ECONOMIC CONSIDERATIONS FOR LOW-COST, GROUNDWATER-BASED RURAL WATER SUPPLY

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ABSTRACT

An estimated 1,800 million rural people will have to be provided with improved water supplies in the 15 years to the end of this century if developing countries are to approach the coverage targets of the International Drinking Water Supply and Sanitation Decade (IDWSSD). Accelerated progress is hampered by financial, technical and institutional resource constraints faced by many developing countries. The problem is also aggravated by the growing number of completed projects which are broken down and abandoned, or functioning well below their potential capacity. The Community Water Supply Project (formerly the Rural Water Supply Handpumps Project) was initiated to address these problems and work towards sustainable, replicable rural water supply programs. As part of this work, the Project has devised a simple, analytical tool, based on traditional cost/benefit analysis, that can be used to evaluate rural water supply projects.

In 1981, as one of the activities in support of the International Drinking Water Supply and Sanitation Decade, the United Nations Development Programme (UNDP) through the Department of Global and Interregional Projects (DGIP), and the World Bank initiated the Rural Water Supply Handpumps Project, now known as the Community Water Supply Project. The goal of the Project is to test and develop designs and implementation strategies to improve the reliability, sustainability and replicability of schemes based on point-source supplies, primarily groundwater and handpumps.

During the first phase of the program, laboratory testing and field trials of 70 types of pumps were carried out in 2,800 locations in 18 developing countries of Africa, Asia and Latin America. The results have been made available to governments and manufacturers and are having an increasing impact on the design and selection of pumps in national investment programs. Resources during the next phase of the program will be directed primarily to the widespread application of the findings in country investment projects, beginning with the organization of integrated demonstration projects. The

*The views and interpretations in this paper are those of the authors and should not be attributed to the World Bank, the UNDP, or their affiliated organizations.

purpose of these projects is to introduce sector authorities to the planning and organizational methods needed if point-source rural water projects are to be sustainable; to refine the approach in relation to diverse physical and social conditions prevailing in different countries; and to influence sector policies and institutional arrangements during the remaining years of the Decade. Work will also be continued on further development and local manufacture of VLOM pumps adapted to the needs of different countries.

2 ECONOMIC PLANNING TOOL FOR RURAL WATER SUPPLY SYSTEMS

In order to evaluate rural water supply (RWS) projects, the Project has devised a simple analytical tool, based on traditional cost/benefit analysis. The model can be used to compare the service levels, costs and benefits of alternative RWS systems. (A full description of the model is presented in an upcoming Applied Research and Technology Note.)

2.1 Service Level

The service level provided by a new or improved water supply involves a combination of factors, including the quantity and quality of the water, the amount of time needed to collect water, and the reliability of the system.

(i) Quantity: Daily water consumption may range from 3 to 300 lcpd (liters per capita per day). The high end of this range is associated with house connections for relatively affluent communities where households have multiple water fixtures and gardens are watered. The low end of the range, which approaches the minimum necessary to sustain life, occurs where water has to be carried for long distances. For point sources (open wells, handpumps and standpipes), household usage in many parts of rural Africa and Asia is commonly between 15 to 25 lcpd.

(ii) Quality: The microbiological, chemical and solids content of water effect the service level. Water-borne diseases must be guarded against either by protecting the water source from contamination or by disinfecting the water before use. The chemical quality, usually of groundwater, may cause water to taste poorly (salts), discolor food and laundry (iron) or cause inefficient soap usage (hardness), while the turbidity, usually of surface waters, can make water aesthetically unacceptable.

(iii) Collection time: A distinction is made between point source and yard tap systems. Point source systems necessitate that water be carried home and so limit the amount that can be used. Yard taps, on the other hand, convey water by pipeline to the point of use. The service level offered by point source systems depends on the number of handpumps or standpipes in the community and the water delivery rate. Either handpumps or standpipes can provide better service in a given instance.

(iv) Reliability: Reliability requires a realistic assessment of the likelihood that a particular system can be operated and maintained at a reasonable cost. The lack of attention to reliability is reflected in the many systems, both handpump and piped, that have fallen into disrepair not long after being constructed. In such instances, the investment is wasted and the traditional source in the community ultimately gives a higher level of service than the new "improved" system.

2.2 Resource Constraints

Choice between technology options is limited by physical (water and energy), organizational and financial constraints. Each of these factors should be considered by planners and the community to be served before a particular water supply system is selected.

