Draft Technical Note

Cost-Benefit Model for Community Water Supply: Technology Choice

Robert J. Roche, Project Officer
Frederick W. Wright, Economist

The World Bank/UNDP
International Water and Sanitation Decade Program
Infrastructure and urban Department
October 1987

Draft 9/87

FORWARD :

This document is the result of a long term effort of staff working on the World ank/UNDP Community Water Supply Project (previously the Handpumps Project) as part of the International Drinking Water Supply and Sanitation Decade. It supplements the recent report "Community Water Supply: The Handpump Option" which presented the conclusions of the first five years of the Project's work and World Bank Discussion Paper No 18 "Rural Water Supply and Sanitation: Time for a Change". During the first phase of the Project, it was recognized that the analytical framework for selection of water supply service levels and cost estimation for low cost systems was lacking. One of the many activities of the Project was the collection of information on the cost of community water supply projects. The development of this technical note has its foundation in the synthesis of this information base.

Using the information gathered by Project staff, an analytical framework was developed for estimating the costs of small-community water supplies. This analytical framework was then codified in a computer model that allows flexible and quick evaluation of the cost of various levels of service and technologies.

The other component of the analytical framework that the project found lacking was an adequate means of estimating the benefits of improved water supplies. After lengthy debate and consultations, a decision was taken to use time savings as an indication of benefits, and a demand curve was developed based on observed practices. Since health and other benefits may play as important a role as time savings in determining the value a person places on a water supply, these may also be incorporated in the analytical framework presented here.

The computer model described in this report is intended to assist planners and those involved in implementation of small community water supply programs. It is not intended to replace feasibility studies or detailed project planning, but merely assist in making rational decisions on technology choice and service levels.

We intend to continue to strengthen, and expand the database and refine the estimates of the parameters that impact the costs and benefits of community water supplies -- we therefore request any comments, information, or data you may have that would help us. Data on unit capital costs, maintenance costs, as well as health and other benefits would be particularly appreciated.

A copy of the computer model, ready for use on an IBM-PC compatible computer system is available upon request. Please write to:

Mr. Saul Arlosoroff, Chief (INUWU)
Infrastructure and Urban Development Department
The World Bank
1818 "H" Street, N.W.
Washington, D.C. 20433 USA

Telex No. ITT 440098
Fax No. 202-477-6391

Acknowledgements:

The development of an analytical framework for the planning of low cost community water supply systems has been a goal of the UNDP/World Bank Handpumps project since its inception. The first attempts were focused on development of a cost estimation system and were done by Melissa Burns in 1982 under the supervision of Anthony Ramuglia.

The work of Ms. Burns and Mr. Ramuglia resulted in a computerized analysis of life cycle present value costing for handpump water supply alternatives under various conditions. This work highlighted the need for the more extensive data collection efforts that were undertaken by the Project in 1984 when a rural water supply cost data collection and analysis program was undertaken coordinated by Nicholas Burnett. Most of this data was either collected by the project field staff or volunteered by the numerous donors and executing agencies that have been supporting the Project. In addition an international survey was conducted and followed up by field visits to numerous countries. The result of this program has been the creation of an information base on the cost of handpump based water supply systems. As time and resources permit this information base will be indexed and made available to those involved in the low cost community water supply sector.

The initial guidance to extend this cost analysis work into a planning and decision model for service levels came from Anthony Churchill, then Director of the Water and Urban Development Department, and Anthony Yezer, Professor of Economics at George Washington University. World Bank Discussion Paper, No. 18 "Rural Water Supply and Sanitation: Time for a Change" outlines the analytical framework used in this analysis. We are also grateful for the support of Michael Cohen when he was a senior advisor in the Water and Urban Development Department.

Thanks also go to all those who have worked on the Handpumps Project, as well as those who have provided information, comments and guidance at various stages of the work. The list is too long to be accommodated here and we do not want to risk missing any of the individuals who have provided valuable data, comments and suggestions since 1984.

COST-BENEFIT MODEL FOR COMMUNITY WATER SUPPLY: Technology Choice

TABLE OF CONTENTS

INTRODUCTION

A Planning Tool for Low-Cost Community Water Supply Systems

This note presents a deliberately simplified analytical tool, based on cost/benefit analysis, that can be used to evaluate proposed community water supply (CWS) projects. A computer model has been developed so that alternative systems can be assessed quickly. The way in which the model can be used in project planning will be described through examples and discussion. The examples are based on field conditions, likely to be the encountered in developing countries, and where possible broad rules of thumb are developed for making decisions on CWS options. A user guide and documentation of the model are provided in the annexes. A copy of the model is available on request, however, the recipients will be requested to send us the data assumptions and results of their applications for use in refining the model.

The model can be used to compare the costs, benefits, and service levels of alternative CWS systems and perform sensitivity analysis on a wide range of assumptions. It is intended that the user of the model adapt the basic assumptions to be used in the model to fit local conditions.

The model should be considered as a simplified working tool, to be used with cautious judgement when applied to a specific community water supply program. The model is in no way intended to replace community 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. The technology chosen should give the community the highest service level that it is willing to pay for, will benefit from and has the institutional capacity to sustain.

The model and analytical framework are supplementary to the conclusions of the first five years of work on the assessment of available technology and management options for the wide-scale implementation of community water supply systems, which have been summarized in the report "Community Water Supply: The Handpump Option" central to both the assumptions in the model, and one of the key themes of this report, is the concept of Village Level Operation and Management of Maintenance (VLOM), as the least cost solution for sustainable water supply systems regardless of technology choice. The VLOM approach has been tested and verified for handpump based systems, but we are currently lacking adequate field data on costs and maintenance requirements of the other technologies, so our conclusions are only tentative in regard to the non-handpump technology options. It is planned that as we refine the data, further technical notes will be forthcoming.

Costs: The model evaluates and compares the costs of alternative pumping technologies and types of water supply systems. Pumping technologies include manual (handpumps), electric, diesel, solar and wind pumps. Water supply systems include point sources (handpumps and public standpipes) and yard taps. 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.

Benefits: The model estimates the benefits from time savings that are derived from improved levels of service and from increased water use. Health benefits, quality differences between alternative sources, and benefits of new productive uses of water can 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 model. This simplified treatment of benefits was necessary because it was beyond the scope of this work to evaluate such benefits and because they tend to be site specific.

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

B. Service Level

The community perception of an improved water supply will largely be determined by the service level provided. This perception will be critical in convincing the community to pay for the costs of the system. 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.

Quantity: Daily water consumption has been reported to 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, may occur 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 15 to 25 lpcd, when water is used only for household purposes. If families also need water for a few head of livestock, consumption can increase to 40 or 50 lpcd, much of which is normally used at the water point source. When water is piped to yard taps, water consumption increases to between 60 and 100 lcd, even if only used for household purposes provided the supply system functions regularly which is often not the case.

Quality: The microbiological, chemical and solids content of water affect 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 handling of the water is closely tied to expected health benefits. 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. These factors can easily be overlooked during project preparation and result in a lower level of service than expected or even failure of the project.

Collection time: The human effort involved in collecting water is evident for the majority of 1.8 billion people without access to improved water systems. This effort is often a major factor in the communities perception of service level. In the analysis presented here, a distinction will be 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.

Reliability: Reliability is very important and often overlooked when considering service levels. It requires a realistic assessment of the likelihood that a particular system can be operated and maintained at a reasonable cost. This lack of attention to reliability is reflected in the many systems, both manual and powered, that have fallen into disrepair not long after being constructed. In such instances the investment is wasted and the new "improved" water system source in the community ultimately gives a lower level of service than the traditional community water source. The analysis presented here assumes reasonable maintenance expenses can provide a reliably operating system. The realization of health benefits is also highly dependent on the reliability of the improved water supply system, since even periodic usage of traditional sources, which are often polluted, can retard the improvement in health.

C. 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.

Water: Surface water sources (rivers, lakes, etc.) need to be identified and compared with groundwater in terms of availability, water quality and cost. (Note: The current version of computerized analytical model is limited to ground water based systems due to its generally universal applicability, however the methodology is applicable to any water source and others will be incorporated as time and resources permit.

Protected surface water sources (springs and upland streams) can provide very reliable service if water can be conveyed by gravity and water is available throughout the year. Treated water from rivers and lakes 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 community.

The depth of the groundwater table and its extraction capacity should also be assessed since it will determine the type of pump that is used. Handpumps provide a good quantities of water for pumping lifts up to about 25 meters but only marginal quantities for lifts in the 40 to 50 meter range. Above this motorized pumps should be used if they can be maintained. A more detailed discussion of handpumps is given in "Community Water Supply: The Handpump Option" by S. Arlosoroff, et al. 1987.

Potential well yields can also affect the choice of pumping technology. This is particularly true in the basement rocks of Africa and India where it can be difficult to site wells even to draw the minimum acceptable flow for a handpump (about 12 liters per minute), and very large drawdowns can be expected if motorized pumps are used. As a result, the cost of a well suitable for motorized pumping can increase markedly because wells may have to be deeper and the number of successful boreholes will decrease. In such cases use of trained hydrogeologists in well siting can increase success rates and lower the average cost per successful well.

Energy: Energy sources incorporated in the model include manual, electric, diesel, solar, and wind. (Note: Animal power may be incorporated in a future version.) 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 proven 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 potential advantage over diesel in that they are not dependent on external fuel supplies. Solar energy is particularly suited to many low income countries because of their proximity to the equator and the high and consistent solar radiation they receive throughout the year; while wind pumps will continue to have limited application because winds of sufficient speed and reliability to make them economical are available in limited locations.

Planners must take account of the fact that as the pumping technology becomes more complex, small communities become more dependent on external resources outside their control. As a result there is an increasing risk that the system will not be maintained and end up providing no service at all.

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 all schemes an organization such as a water committee is needed to manage collection of charges from users, to initiate repair and maintenance activities, to pay for maintenance services, and to procure spare parts. Motorized pumping schemes are more complex since 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 Management of 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 <u>routinely replaceable components</u>; 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.

Self reliance at the community level is the only workable alternative in the long run. Dependence on centrally administered "mobile" maintenance teams has proven untenable both administratively and financially.

While the term VLOM was originally applied to handpumps, the same principles apply to other technologies. Handpumps meet VLOM criteria best for low income communities as spare parts are inexpensive, can be manufactured, and only a few are needed. Electric pumps meet VLOM criteria where electric grid power is reliable and replacement parts are available to and can be afforded by the community. While it is unlikely that the electric motor can be repaired by a village repairer or area mechanic, he or she can be trained to replace it with a new or reconditioned unit.

Solar systems for water pumping have been under development for over 30 years. In the recent years progress has been recorded in their costs and reliability. However before large scale implementation along a number of years (5-10) can be observed and field maintenance costs can be objectively collected we are forced to rely on manufacturers data with the appropriate reservations. As field performance becomes better documented and it is shown that village repairers and/or area mechanics can troubleshoot the systems and repair them, solar pumping will find more widespread application. For diesel pump systems, there are numerous examples where gasoline and diesel engines are being repaired by local technicians. The typical problems with diesel systems in the availability of spare parts and fuel.

Finance: By the year 2000, some 1,500 million people will still 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.

Today capital costs of RWS projects range from US$10-40 per capita for groundwater schemes based on handpumps, $25-60 per capita for standpipe supplies, and $60-120 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 human resources to carry out an information/training component as a part of all CWS 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.

II. COSTS

A.Overview

Water supply systems have both capital costs and operation and maintenance (O&M) costs. Capital costs are incurred when a system is installed or major components are replaced. While O&M costs recur every year. A correct comparison of different options must take into account both capital and O&M costs 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 discount rate can be used to either calculate present values of a cash flow or amortize a single amount into an annualized equal flow over a period of time. In the analysis presented here 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. It was felt that this annualized cost would be easier to communicate to the decision makers in a small community, and is equivalent to using present values when comparing systems over a similar time period.

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. Because the value of time placed on water collection is variable and very difficult to estimate, this overview will begin by summarizing the cost of water in terms of annualized capital plus O&M costs. A brief analysis of the effect that the value of time has on the cost of water will then be presented, and this will be followed by discussion of a method of cost benefit analysis that incorporates both annualized costs and the value of time. This analysis will simply highlight the important factors that affect the cost of water and suggest rule of thumb ranges within which particular technologies are most likely to be most valued by the community and therefore be successful. Perhaps even more important will be the elimination of options through use of the model at the early planning stages so that efforts can be concentrated on viable technologies.

B. Cost Comparison of Pumping Technologies

When comparing the costs of different pumping technologies, it is useful to define a set of characteristics for a "prototype village" and then vary individual parameters to observe their individual effects on the cost of water. A summary of the characteristics of the prototype village is presented in Table 1. In doing these cost comparisons, water use is fixed at 20 lcd, the collection time is held constant at 3.7 hrs/m^3 (4.5 min/trip) for handpumps and 3.0 hrs/m^3 (3.5 min/trip) for standpipes. In so doing the service level is held approximately constant, and as will be shown later, these collection times correspond to optimum handpump and standpipe systems when both capital plus O&M costs and benefits from time savings are considered. For the prototype village of 500 persons and 20 households per hectare there are 4 handpumps (125 persons per handpump) and 3 standpipes (167 persons per standpipe). To keep the collection time constant, the number of HP's and SP's will vary in some of the sensitivity tests which vary on the population, pumping lift, and per capita water consumption.

Table 2 shows the breakdown of costs by component for the five main water pumping technologies (manual, electric, diesel, solar, and wind) in the prototype village. (Note: Annex A provides a detailed description of the basis of the cost calulations used in the computer model.) These figures for the prototype community system closely reflect observed data from a large scale point source program in Nigeria, where the model was found to be a useful pragmatic tool in the planning stage.

Table 1

DEFAULT VALUES FOR COMPONENTS OF PROTOTYPE WATER SUPPLY SYSTEM

Demographic Characteristics	
Total population	500
Family size (persons/household)	8
Number of households	62
Housing density (households/hectare)	25
Persons per hectare	200
Economic Conditions	
Discount rate (%)	10
Useful life mech. equip.	10
Useful life non-mech. equip.	20
Annual O&M/mech. eq. (% cap cost)	10
Annual O&M/non-mech. eq. (% cap cost)	1
Electric Power Cost ($/KWHR)	0.10
Diesel fuel Cost ($/liter)	0.50
Solar Insulation (KWHR/M^2/Day)	5
Average Wind Speed (meters/second)	3

Water Supply System	HP's	SP's	YT's
Distance to old source (m)	500	500	500
Distance to new source (m)	50	45	-
Volume carried per trip (l)	20	20	-
Walking speed (km/hr)	3	3	-
Collection time		*	
Travel time (min/trip)	1.0	1.0	-
Queue time (min/trip)	1.5	0.5	-
Fill time (min/trip)	1.3	1.3	-
Water use (liters/cap/day)	20	20	80
Number of wells	4	1	1
Number of water points	4	3	3
Cost per well	2000	2000	2000
Pumping & storage lift (m)	20	30	30
Storage volume (V/Q)	-	1	1
Water delivery rate (l/min)	15	15	10

*Collection time for yard taps is set at 1 hour per cubic meter of water.

Table 2

THE COST OF WATER SUPPLY SYSTEMS
PROTOTYPE COMMUNITY
CAPITAL COST ($)

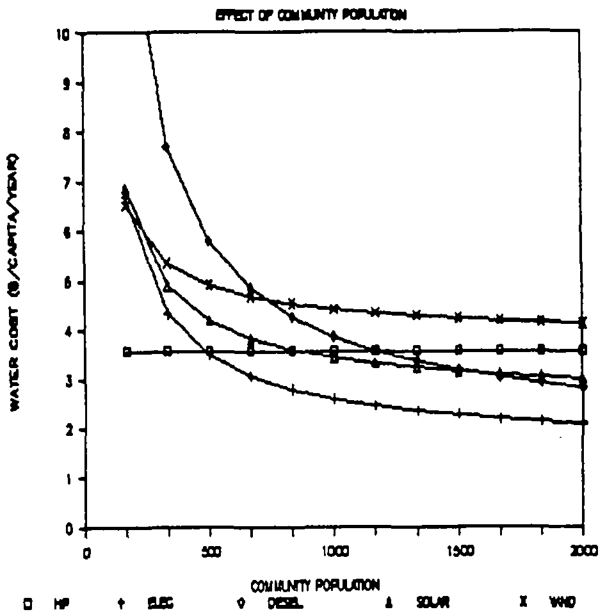
System Component	Manual	Electric	Diesel	Solar	Wind
Wells	8000	2000	2000	2000	2000
Pump	2600	1700	4700	6300	6200
Storage	-	3400	3400	3400	3400
Piping	-	3100	3100	3100	3100
Total	10600	10200	13200	14800	14700

ANNUALIZED PER CAPITA COST ($/capita/year)
PROTOTYPE COMMUNITY

	Manual	Electric	Diesel	Solar	Wind
Capital	2.75	2.65	3.60	3.70	3.70
O&M	0.80	0.75	1.90	0.80	0.75
Elec/Dsl	-	0.20	0.40	-	-
Total	3.55	3.60	5.90	4.50	4.45

Population: The curves in Figure 1 show the cost of water ($/capita/year) for manual, electric, diesel, solar, and wind point source systems as a function of community population. Because handpumps have a limited capacity (m^3/day), additional wells must be added to keep the service level constant (in this case at 125 persons per handpump), so on a per capita basis the cost of manual pumping does not vary with population. Other types of pumps are not limited by the amount of power a person can apply and so require only a single well and exhibit varying economies of scale. Diesel pumps have the greatest economies of scale because the engine is expensive and its price varies little with capacity in the output ranges required for small community water supply. Wind and solar pumps on the other hand can be sized in proportion to the power that is required and exhibit somewhat less economies of scale. As a result, when water demand is 20 lpcd, handpumps provide water at least cost for populations under about 1000, solar do so for populations between 1000 and 2000, while diesel do so for populations above 2000. If larger volumes of water are required, these population ranges will decrease. Electric pumps provide water at least cost in all but the smallest communities.

Figure 1



Water Use: As per capita water use increases, queue time at the source will also increase. In order to keep the service level constant the number of handpumps must increase as water use does. As can be seen in Figure 2 this results in the cost of water from handpumps increasing faster than other pumping technologies and again, the varied economies of scale of the different pumping technologies results in manual, solar, and diesel pumps in turn providing water at least cost as water use increases, with handpumps most economical below 30 lpcd, solar between 30 and 60 lpcd and diesel above 60 lpcd. Electric if available again provides water at least cost in almost all circumstances.

Well Cost: Well cost can vary from as little as $200 per well in Bangladesh, where artisans use the sludge method to drill as deep as 50 meters in alluvial soils, to more than $15,000 in some places in West Africa. More typical well cost are in the range of $1500 (India) to $2500 (East Africa) for wells up to 50 meters.

The potential high cost of manually pumped water can be demonstrated, as shown in Figure 3, by keeping the collection time (hrs/m^3) constant. In actual practice, however, as the cost of wells increase a single handpump will be forced to serve more than the 125 persons used in the prototype village and result in a lower service level. This will tend to moderate the effect of increasing well costs on a per capita basis. Nonetheless, planners should guard against serving too many people with a single handpump. Other pumping technologies are relatively less affected by the well cost where for example a 10 fold increase in well cost from $1000 to $10,000 per well results in only a 50 to 75 percent increase in the cost of water.

