q/E$

where Q = Pump capacity (cubic meters per day)

E = Hours per day of electric power

Standard is 5 hours for all systems.

Diesel engine/generator

$\$ = 275 + 25\ H + 75\ Q/E$

where E = Hours per day that the engine is run

Solar photovoltaic panel

$\$ = 16\ Q\ H$

Windmill

$\$ = 850\ Q\ H/V3$

where V = Average daily wind speed (meters per second)

Assumed that windmill is 1/2 mechanical and 1/2 non-mechanical for O&M costs.

To demonstrate the relative costs of manual, electric, diesel, wind and solar pumping, two conditions are considered. In Figure A.2 water costs are based on a small village (200 people) where the pumping lift is 20 meters and the cost of a well is $2000. In Figure A.3 water costs are based on a large village (800 people) where the pumping lift is 40 meters and the cost of a well is $8000.

From these two figures it can be seen that water can be pumped for substantially less cost if an electric grid is available than if a pump is powered by diesel, wind, or solar power. In fact, only handpumps are competitive with electric grid pumping and then only if pumping lift is low, the cost of a well is less than about $2000, and water use is low. It should be borne in mind, however, that 30% to 50% of the cost of water from handpumps in this example is attributable to labor and that the value people place on their time will have a significant effect on the cost of water, and, as demonstrated in Chapter 3, on the benefits achieved by reductions in the haul distance.

The cost of diesel and solar pumping is about the same, with solar pumping tending to be less than diesel pumping, particularly if pumping lift and water use are low. Conversely, as pump capacity and pumping lift increase, diesel pumping tends to cost less than solar pumping. If reliability is considered, the difficulty of maintaining an uninterrupted supply of fuel can be a major problem in rural areas, particularly in small villages. Consequently, it appears that solar pumping may be a better technology choice than diesel powered pumps in small to medium sized villages. However, before such a conclusion can be reached, the performance of solar pumps in the field must be carefully evaluated. Of particular importance are the useful life of the photovoltaic panels and their susceptibility to vandalism.