(i) Water: Surface water sources (rivers, lakes, etc.) need to be identified and compared with groundwater in terms of availability, water quality and cost.

Protected surface water sources (springs and upland streams) can provide the most reliable service if water can be conveyed by gravity and water is available throughout the year. Treated river and lake water also provide good service if reliable operators, spare parts and uninterrupted supplies of fuel and chemicals are available. However, even temporary failure of the treatment system can result in serious outbreak of water-borne disease.

Compared with surface water, groundwater has several important advantages:

- It yields safe water that rarely needs treatment.
- It provides a substantial storage buffer to cope with seasonal variations in supply and demand and with prolonged droughts.
- It allows the community to manage and maintain the system more effectively because the entire system is located in or near the village.

The level of groundwater should also be assessed since it will determine the type of pump that is used. Handpumps provide good service for pumping lifts up to about 25 meters but only marginal service for lifts in the 40 to 50 meter range. Above this point, motorized pumps should be used if they can be maintained. The pumping lift rarely limits handpump use, for some 90 percent of wells worldwide have pumping lifts below 25 meters and 99 percent have pumping lifts below 50 meters.

(ii) Energy: Energy resources include manual, electric, diesel, solar and wind. Manual pumps have the advantage that their operation is not susceptible to supply interruptions. However, manual pumping is limited by the amount of power (rate of energy expenditure) that a person can apply to a pump. This limits both the depth from which water can be pumped and the amount of water a person can draw each day.

Electric pumps are a tried technology that can reliably provide large quantities of water. Whenever a community is served by an electric grid that is not subject to frequent power outages, electric pumps are likely to be the technology of choice.

Diesel pumps are more problematic because of the difficulty of maintaining fuel on hand, when it can be diverted to other buyers or delivery trucks either breakdown or are prevented from reaching their delivery points because of bad road conditions.

Solar and wind pumps have one clear advantage over diesel in that they are not dependent on external fuel supplies. Solar energy is particularly suited to most low-income countries because of their proximity to the equator and the high and consistent solar radiation they receive throughout the year. Wind pumps will continue to have limited application because winds of sufficient speed and reliability to make them economical are available in few locations.

Planners must take account of the fact that as the pumping technology becomes more complex, the community becomes more dependent on external resources outside its control. As a result, there is an increasing risk that the system will not be maintained and end up abandoned.

(iii) Organization: It is clear that many projects have failed because the necessary skills, supplies, and institutional structures were not available to keep them functioning. For every scheme, an organization such as a water committee is needed to manage collection of charges from users, to initiate repair and maintenance activities, to manage payments for maintenance services, and to procure spare parts. Motorized pumping schemes are more complex. In addition, they require, a reliable power supply, a greater variety of spare parts and tools, and more advanced mechanical skills.

VLOM -- for Village Level Operation and Maintenance -- was coined to highlight the need for strong community involvement in the maintenance of water supply systems. This leads to a number of specific design targets related to routinely replaceable components; they should be

- readily available locally and preferably made in country;
- easily transported by a person on foot, on a bicycle or on a bus;
- replaceable by a local artisan or technician, using only a few simple hand tools without need of lifting equipment;
- easily affordable to the community.

Reliance at the community level is the only workable alternative in the long run for dependence on centrally administered "mobile" maintenance teams, which have proven untenable both administratively and financially.

(iv) Finance: By the year 2000, some 1,500 million people will need new or improved service if substantial rural water supply coverage is to be achieved. Globally, it has been estimated that approximately US$1,500 million is spent each year on the construction or rehabilitation of RWS projects, or $1 per capita per year.

Today, capital costs of RWS projects range from US$2-4 per capita for groundwater schemes based on handpumps, $3-8 per capita for standpipe supplies, and $6-16 per capita for yard taps. To meet the global needs financially, it is clear that either those communities in need of improved water supplies will have to pay a significant portion of the costs, even for low-cost solutions; or governments must greatly increase their expenditures on RWS and maintain them indefinitely.

The cost implications of developing a viable program of community involvement must not be overlooked. There should be an explicit allowance in project design for staff resources to carry out an information/training component as a part of all RWS projects. Where possible, this might be coordinated with an existing health program or agricultural extension service. Experience has shown that where community involvement programs have not been successful in raising the communities' understanding, the negative costs in terms of failed systems (wasted investments) can be very high.

3 COSTS

3.1 Discussion

The Project's model evaluates and compares the costs of alternative pumping technologies and types of water supply systems. The cost of system components such as pumps, wells, and storage tanks; village characteristics such as population and housing density; and economic parameters such as discount rate and useful life of equipment can be varied to fit site specific conditions.