Figure 2

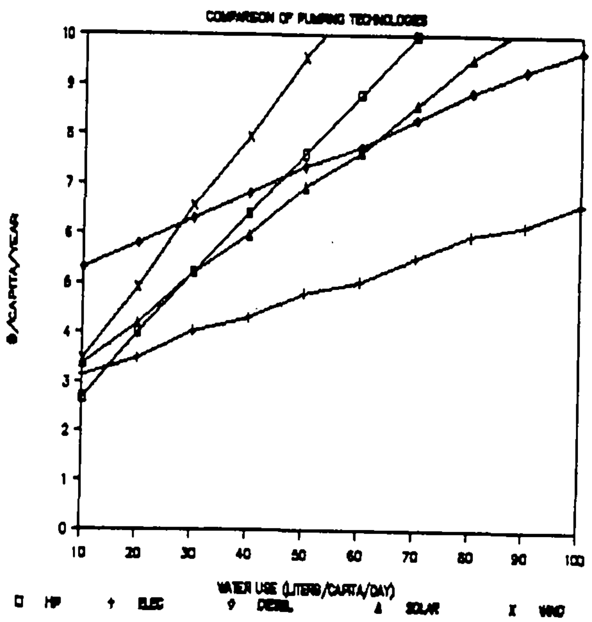
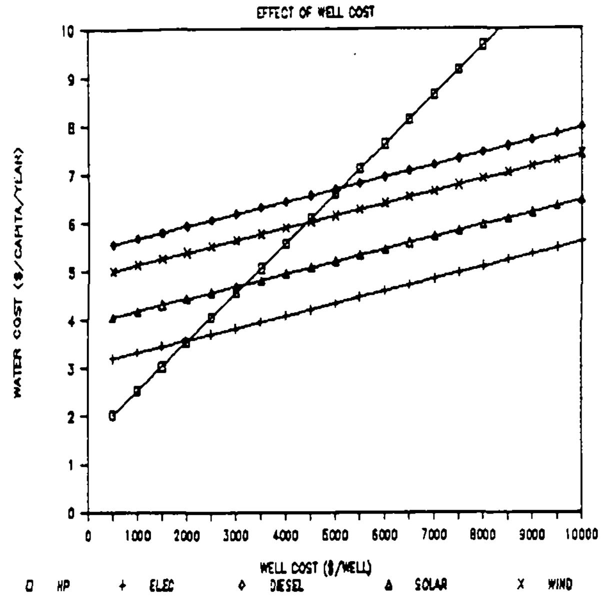


Figure 3



Lift: Because the amount of effort required to pump water increases with increasing pumping lift and because the amount of power a person can apply to a handpump is limited, the cost of manually pumped water is more sensitive to pumping lift than other technologies. As a result, in the prototype village handpumps are more economical than electric pumps only below about 20m, solar below 25m, and diesel below 35m. (See Figure 4). Again, in actual practice the handpump cost will not increase as suggested here because service levels will be allowed to decrease somewhat with increasing pumping lift.

Figure 4

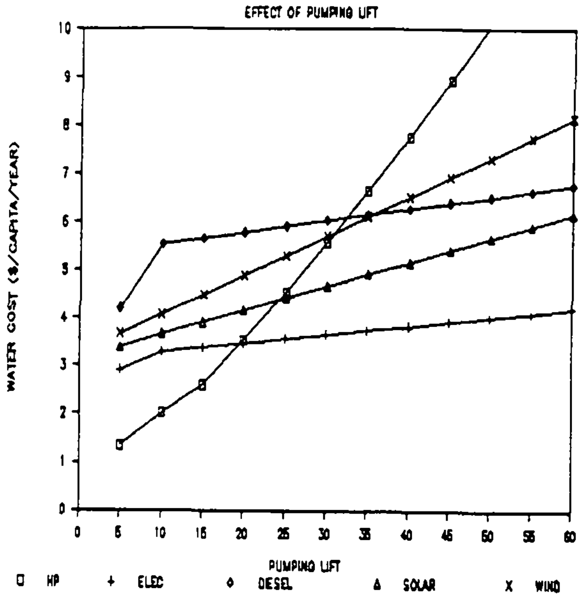
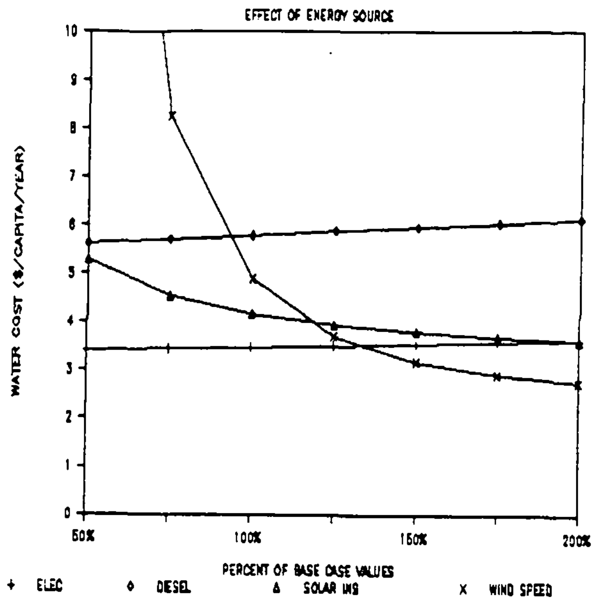


Figure 5



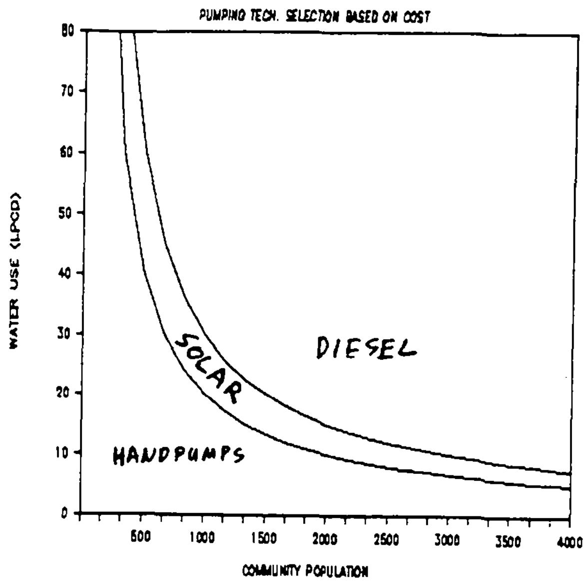
Energy Cost: Electric power cost has little effect on the cost of water (see Figure 5). For example, doubling the electric power cost from 10 to 20 cents/KWHR causes the cost of water to rise by 4 percent (0.14 $/capita/year). Diesel fuel has a somewhat greater effect, for doubling the cost of diesel fuel from $0.50 to $1.00 per liter causes the cost of water to rise a 14 percent (0.80 $/capita/year). Solar insulation has a greater effect on the cost of water, since the size of the solar array is inversely proportional to the radiant solar energy. Solar insulation is typically between 4 and 6 KWHR/m^2 /day, corresponding to water costs between 4 and 5 dollars/day. Wind speed has a major impact on the cost of water from wind pumps because the cost of a wind pump is inversely proportional to the cube of the wind steed (v^3). Average wind speeds above 3 m/sec are unusual, but to be competitive wind speeds must be at least 4 m/sec or more.

C. Technology Choice Based on Cost

Population, per capita water use, pumping lift, 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 expatriate involvement. Where these factors are favorable such as in India and some locations in Africa well costs are in the range of $1500 to $3000 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 cost of wells to drive technology selection.

Population, per capita, water use, and pumping lift therefore are 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 rule of thumb for choice of pumping technologies as summarized in Figure 6. For the prototype village where the pumping lift is 20 meters, 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 is 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.

Figure 6



The results in Figure 6 were for 20m 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 (assuming that solar systems can be sustained with a VLOM approach), and diesel pumps do so above 600 m^4/day.

D.Comparison of Handpump, Public Standpipe, and Yard Tap Costs

Before concluding the discussion of costs, attention should be drawn to the relative costs of handpump, standpipes and yard tap systems. As shown in Figures 7 and 8, the cost of water increases substantially when the service level shifts from point sources to yard taps. Part of the increased costs for yard taps stems from the inevitable high consumption of water, which includes wastage, and the need for drainage improvements. The effect of population and housing density on the cost of water is also demonstrated in these Figures. The combined effect of population and housing density on the cost of water from yard taps is shown in Figure 9.

Figure 7

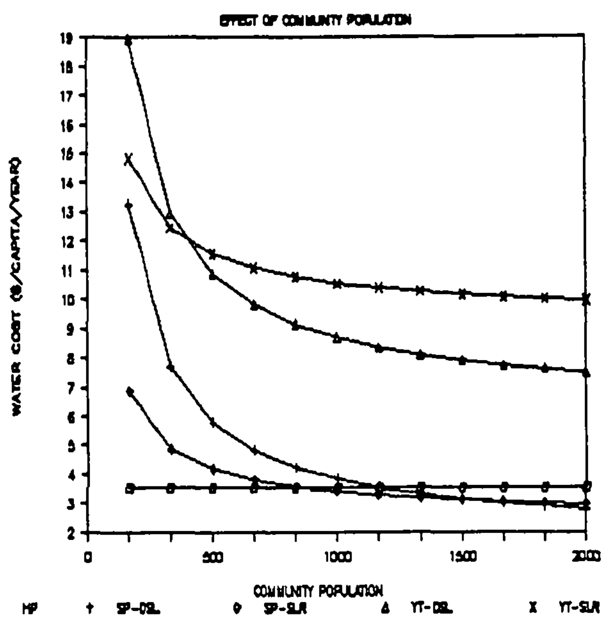


Figure 8

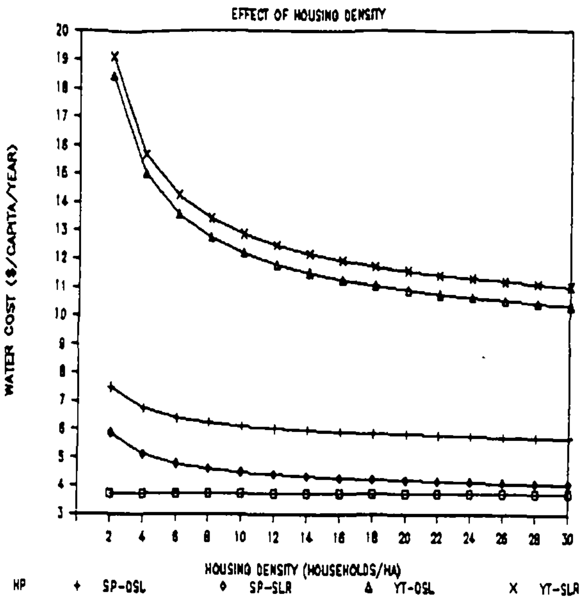
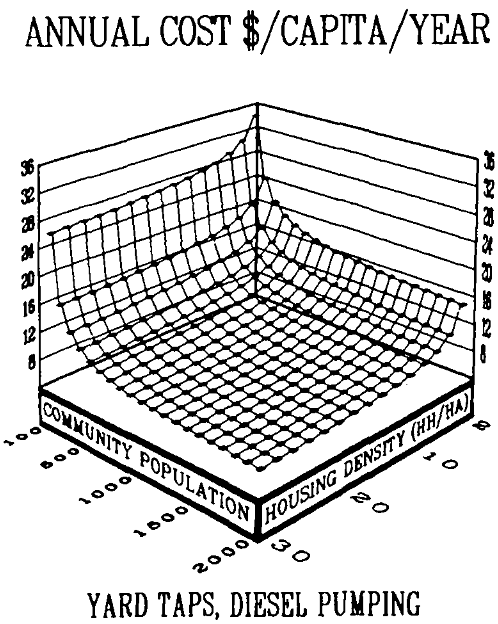


Figure 9



III. Benefits

A. Types of benefits

A number of benefits arise from rural water supply projects. These include reduction of the time spent collecting water, improved health, increased productive uses of water, and social benefits related to an improved service level. Quantitative research into the demand for water and the benefits of improved water supply systems is an ongoing part of UNDP/World Bank activities.

Time savings: 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, taking more than 2 hours/day of women's time in many areas. CWS projects reduce that burden by introducing water into the community, or by increasing the number of water points within the community. A properly planned and implemented 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.

Health: Health benefits also result from an improved water supply. However, there is limited data linking improved health to improved water supplies only and for converting health benefits into monetary terms.

Quantification of health impacts from improved water supplies has proved difficult largely because there are many alternative routes of infection. Two main categories of water related infections may be distinguished: water-borne infections and hygiene related infections.

Water-borne infections will be reduced by protecting the water source from pollution but will not be eliminated unless contamination is avoided during transport to and storage in the home through an integrated training program that includes lowcost sanitation advice.

Hygiene related infections will be reduced by improved water supplies only in-so-far as they encourage water to be used to improve hygiene. To obtain the full health benefits that improved water supplies offer, people must learn to avoid contaminating their home water supplies and to use water effectively in food preparation and for personal hygiene. In addition, excreta must be disposed of properly. As a result, a protected water supply close to ones home is a necessary but not a sufficient condition for improved health.

Other Benefits: In addition to improved health and observed time savings, other benefits from improved CWS often exist, such as garden irrigation, animal watering and cottage industries that formally 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 technical skills development.

In the computer model benefits other than time savings are grouped as a single variable. The default value for these benefits is zero, but they can be input in terms of dollars per capita per year.

B. Method of calculating benefits for time savings

Demand curve: If water consumption was constant (i.e. not a function of level of service) the calculation of benefits from time savings could be quite simple. It would be directly proportional to the reduction in collection time. However, in reality the closer the source, the greater the quantity of water that is used. To allow for increasing water usage, one must consider how sensitive consumers are to marginal changes in the cost of water.

While available information about the relationship between the cost of water ($/m^3$) and amount of consumption is not adequate to define a demand curve, observations of collection time (hrs/m^3) and water consumption allow one to be constructed.

This is shown in Figure 10 where the demand curve was constructed on the basis of the following information. First, when water is provided at a few point sources in a community with corresponding collection times as low as 3 hrs/m^3 (3.5 min/trip) water use is usually about 20 lcd; second, as collection times increase to as much as 30 hrs/m^3 (40 min per trip) there is very little change in per capita consumption; third, when collection times drop below 3 hrs/m^3, either by providing piped water close to individual homes or by using water at the source, consumption will increase; and fourth, water consumption above 100 lcd is not needed and individuals are not prepared to pay for greater volumes of water. By multiplying collection time (hrs/m^3) by the value of time, the range of demand curves in figure 11 can be obtained.

Figure 10

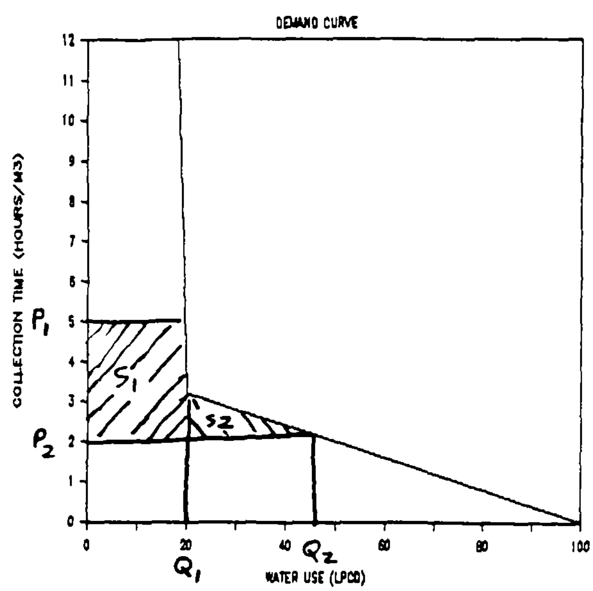
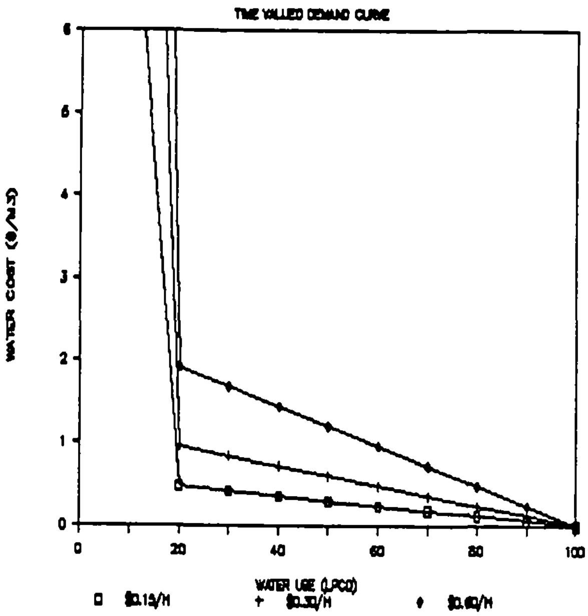


Figure 11



In the model, reductions in the cost of water account for part of the total benefit, and a further benefit comes from the increased consumption induced by a reduced cost. These two elements are shown graphically in the demand curve in Figure 10 shaded S1 and S2. If a water supply improvement reduces the cost of water from P1 to P2, with a corresponding increase in per capita consumption from Q1 to Q2. The consumer benefits in two ways: first, the price P1 of the original Q1 liters falls to P2 (shaded area S1 represents the benefit); and second, the value placed on the extra water exceeds the price (benefit = shaded area S2).

Value of time: A key step in estimating the monetary benefits of time-savings is placing a value on the time saved. 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.

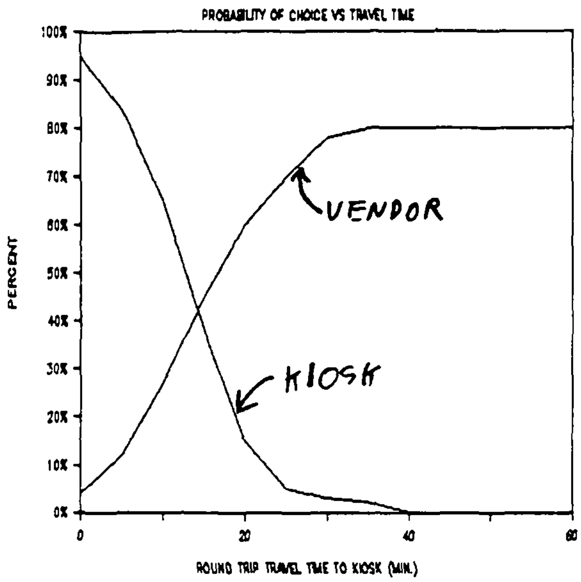
Also, if water-hauling time had no value, one would expect to find that people using the same amount of water regardless of the distance to the source. That, too, is unrealistic. Although the quantity of water consumed may be relatively insensitive to the time factor over a narrow range, people who must 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. Antoniou, for instance, examined vendor sales in poor urban fringe areas in the Sudan where vendors compete with kiosks (supervised standpipes). At the kiosks, water is dispensed for little charge, but there is often a queue and hence, a wait which increases time component of water cost. Vendors were able to charge four times as much as kiosks, showing that households will pay more as the alternative of fetching water themselves becomes more burdensome.

Similar results were found in the Kwale District of Kenya where people in one community rely heavily on vended water. In this case vended water ($5.00/m^3) was ten times the price of water purchased at kiosks ($0.50/m^3) and many families were paying more than the estimated full cost of a yard tap system. It was also shown that the number of families who purchased water from vendors increased as the round trip travel time to kiosks increased. This is shown in Figure 12 where 85 percent of the households chose kiosks if the round trip travel time was less than 5 minutes (150 meters one way travel distance). However, when the round trip travel time increased to 30 minutes, 75 percent of households would be expected to purchase water from vendors. The remainder of households used water from open wells that were close to their homes. In this community the average value of time was estimated to be

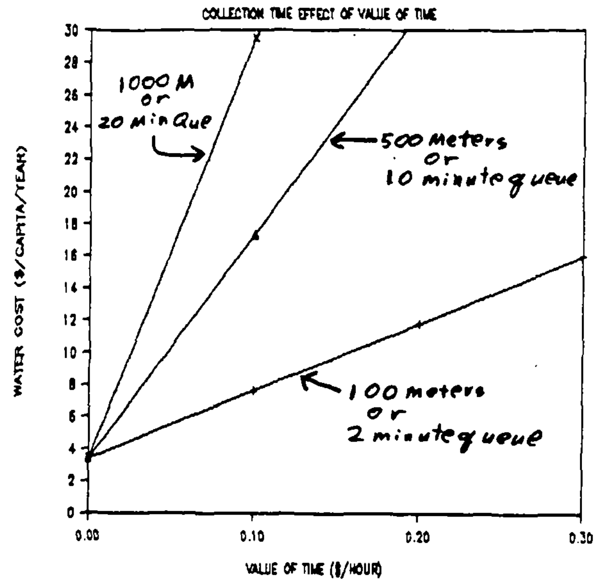
25 cents per hour, the same as the local unskilled wage rate. In several other communities in the Kwale District, where incomes were lower and a smaller fraction of it was in cash, water vending was must less prevalent.

Figure 12



The effect that the value of time has on the cost of water is demonstrated in Figure 13, where each line corresponds to a different distance to or queue at the source. When the water sources is outside the community (i.e., the one way distance is greater than 100 m) the cost of water can be very high, even for low values of time. Similarly, if the distance to the water source is short but people must queue for more than a few minutes, the cost of meter may be quite high.

Figure 13



IV. Cost Benefit Analysis

A. Method

In comparing different CWS options, the model first determines the optimum handpump 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. This is shown graphically in Figures 14 and 15 where the optimum number of handpumps in the prototype village is four when the assumed value of time is $0.15 per hour, and the optimum number of standpipes is three.