FIGURE A.2

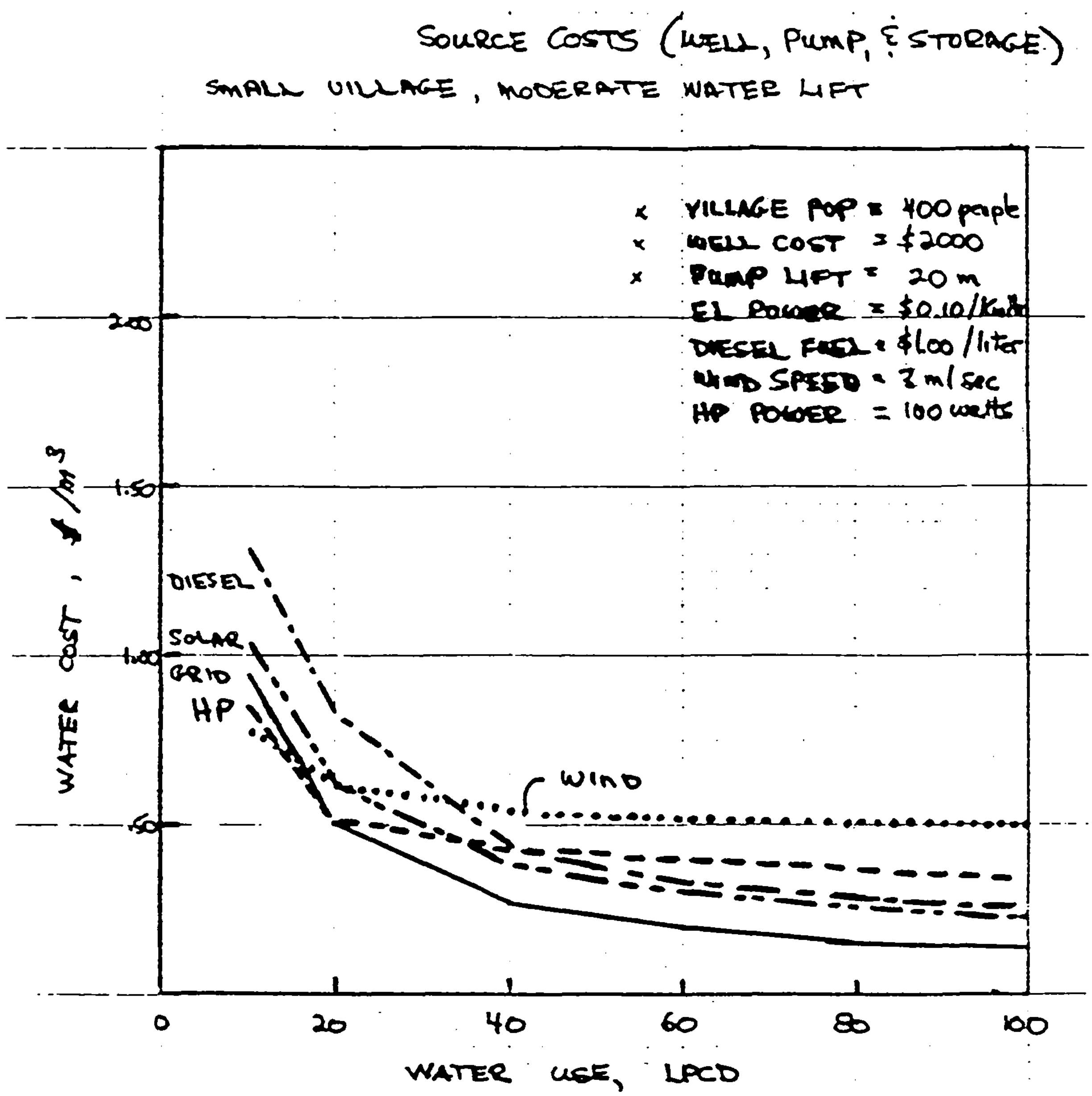
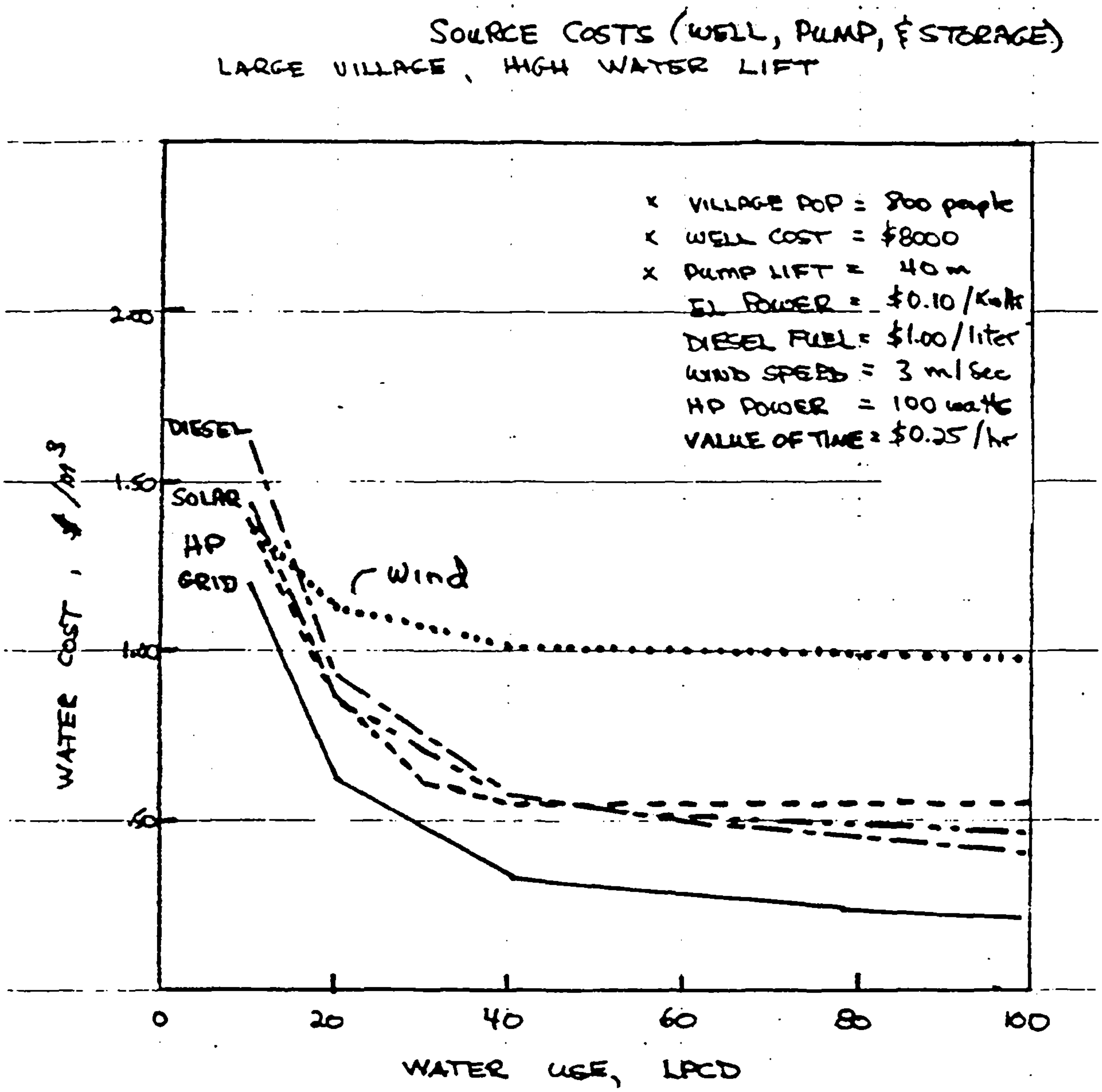