Water supply systems have both capital costs and operation and maintenance (O&M) costs, and a correct comparison of different options must take both into account over the expected physical life of the equipment. This is done by discounting, or taking into consideration the time value of money (discount rate). The capital cost is converted into its annual equivalent taking into account the expected life of the components. To this annual equivalent of the capital cost is added the undiscounted annual O&M cost to give the total "annualized" cost. In addition, labor to manually pump water and/or to carry it to the point of use from a handpump or standpipe has a cost associated with it. The value of time placed on water collection is variable and can have a major effect on the cost of water.

3.2 Technology Choice Based on Cost

Population, per capita water use, pumping lift, and well cost all affect the cost of water. Well costs are largely dependent on external factors such as construction management efficiency, type of well rig, competition between drillers and amount of expatriot involvement. Where these factors are favorable such as in India and some locations in Africa, well costs are in the range of $1,500 to $3,000 and are not an important factor in technology selection. Where well costs are high, efforts should be made to reduce the costs of wells, rather than allow the high costs of wells to drive technology selection.

Population, per capita water use, and pump lift are therefore the most important factors. The combination of population and per capita water use sets the amount of water that is pumped each day (m^3/day). This leads to a choice of pumping technologies as summarized in Figure 1 for a prototype village where the pumping lift is 20 meters. (Further characteristics of the prototype village used in the model are presented in the complete technical note.)

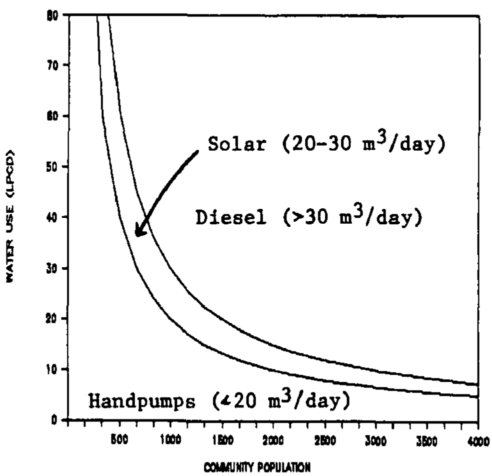

Fig. 1. Pumping technology selection based on cost.

If the water consumption in the community is less than about 20 m^3/day, handpumps are the least cost alternative; if consumption is between 20 and 30 m^3/day, solar becomes the least cost alternative; and if consumption exceeds 30

m^3/day, diesel the least cost alternative. If grid power is available in the community, electric pumps can provide water at least cost if consumption exceeds about 10 m^3/day.

The results in Figure 1 were for 20 m pumping lift. A rule of thumb that takes pumping lift into account can be derived by taking the product of the pumped volume (m^3/day) and pumping lift (m); this gives the amount of energy (m^4/day) required to pump water. For the characteristics of the prototype village, handpumps provide water at least cost if the product of the pumped volume and pumping lift is less than 400 m^4/day, solar pumps provide water at least cost in the range of 400 to 600 m^4/day, and diesel pumps do so above 600 m^4/day.

4 BENEFITS

The model evaluates the benefits from time savings that are derived from different levels of service. Health benefits, quality differences between alternative sources, and benefits of new productive uses of water can also be incorporated into the model, but only in a more artificial manner, by adding estimated benefits for them to the time savings benefits calculated by the mode. Quantitative research into the demand for water and the benefits of improved water supply systems is an ongoing part of World Bank activities. Quantification of health impacts from improved water supplies has proved difficult largely because there are many alternative routes of infection, the main two categories of water-related infections being water-borne infections and hygiene-related infections.

The most easily observable benefit from an improved water supply system is the reduction in the time required to collect water. This makes more time available for women, who normally collect the water, to care for themselves and their children, to increase family food production and income, and to improve their quality of life.

Time savings are often substantial. For the vast majority of rural families or communities, water collection is time consuming and heavy work, often taking more than two hours per day of women's time in many areas. RWS projects reduce that burden by introducing water into the community, or by increasing the number of water points within the community. A well designed handpump- or standpipe-based system can reduce collection time for a family to 30 to 45 minutes per day. Water delivery time at yard taps is in this same range, the difference being that handpumps and standpipes provide 20 lcd while yard taps provide 80 lcd.

Saving time has greater or lesser value to a household, depending on what its members can do with the extra time and how they value these activities.