Figure 14

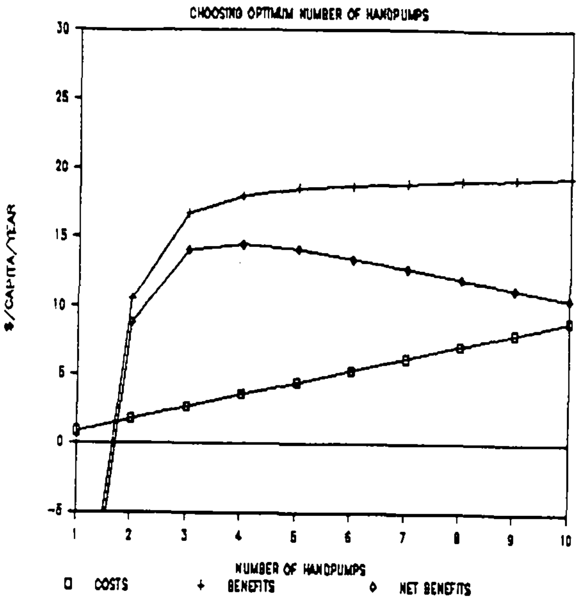
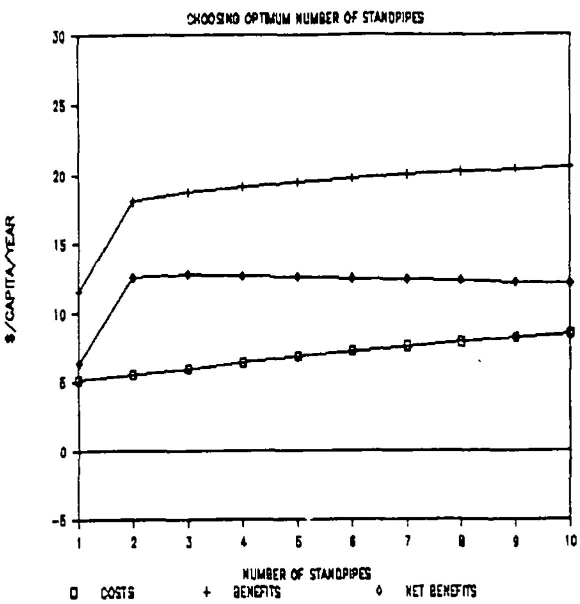


Figure 15



The next step is to use the output from the computer model to compare the net benefits of the optimum handpump, the optimum standpipe, and yard tap system. For the prototype village the net benefits are summarized in Table 3 are $14.50 for handpumps, $12.75 for standpipes and $13.25 for yard taps. Consequently, the best choice would be a handpump-based system.

Table 3

SUMMARY OF COSTS AND BENEFITS FOR THE PROTOTYPE VILLAGE ($/CAPITA/YEAR)

	Total Benefit	Total Cost	Net Benefit
Handpumps	18.00	3.50	14.50
Standpipes	18.75	6.00	12.75
Yard Taps	24.25	11.00	13.25

The total benefits and in turn the net benefits, largely depend on the collection time at the old source and the value of time assumed when running the model. This is illustrated in Figures 16 and 17 where the relationship between net benefits and distance to the old source is shown. When the value of time is $0.15 per hour handpumps give the greatest net benefit, however, benefits exceed costs (positive net benefits) only if the distance to the old source was 150 meters. (In effect, this means that the old source was located outside the village, or equivalently, the queue time exceeded about 5 minutes). This conclusion changes as the value of time increases. Figure 17 shows the net benefits calculated at $0.30 per hour and illustrates that yard taps would provide the greatest net benefit and are the best choice if the resource constraints can be overcome.

Figure 16

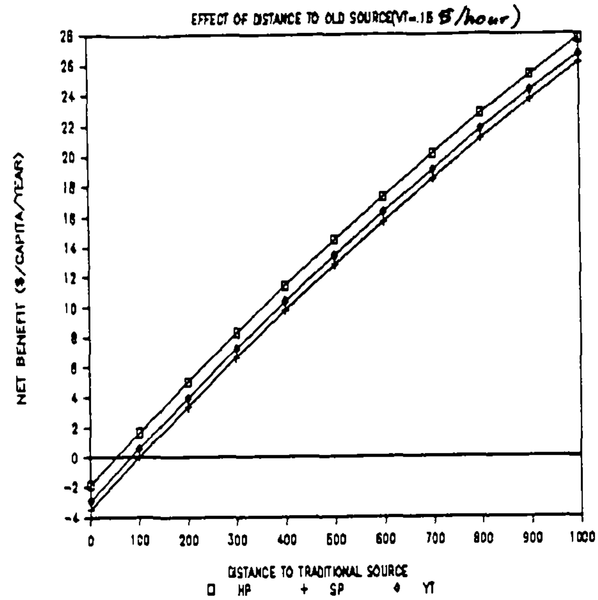
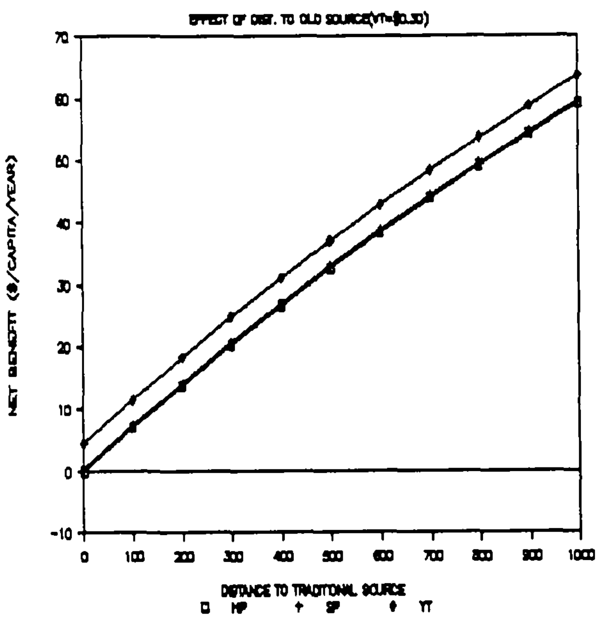


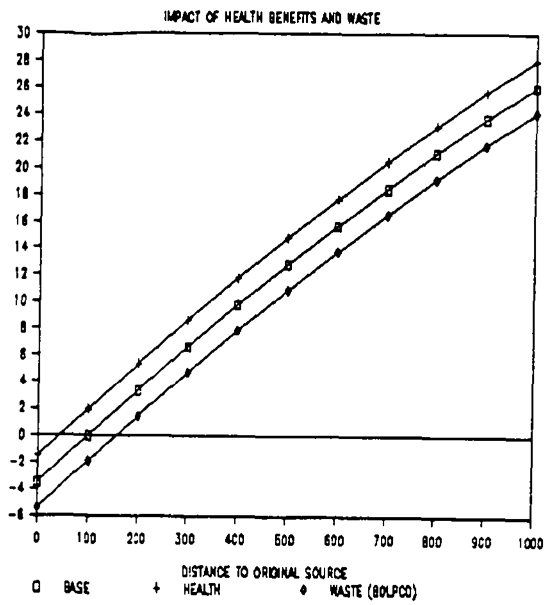
Figure 17



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. In this instance a benefit of $2.00 per capita per year was estimated by assuming the water supply provided an extra week of productive activities at a wage rate of $0.25 per hour that otherwise would have been lost to illness. (See Figure 18.)

Similarly, costs due to water wastage can be included in the model. Here a 50 percent wastage rate (25 lpcd) was assumed resulting in an increased cost (negative benefit) of $1.50 per capita per year for the yard tap system.

Figure 18

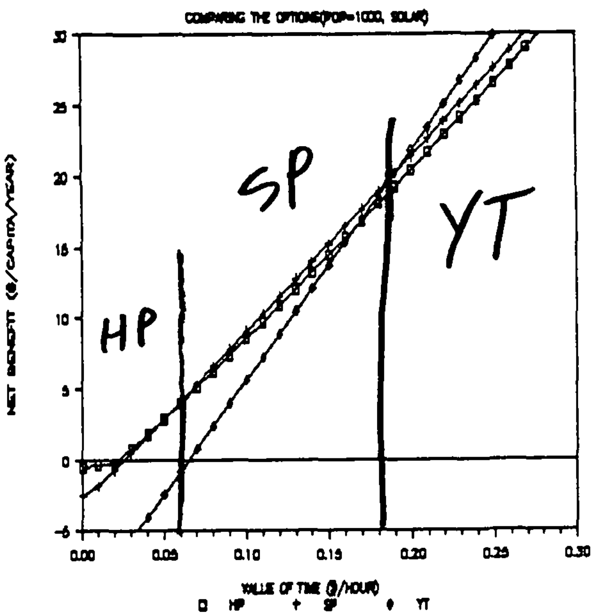


B. Comparing the Options

Because the value of time has such a major effect on the choice of options, the model has been designed so that no value to time is assumed. Rather options and assumptions are compared across a range of time values.

Figure 19 graphically shows how the choice of options depend on the value of time.

Figure 19



In this instance manual and solar pumping in a community of 1000 persons is being considered. All other factors are the same as in the prototype village. When the value of time is below $0.05 per hour handpumps provide the greatest net benefit when it is between $0.05 per hour and $0.18 per hour standpipes do, and when it is above $0.18 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 20 and 21 for solar and diesel pumps.

Figure 20

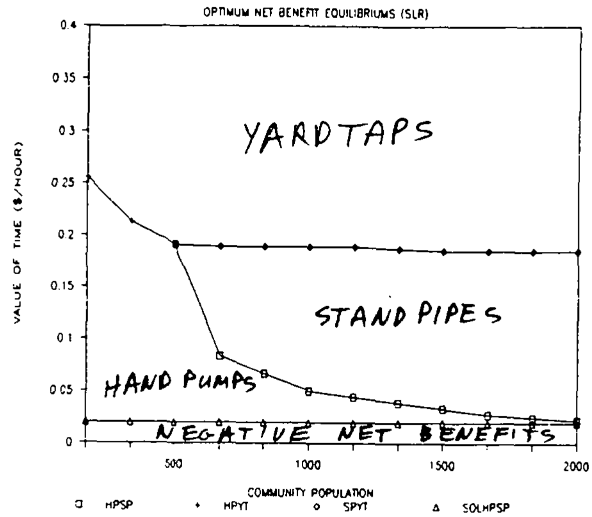
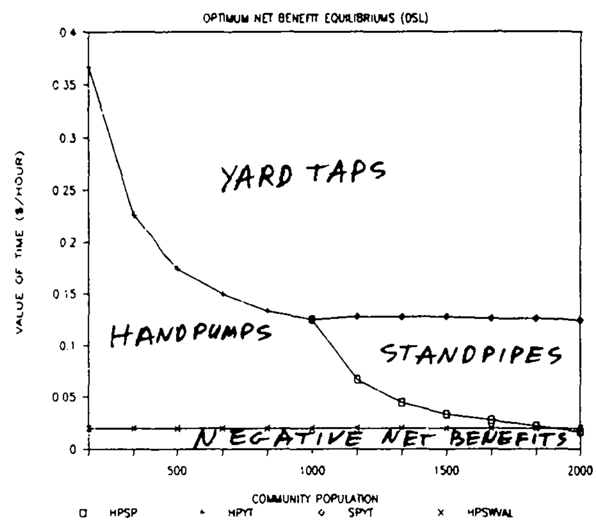


Figure 21



The curves are derived from model runs similar to those used to generate Figure 19. 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.

Earlier it was 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 economics 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. Figures 22, 23, and 24 show this where handpumps, then solar, and then diesel are the best economic choice depending on the volume that is pumped.

Figure 22

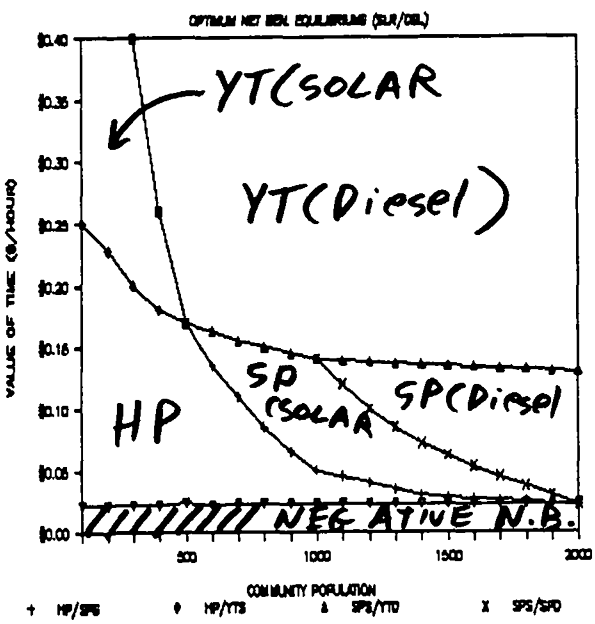


Figure 23

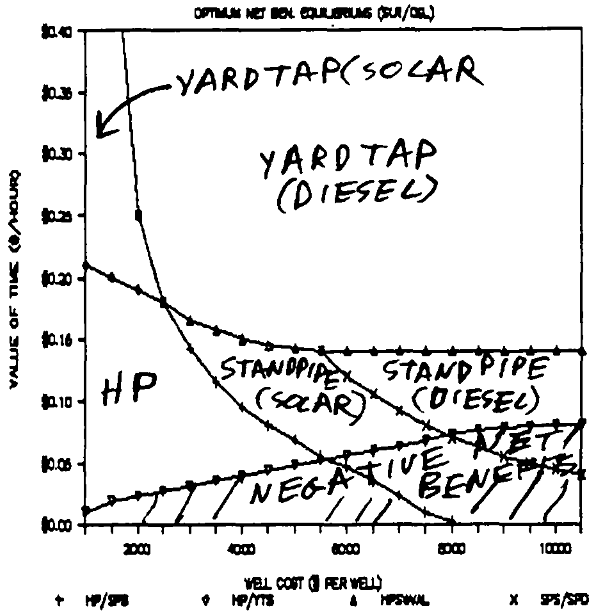
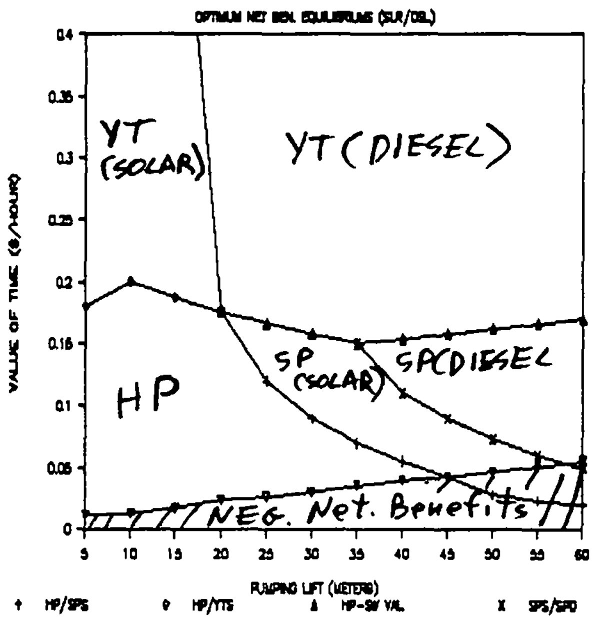


Figure 24



V.Summary and Conclusions

The development of this model was the result many years of effort to develop a set of simple "rules of thumb" that could be applied to the decisions on level of service and technology choice for small community water supplies in developing countries. In the initial phases of this work it was thought that some simple criteria could be written down to guide the planner through the decision process, but as further research was conducted it became clear that the decision process was complex. This led to the development of the financial/economic cost benefit framework that has been presented here.

The model incorporates analysis of collected data and best of judgement estimates for the critical modelling parameters for planning small community water supply projects. However as illustrated by the sensitivity analysis done in this note, it is clear that many of these parameters can have a relatively significant impact on the technology of choice when they are varied over their observed domain of real world values. Hence the model was designed to allow the parameters to be reset to values representing local conditions, and only once this has been done can specific rules of thumb be developed for a particular area which will assist in the formulation of community water supply policies and programs.

The critical parameters of the model must be estimated by the user for a particular area, which is clearly the most difficult part of using the model. In particular the estimation of the economic value of time in small communities is critical to setting the most valued level of service.

ANNEX A

I. Costs: Assumptions, Data References, Equations

This annex describes the straightforward analytical framework that was used in the computer model to allow comparison of the RWS options that provide different levels of service at different costs. Three basic RWS systems; handpumps, standpipes and yardtaps can be analyzed in an annualized cost/benefit framework.

This section will introduce the structure, assumptions, and calculations of the computer model itself as well as its potential application and limitations. Almost all of the data assumptions can be changed by the user and will be specified in Annex B: Users Guide. To the extent practical the computer program variable names will be used to illustrate the formulas. Only the main formulas used in the model are described in detail, readers who would like a more detailed look at the model structure should refer to the BASIC listing in Annex B.

WELLS

The costs of water extraction (referred to as source costs in the model) are dominated by the borehole cost, particularly for handpump based systems which is often many times greater than the cost of the pump. The cost of establishing a borehole, including drilling, casing and screen, is not only the most costly component of the initial capital investment in a handpump project, but it is also the largest component of annualized costs for handpump systems.

Because the cost of well drilling is highly dependent on the type of drilling equipment, the amount of expatriate labor, construction efficiency, and borehole success rate, well construction costs are specified on a lump-sum basis. 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 for less than $2,000. For the computer model it has been assumed that wells can be drilled at basic cost of $2,000. The well cost can also be specified by the user to reflect particular situations.

A single well is used for standpipe and yard tap systems. Handpump systems, however, are limited by the amount of power a person can exert. Consequently there is a trade-off between increased numbers of wells with relatively inexpensive handpumps, and a single well with a more expensive motorized pump and distribution system.

The capacity of a well fitted with a handpump is inversely proportional to the pumping lift. The well capacity (variable QMAX in the model) is given by equation 1, where LPM is the water delivery rate in liters per minute and HRPUMP is the hours per day that the pump is operated (default = 8 hr/day). The water delivery rate in turn is given by the equation 1*, where WATTS is the power input in watts, EFF is the mechanical efficiency of the pump, and LIFT is the height between the dynamic water level (static lift plus drawdown) and the ground surface in meters. Typical adult women input about 100 watts of power when the pumping lift is greater than 15 meters and somewhat lower power inputs at lower pumping lifts. The power input is assumed to be 100 watts for lifts above 15 meters and the empirical relationship in equation 2* is used to approximate power inputs for pumping lifts below 15 meters. Typically manual power input is in the range of 60 to 100 WATTS. The mechanical efficiency is also a function of the pumping lift; the empirical relationship in equation 3* reflects typical handpump efficiencies.

QMAX = LPM*HRPUMP*60/1000 (1*)

LPM = 6*WATTS*EFF/LIFT (1*)

WATTS = 40 + 4*LIFT (2*)
(WATTS = 100 if LIFT>15 METERS)

EFF = 0.4 + 0.0067*LIFT (3*)

PUMPS

Handpumps: 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, the installed cost of low-lift handpumps (pumping lifts less than 12 meters) is set at $200, and the cost of community handpumps for pumping lifts greater than 12 meters is given by equation 4*. For example, the installed cost of a handpump with a 20 meter pumping lift is $660.

PUMC = 200
IF LIFT<12 METERS

PUMPC = 500 + 8*LIFT (4*)
IF LIFT>12 METERS

Electric pumps: The cost of electric, surface-mounted pumps (suction lift less than 7 meters) for small communities is assumed to be $750. For higher pumping lifts the cost of electric submersible pumps is dependent on both the pumping lift and required water delivery rate. The installed pump cost used here (including discharge pipe, electric panel, and wiring) is given by equation 5*, where Q is the daily water demand of the community in cubic meters per day and (STORLIFT) is a combination of the frictional losses in the piping leading to the storage tank and the height of the water level in the storage tank above the ground surface. For the conditions in the prototype village LIFT = 20 meters, total volume (Q) = 30 m3/day, hours pumping (HRPUMP) = 5 hours/day) the installed cost is $1475. Annual energy costs (ANEC) are given by equation 6* where the electric power cost is assumed to be $0.10/KW (ELPOWERC) $/KWHr and the mechanical efficiency is assumed to be 40 percent.

PUMPC = (5*)
275+25*(LIFT+STORLIFT)+75*Q/HRPUMP+500

ANEC = (6*)
2.5*Q*(LIFT+STORLIFT)*ELPOWERC

Diesel Pumps: The cost of low-lift diesel pumps is assumed to be $2000 per pump. However, for lifts above 7 meters, the cost of a diesel-powered generator and submersible electric pump set is significantly higher. For estimation purposes, it is assumed that the cost of a diesel-powered pump is given by equation 5*. The annual energy cost for a diesel pump is given by equation 6*, where DIESELC is the cost of diesel which defaults to $0.5/liter. It is assumed the energy content of diesel fuel is 150,000 Btu/liter, and the fuel-to-water efficiency is 7.5 percent.