SOURCE COSTS (WELL, PUMP, & STORAGE)
SMALL VILLAGE, MODERATE WATER LIFT
x VILLAGE POP = 400 people
x WELL COST = $2000
x PUMP LIFT = 20 m
EL POWER = $0.10/KwH
DIESEL FUEL = $1.00/liter
WIND SPEED = 3 m/sec
HP POWER = 100 watts
DIESEL
SOLAR
GRID
HP
WIND
2.00
1.50
1.00
.50
0
20
40
60
80
100
WATER COST, $/m3
WATER USE, LPCD

FIGURE A.3


SOURCE COSTS (WELL, PUMP, & STORAGE)
LARGE VILLAGE, HIGH WATER LIFT
x VILLAGE POP = 800 people
x WELL COST = $8000
x PUMP LIFT = 40 m
EL POWER = $0.10/KwHr
DIESEL FUEL = $1.00/liter
WIND SPEED = 3 m/sec
HP POWER = 100 watts
VALUE OF TIME = $0.25/hr
DIESEL
SOLAR
HP
GRID
wind
WATER COST, $/m³
2.00
1.50
1.00
.50
0
20
40
60
80
100
WATER USE, LPCD

Wind pumping is shown here to be considerably more expensive than other types of pumping, this is partly because costs were based on purchase prices in the United States and Australia. If windmills were locally manufactured, costs might be significantly reduced. Also, as will be discussed, average wind speed has a major impact on the cost of pumping water and costs drop rapidly as average windspeeds increase above the average 3 meter per second wind speed used to generate the cost curves in Figures A.2 and A.3.

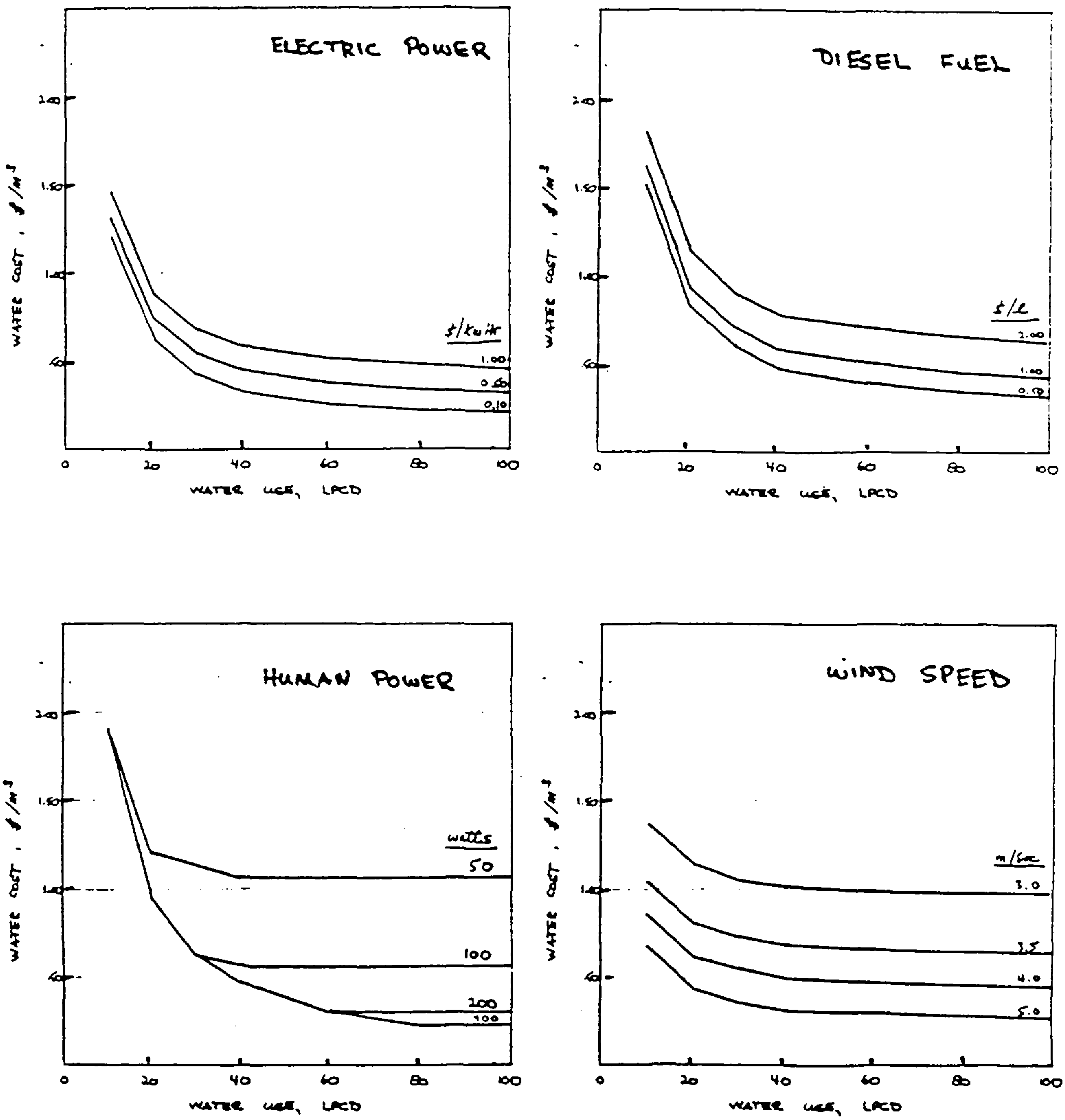
To demonstrate the impact of wind speed, electric power costs, diesel fuel cost, and human power on the cost of water, the graphs in Figure A.4 are presented. The standard value of 10 cents per kilowatt hour for electric power from a grid, particularly if the grid must be extended to provide electricity to a village, may be quite low. For example, if the real, non-subsidized cost of power is $1.00 per kilowatt hour, the cost of water will double. In our standard village this would have the effect of making electric grid pumping more expensive than diesel, solar, or manual pumping.