Regardless of what the members actually would do with the time, a reasonable measure of its value to them can be inferred from how much they could earn if they used it in income-producing work. The model uses an average time valuation for a community.

In addition, if water-hauling time had no value, one would expect to find that people use the same amount of water regardless of the distance to the source. That, too, is unrealistic. Although the quantity of water consumed may be relatively insensitive to the time factor over a narrow range, people who must travel more than, say, an hour to reach a water source are observed to consume significantly less water than those who have a tap a few meters from their home. Finally, the most compelling evidence of all that time spent getting water does have a value is that households often choose to pay others to get their water.

Other benefits from improved RWS often exist, such as garden irrigation, animal watering and cottage industries that formerly were limited by the amount of time and effort it took to get water. There are also benefits that are related to an improved quality of life. Finally, with handpump-based systems there is potential to start the community path toward a higher (more technically complex) level of development.

5 COST/BENEFIT ANALYSIS

By subtracting the total cost from the total benefit of a water supply option, the resulting net benefit provides a means of comparing different service levels. This comparison can either be between different types of systems (i.e., handpumps, standpipes, and yard taps) or within systems (i.e., one, two, or three handpumps or standpipes in a community).

5.1 Method

In comparing different RWS options, the model first determines the optimum handpumps and standpipe systems by computing the annualized costs and benefits of providing different numbers of handpumps or standpipes and choosing the number of handpumps or standpipes that provides the greatest net benefit. The next step is to compare the net benefits of the optimum handpump, optimum standpipe and optimum yard tap system. The total benefits, and in turn the net benefits, largely depend on the collection time at the old source and the value of time. Other benefits can be included in the model by adding an estimate of their value in units of dollars per capita per year to the total benefits. As a result, if a community has good access to water but the source is not protected from contamination, the project can provide a positive net benefit if the community perceives health benefits. Similarly, costs due to water wastage can be included in the model.

5.2 Comparing the Options

Because the value of time has such a major effect on the choice of options, no value of time is assumed. Rather options are compared across a range of time values. Figure 2 graphically shows how the choice of options depends on the value of time.

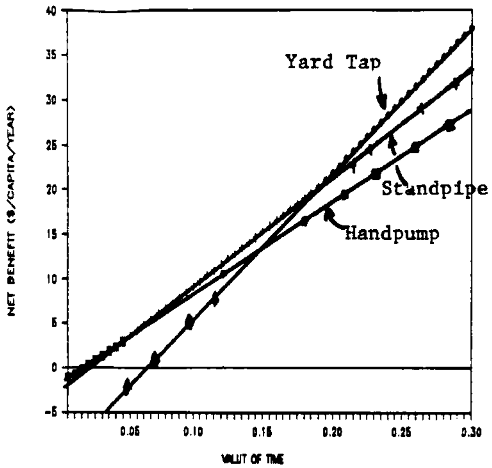

Fig. 2. Selection of the best water supply system (pop. = 1,000, solar)

In this example, manual and solar pumping in a community of 1,000 persons is being considered, with all other factors the same as the Project's prototype village. When the value of time is below $0.15 per hour, handpumps provide the greatest net benefit; when it is between $0.15 and $0.25 per hour, standpipes do, and when it is above $0.25 per hour, yard taps do. This type of analysis will be used to generate the figures that follow.

The effect of community population on the choice of handpump, standpipe, and yard tap systems is shown in Figures 3 and 4 for solar and diesel pumps.

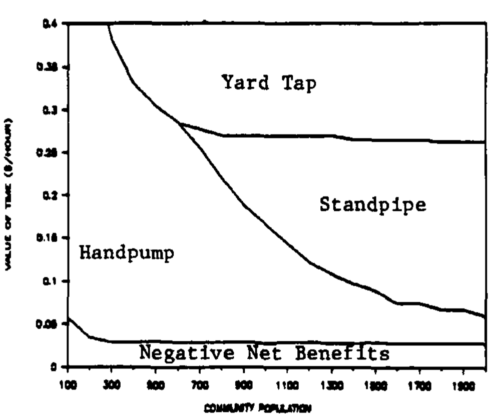

Fig. 3. Optimum net benefit equilibriums (diesel).