PUMPC = (5*)
275+25*(LIFT+STORLIFT)+75*Q/HRPUMP+3500

ANEC = (6*)
0.086*(LIFT+STORLIFT)+75*Q/HRPUMP

Solar Pumps: Solar pumping systems consist of an electric pump plus photovoltaic panels and appurtenant electric equipment. The pump cost is about the same as other electric submersible pumps (see equation 5*) and the photovoltaic panel cost (SOLARPVC) is given by equation 7a* where WP is the array size in watts-peak and CPPWATT is the installed cost per peak watt. The required array size is given by equation 7b* where INS is the average solar insolation in KWHR/DAY during the month with the least insolation and PVEFF, assumed to be about 30%, is the mechanical efficiency of the system.

$$SOLARPVC = CPPWATT*WP \quad (7a*)$$

$$WP = 2.72*Q*(LIFT+STORLIFT)/PVEFF/*INS \quad (7b*)$$

Wind pumps: The cost of a wind pump is proportional to the cross-sectional area of wind intercepted by its blades. This is given in equation 8*, where WMILLC is the cost per square meter of blade area and V is the average daily wind speed in meters per second. Costs vary roughly between \$250/m2 for locally made, light-weight wind pumps to \$750/m2 for heavy-duty pumps made in Australia and the United States. A cost of \$500/m2 is used in this analysis.

$$PUMPC = WMILLC*1.13*Q*(LIFT+STORLIFT)/V^3 \quad (8*)$$

STORAGE TANKS

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 with the tank placed on the ground. In this analysis it is assumed that tanks are raised. The cost of storage tanks is given by equation 9*, where STORAGE is the fraction of the daily consumption that is stored and BCSTORAGE is a proportionality constant. In this analysis one day of storage was used (STORAGE=1) and 1000 was used for BCSTORAGE. For the prototype village this results in a cost of \$3200 for a 10 m^3 standpipe system and \$6300 for 40 m^3 yardtap system.

$$STORC = BCSTORAGE*(Q*STORAGE)^{1/2} \quad (9*)$$

OUTLETS

When water is pumped by hand and carried home, water use is typically between 15 and 25 liters per capita per day (lpcd). Water use at standpipes is about the same, although wastage can be significant, and when it is piped to individual yards, consumption increases to between 50 and 125 lpcd. Because the water use generated by standpipe and particularly yard tap systems 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 \$500 per standpipe outlet and \$100 per yardtap outlet used in this analysis includes the installed cost an outlet, splash pad, and drain field.

CONVEYANCE COST

The cost of collecting water depends on the distance to the source, queue time, the water delivery rate at the water point, and the quantity of water carried per trip. The cost of water collection is then determined by multiplying the collection time by the value people place on their time to collect water. It should be noted, however, that in this analysis no assumption has been made about how people value their time; rather, throughout this analysis the value of time is approached in terms of a sensitivity analysis, where the a range of time values are used.

The collection time T (minutes/trip) is given by equation 15*, where DIST is the one-way travel distance in meters, WALK is the walking speed in km/hr, QUE is the queue time in minutes/trip, VOL is the volume carried in liters/trip, and DEL is the water delivery rate at the source in liters/minute. The collection cost of water, in dollars cost per cubic (PM3C) meter is then given by the equation 16* where VT is the value of time in dollars/hour.

$$T = 2*DIST/WALK*60/1000 + QUE + VOL/DEL \quad (15*)$$

$$PM3C = T*VT \quad (16*)$$

If it is assumed that the community is laid out in a rectangular pattern and that water points are evenly spaced, the one way travel distance (DIST) is given by equation 11*a and

11*b, where AREA is the area of the community in hectares, and NHP is the number of handpumps and NSP is the number of standpipes in the community. The areal of the community is a function of the population (POP), housing density (HD) in householes per hectare, and the average family size (FSIZE).

$$DIST = (AREA*10000/NHP)^{1/2}/2 \qquad (11*a)$$

$$DIST = (AREA*10000/NSP)^{1/2}/2 \qquad (11*b)$$

$$AREA = POP/HD/FSIZE \qquad (12*)$$

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 per day (lcd) will spend about 3 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, and if there is a 2 minute queue each time a family member goes to the well, about 40 minutes per day will be needed to collect water.

PIPING

The required length of piping depends on the number of outlets, size and layout of the community. The length of distribution piping is approximated by equation 13*a and 13*b and the length of individual house laterals by equation 14*, where NSP and NYT is the number of water points standpipes or yard tapes in the community and AREA is the size of the community in hectares.

$$LPIPE = 90*NSP^{0.4}*AREA^{0.6} \qquad (13*)$$

$$LPIPE = 90*NYT^{0.4}*AREA^{0.6} \qquad (13*)$$

$$LLAT = 40*(AREA/NYT)^{0.63} \qquad (14*)$$

For the range of conditions typical of small community water supplies, 1.5 to 2 inch diameter pipes are suitable for distribution piping and 0.5 to 1 inch diameter pipe is suitable for house laterals. An installed cost of $8 per meter is used for distribution piping and $6 per meter is used for house laterals.

Operation and maintenance costs

By and large, one can distinguish between two different kinds of maintenance systems for costing purposes: centralized and community based Village Level Operation and Maintenance (VLOM). Under a centralized system, the principal components of maintenance costs are personnel, transport, spare parts, and building and equipment depreciation. Personnel costs would include all wages, salaries, per diems, pension contributions, and the like, of both local and expatriate workers and supervisors, plus a proportion of general management costs allocable to pump maintenance. Transport costs include vehicle depreciation and running costs (fuel, lubricants, tires, spare parts, etc.). Attention must also be given to the foreign versus local mix of costs for each type system. Generally the centralized systems impose a greater demand on scarce foreign exchange due to their reliance on motorized transport. Community based maintenance, where repairs are made by a local resident, eliminates most of the costs associated with transport, supervision and general management. This essentially reduced costs to the time and materials required to make repairs.

The recurrent costs that have been estimated for the computer model assume that village based maintenance is possible, with minimal dependence on centralized maintenance services. Refer to main text Section I, where resource constraints are discussed. In the computer model it has been assumed that annual costs will amount to 10% of the initial capital costs for all mechanical parts (e.g., pumps), and 3% for all non- mechanical parts (e.g., boreholes, storage tanks and pipes).

Overhead

The overhead costs for planning, implementing, supervising, and managing investments in CWS are perhaps the most difficult to evaluate. It is often assumed at the project preparation phase that these costs, when spread out over a thousand boreholes, are negligible. This simplistic assumption should be avoided, particularly as it is necessary to mobilize the community to assume responsibility for maintaining their new water system. During the preparation phase an appropriate overhead structure must be planned and realistically costed so that it can be allocated to each technical option for economic comparison and evaluation of financial affordability. In the computer model these costs are included as part of the capital costs for the physical components and the maintenance cost coefficients.

II. Benefits: Demand curve

A discussion of the assumptions used to construct the demand curve and method used to estimate benefits from time savings in the discussion of benefits is provided in Section II. As noted there, the demand curve is based on actual water use observations, which show that when water must be carried home per capita water use is usually about 20 lpcd and does not change much whether the water source is in the community or is as much as a kilometer away. However, if water is used at the source,either by taking clothes or cattle to it, or by providing yard taps, water consumption will increase. This results in two regions an inelastic one below 3.5 minutes per trip and an elastic one above 3.5 minutes per trip.

This information allows a functional relationship between water use and collection time to be estimated. The demand curve is delivered by equations 15a* and 15b* where water use is in liters per capita per day and collection time (T) is in minutes per trip (assuming that 20 liters are carried each trip).

LPCD = LPCD =(103-T)/5   15a*

LPCD = 4-T/0.04   15b*

Once the consumption from the improved system is estimated the difference in area under the demand curve between the old and new costs of water is used as an estimate of benefits, as was explained in main text section III.

ANNEX B

Users Guide for the Computer Model

Introduction

This annex provides information on running the computer model that has been described in this technical note and is included on a computer disk. The computer model can be used in two basic modes, for point source systems specific service level where the user can set the number of persons per outlet (standpipe or handpump) or the user can request the computer model to optimize the number of outlets that maximizes net benefits. A detailed discussion of the demand curve used to calculate time savings benefits is presented in Annex 1.

It is assumed that the user is generally familiar with the IBM-PC[1] type of personal computer. In order to produce graphic output, similar to that in the body of this technical note, the user must also be familiar with the LOTUS 123[2] software system.

The model has been written in Microsoft Quick Basic[3], and has been compiled using the Microsoft Quick Basic Compiler (version 3.0). The distribution diskette contains several files:

RWS.EXE	the executable version of the model that can be run on any IBM-PC compatible computer
RWS.BAS	The BASIC source code that can be examined by the user and if desired modified to meet individual user needs and then run using interpreter BASIC which is typically provided with the IBM-PC (running with interpreter BASIC is much slower)
RWSFORM.WKS	A LOTUS 123 template formatted for importing data that was output by the RWS Model
DEMO.PRN	A sample output from the program that can be imported into LOTUS 123 for producing graphs.

Starting the Model

To start the model you must first have your PC turned on and at the DOS prompt. It is also necessary to have your printer connected to the PC and ON LINE selected, since the program uses the printer for output and some error messages.

---

[1] IBM-PC is a registered trademark of the IBM corporation

[2] LOTUS 123 is a registered trademark of the Lotus Corp.

[3] Microsoft Quick Basic is a registered trademark of the Microsoft Corporation

After placing the RWS Model disk in the active drive, you should type the command "RWS" followed by a carriage return (CR). The following screen will then appear:

RURAL WATER SUPPLY COST/BENEFIT MODEL
UNDP/WORLD BANK HANDPUMPS PROJECT

DO YOU WISH TO SET ANY INDIVIDUAL DEFAULT VARIABLES OR FLAGS?
(Y/N)?

You are now running the model and all you need to do is read the questions it asks and respond in **UPPER CASE LETTERS**. The program requires upper case input, and expects numeric input to consist of numbers (ie do not use the letter L as a one). All of your responses should be followed by a carriage return.

By responding to the above "(Y/N)" prompt with a "Y" the program then gives you the opportunity to modify any of the default variables by displaying the following screen.

LIST OF VARIABLES AND THEIR SETTINGS

POP= 500 -VILLAGE POPULATION
FSIZE= 8 -FAMILY SIZE
HD= 20 -HOUSING DENSITY
LIFT= 20 -PUMPING LIFT (M)
DISTO= 500 -DISTANCE TO OLD SOURCE (M)
VT= .15 -VALUE OF TIME ($/HR)
WELLC= 2000 -WELL COST ($)
NHP= 4 -NUMBER OF HANDPUMPS
NSP= 3 -NUMBER OF STANDPIPES
CPHP= 0 -COST PER HANDPUMP ($)
CPSP= 0 -SP + DRAINAGE COST ($/SP)

LPCD= 20 -LPCD AT NEW SOURCE (LPCD)
LPCDO= 20 -LPCD AT OLD SOURCE (LPCD)
I= .1 -DISCOUNT RATE (PERCENT)

OTHER- ENTER THIS FOR A LIST OF ADDITIONAL VARIABLES

PLEASE ENTER THE VARIABLE NAME. (UPPER CASE ONLY)
VARIABLE??

By responding to the "VARIABLE??" prompt by entering "OTHER" you will get an additional list of default variables on the screen that can be set by the user. This screen is shown below:

```
THIS IS A LIST OF ADDITIONAL VARIABLES

 STORLIFT= 10 -LIFT TO STORAGE (M)        STORAGE= 1  -NUMBER OF DAYS FLOW (DAY)
 PUMPC= 0 COST OF MOTORIZED PUMPS ($)    *SOLARPVC= 0 -COST OF PV ARRAY ($)
 CPMPIPE= 8 -DISTRIBUTION PIPE ($/M)      CPMLAT= 6 -HOUSE LATERAL PIPE ($/M)
*LPIPE=   0 -TOTAL DIST PIPE LENGTH (M) *LLAT=    0 -HOUSE LATERAL PIPE (M/LAT)
*DISTHP= 50 -DISTANCE TO HANDPUMP (M)    *DISTSP= 50 -DISTANCE TO STANDPIPE (M)
*QUEHP= 0 -QUEUE TIME AT HP (MIN/TRIP)   *QUESP= 0 -QUEUE TIME AT SP (MIN/TRIP)
 DELHP= 15  -DELIVERY OF HP (LITERS/MIN) DELSP= 15  -DELIVERY OF SP (L/MINUTE)
 CPYT= 50 -YT COST INCL. DRAINAGE ($/YT) TYT=  1 -TIME AT YARD TAP (MINUTES)
 DIESELC= .5 -DIESEL FUEL COST ($/LITER) ELPOWERC= .1 -ELECTRIC COST ($/KWH)
 LIFEME= 10 -LIFE OF MECH EQUIP (YR)      INS= 5 -SOLAR INSOLATION (KWH/M2/DAY)
 LIFENME= 20 -LIFE NON-MECH EQUIP (YR)   CPPWATT= 8 -SOLAR ARRAY COST ($/WP)
 OMME= .1 -O&M MECH EQUIP (% CAP COST)   V= 3 -AVERAGE WIND SPEED (M/SEC)
 OMNME= .01 -O&M NON-MECH EQUIP (% CAP)  WATTS= 0 -POWER INPUT TO HP (WATTS)
 HRPUMP= 5  - HOURS OF PUMPING TIME      *SOLARPVC= 0 -COST OF PV ARRAYS ($)
 DSLEFF= .075  -DIESEL EFFICIENCY (%)     AHPW= 0 ATTENDANT HOURS PER WEEK
 CAPSUB= 1 -CAPITAL SUBSIDY(0=FULL,1=NO) EXRATIO= 1 -NET BEN RATIO (OPTION 8)
 OTPCB= 0  -OTHER BENEFITS ($/CAP/YEAR)

                        (*) NORMALLY CALCULATED BUT CAN BE SET

PLEASE ENTER THE VARIABLE NAME. (UPPER CASE ONLY)
VARIABLE??
```

To set any of these variables, you need only respond to the "VARIABLE??" prompt with the name of the variable (in upper case) and then hit return. The program will then prompt you for a new value for that variable, which you should type in and hit return. The program then will ask if you wish to set any additional default variables. An example of this process follows(user inputs have been underlined and are followed by carriage returns):

PLEASE ENTER THE VARIABLE NAME. (UPPER CASE ONLY)
VARIABLE?? POP
PLEASE ENTER THE NEW VALUE FOR POP?? 1000

DO YOU WISH TO SET ANY INDIVIDUAL DEFAULT VARIABLES OR FLAGS?

(Y/N)?

In this example we have changed the default community population to a value of 1000. You would then input a "Y or N" if you wished to change any additional default variables.

If you make a typing error in this process the computer will display the following message:

UNABLE TO FIND YOUR VARIABLE, PLEASE TRY AGAIN.

DO YOU WISH TO SET ANY INDIVIDUAL DEFAULT VARIABLES OR FLAGS?

(Y/N)?

Once you have set as many of the default variables as desired you should respond to the "(Y/N)?" prompt with a "N", and the program will display the following screen:

YOU HAVE THE FOLLOWING RUN OPTIONS:

1----------------HANDPUMP ONLY------1
2----------------STANDPIPE ONLY-----2
3----------------YARD TAPS ONLY------3
4----------------HANDPUMPS AND STANDPIPES-----4
5----------------HANDPUMPS AND YARD TAPS ----5
6----------------STANDPIPES AND YARD TAPS ---6
7----------------HANDPUMPS AND STANDPIPES AND YARD TAPS ---7
8----------------OPTIMIZED NET BENEFITS RATIOS -SPECIAL RUN--8
9----------------NET BENEFIT SWITCHING VALUES -SPECIAL RUN--9

SELECT 1, 2, 3, 4, 5, 6, 7, 8, OR 9: ?

This screen allows you to select which technology choices are to be used for this particular run. Selections 1-7 are fairly straight forward and allow the user to run the model for either a single technology or automatically loop through any combination of technologies.

Selection 8 is a special run where the model determines the value of time (VT) where the net benefits of each pair of technologies (handpumps vs. standpipes, handpumps vs yardtaps, and standpipes vs yardtaps) are equal. Selection 8 was used to produce the data for the phase diagrams discussed in the main text.

Selection 9 is a special run where the model determines the value of time (VT) where the net benefits of each technology switch from being positive to negative (ie value of zero).

The user should respond with a numeric input of 1-9 and then a carriage return. If the selection is anything other than options 4,8 or 9 the computer will then ask if optimization of net benefits is desired and display the following question:

DO YOU WISH TO OPTIMIZE HANDPUMP/STANDPIPE NET BENEFITS?

(Y/N)?

The reason for not asking this question for options 4,8 or 9 is that there is no need for optimization for just yardtaps, and options 8 and 9 automatically optimize.

The decision on optimization allows the user to effectively use the model for either analysis of costs for different levels of service or allow the model to suggest the most valued (highest net benefit) level of service. The process of optimization used by the computer model is quite simple and involves the following steps: 1. Start with the minimum number of outlets (1) 2. Calculate consumption 3. Calculate the costs 4. Calculate the benefit 5. Calculate Net benefits 6. Perform steps 2-5 with 1 additional outlet 7. Compare Net benefits from steps 5 and 6 and repeat process until the addition of one outlet reduces net benefits and set the optimum number of outlets at the previous level. This determination of optimum service levels is one of the most useful aspects of the computer model. Particularly useful is the ability to calculate the optimum net benefit sensitivity over a variable range.

After the decision on optimization the user is then requested to select the form of output that is desired. There are three choices as outlined below:

YOU HAVE THE FOLLOWING OUTPUT CHOICES:

1 ------------ SUMMARY TO PRINTER ------------ 1
2 ------------ SUMMARY TO 123 FILE ------------ 2
3 ------------ DETAILS TO PRINTER ------------ 3

SELECT OUTPUT CHOICE 1, 2, OR 3: ?

Output selection 1 gives you a the output that will be presented later in this note which is sent to your printer. There will be one line for each run, and multiple lines if the run loops through a series of variable values. The format of this output is shown late in table at the end of the User's Guide:

The columns of the output are as follows:

SYSTEM -identifier for technology
- HP-Handpumps
- SP-Standpipes
- YT-Yardtaps

PUMP-identifier for energy source
- D-Diesel
- S-Solar
- W-Wind
- E-Electric

POP -population of the community
HD -housing density (households per hectare)
PP -persons per water outlet
VT -value of time ($/hour)
LIFT -pumping lift (meters)
WELLC -cost per well ($)
LPCD -liter per capita per day consumption (liters)
HPM3 -hours required to collect 1 cubic meter of water
PCC -capital cost per capita ($)
ANPCTC -annualized total cost per capita ($)
PM3C -annualized total cost per cubic meter ($)
ANPCC -annualized cash cost per capita ($)
ANPCB -annualized per capita benefits ($)
ANPCNB -annualized per capita net benefits ($)
Loop1 -primary looping variable
Loop2 -secondary looping variable

Output selection 2 gives the same output, but it is put in a LOTUS 123 print file. You will be prompted for the name of the file as follows:

FOR 123 OUTPUT PLEASE ENTER DRIVE AND FILENAME - B:RUN1.PRN -? A:DEMO.PRN

YOU MAY ENTER A COMMENT FOR THE FIRST LINE OF THE 123 FILE

PLEASE INPUT YOUR COMMENT? YOU MAY ENTER UP TO ONE LINE OF COMMENTS WITHOUT PUNCTUATION

You should be careful to specify a valid disk drive and file name. For the file name I suggest that you use the extension that will allow the data to be imported into LOTUS 123 (ie "XXX1.PRN"). The system will then prompt you for a one line comment to be placed in the 123 file, I suggest that this line be descriptive of the run (ie settings of specific variables, looping variables, run selection etc) One note of caution, the program does not like this comment line to have commas ",".

Once the data is in a 123 file, you may retrieve it using the LOTUS 123 commands "/File Import", and then use 123 to create graphics for presentation. Another word of caution when using 123 output is that the program appends (tacks on to the end) to the named file, therefore if you use the same name more than once you may get confused.

Output selection 3 gives a detailed printout of the key input variables and some intermediate results primarily used for checking the calculations and uses variable names similar to those in the computer listing in Annex B.II. An example of the detailed printout for the optimized prototype village for handpumps, standpipes and yardtaps is shown on the following page.