If the cost of diesel fuel increases substantially above the standard $1.00 per liter cost used to generate the curves in Figures A.2 and A.3, the result is to make solar pumping even more attractive. Conversely, if the fuel cost is halved, there is not a similar major effect on the choice of technologies. Again this suggests the relative benefits of solar over diesel power for village water supplies.

It is also clear that the power input to a handpump is critical to the cost of water. Field experience indicates that adults tend to apply about 100 watts to a handpump when pumping for a few minutes and that users tend to favor pumps with a higher delivery rate even. The curves for power input in Figure A.4 suggest that when water use is 20 lpcd or less power inputs have little effect on the cost of water. However, as water consumption increases,

FIGURE A.4

## EFFECT OF ENERGY COST AND POWER INPUT ON THE COST OF WATER



it becomes more and more important. This effect becomes even more important if queue time is included in the analysis, since higher delivery rates will reduce the time a person must wait in line. In fact, if two persons can operate a pump the next in line often assist the person who is drawing water. From this it is clear that ergonomics in handpump design and pumps that can be operated by two persons are very important when per capita water consumption is high.

Because wind power is proportional to the cube of the wind speed, the cost of water from windmills is highly sensitive to average wind speed. For example, increasing the wind speed from 3 to 4 meters per second (6.7 to 8.9 miles per hour) reduces the cost of water by half and makes wind power more competitive with the other power sources, particularly at water use below about 40 lpcd.

## ANNEX B

## TECHNICAL IMPLEMENTATION OF BENEFIT MEASURES

As noted in Chapter II on measuring benefits, households have a common water demand equation in which annual water consumption in liters per household per year, Q, is related to annual household income, Y, and the price of water in cents per liter. Specifically the water demand equation is:

$$Q = 0.025\ Y/P \qquad (1)$$

Further analysis in Chapter II demonstrated that, for households that haul water, P is based on the time spent hauling water and on the value of that time that is approximated by the area wage.