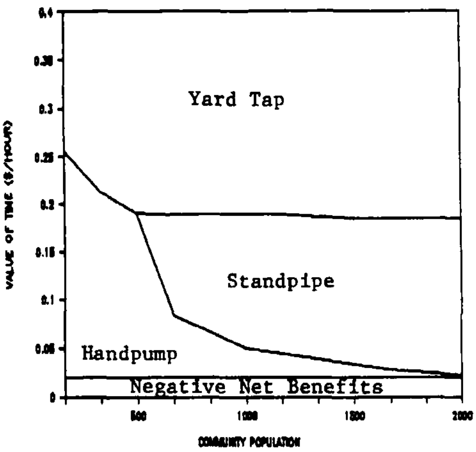

Fig. 4. Optimum net benefit equilibriums (solar).

The areas marked handpumps, standpipes and yard taps correspond to combinations of the value of time and population where that particular type of system has the greatest net benefit. The shaded area at the bottom indicates a negative net benefit. It is in this area that consideration of other benefits (e.g., health) would be necessary to justify investment in RWS improvements.

The curves are characterized by a value of time above which yard taps are the best solution. At lower values of time, point source systems are best, with handpumps suited to small populations and solar or diesel pumps suited to larger populations.

It has been shown that the different economies of scale of manual, solar and diesel pumps have a major bearing on the cost of water, and that at low pumped volumes (m^3/day) handpumps provide water at lowest cost, at intermediate volumes solar pumps do, and at higher volumes diesel pumps do. These economies of scale also affect technology selection based on cost benefit analysis. Again, handpumps are the best option when pumped volumes are low and diesel pumps are best when pumped volumes are high, with solar having a niche between them. Figure 5 shows this where handpumps, then solar, and then diesel are the best economic choices depending on the volume that is pumped. Figures 6 and 7 show the effect of well cost and pumping lift on technology choice.

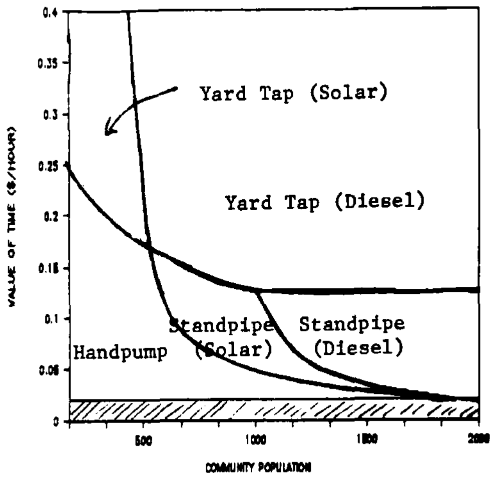

Fig. 5. Optimum net benefit equilibriums (diesel). Effect of community population.

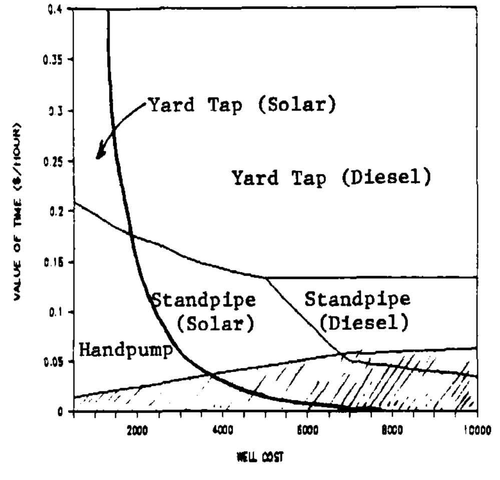

Fig. 6. Optimum net benefit equilibriums (diesel). Effect of well cost.

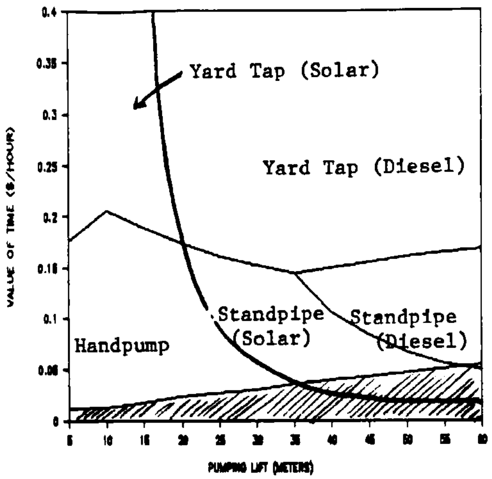

Fig. 7. Optimum net benefit equilibriums (diesel). Effect of pumping lift (m).

The model should be considered as a simple working tool, to be used with cautious judgment when applied to a specific rural water supply program. The model is in no way intended to replace choice, for the community must be responsible for its water supply system and so must make the final decision on what type of system it wants, can afford, and can maintain.