SYSTEM	PUMP	POP	HD	AREA	PP	LPCD	LIFT
HP	D	1000	20	6	125	19.9	20

LPCDO	WALK	DISTO	QUEO	DELO	TO	DIST	QUE	DEL	T	WCO	WCX	WC
20	3	500	5.0	15.0	21.9	44	1.4	16.0	3.7	3.29	0.48	0.56

VT	I	LIFEME	LIFENME	OMME	OMNME	CAPSUB	EXRATIO	W	AHPW	OTPCB
0.15	0.10	10	20	0.10	0.01	1.00	1.00	0.15	16.0	0.00

NHP	CPHP	WELLC	WATTS	EFFHP	DELHP	Q/HP	QMAXHP	% CAP
8	560	2000	100.0	0.53	16.0	2.5	5.5	0.45

PCC	TOTALC	WELLC	PUMPC
21.28	21280	2000	5280

ANPCCC	ANPCOMC	ANPCAC	ANPCEC	ANPCHC	ANPCMC	ANPCTC	PM3C	ANPCC	ANPCB	ANPCNB
2.74	0.69	0.12	1.13	2.91	0.00	7.59	1.05	3.55	17.99	14.44

SYSTEM	PUMP	POP	HD	AREA	PP	LPCD	LIFT	TDH
SP	D	1000	20	6	200	20.0	20	0

LPCDO	WALK	DISTO	QUEO	DELO	TO	DIST	QUE	DEL	T	WCO	WCX	WC
20	3	500	5.0	15.0	21.9	56	0.3	15.0	3.2	3.29	0.48	0.49

VT	I	LIFEME	LIFENME	OMME	OMNME	CAPSUB	EXRATIO	W	AHPW	OTPCB
0.15	0.10	10	20	0.10	0.01	1.00	1.00	0.15	45.0	0.00

NSP	CPSP	WELLC	STORAGE	QSTORE	LPIPE	CPMPIPE	DIESELC	HRPUMP	DSLEFF
5	300	2000	1.00	20.0	514	8.00	0.50	5.0	0.08

PCC	TOTALC	WELLC	PUMPC	XSPC	STORC	PIPEC
16.91	16907	2000	4824	1500	4467	4116

ANPCCC	ANPCOMC	ANPCAC	ANPCEC	ANPCHC	ANPCMC	ANPCTC	PM3C	ANPCC	ANPCB	ANPCNB
2.27	0.74	0.35	0.34	3.53	0.00	7.24	0.99	3.71	18.52	14.82

SYSTEM	PUMP	POP	HD	AREA	PP	LPCD	LIFT	TDH
YT	D	1000	20	6	8	80.0	20	30

LPCDO	WALK	DISTO	QUEO	DELO	TO	DIST	QUE	DEL	T	WCO	WCX	WC
20	3	500	5.0	15.0	21.9	56	0.0	15.0	1.0	3.29	0.48	0.15

VT	I	LIFEME	LIFENME	OMME	OMNME	CAPSUB	EXRATIO	W	AHPW	OTPCB
0.15	0.10	10	20	0.10	0.01	1.00	1.00	0.15	35.0	0.00

NYT	CPYT	WELLC	STORAGE	QSTORE	LPIPE	CPMPIPE	LLAT	CPMLAT	DIESELC
125	50	2000	1.00	80.0	1864	8.00	6	6.00	0.50

PCC	TOTALC	WELLC	PUMPC	YTC	STORC	PIPEC
42.38	42379	2000	5725	6250	8944	14915

ANPCCC	ANPCOMC	ANPCAC	ANPCEC	ANPCHC	ANPCMC	ANPCTC	PM3C	ANPCC	ANPCB	ANPCNB
5.52	1.50	0.27	1.38	0.00	[illegible]	8.67	0.30	8.67	24.28	15.61

After selecting the output option, if you have selected a technology other than Handpumps, the program will prompt you and ask for the mechanized pumping method to be used for this run by displaying the following screen:

YOU HAVE THE FOLLOWING MECHANIZED PUMPING OPTIONS:

```
1---------------ELECTRIC GRID--------1
2---------------DIESEL GENERATOR-----2
3---------------SOLAR PHOTO VOTALIC--3
4---------------WIND MILL------------4
```

SELECT 1, 2, 3, OR 4: ?

The user should respond with a number between 1 and 4 followed by a return.

The program will then ask if you wish to loop by any particular variable, with the following screen:

SELECT THE TYPE OF LOOPING YOU WISH

```
0---------------NO LOOPING
1---------------SINGLE LOOPING
2---------------DOUBLE LOOPING
```

SELECT 0, 1, OR 2: ?

The decision on looping allows the user to run the model over a range of values for various key variables, and is very useful in carrying out sensitivity analysis when the specific value of the variable is not known. By responding with either a 1 or a 2 the program then gives the user a list of variables that may be used for looping which is almost identical to those used for setting of default variables at the beginning of the program. After the screens are displayed the program prompts you to input the variable name and the range of values and the increment to loop by as follows:

The program can be run just for a single pass (selection 0) or be looped through a single variable range, or through two variables. It is important to understand the meaning of looping in the context of each run selection, for run selections 1-7 looping is identical to setting one or two of the default variables and doing a single run. For selections 7 and 8 it is slightly different, in that the programs main output is a specific value of time and it does not give very clear output if you loop by two variables (selection 2). When looping by two, the system first sets the primary loop, and then loops the secondary loop within each setting of the primary loop.

Another point to remember is looping while optimizing. The optimization routine in the program works by setting the number of outlets (handpumps or standpipes) and therefore it would be meaningless to loop by either NHP (number of handpumps) or NSP (number of standpipes) or for that matter either PPSP or PPHP (persons per standpipe of handpump).

Some of the more common looping variables are BCPWELL, LIFT, DISTO (distance to old source note the O at the end is a zero), POP, DENSITY etc.

Looping is particularly useful when looking at a the sensitivity of uncertain assumptions, also it is essential to produce meaningful graphic results

SELECT ONE OF THE ABOVE VARIABLES FOR PRIMARY LOOP: ? LIFT
SELECT LOWER LIMIT: ? 20
SELECT UPPER LIMIT: ? 60
SELECT INCREMENT: ? 20

If you ar looping twice a second set of screens will be displayed and you will be prompted again for the secondary loop as follows:

SELECT ONE OF THE ABOVE VARIABLES FOR SECONDARY LOOP: ? WELLC
SELECT LOWER LIMIT: ? 2000
SELECT UPPER LIMIT: ? 5000
SELECT INCREMENT: ? 1000

After selecting these values the program will begin its calculations, and will display either the words "PROCESSING" or display some of the results of the calculations on the screen so as to reassure you that it is working.

The output from this sample run for handpumps with optimization selected is shown on the next page.

SYSTEM	PUMP	POP	HD	PP	VT	LIFT	WELLC	LPCD	HPM3	PCC	ANPCTC	PM3C	ANPCC	ANPCB	ANPCNB	LIFT	WELLC
HP	D	500	20	125	0.15	20	2000	19.9	3.7	21.28	7.59	1.05	3.55	17.99	14.44	20.00	2000.00
HP	D	500	20	125	0.15	20	3000	19.9	3.7	29.28	8.61	1.19	4.57	17.99	13.42	20.00	3000.00
HP	D	500	20	167	0.15	20	4000	19.6	4.9	27.96	9.45	1.32	4.19	16.72	12.53	20.00	4000.00
HP	D	500	20	167	0.15	20	5000	19.6	4.9	33.96	10.22	1.43	4.96	16.72	11.77	20.00	5000.00

SYSTEM	PUMP	POP	HD	PP	VT	LIFT	WELLC	LPCD	HPM3	PCC	ANPCTC	PM3C	ANPCC	ANPCB	ANPCNB	LIFT	WELLC
HP	D	500	20	100	0.15	40	2000	19.6	5.1	28.20	10.38	1.45	4.86	16.45	11.59	40.00	2000.00
HP	D	500	20	100	0.15	40	3000	19.6	5.1	38.20	11.65	1.63	6.13	16.45	10.32	40.00	3000.00
HP	D	500	20	100	0.15	40	4000	19.6	5.1	48.20	12.93	1.81	7.41	16.45	9.04	40.00	4000.00
HP	D	500	20	125	0.15	40	5000	19.3	6.6	46.56	13.96	1.98	6.95	14.86	7.91	40.00	5000.00

SYSTEM	PUMP	POP	HD	PP	VT	LIFT	WELLC	LPCD	HPM3	PCC	ANPCTC	PM3C	ANPCC	ANPCB	ANPCNB	LIFT	WELLC
HP	D	500	20	83	0.15	60	2000	19.4	5.8	35.76	12.55	1.77	6.34	15.71	9.37	60.00	2000.00
HP	D	500	20	83	0.15	60	3000	19.4	5.8	47.76	14.08	1.99	7.87	15.71	7.84	60.00	3000.00
HP	D	500	20	100	0.15	60	4000	19.2	7.1	49.80	15.32	2.19	7.83	14.35	6.52	60.00	4000.00
HP	D	500	20	100	0.15	60	5000	19.2	7.1	59.80	16.59	2.37	9.10	14.35	5.24	60.00	5000.00

SYSTEM	PUMP	POP	HD	PP	VT	LIFT	WELLC	LPCD	HPM3	PCC	ANPCTC	PM3C	ANPCC	ANPCB	ANPCNB	LIFT	WELLC
SP	D	500	20	167	0.15	20	2000	23.5	3.1	26.48	9.87	1.15	5.94	18.73	12.79	20.00	2000.00
SP	D	500	20	167	0.15	20	3000	23.5	3.1	28.48	10.13	1.18	6.19	18.73	12.54	20.00	3000.00
SP	D	500	20	167	0.15	20	4000	23.5	3.1	30.48	10.38	1.21	6.45	18.73	12.28	20.00	4000.00
SP	D	500	20	167	0.15	20	5000	23.5	3.1	32.48	10.64	1.24	6.70	18.73	12.03	20.00	5000.00

SYSTEM	PUMP	POP	HD	PP	VT	LIFT	WELLC	LPCD	HPM3	PCC	ANPCTC	PM3C	ANPCC	ANPCB	ANPCNB	LIFT	WELLC
SP	D	500	20	167	0.15	40	2000	23.5	3.1	27.48	10.40	1.21	6.47	18.73	12.26	40.00	2000.00
SP	D	500	20	167	0.15	40	3000	23.5	3.1	29.48	10.66	1.24	6.72	18.73	12.00	40.00	3000.00
SP	D	500	20	167	0.15	40	4000	23.5	3.1	31.48	10.91	1.27	6.98	18.73	11.75	40.00	4000.00
SP	D	500	20	167	0.15	40	5000	23.5	3.1	33.48	11.17	1.30	7.23	18.73	11.49	40.00	5000.00

SYSTEM	PUMP	POP	HD	PP	VT	LIFT	WELLC	LPCD	HPM3	PCC	ANPCTC	PM3C	ANPCC	ANPCB	ANPCNB	LIFT	WELLC
SP	D	500	20	167	0.15	60	2000	23.5	3.1	28.48	10.94	1.28	7.00	18.73	11.73	60.00	2000.00
SP	D	500	20	167	0.15	60	3000	23.5	3.1	30.48	11.19	1.31	7.26	18.73	11.47	60.00	3000.00
SP	D	500	20	167	0.15	60	4000	23.5	3.1	32.48	11.45	1.34	7.51	18.73	11.22	60.00	4000.00
SP	D	500	20	167	0.15	60	5000	23.5	3.1	34.48	11.70	1.36	7.77	18.73	10.96	60.00	5000.00

SYSTEM	PUMP	POP	HD	PP	VT	LIFT	WELLC	LPCD	HPM3	PCC	ANPCTC	PM3C	ANPCC	ANPCB	ANPCNB	LIFT	WELLC
YT	D	500	20	8	0.15	20	2000	80.0	1.0	52.72	10.88	0.37	10.88	24.28	13.40	20.00	2000.00
YT	D	500	20	8	0.15	20	3000	80.0	1.0	54.72	11.14	0.38	11.14	24.28	13.14	20.00	3000.00
YT	D	500	20	8	0.15	20	4000	80.0	1.0	56.72	11.39	0.39	11.39	24.28	12.89	20.00	4000.00
YT	D	500	20	8	0.15	20	5000	80.0	1.0	58.72	11.65	0.40	11.65	24.28	12.63	20.00	5000.00

SYSTEM	PUMP	POP	HD	PP	VT	LIFT	WELLC	LPCD	HPM3	PCC	ANPCTC	PM3C	ANPCC	ANPCB	ANPCNB	LIFT	WELLC
YT	D	500	20	8	0.15	40	2000	80.0	1.0	53.72	12.07	0.41	12.07	24.28	12.21	40.00	2000.00
YT	D	500	20	8	0.15	40	3000	80.0	1.0	55.72	12.32	0.42	12.32	24.28	11.96	40.00	3000.00
YT	D	500	20	8	0.15	40	4000	80.0	1.0	57.72	12.58	0.43	12.58	24.28	11.70	40.00	4000.00
YT	D	500	20	8	0.15	40	5000	80.0	1.0	59.72	12.83	0.44	12.83	24.28	11.45	40.00	5000.00

SYSTEM	PUMP	POP	HD	PP	VT	LIFT	WELLC	LPCD	HPM3	PCC	ANPCTC	PM3C	ANPCC	ANPCB	ANPCNB	LIFT	WELLC
YT	D	500	20	8	0.15	60	2000	80.0	1.0	54.72	13.25	0.45	13.25	24.28	11.03	60.00	2000.00
YT	D	500	20	8	0.15	60	3000	80.0	1.0	56.72	13.51	0.46	13.51	24.28	10.78	60.00	3000.00
YT	D	500	20	8	0.15	60	4000	80.0	1.0	58.72	13.76	0.47	13.76	24.28	10.52	60.00	4000.00
YT	D	500	20	8	0.15	60	5000	80.0	1.0	60.72	14.01	0.48	14.01	24.28	10.27	60.00	5000.00

When the calculation are finished the program will prompt you for another run as shown below:

DO YOU WISH TO MAKE ANOTHER RUN?

(Y/N)?

The final thing the program does, after completing the calculations is ask if you desire another run, which just takes you back to the start after resetting all of the variables to the default conditions. The prompt appears as follows:

DO YOU WISH TO RESET VARIABLES TO DEFAULT VALUES?

CAUTION: IF YOU ARE LOOPING, VALUES WILL BE THOSE OF LAST RUN.

(Y/N)?

Then the program starts over again.

Words of Advice and Caution

The program is not very flexible in terms of its inputs (which must all be in caps or numbers) and its outputs, which are pre formatted. It has been tested quite a bit, however, I am aware of one or two remaining errors (screen output etc) that do not affect the calculations but will someday need to be fixed. It is also not very forgiving if the printer is not turned on, and it is difficult to stop the program in the middle (you might try turning the printer off this sometimes works, or hitting the "ctrl break" keys at the same time while the system is waiting for a prompt response.