Households experiencing a fall in the price of water, perhaps from P1 to P2, will have a gain in their own welfare that reflects a willingness to pay for the service improvement that caused the fall in price. There is also an increase in water consumption from Q1 = 0.025 Y/P1 to Q2 = 0.025 Y/P2. The increased willingness to pay reflects both the saving in cost on the first Q1 liters of water or [(P1 - P2) Q1] and also the value that the household places on the additional water consumption, Q2 - Q2, above the P2 purchase price. This willingness to pay was shown as an area to the left of a demand curve in Figure 2.1. This area, S(P2, P1; Y) may be computed by integrating the demand curve over the price interval P2 to P1 to yield:

$$S(P_2,P_1,Y)=\int_{P_2}^{P_1} [0.025Y/P]\ dP= 0.025Y\ [\ln P_1 - \ln P_2] \qquad (2)$$

In the application of this approach to measuring individual household willingness to pay for water service improvements, P1 is based on an initial availability of water from "traditional" sources. Thus P1 is based on the distance to streams, wells, etc. where villagers haul water and on the value of hauling time. In the case of water supply improvements that still require water hauling, i.e., handpumps and standpipes, P2 would also be computed based on haul time and the wage rate. If a system of yard taps is installed, then it is not obvious what price to use for P2. For purposes of this study, the appropriate residual price of water obtained through a yard tap was determined by inverting the demand equation and solving for the water price that would generate daily water consumption per capita of 100 liters because this level of use has been observed after installation of yard taps in rural villages. Given the water demand curve and assumption of an eight person household, the implied price of water from yard taps is PT = 0.000009Y cents per liter - a low price indeed. Of course any metered charge for yard taps would be added to this price in determining water use where meters were installed.

Given equation (2) and the price of water from yard taps, PT, developed above, one finds that the willingness to pay for water improvements in dollars per year on the part of households going from traditional water sources available at price P1 to yard taps at PT is given by:

$$S(PT, P1; Y) = 0.025Y\,[\ln P1 - \ln PT] \qquad (3)$$

Total willingness to pay in dollars per year for a village of N households would then be given by multiplying equation (3) by N. Thus determination of willingness to pay for yard taps is relatively straightforward and depends only on local income levels and the time and distance involved in accessing traditional water sources. Clearly increases in local income, Y, or haul cost from traditional sources, P1, result in higher willingness to pay.

In the case of water obtained from handpumps or standpipes, the distribution point is some distance from this household and hence P2 depends on household proximity to the new and old water sources. Obviously, if P2 exceeds P1, households will continue to use the old source and willingness to pay will be zero. For the interesting case, in which P2 is less than P1, equation (2) may be used to compute the willingness to pay on the part of specific households at specific locations. Overall willingness to pay on the part of all households served by a single handpump is computed by defining a market area served by the handpump in terms of a maximum distance or market radius R in meters to the furthest household using the pump. It is also necessary to express the price of water from the handpump, P2, as a function of distance in meters from the household to the water source, r, so that P2(r) is derived. Finally households are assumed to be distributed uniformly at density g households/square meter (a very small number but one that allows simplicity in notation) around the water point. Total willingness to pay for the circular market area around the handpump ranging from r=0 to r=R meters, is given by integrating the willingness to pay function from equation (2) so that:

$$S(P2(r), P1, R; Y) = \int_0^R g\,(3.14)r \quad 0.25Y\,[\ln P2(r) - \ln P1]\,dr \qquad (4)$$

The willingness to pay function obtained from this integration is rather complex but may be evaluated easily, and willingness to pay is found to be an increasing function of village income, Y, maximum market radius, R, density of households, g, and the distance to the traditional water source as reflected in P1. Note that this distance to traditional water is based on an average figure because there is no practical way of expressing the proximity to the traditional water source as a function of distance to the handpump.

One objection to this procedure for determining willingness to pay is that R may be chosen at such a large value that the handpump could never serve the households located within the implied market area of $3.14_{gR}2$ square meters. This possibility is checked by computing Rmax, the maximum market radius that could be served by a handpump whose pumping capacity in is given by C. Total water demand for the market area ranging from r=0 to r=Rmax is given by:

$$D\ (P2(r),\ Rmax,\ g;\ Y) = \int_0^{Rmax} 3.14g\ r\ [0.25Y/P2\ (r)]\ dr \qquad (5)$$

Given an expression for D(P2(r), Rmax, g; Y) from (5), it is possible to solve for the maximum market radius that can be served by a handpump with capacity C by equating C=D(.) and solving for Rmax. This is the largest market radius that is used to compute willingness to pay. The actual market radius of handpumps in a village is computed by dividing total village area, A, by the number of handpumps, H, to get area served by handpump, A/H. The market radius required to serve such an area is found by solving $3.1R^2 = A/H$ for R. Then R can be compared with Rmax and the actual radius used to compute willingness to pay per handpump is the smaller of these two numbers.

The techniques described here allow one to compute annual willingness to pay for yard taps or for different numbers of handpumps on the part of residents of rural villages depending on the density, income level, and proximity to traditional water sources that characterize the village. The calculated annual cost of different types of water facilities computed according to techniques described in Annex B is then subtracted from the total willingness to pay to obtain net benefit measures that are reported in Chapter V.