ANNEX B-III

```
100 CLEAR:,REM FRONT END TO INITIALIZE PROCESSING
110 PRINT:PRINT "RURAL WATER SUPPLY COST/BENEFIT MODEL"
120 PRINT "UNDP/WORLD BANK HANDPUMPS PROJECT"
130 PRINT "================================="
150 GOSUB 2000 ' VILLAGE CHARACTERISTICS
155 GOSUB 45000 ' DECISION ON CUSTOMIZATION
160 GOSUB 41000 'CHOICE OF RUN AND IF WISH OPTIMIZATION
170 GOSUB 42000 'OUTPUT CHOICES
180 IF (RUNCHOICE >1) THEN GOSUB 40000 'SELECT TYPE OF MECHANIZED PUMP
190 GOSUB 50200 'DECISION ON LOOPING
210 GOSUB 41100 'THIS SENDS THE PROGRAM TO THE SUBROUTING FOR A PARTICULAR RUN
220 IF (OUTCHOICE = 2) THEN CLOSE #1
230 IF (OUTCHOICE) = 1 THEN LPRINT " "
410 CLS:PRINT:PRINT
411 PRINT "DO YOU WISH TO MAKE ANOTHER RUN?"
412 PRINT:INPUT "(Y/N)";RUNAGAIN$
430 IF RUNAGAIN$ <> "Y" AND RUNAGAIN$ <> "N" THEN PRINT "INVALID INPUT":GOTO 412
435 IF RUNAGAIN$ = "N" THEN END
440 CLS:PRINT:PRINT:PRINT "DO YOU WISH TO RESET VARIABLES TO DEFAULT VALUES?"
442 PRINT:PRINT "CAUTION: IF YOU ARE LOOPING, VALUES WILL BE THOSE OF LAST RUN."
446 PRINT:INPUT "(Y/N)";CLEARYN$
448 IF CLEARYN$ <> "Y" AND CLEARYN$ <> "N" THEN PRINT "INVALID INPUT":GOTO 440
449 IF CLEARYN$ = "Y" THEN GOTO 100 ELSE GOTO 155
450 END
510 REM     ALL FLAGS DEFAULT TO VALUES OF ZERO AT THE FIRST ENCOUNTER,
515 REM     WHEN VARIABLE IS SET BY USER CORRESPONDING FLAG IS SET TO 1 AND
516 REM     DEFAULT VALUE IS OVERRIDDEN.
2000 REM ##################################################
2020 IF POPFLAG = 0 THEN POP=500 '            VILLAGE POPULATION
2030 IF FSIZEFLAG = 0 THEN FSIZE=8 '          NUMBER OF PERSONS IN HOUSEHOLD
2040 IF HDFLAG = 0 THEN LET HD=20 '           HOUSEHOLDS PER HECTARE
2050 IF LIFTFLAG = 0 THEN LIFT = 20 '         PUMPING LIFT (METERS)
2055 IF STORLIFTFLAG = 0 THEN STORLIFT = 10 'FRICTION LOSS + LIFT TO STORAGE TANK FOR MECHANIZED PUMPS
2057 IF PUMPTYPE >= 1 AND PUMPTYPE <= 4 THEN TDH = LIFT + STORLIFT ' TOTAL DYNAMIC HEAD FOR MECHANIZED PUMPS
2060 IF VTFLAG = 0 THEN VT=.15 '              VALUE OF TIME TO HAUL WATER ($/HOUR)
2062 IF WFLAG = 0 THEN W = VT '               ATTENDANT WAGE RATE ASSUMED EQUAL TO VALUE OF TIME UNLESS SPECIFIED ($/HOUR)
2065 IF LPCDFLAG = 0 THEN LPCD = 20:LET LPCDHP=20:LET LPCDSP=20:LET LPCDYT=75 '  WATER USE, (LITERS PER CAPITA PER DAY)
2092 IF TYTFLAG = 0 THEN  TYT = 1 '           ESTIMATED TIME FOR COLLECTING WATER FROM A YARD TAP (HRS/M3)
2110 IF WELLCFLAG = 0 THEN WELLC = 2000 '     THIS IS THE BASE COST PER WELL
2120 IF QUEOFLAG = 0 THEN LET QUEO=5.0 '      QUEUE TIME AT OLD SOURCE (MINUTES PER TRIP)
2145 IF DELOFLAG = 0 THEN LET DELO=15 '       DELIVERY RATE AT OLD SOURCE (LITERS PER MINUTE)
2150 IF DELHPFLAG = 0 THEN LET DELHP=15 '     DELIVERY RATE AT HANDPUMP (LITERS PER MINUTE)
2154 IF DELSPFLAG = 0 THEN LET DELSP=15 '     DELIVERY RATE AT STANDPIPE (LITERS/MIN)
2156 IF VOLFLAG = 0 THEN LET VOL=20 '         VOLUME CARRIED PER TRIP FROM HP OR SP
2158 IF DISTOFLAG = 0 THEN LET DISTO=500 '    DISTANCE TO OLD SOURCE (METERS)
2160 IF WALKFLAG = 0 THEN LET WALK=3 '        WALKING SPEED (KM/HOUR)
2162 IF DISTFLAG = 0 THEN LET DISTHP=50: LET DISTSP=50 '   ONE WAY TRAVEL DISTANCE TO HP OR SP
2174 IF STORAGEFLAG = 0 THEN STORAGE =1.0 '   FRACTION OF DAILY FLOW THAT IS STORED.
2180 IF CPYTFLAG = 0 THEN LET CPYT=50 '       COST PER YARD TAP INCLUDING DRAINAGE
2185 IF CPSPFLAG = 0 THEN LET CPSP=300 '      COST PER STANDPIPE INCLUDING DRAINAGE
2190 IF CAPSUBFLAG = 0 THEN LET CAPSUB = 1 '  THIS IS A MULTIPLIER FOR CAPITAL COSTS. DEFAULT CONDITION IS A VALUE OF 1. A VALUE OF 0 MEANS NO CAPITAL COSTS.
2192 REM          SETTING THIS FLAG TO 1 GIVES A STANDARD RUN INCLUDING ALL COSTS
2200 IF NHPSETFLAG = 0 THEN NHP = 4 '         DEFAULT NUMBER OF HANDPUMPS
2205 IF NSPSETFLAG = 0 THEN NSP = 3 '         DEFAULT NUMBER OF STANDPIPES
2210 IF IFLAG = 0 THEN LET I=10 '             DISCOUNT RATE (PERCENT)
2220 IF LIFEMEFLAG = 0 THEN LET LIFEME=10 '   LIFE EXPECTANCY OF MECHANICAL EQUIPMENT (YEARS)
2230 IF LIFENMEFLAG = 0 THEN LET LIFENME=20 'LIFE OF NON-MECHANICAL EQUIPMENT (YEARS)
2260 IF HRPUMPFLAG = 0 THEN LET HRPUMP=5 '    HOURS OF ELECTRIC OR DIESEL PUMPING PER DAY
2265 IF HRDELFLAG = 0 THEN LET HRDEL = 8'     HOURS PER DAY HP OR SP IN USE
2270 IF VFLAG = 0 THEN LET V=3 '              AVERAGE WIND SPEED (M/SEC)
2275 IF WMILLCFLAG = 0 THEN LET WMILLC=500 ' CAPITAL COST OF WINDMILL ($/M2 OF AREA)
2280 IF ELPOWERCFLAG=0 THEN LET ELPOWERC=.1 'COST OF ELECTRIC POWER ($/KWH)
2290 IF DIESELCFLAG = 0 THEN LET DIESELC=.5 'COST OF DIESEL FUEL ($/LITER)
2292 IF DSLEFFFLAG =0 THEN LET DSLEFF=0.075 'DIESEL EFFICIENCY - FUEL TO WATER
2294 IF PVEFFFLAG=0 THEN PVEFF=.1'            EFFICIENCY OF THE PHOTOVOTAIC SYS
```

```
2298 IF SCPM3FLAG=0 THEN SCPM3=0'            NEW SOURCE COST ($/M3)
2300 IF LPCDOFLAG = 0 THEN LPCDO=20 '        INELASTIC REGION OF DEMAND CURVE
2320 IF OMMEFLAG = 0 THEN LET OMME=10 '      FACTOR FOR ANNUAL O&M COST OF MECH EQUIP (% CAPITAL COST)
2330 IF OMNMEFLAG = 0 THEN LET OMNME=1''     FACTOR FOR O&M COST OF NON-MECH EQUIP (% CAPITAL COST)
2340 DEF FNPUMP(VOL,DEL,VT,LPCD)=(VOL/DEL/60)*VT*LPCD*365/VOL 'PUMPING COSTS PER CAPITA PER YEAR
2350 DEF FNCONVEY(DIST,WALK,QUE,VOL,VT,LPCD)=(DIST*2/WALK/1000+QUE/60)*VT*LPCD*365/VOL ' COLLECTION TIME (HRS/PERSON/YEAR)
2352 IF BCSTORAGEFLAG = 0 THEN LET BCSTORAGE = 1000 'BASE STORAGE COST
2354 IF CPPWATTFLAG =0 THEN LET CPPWATT = 8 'COST PER PEAK WATT PHOTOVOLTAIC ARRAY INSTALLED
2356 IF CPMPIPEFLAG =0 THEN LET CPMPIPE = 8 'COST PER METER OF MAIN PIPE
2358 IF CPMLATFLAG = 0 THEN LET CPMLAT = 6 ' COST PER METER OF LATERAL PIPE
2370 IF OTPCBFLAG = 0 THEN LET OTPCB=0 '     HEALTH/OTHER BENEFITS
2420 IF I >.99 THEN LET I=I/100 '            CONVERT TO DECIMAL
2430 IF OMME > .99 THEN LET OMME=OMME/100 '  CONVERT TO DECIMAL
2440 IF OMNME >.99 THEN LET OMNME=OMNME/100 'CONVERT TO DECIMAL
2450 IF EXRATIOFLAG =0 THEN LET EXRATIO = 1 'DEFAULT VALUE FOR EXRATIO (SEE SUB 12000)
2460 RETURN
2500 REM  FORMULAS  ################################################
2510 REM THIS SECTION IS FOR ASSIGNING FORMULAS AND CONSTANTS
2512 REM SHORT SECTION FOR CALCULATING PRESENT VALUE FACTOR FOR MECH EQUIP
2514 LET PV=0 '                              INITIALIZE PV FACTOR
2516 FOR PERIOD = 0 TO LIFENME STEP LIFEME ' BEGIN LOOP
2518 IF PERIOD => LIFENME GOTO 2522 '        END LOOP
2520 LET PV = PV + (1+I)^-PERIOD '           SUM THE PV FACTORS FOR EACH REPLACEMENT
2522 NEXT PERIOD
2530 LET AN = ((1-(1+I)^-LIFENME)/I)^-1 '    FACTOR FOR ANNUALIZING COSTS
2540 LET AREA = POP/HD/FSIZE
2570 LET NYT = INT(POP/FSIZE+.9)
2580 IF WATTSFLAG=1 THEN GOTO 2620 '         SKIP CALCULATING WATTS AS FN OF LIFT
2590 IF LIFT < 15 THEN WATTS = 4*LIFT+40 ELSE WATTS = 100 'POWER INPUT TO HANDPUMPS
2620 IF DELHPFLAG=1 THEN GOTO 2641 '         OVERRIDE CALC OF HP DELIVERY
2630 LET EFFHP=.4+.00667*LIFT '              EFFICIENCY OF HP
2640 LET DELHP=WATTS*6*EFFHP/LIFT '          DELIVERY OF HANDPUMP (LITERS/MIN)
2641 LET WCX=(4-0.04*LPCDO)*VT  '            CALCULATES THE CROSSOVER POINT ON THE DEMAND CURVE
2642 LET WCYT=TYT*VT+SCPM3
2643 IF NHPSETFLAG=1 THEN NHP = NHPSET
2644 IF NSPSETFLAG=1 THEN NSP = NSPSET
2655 IF LPCDFLAG = 1 THEN LPCDHP = LPCD:LPCDYT = LPCD:LPCDSP = LPCD
2660 IF LPCDFLAG = 0 AND IDENT$ ="HP" THEN GOSUB 54000
2670 IF LPCDFLAG = 0 AND IDENT$ ="SP" THEN GOSUB 55000
2674 IF LPCDFLAG = 0 AND IDENT$ ="YT" THEN LPCDYT = (5-TYT)*20: IF WCYT>WCX THEN LET LPCDYT = LPCDO
2690 IF IDENT$ = "HP" THEN Q = LPCDHP*POP/1000
2700 IF IDENT$ = "SP" THEN Q = LPCDSP*POP/1000
2710 IF IDENT$ = "YT" THEN Q = LPCDYT*POP/1000:LET NYT = INT(POP/FSIZE+.9):GOTO 2890 ' SKIP OVER HP AND SP CALC WHEN RUNNING YT (RUNS FASTER)
2750 LET SRHP = (60*DELHP)/(VOL+DELHP/2)'   SR**= SERVICE RATE
2760 LET QMAXHP = SRHP*HRDEL*VOL/1000
2770 LET SRSP=(60*DELSP)/(VOL+DELSP/2)
2780 LET QMAXSP = SRSP*HRDEL*2*20/1000
2785 IF OPTIMIZE$="Y" THEN GO TO 2800 'SKIP CHECK FOR SUFFICIENT NUMBER OF HP OR SP TO MEET DEMAND
2790 IF IDENT$="SP" AND POP*LPCDSP/1000>NSP*QMAXSP THEN NSP=NSP+1:PRINT "INSUFFICIENT STANDPIPES, AN ADDITIONAL WATER POINT HAS BEEN ADDED":GOTO 2785
2795 IF IDENT$="HP" AND POP*LPCDHP/1000>NHP*QMAXHP THEN NHP=NHP+1:PRINT "INSUFFICIENT HANDPUMPS, AN ADDITIONAL PUMP HAS BEEN ADDED":GOTO 2785
2800 LET PPHP=POP/NHP
2810 LET PPSP=POP/NSP
2820 IF DISTFLAG =1 THEN GOTO 2850  'DECISION ON CALC DISTANCE TO NEW SOURCE
2830 LET DISTHP = SQR(AREA*10000/NHP)/2 'ONE WAY TRAVEL DISTANCE
2840 LET DISTSP = SQR(AREA*10000/NSP)/2
2850 REM
2860 IF QUEFLAG = 0 THEN LET ARHP=LPCDHP*POP/NHP/HRDEL/VOL:QUEHP=ARHP*60/SRHP/(SRHP-ARHP)'  AR**=ARRIVAL RATE (TRIPS/HR)
2880 IF QUEFLAG = 0 THEN LET ARSP=LPCDSP*POP/NSP/HRDEL/VOL:QUESP=ARSP^2*60/SRSP/(4*SRSP^2-ARSP^2)
2890 REM
2892 LET TO=(2*DISTO/WALK/1000+QUEO/60+VOL/DELO/60)*1000/VOL
2894 LET THP=(2*DISTHP/WALK/1000+QUEHP/60+VOL/DELHP/60)*1000/VOL
2896 LET TSP=(2*DISTSP/WALK/1000+QUESP/60+VOL/DELSP/60)*1000/VOL
2897 LET WCO=TO*VT+SCPM30
2898 LET WCHP=THP*VT+SCPM3
2899 LET WCSP=TSP*VT+SCPM3
```

```
3000 REM ****************************************************
3005 REM OPTIMIZE NUMBER OF HANDPUMPS OR STANDPIPES
3007 REM PRINT "ENTERING OPTIMIZATION FOR --";IDENT$
3010 IF IDENT$="HP" THEN LET NHP=1:LET NHPSETFLAG = 1:LET NHPSET = 1:LET PPHP=POP/NHP 'SET NUMBER OF OUTLETS TO 1
3012 IF IDENT$="SP" THEN LET NSP=1:LET NSPSETFLAG = 1:LET NSPSET = 1:LET PPSP=POP/NSP 'SET NUMBER OF OUTLETS TO 1
3020 LET NBOLD=-9999999
3040 IF IDENT$ = "HP" THEN GOSUB 2500:GOSUB 7000:GOSUB 10000 'CALC HANDPUMP COSTS AND BENEFITS
3047 IF IDENT$ = "SP" THEN GOSUB 2500:GOSUB 40100:GOSUB 7500:GOSUB 10500 'CALC STANDPIPE COSTS AND BENEFITS
3050 REM     LPRINT NHP,ANPCC,ANPCB,ANPCNB,NBOLD
3060 LET NBNEW=ANPCNB
3070 IF NBNEW<NBOLD THEN 3110
3080 LET NBOLD=NBNEW
3090 IF (IDENT$ = "HP") THEN NHP=NHP+1:LET NHPSET = NHPSET +1:PPHP = POP/NHP
3092 IF (IDENT$ = "SP") THEN NSP=NSP+1:LET NSPSET = NSPSET +1:PPSP = POP/NSP
3100 GOTO 3040
3110 IF (IDENT$ = "HP") THEN LET NHP=NHP-1:LET NHPSET = NHP:LET PPHP = POP/NHP:GOSUB 2500:GOSUB 7000:GOSUB 10000
3120 IF (IDENT$ = "SP") THEN LET NSP=NSP-1:LET NSPSET = NSP:LET PPSP = POP/NSP:GOSUB 2500:GOSUB 40100:GOSUB 7500:GOSUB 10500
3140 RETURN
3200 REM
4500 REM  GRID  SOURCE COSTS  ****************************************
4520 IF PUMPCFLAG=0 AND LIFT=<7 THEN PUMPC=750
4530 IF PUMPCFLAG=0 AND LIFT>7 THEN PUMPC=275+25*(LIFT+STORLIFT)+75*Q/HRPUMP+500
4540 IF PUMPCFLAG=0 AND PUMPC<750 THEN PUMPC=750
4560 LET ANEC=2.5*Q*(LIFT+STORLIFT)*ELPOWERC
4570 IF STORCFLAG=0 THEN STORC=BCSTORAGE*SQR(Q*STORAGE)
4660 RETURN
4700 REM
5000 REM  DIESEL SOURCE COSTS  ************************************
5020 IF PUMPCFLAG=0 AND LIFT=<7 THEN PUMPC=2000
5030 IF PUMPCFLAG=0 AND LIFT>7 THEN PUMPC=(275+25*(LIFT+STORLIFT)+75*Q/HRPUMP)+3500
5040 IF PUMPCFLAG=0 AND PUMPC<750 THEN PUMPC=750
5060 LET ANEC=0.08625*Q*(LIFT+STORLIFT)*DIESELC/DSLEFF
5070 IF STORCFLAG=0 THEN STORC=BCSTORAGE*SQR(Q*STORAGE) 'STORAGE COSTS
5080 RETURN
5100 REM
5500 REM SOLAR SOURCE COSTS  ********************************************
5520 IF PUMPCFLAG=0 AND LIFT < 7 THEN PUMPC=750
5530 IF PUMPCFLAG=0 AND LIFT=>7 THEN PUMPC = 275+25*(LIFT+STORLIFT)+75*Q/HRPUMP
5540 IF PUMPCFLAG=0 AND PUMPC<750 THEN PUMPC=750
5545 LET WP = 2.72*Q*(LIFT+STORLIFT)/PVEFF/INS
5550 IF SOLARPVCFLAG=0 THEN SOLARPVC = CPPWATT*WP
5570 IF STORCFLAG=0 THEN STORC=BCSTORAGE*SQR(Q*STORAGE)
5600 LET ANEC = 0
5640 RETURN
5700 REM
6500 REM WIND SOURCE COSTS   ********************************************
6510 LET ANEC = 0
6550 IF PUMPCFLAG=0 THEN PUMPC=WMILLC*1.13*Q*(LIFT+STORLIFT)/V^3
6560 IF STORCFLAG=0 THEN STORC=BCSTORAGE*SQR(Q*STORAGE)
6670 RETURN
6700 REM
7000 REM  HANDPUMP COST CALULATIONS **********************************
7005 IF CPHPFLAG = 1 GO TO 7010
7007 IF LIFT <= 12 THEN CPHP = 250 ELSE LET CPHP=500+8*LIFT
7010 LET PUMPC=CPHP*NHP
7015 LET HPWELLC=WELLC*NHP
7020 LET PCC=(PUMPC+HPWELLC)/POP
7025 LET ANPCCC=(PUMPC*PV+HPWELLC)*AN/POP
7030 LET ANPCOMC=(PUMPC*OMME+HPWELLC*OMNME)/POP
7031 LET ANPCCC = ANPCCC*CAPSUB 'ADJUSTS CAPITAL COSTS FOR ANY SUBSIDY
7032 LET ANPCEC=FNPUMP(VOL,DELHP,VT,LPCDHP)
7033 LET ANPCMC=LPCDHP*SCPM3*365/1000
7035 IF AHPWFLAG=0 THEN AHPW=NHP*2
7037 LET ANPCAC=AHPW*W*52/POP
7038 ANPCHC=FNCONVEY(DISTHP,WALK,QUEHP,VOL,VT,LPCDHP)
```

```
7045 LET [illegible]
7047 LET PM3C=ANPCTC*1000/LPCDHP/365
7050 RETURN
7100 REM
7500 REM STANDPIPE COST CALCULATIONS ********************************
7520 IF LPIPEFLAG=0 THEN LPIPE=90*NSP^.4*AREA^.6
7523 IF PIPECFLAG=0 THEN PIPEC=LPIPE*CPMPIPE
7530 LET XSPC=CPSP*NSP
7533 IF PUMPTYPE <> 3 THEN SOLARPVC=0
7535 LET PCC=(WELLC+PUMPC+STORC+SOLARPVC+PIPEC+XSPC)/POP
7540 LET ANPCCC=((PUMPC+XSPC)*PV+WELLC+STORC+SOLARPVC+PIPEC)*AN/POP
7545 LET ANPCOMC=((PUMPC+XSPC)*OMME+(WELLC+STORC+SOLARPVC+PIPEC)*OMNME)/POP
7550 IF PUMPTYPE=4 THEN ANPCOMC=((PUMPC/4+XSPC)*OMME+(PUMPC*3/4+WELLC+STORC+PIPEC)*OMNME)/POP
7553 LET ANPCCC = ANPCCC*CAPSUB 'ADJUSTS CAPITAL COSTS FOR ANY SUBSIDY
7555 LET ANPCEC=ANEC/POP
7556 LET ANPCMC=LPCDSP*SCPM3*365/1000
7557 IF AHPWFLAG=0 THEN AHPW=NSP*2
7558 IF PUMPTYPE = 2 AND AHPWFLAG = 0 THEN AHPW = NSP*2+HRPUMP*7
7559 LET ANPCAC=AHPW*W*52/POP
7563 ANPCHC=FNCONVEY(DISTSP,WALK,QUESP,VOL,VT,LPCDSP)+FNPUMP(VOL,DELSP,VT,LPCDSP) 'HAUL INCLUDES CONVEYING AND QUE TIME
7565 LET ANPCC=ANPCCC+ANPCOMC+ANPCEC+ANPCAC
7570 LET ANPCTC=ANPCC+ANPCHC+ANPCMC
7575 LET PM3C=ANPCTC*1000/LPCDSP/365
7580 RETURN
7600 REM
8000 REM YARD TAP COST CALCULATIONS *************************************
8120 IF LPIPEFLAG=0 THEN LPIPE=90*NYT^.4*AREA^.6
8125 IF LPIPCFLAG=0 THEN PIPEC = LPIPE*CPMPIPE
8140 IF LLATFLAG=0 THEN LLAT=40*(AREA/NYT)^.63
8145 IF LLATCFLAG=0 THEN LATC=LLAT*CPMLAT*NYT
8150 LET YTC=CPYT*NYT
8152 IF PUMPTYPE <> 3 THEN SOLARPVC=0
8153 LET PCC=(WELLC+PUMPC+STORC+SOLARPVC+PIPEC+LATC+YTC)/POP
8155 LET ANPCCC=((PUMPC+YTC)*PV+WELLC+STORC+SOLARPVC+PIPEC+LATC)*AN/POP
8160 LET ANPCOMC=((PUMPC+YTC)*OMME+(WELLC+STORC+SOLARPVC+PIPEC+LATC)*OMNME)/POP
8165 IF PUMPTYPE=4 THEN ANPCOMC=((PUMPC/4+YTC)*OMME+(PUMPC*3/4+WELLC+STORC+PIPEC+LATC)*OMNME)/POP
8167 LET ANPCCC = ANPCCC*CAPSUB 'ADJUSTS CAPITAL COSTS FOR ANY SUBSIDY
8170 LET ANPCEC=ANEC/POP
8172 LET ANPCMC=LPCDYT*SCPM3*365/1000
8175 IF PUMPTYPE = 2 AND AHPWFLAG = 0 THEN AHPW = HRPUMP*7
8176 IF AHPWFLAG =0 AND PUMPTYPE <>2 THEN AHPW = 0
8177 LET ANPCAC=AHPW*W*52/POP
8180 LET ANPCC=ANPCCC+ANPCOMC+ANPCEC+ANPCAC
8185 LET ANPCTC=ANPCC+ANPCHC+ANPCMC
8190 LET PM3C=ANPCTC*1000/LPCDYT/365
8195 RETURN
8200 REM
10000 REM  HANDPUMP BENEFIT CALCULATIONS ****************************
10010 IF WCO=>WCX AND WCHP=>WCX THEN ANPCB=(103/5*(WCO-WCHP)-1/5/2/VT*(WCO^2-WCHP^2))*365/1000 +OTPCB
10020 IF WCO=<WCX AND WCHP=<WCX THEN ANPCB=(4/0.04*(WCO-WCHP)-1/0.04/2/VT*(WCO^2-WCHP^2))*365/1000+OTPCB
10030 IF WCO=>WCX AND WCHP=<WCX THEN ANPCB=(103/5*(WCO-WCX)-1/5/2/VT*(WCO^2-WCX^2))*365/1000+(4/0.04*(WCX-WCHP)-1/0.04/2/VT*(WCX^2-WCHP^2))*365/1000+OTPCB
10035 IF WCO=<WCX AND WCHP=>WCX THEN ANPCB=(103/5*(WCX-WCHP)-1/5/2/VT*(WCX^2-WCHP^2))*365/1000+(4/0.04*(WCO-WCX)-1/0.04/2/VT*(WCO^2-WCX^2))*365/1000+OTPCB
10037 REM   LPRINT ANPCB,WCO,WCX,WCHP,LPCDO,LPCDHP,VT,OTPCB;"ANPCB,WCO,WCX,WCHP,LPCDO,LPCDHP,VT,OTPCB"
10040 ANPCNB=ANPCB-ANPCC
10050 RETURN
10100 REM
10500 REM STANDPIPE BENEFIT CALCULATIONS ****************************
10510 IF WCO=>WCX AND WCSP=>WCX THEN ANPCB=(103/5*(WCO-WCSP)-1/5/2/VT*(WCO^2-WCSP^2))*365/1000 +OTPCB
10520 IF WCO=<WCX AND WCSP=<WCX THEN ANPCB=(4/0.04*(WCO-WCSP)-1/0.04/2/VT*(WCO^2-WCSP^2))*365/1000+OTPCB
10530 IF WCO=>WCX AND WCSP=<WCX THEN ANPCB=(103/5*(WCO-WCX)-1/5/2/VT*(WCO^2-WCX^2))*365/1000+(4/0.04*(WCX-WCSP)-1/0.04/2/VT*(WCX^2-WCSP^2))*365/1000+OTPCB
10535 IF WCO=<WCX AND WCSP=>WCX THEN ANPCB=(103/5*(WCX-WCSP)-1/5/2*VT*(WCX^2-WCSP^2))*365/1000+(4/0.04*(WCO-WCX)-1/0.04/2/VT*(WCO^2-WCX^2))*365/1000+OTPCB
10540 ANPCNB=ANPCB-ANPCC
10550 RETURN
10600 REM
11000 REM YARD TAP BENEFIT CALCULATIONS ****************************
```

```
11020 IF WCO=<WCX A[illegible]
11030 IF WCO=>WCX AND WCYT=<WCX THEN ANPCB=(103/5*(WCO-WCX)-1/5/2/VT*(WCO^2-WCX^2))*365/1000+(4/0.04*(WCX-WCYT)-1/0.04/2/VT*(WCX^2-WCYT^2))*365/1000+OTPCB
11035 IF WCO=<WCX AND WCYT=>WCX THEN ANPCB=(103/5*(WCX-WCYT)-1/5/2/VT*(WCX^2-WCYT^2))*365/1000+(4/0.04*(WCO-WCX)-1/0.04/2/VT*(WCO^2-WCX^2))*365/1000+OTPCB
11060 LET ANPCNB=ANPCB-ANPCC
11070 RETURN
11190 REM
12000 REM THIS SUBROUTINE IS FOR DETERMINATION OF THE SET OF POINTS ALONG AN OPTIMIZATION LINE BETWEEN HANDPUMPS AND STANDPIPES OR HP AND YT OR SP AND YT
12010 REM  THIS SUBROUTINE MUST HAVE ONE OF THREE FLAGS SET TO ZERO AND ONLY ONE OF THE THREE FLAGES, WHICH ARE HPSP,HPYT,SPYT
12020  REM
12035 LET VT=.1 'INITIALIZE THE WAGE RATE TO A LOW VALUE
12050 LET CNT=1
12060 LET INC=.15
12070 IF (HPSPFLAG = 1) OR (HPYTFLAG = 1) THEN IDENT$= "HP":GOSUB 3000:LET ANPCBHP=ANPCB:LET ANPCCHP=ANPCC:LET ANPCNBHP=ANPCNB
12080 IF HPSPFLAG = 1 OR SPYTFLAG = 1 THEN IDENT$= "SP":GOSUB 3000:LET ANPCBSP=ANPCB:LET ANPCCSP=ANPCC:LET ANPCNBSP=ANPCNB
12090 IF HPYTFLAG = 1 OR SPYTFLAG = 1 THEN IDENT$= "YT":GOSUB 2500:GOSUB 40100:GOSUB 8000:GOSUB 11000:LET ANPCBYT=ANPCB:LET ANPCCYT=ANPCC:LET ANPCNBYT=ANPCNB
12120 IF HPYTFLAG = 1 THEN LET DELBEN=ANPCNBYT-ANPCNBHP*EXRATIO
12140 IF HPSPFLAG = 1 THEN LET DELBEN=ANPCNBSP-ANPCNBHP*EXRATIO
12150 IF SPYTFLAG = 1 THEN LET DELBEN=ANPCNBYT-ANPCNBSP*EXRATIO
12155 IF CNT=1 AND DELBEN>0 AND VT > 0 THEN LET VT=VT-.5:GOTO 12060
12157 IF CNT=1 AND DELBEN>0 AND VT < 0 THEN LET VT=VT+.2:GOTO 12060
12160 PRINT "CNT=";CNT
12170 PRINT "EXRATIO=";EXRATIO,"VT=";VT,"INC=";INC,"DELBEN=";DELBEN
12180 IF SPYTFLAG = 1 THEN PRINT "SPYT=,NBSP=";ANPCNBSP,"NBYT=";ANPCNBYT
12190 IF HPSPFLAG = 1 THEN PRINT "HPSP=,NBHP=";ANPCNBHP,"NBSP=";ANPCNBSP
12200 IF HPYTFLAG = 1 THEN PRINT "HPYT=,NBHP=";ANPCNBHP,"NPYT=";ANPCNBYT
12210 LET CNT=CNT+1
12230 IF CNT>25 THEN 12320
12250 IF ABS(DELBEN) <.05 THEN 12360
12260 IF DELBEN >0 THEN 12290
12265 IF VT>1 THEN LPRINT "VT GREATER THAN $1.00":GOTO 12360
12270 LET VT=VT+INC
12280 GOTO 12070
12290 IF VT < 0 THEN PRINT "VT LESS THAN ZERO ":GOTO 12360 'THIS IS ONLY EXECUTED WHEN VT IS BELOW ZERO AND STILL NEEDS TO GO LOWER TO FIND A CROSSOVER POINT
12295 LET VT=VT-INC+INC/3
12300 LET INC=INC/3
12310 GOTO 12070
12320 LPRINT "MORE THAN 25 ITERATIONS"
12330 END
12350 END
12360 IF OUTCHOICE = 2 THEN GOTO 12390
12362 IF FIRSTIME$ = "Y" THEN LPRINT "RUN,IDENT,EXRATIO,VT,LIFT,DRATE,POP,WELLC,NOF__/NOF__,ANPCNB,ANPCNB"
12365 IF SPYTFLAG = 1 THEN LPRINT "SPYT=";EXRATIO,VT,LIFT,1,POP,WELLC,NSP,NYT,ANPCNBSP,ANPCNBYT,DELBEN
12370 IF HPYTFLAG = 1 THEN LPRINT "HPYT=";EXRATIO,VT,LIFT,1,POP,WELLC,NHP,NYT,ANPCNBHP,ANPCNBYT,DELBEN
12380 IF HPSPFLAG = 1 THEN LPRINT "HPSP=";EXRATIO,VT,LIFT,1,POP,WELLC,NHP,NSP,ANPCNBHP,ANPCNBSP,DELBEN
12382 LET FIRSTIME$ = "N"
12385 RETURN
12390 IF FIRSTIME$ = "Y" THEN WRITE #1,"RUN,IDENT,EXRATIO,VT,LIFT,DRATE,POP,WELLC,DENS,ANPCNB,ANPCNB"
12392 IF FIRSTIME$ = "Y" THEN PRINT "RUN,IDENT,EXRATIO,VT,LIFT,DRATE,POP,WELLC,DENS,ANPCNB,ANPCNB"
12395 IF SPYTFLAG = 1 THEN WRITE #1, "SPYT=";EXRATIO,VT,LIFT,1,POP,WELLC,HD,ANPCNBSP,ANPCNBYT,DELBEN
12396 IF SPYTFLAG = 1 THEN PRINT "SPYT=";EXRATIO,VT,LIFT,1,POP,WELLC,HD,ANPCNBSP,ANPCNBYT,DELBEN
12400 IF HPYTFLAG = 1 THEN WRITE #1, "HPYT=";EXRATIO,VT,LIFT,1,POP,WELLC,HD,ANPCNBHP,ANPCNBYT,DELBEN
12402 IF HPYTFLAG = 1 THEN PRINT "HPYT=";EXRATIO,VT,LIFT,1,POP,WELLC,HD,ANPCNBHP,ANPCNBYT,DELBEN
12410 IF HPSPFLAG = 1 THEN WRITE #1, "HPSP=";EXRATIO,VT,LIFT,1,POP,WELLC,HD,ANPCNBHP,ANPCNBSP,DELBEN
12412 IF HPSPFLAG = 1 THEN PRINT "HPSP=";EXRATIO,VT,LIFT,1,POP,WELLC,HD,ANPCNBHP,ANPCNBSP,DELBEN
12430 LET FIRSTIME$ = "N"
12450 RETURN
12500 REM
13000 REM THIS SUBROUTINE IS FOR DETERMINATION OF NET BENEFITS SWITHCING VALUES AT AN OPTIMIZATION LINE BETWEEN HP AND SP, HP AND YT, OR SP AND YT
13020  REM
13035 IF FIRSTIME$ = "Y" THEN LET VT=.01 'INITIALIZE THE WAGE RATE TO A LOW VALU
13050 LET CNT=1
13060 LET INC=.15
13070 IF IDENT$= "HP" THEN GOSUB 3000
13080 IF IDENT$= "SP" THEN GOSUB 3000
13090 IF IDENT$= "YT" THEN GOSUB 2500:GOSUB 40100:GOSUB 8000:GOSUB 11000
```

```
13170 PRINT "IDENT=";IDENT$,"VT=";VT,"INC=";INC
13180 IF IDENT$="HP" THEN PRINT "NHP=";NHP,"QUEHP="QUEHP,"DISTHP=";DISTHP
13190 IF IDENT$="SP" THEN PRINT "NSP=";NSP,"QUESP="QUESP,"DISTSP=";DISTSP
13210 LET CNT=CNT+1
13220 IF VT>2' THEN 13340
13230 IF CNT>25 THEN 13320
13250 IF ABS(ANPCNB)<.01 THEN 13360
13260 IF ANPCNB >0 THEN 13290
13270 LET VT=VT+INC
13280 GOTO 13070
13290 REM
13295 LET VT=VT-INC+INC/3
13300 LET INC=INC/3
13305 IF VT <0 THEN LET VT=INC
13310 GOTO 13070
13320 LPRINT "MORE THAN 25 ITERATIONS"
13322 GOTO 13360
13340 LPRINT "VALUE OF TIME GREATER THAN $2.00"
13360 GOSUB 18000
13440 LET FIRSTIME$ = "N"
13450 RETURN
15250 REM PRINT DETAILED SUMMARY ***********************************
15252 PRCNT=PRCNT+1:IF PRCNT=4 THEN LPRINT CHR$(12):PRCNT=1
15258 LPRINT CHR$(15)
15260 WIDTH "LPT1:",255
15265 IF IDENT$="HP" THEN LPRINT "  SYSTEM    PUMP     POP      HD    AREA      PP    LPCD    LIFT  "
15270 IF IDENT$="HP" THEN LPRINT "      ";IDENT$;"       ";PUMP$ USING "    ####       ##      ###      ###   ###.#       ##";POP,HD,AREA,PP,PRLPCD,LIFT:LPRINT
15271 IF IDENT$="SP" OR IDENT$="YT" THEN LPRINT "  SYSTEM    PUMP     POP      HD    AREA      PP    LPCD    LIFT     TDH"
15272 IF IDENT$="SP" OR IDENT$="YT" THEN LPRINT "     ";IDENT$;"       ";PUMP$ USING "    ####       ##      ###      ###   ###.#       ##      ##";POP,HD,AREA,PP,PRLPCD,LIFT,TDH:LPRINT
15275 LPRINT "   LPCDO     WALK   DISTO     QUEO     DELO       TO     DIST      QUE      DEL       T       WCO      WCX      WC"
15280 LPRINT USING "     ###        #     ####     ##.#     ##.#     ##.#     ####     ##.#     ##.#     ##.#    ##.##    ##.##    ##.##";LPCDO,WALK,DISTO,QUEO,DELO,TO,DIST,QUE,DEL,T,WCO,WCX,PRWC:LPRINT
15285 LPRINT "      VT        I   LIFEME LIFENME    OMME   OMNME  CAPSUB EXRATIO       W    AHPW   OTPCB"
15290 LPRINT USING "    #.##     #.##       ##       ##     #.##     #.##     #.##     #.##     #.##     ##.#    ##.##";VT,I,LIFEME,LIFENME,OMME,OMNME,CAPSUB,EXRATIO,W,AHPW,OTPCB:LPRINT
15295 IF IDENT$="HP" THEN LPRINT "      NHP    CPHP WELLC    WATTS    EFFHP    DELHP     Q/HP   QMAXHP    % CAP"
15300 IF IDENT$="HP" THEN LPRINT USING "       ##    ####    #####    ###.#     #.##     ##.#     ##.#     ##.#     #.##";NHP,CPHP,WELLC,WATTS,EFFHP,DELHP,Q/NHP,QMAXHP,Q/NHP/QMAX:LPRINT
15305 IF IDENT$="SP" AND PUMP$="E" THEN LPRINT "     NSP     CPSP WELLC STORAGE   QSTORE    LPIPE CPMPIPE ELPOWERC HRPUMP"
15310 IF IDENT$="SP" AND PUMP$="E" THEN LPRINT USING "       ##      ###    #####     #.##    ###.#    #####    ##.##     #.##     ##.#";NSP,CPSP,WELLC,STORAGE,Q*STORAGE,LPIPE,CPMPIPE,ELPOWERC,HRPUMP
15315 IF IDENT$="SP" AND PUMP$="D" THEN LPRINT "     NSP     CPSP WELLC STORAGE   QSTORE    LPIPE CPMPIPE DIESELC   HRPUMP   DSLEFF"
15320 IF IDENT$="SP" AND PUMP$="D" THEN LPRINT USING "       ##      ###    #####     #.##    ###.#    #####    ##.##     #.##     ##.#     #.##";NSP,CPSP,WELLC,STORAGE,Q*STORAGE,LPIPE,CPMPIPE,DIESELC,HRPUMP,DSLEFF:LPRINT
15325 IF IDENT$="SP" AND PUMP$="S" THEN LPRINT "     NSP     CPSP WELLC STORAGE   QSTORE    LPIPE CPMPIPE CPPWATT        I        WP"
15330 IF IDENT$="SP" AND PUMP$="S" THEN LPRINT USING "       ##      ###    #####     #.##    ###.#    #####    ##.##    ##.##       #.#";NSP,CPSP,WELLC.STORAGE,Q*STORAGE,LPIPE,CPMPIPE,CPPWATT,I,WP:LPRINT
15335 IF IDENT$="SP" AND PUMP$="W" THEN LPRINT "     NSP     CPSP WELLC STORAGE   QSTORE    LPIPE CPMPIPE   WMILLC        V"
15340 IF IDENT$="SP" AND PUMP$="W" THEN LPRINT USING "       ##      ###    #####     #.##    ###.#    #####    ##.##     ####       #.#";NSP,CPSP,WELLC,STORAGE,Q*STORAGE,LPIPE,CPMPIPE,WMILLC,V:LPRINT
15345 IF IDENT$="YT" AND PUMP$="E" THEN LPRINT "     NYT     CPYT WELLC STORAGE   QSTORE    LPIPE CPMPIPE      LLAT   CPMLAT     ELPC"
15350 IF IDENT$="YT" AND PUMP$="E" THEN LPRINT USING "      ###      ###    #####     #.##    ###.#    #####    ##.##    #####    ##.##     #.##";NYT,CPYT,WELLC,STORAGE,Q*STORAGE,LPIPE,CPMPIPE,LLAT,CPMLAT,ELPC:LPRINT
15355 IF IDENT$="YT" AND PUMP$="D" THEN LPRINT "     NYT     CPYT WELLC STORAGE   QSTORE    LPIPE CPMPIPE      LLAT   CPMLAT DIESELC"
15360 IF IDENT$="YT" AND PUMP$="D" THEN LPRINT USING "      ###      ###    #####     #.##    ###.#    #####    ##.##    #####    ##.##     #.##";NYT,CPYT,WELLC,STORAGE,Q*STORAGE,LPIPE,CPMPIPE,LLAT,CPMLAT,DIESELC:LPRINT
15365 IF IDENT$="YT" AND PUMP$="S" THEN LPRINT "     NYT     CPYT WELLC STORAGE   QSTORE    LPIPE CPMPIPE      LLAT   CPMLAT CPPWATT       WP"
15370 IF IDENT$="YT" AND PUMP$="S" THEN LPRINT USING "      ###      ###    #####     #.##    ###.#    #####    ##.##    #####    ##.##     #.##   #####";NYT,CPYT,WELLC,STORAGE,Q*STORAGE,LPIPE,CPMPIPE,LLAT,CPMLAT,CPPWATT,WP:LPRINT
15375 IF IDENT$="YT" AND PUMP$="W" THEN LPRINT "     NYT     CPYT WELLC STORAGE   QSTORE    LPIPE CPMPIPE      LLAT   CPMLAT   WMILLC        V"
15380 IF IDENT$="SP" AND PUMP$="W" THEN LPRINT USING "      ###      ###    #####     #.##    ###.#    #####    ##.##    #####    ##.##     ####      #.#";NYT,CPYT,WELLC,STORAGE,Q*STORAGE,LPIPE,CPMPIPE,LLAT,CPMLAT,WMILLC,V:LPRINT
15385 IF IDENT$="HP" THEN LPRINT "      PCC   TOTALC    WELLC    PUMPC"
15390 IF IDENT$="HP" THEN LPRINT USING "  ###.##  ######    #####     ####";PCC,PCC*POP,WELLC,PUMPC:LPRINT
15395 IF IDENT$="SP" AND PUMP$<>"S" THEN LPRINT "      PCC   TOTALC    WELLC    PUMPC     XSPC    STORC    PIPEC"
15400 IF IDENT$="SP" AND PUMP$<>"S" THEN LPRINT USING "  ###.##  ######    #####     ####    #####    #####    #####";PCC,PCC*POP,WELLC,PUMPC,XSPC,STORC,PIPEC:LPRINT
15405 IF IDENT$="YT" AND PUMP$<>"S" THEN LPRINT "      PCC   TOTALC    WELLC    PUMPC      YTC    STORC    PIPEC"
15410 IF IDENT$="YT" AND PUMP$<>"S" THEN LPRINT USING "  ###.##  ######    #####     ####    #####    #####    #####";PCC,PCC*POP,WELLC,PUMPC,YTC,STORC,PIPEC:LPRINT
15415 IF IDENT$="SP" AND PUMP$="S" THEN LPRINT "      PCC   TOTALC    WELLC    PUMPC     XSPC    STORC    PIPEC SOLARPVC"
15418 IF IDENT$="SP" AND PUMP$="S" THEN LPRINT USING "  ###.##  ######    #####     ####    #####    #####    #####    #####";PCC,PCC*POP,WELLC,PUMPC,XSPC,STORC,PIPEC,SOLARPVC:LPRINT
15420 IF IDENT$="YT" AND PUMP$="S" THEN LPRINT "      PCC   TOTALC    WELLC    PUMPC      YTC    STORC    PIPEC SOLARPVC"
15422 IF IDENT$="YT" AND PUMP$="S" THEN LPRINT USING "  ###.##  ######    #####     ####    #####    #####    #####    #####";PCC,PCC*POP,WELLC,PUMPC,YTC,STORC,PIPEC,SOLARPVC:LPRINT
15424 LPRINT "  ANPCCC ANPCOMC  ANPCAC  ANPCEC  ANPCHC  ANPCMC  ANPCTC    PMJC   ANPCC   ANPCB  ANPCNB"
15426 LPRINT USING "   ##.##    ##.##    ##.##    ##.##    ##.##    ##.##    ##.##    ##.##    ##.##    ##.##    ##.##";ANPCCC,ANPCOMC,ANPCAC,ANPCEC,ANPCHC,ANPCMC,ANPCTC,PMJC,ANPCC,ANPCB,ANPCNB:LPRINT:LPRINT:LPRINT
15430 RETURN
18000 REM THIS SECTION IS FOR DIRECTING OUTPUT TO A PRINTER OF DISK DRIVE
```

```
18006 IF (IDENT$="VT") THEN LET PP=FSIZE:PRLPCD=LPCDVT:QUE=0:QMAX=0:PRWELLC=WELLC:T=TVT:PRWC=WCVT
19008 IF PUMPTYPE=1 THEN PUMP$="E"
18010 IF PUMPTYPE=2 THEN PUMP$="D"
18012 IF PUMPTYPE=3 THEN PUMP$="S"
18014 IF PUMPTYPE=4 THEN PUMP$="W"
18016 IF (OUTCHOICE = 1) THEN GOSUB 18200 'OUTOUT SHORT SUMMARY TO LINE PRINTER
18018 IF (OUTCHOICE = 2) THEN GOSUB 18300 'OUTPUT SHORT SUMMARY TO 123 FILE
18020 IF (OUTCHOICE = 3) THEN GOSUB 15250 'OUTPUT DETAILED SUMMARY TO PRINTER
18100 RETURN
18200 REM PRINTING TO LINE PRINTER ########################################
18202 IF OUTCHOICE=2 THEN GOTO 18300
18205 WIDTH "LPT1:",255
18206 LPRINT CHR$(15)
18208 IF PL=PLLL AND SL=SLLL OR looop=2 AND SL=SLLL THEN PRINT "SYSTEM  PUMP  POP  HD   VT   LIFT  WELLC  LPCD";"       ";PLVAR$;"     ";SLVAR$
18210 IF PL=PLLL AND SL=SLLL OR looop=2 AND SL=SLLL THEN LPRINT:LPRINT "SYSTEM  PUMP  POP   HD    PP    VT   LIFT   WELLC   LPCD  HPM3    PCC  ANPCTC   PM3C  ANPCC  ANPCB  ANPCNB";"       ";PLVAR$;"    ";SLVAR$
18212 PRINT "  ";IDENT$;"     ";PUMP$ USING "   #### ## #.##    ## ##### ##.# ####.##   ####.##";POP,HD,VT,LIFT,PRWELLC,LPCD,PL,SL
18214 LPRINT "  ";IDENT$;"     ";PUMP$ USING "   ####   ##   ###   #.##    ##   #####   ##.#  ##.#   ##.##  ##.##  ##.##  ##.##  ##.##   ##.##  ####.##  ####.##";POP,HD,PP,VT,LIFT,PRWELLC,PRLPCD,T,PCC,ANPCTC,PM3C,ANPCC,ANPCB,ANPCNB,P
L,SL,
18216 RETURN
18300 REM PRINTING TO 123 FILE ############################################
18301 IF PL=PLLL AND SL=SLLL OR looop=2 AND SL=SLLL THEN PRINT "SYSTEM  PUMP   POP  HD    VT  LIFT  WELLC  LPCD";"       ";PLVAR$;"      ";SLVAR$
18302 PRINT "  ";IDENT$;"     ";PUMP$ USING "   #### ## #.##    ## ##### ##.# ####.##   ####.##";POP,HD,VT,LIFT,PRWELLC,LPCD,PL,SL
18303 IF PL=PLLL AND SL=SLLL OR looop=2 AND SL=SLLL THEN WRITE #1,"SYS","PT","POP","HD","PP","VT","LIFT","WELLC","LPCD","  T"," PCC","ANPCTC"," PM3C","ANPCC","ANPCB","ANPCNB",PLVAR$,SLVAR$
18304 WRITE #1, IDENT$,PUMP$,POP,HD,PP,VT,LIFT,PRWELLC,PRLPCD,T,PCC,ANPCTC,PM3C,ANPCC,ANPCB,ANPCNB,PL,SL
18310 RETURN
31000 REM SUB FOR HANDPUMPS ONLY CALCUALTIONS ############################
31010 IDENT$="HP" 'SET IDENTIFICATION FOR PRINTING
31015 IF looop=0 THEN 31050
31020 FOR PL = PLLL TO PLUL STEP PLINC
31025 GOSUB 52000 'SELECT VAR FOR PL(PRIMARY looop)
31030 IF looop = 1 THEN GOTO 31050
31040 FOR SL = SLLL TO SLUL STEP SLINC
31042 GOSUB 53000 'SELECT VARIABLE ASSIGNMENT FOR SL
31050 IF (OPTIMIZE$ = "Y") THEN GOSUB 3000:GOTO 31090
31060 GOSUB 2000: GOSUB 2500 'FORMULA ASSIGNMENT
31070 GOSUB 7000 'HAND PUMP COSTS
31080 GOSUB 10000 'HAND PUMP BENEFITS
31090 GOSUB 18000 'FOR PRINTING OUT RESULTS
31095 IF looop=0 THEN RETURN
31100 IF looop=1 THEN GOTO 31120
31110 NEXT SL
31115 REM
31120 NEXT PL
31130 RETURN
31200 REM
32000 REM SUB FOR STANDPIPE CALCULATIONS ############################
32010 IDENT$="SP" 'SET IDENTIFICATION FOR PRINTING
32020 IF looop=0 THEN 32080
32030 FOR PL = PLLL TO PLUL STEP PLINC
32040 GOSUB 52000 'SELECT VAR FOR PL(PRIMARY looop)
32050 IF looop = 1 THEN GOTO 32080
32060 FOR SL = SLLL TO SLUL STEP SLINC
32070 GOSUB 53000 'SELECT VARIABLE ASSIGNMENT FOR SL
32080 IF (OPTIMIZE$ = "Y") THEN GOSUB 3000:GOTO 32130
32090 GOSUB 2000:GOSUB 2500 'FORMULA ASSIGNMENT
32100 GOSUB 40100 'CALCULATE SOURCE COSTS
32110 GOSUB 7500 'CALCULATE CONVEYANCE COSTS PIPE AND CARRY
32120 GOSUB 10500 'STANDPIPE BENEFITS
32130 GOSUB 18000 'FOR PRINTING OUT RESULTS
32140 IF looop=0 THEN RETURN
32150 IF looop=1 THEN GOTO 32180
32160 NEXT SL
32180 NEXT PL
32190 RETURN
```

```
33010 IDENT$="YT" 'SET IDENTIFICATION FOR PRINTING
33020 IF looop=0 THEN 33090
33030 FOR PL = PLLL TO PLUL STEP PLINC
33040 GOSUB 52000 'SELECT VAR FOR PL(PRIMARY looop)
33050 IF looop = 1 THEN GOTO 33090
33060 FOR SL = SLLL TO SLUL STEP SLINC
33070 GOSUB 53000 'SELECT VARIABLE ASSIGNMENT FOR SL
33090 GOSUB 2000:GOSUB 2500 'FORMULA ASSIGNMENT
33100 GOSUB 40100 'CALCULATE SOURCE COSTS
33110 GOSUB 8000 'CALCULATE CONVEYANCE COSTS
33120 GOSUB 11000 'YARD TAP BENEFITS
33130 GOSUB 18000 'FOR PRINTING OUT RESULTS
33140 IF looop=0 THEN RETURN
33150 IF looop=1 THEN GOTO 33180
33160 NEXT SL
33170 REM
33180 NEXT PL
33190 RETURN
34000 REM THIS SECTION EXECUTES THE HANDPUMPS & STANDPIPES RUN
34020 GOSUB 31000 'EXECUTES THE HAND PUMPS SECTION
34030 GOSUB 32000 'EXECUTES THE STANDPIPES SECTION
34050 RETURN
35000 REM THIS SECTION EXECUTES THE HANDPUMPS & YARD TAPS RUN
35020 GOSUB 31000 'EXECUTES THE HAND PUMPS SECTION
35025 LET ANPCHC=0
35030 GOSUB 33000 'EXECUTES THE YARD TAPS SECTION
35050 RETURN
36000 REM THIS SECTION EXECUTES THE STANDPIPES & YARD TAPS RUN
36020 GOSUB 32000 'EXECUTES THE STANDPIPES SECTION
36025 LET ANPCHC=0
36030 GOSUB 33000 'EXECUTES THE YARD TAPS SECTION
36050 RETURN
37000 REM THIS SECTION EXECUTES THE HANDPUMPS & STANDPIPES & YARD TAPS RUN
37020 GOSUB 31000 'EXECUTES THE HAND PUMPS SECTION
37030 GOSUB 32000 'EXECUTES THE STANDPIPES SECTION
37035 LET ANPCHC=0
37040 GOSUB 33000 'EXECUTES THE YARD TAPS SECTION
37060 RETURN
38000 REM THIS IS THE SUBROUTINE FOR TRADEOFF LINES OF NET BENEFIT RATIOS
38050 REM SUBROUTINE FOR NET BENEFIT RATIO CALCULATIONS
38055 LET OPTIMIZE$ = "Y" 'SET OPTIMIZATION FLAG
38060 FOR pairloop =1 TO 3
38065 LET FIRSTIME$ = "Y"
38070 IF pairloop = 1 THEN HPSPFLAG = 1:HPYTFLAG = 0:SPYTFLAG = 0
38080 IF pairloop = 2 THEN HPYTFLAG = 1:HPSPFLAG = 0:SPYTFLAG = 0
38090 IF pairloop = 3 THEN SPYTFLAG = 1:HPSPFLAG = 0:HPYTFLAG = 0
38100 IF looop = 0 THEN GOTO 38150
38110 FOR PL = PLLL TO PLUL STEP PLINC
38120 GOSUB 52000 'SELECT VARIABLE FOR PRIMARY looop
38130 IF looop = 1 THEN GOTO 38150
38140 FOR SL = SLLL TO SLUL STEP SLINC
38145 GOSUB 53000 'SELECT THE SECONDARY looop VARIABLE
38150 GOSUB 12000 'THE SUBROUTINE FOR CALCULATING THE TRADEOFF POINTS
38160 IF looop = 0 THEN GOTO 38210
38170 IF looop = 1 THEN GOTO 38200
38180 NEXT SL
38200 NEXT PL
38210 NEXT pairloop
38220 RETURN
39000 REM THIS IS THE SUBROUTINE FOR SWITCHING VALUES OF NET BENEFITS
39005 PRINT:PRINT
39010 PRINT "DO YOU WISH TO RUN SWITCHING VALUES FOR JUST HANDPUMPS"
39015 PRINT: INPUT "INPUT 1 FOR JUST HP OR 2 FOR ALL THREE";HPSWVAL
39020 IF HPSWVAL >0 AND HPSWVAL <3 THEN GOTO 39055 ELSE PRINT "INVALID INPUT":GOTO 39000
39055 REM SUBROUTINE FOR NET BENEFIT TRADEOFF CALCULATIONS
```

```
39055 LET OPTIMIZE$ = "Y"   [illegible]
39060 FOR pairloop =1 TO 3
39065 LET FIRSTIME$ = "Y"
39070 IF pairloop = 1 THEN IDENT$="HP"
39080 IF pairloop = 2 THEN IDENT$="SP"
39090 IF pairloop = 3 THEN IDENT$="YT"
39100 IF looop = 0 THEN GOTO 39150
39110 FOR PL = PLLL TO PLUL STEP PLINC
39120 GOSUB 52000 'SELECT VARIABLE FOR PRIMARY looop
39130 IF looop = 1 THEN GOTO 39150
39140 FOR SL = SLLL TO SLUL STEP SLINC
39145 GOSUB 53000 'SELECT THE SECONDARY looop VARIABLE
39150 GOSUB 13000 'THE SUBROUTINE FOR CALCULATING THE TRADEOFF POINTS
39160 IF looop = 0 THEN GOTO 39210
39170 IF looop = 1 THEN GOTO 39200
39180 NEXT SL
39200 NEXT PL
39210 IF HPSWVAL = 1 THEN pairloop = 3
39211 NEXT pairloop
39220 RETURN
40000 REM THIS IS THE PROMPTING SECTION FOR TYPE OF SOURCE ************
40005 CLS
40010 PRINT:PRINT
40020 PRINT "YOU HAVE THE FOLLOWING MECHANIZED PUMPING OPTIONS:"
40030 PRINT
40040 PRINT "1----------------ELECTRIC GRID--------1"
40050 PRINT "2----------------DIESEL GENERATOR-----2"
40060 PRINT "3----------------SOLAR PHOTO VOTALIC--3"
40070 PRINT "4----------------WIND MILL------------4"
40075 PRINT:PRINT
40080 INPUT "SELECT 1, 2, 3, OR 4: ";PUMPTYPE
40090 IF (PUMPTYPE > 0) AND (PUMPTYPE < 5) THEN GOTO 40097 ELSE PRINT "INVALID INPUT":GOTO 40080
40097 RETURN
40100 REM VALID INPUT FOR PUMPTYPE ********************************
40110 IF (PUMPTYPE = 1) THEN GOSUB 4500 'ELECTRIC SOURCE
40120 IF (PUMPTYPE = 2) THEN GOSUB 5000 'DIESEL SOURCE
40130 IF (PUMPTYPE = 3) THEN GOSUB 5500 'SOLAR SOURCE
40140 IF (PUMPTYPE = 4) THEN GOSUB 6500 'WIND POWER SOURCE
40160 RETURN
41000 REM THIS IS THE PROMPTING SECTION FOR TYPE OF RUN ************
41005 CLS
41010 PRINT :PRINT
41020 PRINT "YOU HAVE THE FOLLOWING RUN OPTIONS:"
41030 PRINT:PRINT
41035 PRINT "1----------------HANDPUMP ONLY------1"
41040 PRINT "2----------------STANDPIPE ONLY-----2"
41045 PRINT "3----------------YARD TAPS ONLY------3"
41050 PRINT "4----------------HANDPUMPS AND STANDPIPES-----4"
41055 PRINT "5----------------HANDPUMPS AND YARD TAPS ----5"
41060 PRINT "6----------------STANDPIPES AND YARD TAPS ---6"
41065 PRINT "7----------------HANDPUMPS AND STANDPIPES AND YARD TAPS ---7"
41066 PRINT "8----------------OPTIMEZED NET BENEFITS RATIOS -SPECIAL RUN--8"
41067 PRINT "9----------------NET BENEFIT SWITCHING VALUES -SPECIAL RUN--9"
41069 PRINT:PRINT
41070 INPUT "SELECT 1, 2, 3, 4, 5, 6, 7, 8, OR 9: ";RUNCHOICE
41075 IF (RUNCHOICE > 0) AND (RUNCHOICE < 10) THEN GOTO 41080 ELSE PRINT "INVALID INPUT":GOTO 41070
41080 IF (RUNCHOICE = 3) OR RUNCHOICE > 7 THEN RETURN
41081 PRINT:PRINT
41083 PRINT "DO YOU WISH TO OPTIMIZE HANDPUMP/STANDPIPE NET BENEFITS?"
41085 PRINT: INPUT "(Y/N)";OPTIMIZE$
41090 IF OPTIMIZE$ <> "Y" AND OPTIMIZE$ <> "N" THEN PRINT "INVALID INPUT, PLEASE TRY AGAIN":GOTO 41085
41095 RETURN
41100 REM VALID INPUT FOR RUNCHOICE ********************************
41105 PRINT:PRINT "PROCESSING INITIATED":PRINT:PRINT
41110 IF (RUNCHOICE = 1) THEN GOSUB 31000 'HANDPUMP ONLY
```

```
411[illegible] IF (RUNCHOICE = 4) THEN [illegible]
41130 IF (RUNCHOICE = 5) THEN GOSUB 35000 'HANDPUMPS AND YARD TAPS
41135 IF (RUNCHOICE = 6) THEN GOSUB 36000 'STANDPIPES AND YARD TAPS
41140 IF (RUNCHOICE = 7) THEN GOSUB 37000 'HANDPUMPS & STANDPIPES AND YARD TAPS
41145 IF (RUNCHOICE = 8) THEN GOSUB 38000 'EQUALIZED NET BENEFIT RATIOS
41146 IF (RUNCHOICE = 9) THEN GOSUB 39000 'NET BENEFIT SWITCHING VALUES
41160 RETURN
42000 REM SELECT OUTPUT MODE
42010 REM THERE ARE FOR NOW THREE CHOICES
42015 CLS
42030 PRINT:PRINT:PRINT "YOU HAVE THE FOLLOWING OUTPUT CHOICES:"
42040 PRINT:PRINT
42050 PRINT "1 ------------ SUMMARY TO PRINTER  ------------ 1"
42060 PRINT "2 ------------ SUMMARY TO 123 FILE ------------ 2"
42070 PRINT "3 ------------ DETAILS TO PRINTER  ------------ 3"
42080 PRINT:PRINT
42090 INPUT "SELECT OUTPUT CHOICE 1, 2, OR 3: ";OUTCHOICE
42100 IF (OUTCHOICE >=1) AND (OUTCHOICE <4) THEN GOTO 42110 ELSE PRINT "INVALID INPUT PLEASE TRY AGAIN":GOTO 42090
42110 IF (OUTCHOICE = 2) THEN GOTO 42115 ELSE RETURN
42115 INPUT "FOR 123 OUTPUT PLEASE ENTER DRIVE AND FILENAME - B:RUN1.PRN -";F$
42120 OPEN F$ FOR APPEND AS #1 'F$ IS THE DRIVE,FILENAME AND FILETYPE
42130 PRINT:PRINT "YOU MAY ENTER A COMMENT FOR THE FIRST LINE OF THE 123 FILE"
42150 PRINT:INPUT "PLEASE INPUT YOUR COMMENT";CMT123$
42160 WRITE #1,CMT123$
42170 RETURN
45000 REM THIS SUB IS FOR ALLOWING CHANGES IN BASE CASE VARIABLES AND FLAGS
45010 REM TO ALLOW EASIER USE OF THE COMPILED VERSION OF THIS PROGRAM
45020 REM
45035 PRINT:PRINT:PRINT "DO YOU WISH TO SET ANY INDIVIDUAL DEFAULT VARIABLES OR FLAGS?":PRINT
45040 INPUT "(Y/N)";SETVAR$
45050 IF SETVAR$ <> "Y" AND SETVAR$ <> "N" THEN PRINT CHR$(7):CLS:PRINT:PRINT:PRINT "INVALID INPUT, PLEASE ENTER 'Y' OR 'N'.  (USE UPPER CASE ONLY)":PRINT:PRINT:GOTO 45035
45060 IF SETVAR$ ="N" THEN RETURN
45062 CLS
45065 PRINT "LIST OF VARIABLES AND THEIR SETTINGS"
45070 GOSUB 43000
45072 PRINT "PLEASE ENTER THE VARIABLE NAME. (UPPER CASE ONLY)":INPUT "VARIABLE?";SET$
45075 IF SET$ = "OTHER" THEN GOSUB 43500 ELSE GO TO 45080
43350 PRINT "PLEASE ENTER THE VARIABLE NAME. (UPPER CASE ONLY)":INPUT "VARIABLE?";SET$
45080 GO TO 45375
43000 REM THIS SECTION IS FOR DISPLAYING SCREENS OF VARIABLES
43090 PRINT
43130 PRINT " POP=";POP;"-VILLAGE POPULATION"
43135 PRINT " FSIZE=";FSIZE;"-FAMILY SIZE"
43140 PRINT " HD=";HD;" -HOUSING DENSITY"
43145 PRINT " LIFT=";LIFT;" -PUMPING LIFT (M)"
43160 PRINT USING " DISTO=#### -DISTANCE TO OLD SOURCE (M)";DISTO
43170 PRINT " VT=";VT;"-VALUE OF TIME ($/HR)"
43175 PRINT " WELLC=";WELLC;" -WELL COST ($)"
43180 PRINT " NHP=";NHP;"-NUMBER OF HANDPUMPS"
43185 PRINT " NSP=";NSP;"-NUMBER OF STANDPIPES"
43190 PRINT " CPHP=";CPHP;" -COST PER HANDPUMP ($)"
43192 PRINT " CPSP=";CPHP;" -SP + DRAINAGE COST ($/SP)"
43195 PRINT
43200 PRINT " LPCD=";LPCD;"-LPCD AT NEW SOURCE (LPCD)"
43210 PRINT " LPCDO=";LPCDO;" -LPCD AT OLD SOURCE (LPCD)"
43250 PRINT " I=";I;"-DISCOUNT RATE (PERCENT)"
43255 PRINT
43300 PRINT " OTHER- SELECT THIS FOR LIST OF ADDITIONAL VARIABLES
43305 PRINT
43310 PRINT
43370 RETURN
43500 REM THIS SECTION IS FOR OTHER VARIABLES
43505 CLS
43510 PRINT "THIS IS A LIST OF ADDITIONAL VARIABLES"
43520 PRINT
```

```
43530 PRINT [illegible] COST OF MOTORIZED [illegible]
43532 PRINT "*CPMPIPE=";CPMPIPE;"-DISTRIBUTION PIPE ($/M)     CPMLAT=";CPMLAT;"-HOUSE LATERAL PIPE ($/M)"
43534 PRINT USING "*LPIPE=#### -TOTAL DIST PIPE LENGTH (M) *LLAT=#### -LATERAL PIPE LENGTH (M/LAT)";LPIPE;LLAT
43536 PRINT USING "*DISTHP=### -DISTANCE TO HANDPUMP (M)   *DISTSP=### -DISTANCE TO STANDPIPE (M)";DISTHP;DISTSP
43545 PRINT USING "*QUEHP=## -QUEUE TIME AT HP (MIN/TRIP)  *QUESP=## -QUEUE TIME AT SP (MIN/TRIP)";QUEHP;QUESP
43550 PRINT " DELHP=";DELHP;" -DELIVERY OF HP (LITERS/MIN) DELSP=";DELSP;" -DELIVERY OF SP (L/MINUTE)"
43555 PRINT USING " CPYT=### -YT COST INCL. DRAINAGE ($/YT) TYT=### -TIME AT YARD TAP (MINUTES)";CPYT;TYT
43560 PRINT " DIESELC=";DIESELC;"-DIESEL FUEL COST ($/LITER) ELPOWERC=";ELPOWERC;"-ELECTRICITY COST ($/KWH)"
43565 PRINT " LIFEME=";LIFEME;"-LIFE OF MECH EQUIP (YR)     INS=";INS;"-SOLAR INSOLATION (KWH/M2/DAY)"
43570 PRINT " LIFENME=";LIFENME;"-LIFE NON-MECH EQUIP (YR)   CPPWATT=";CPPWATT;"-SOLAR ARRAY COST ($/WP)"
43580 PRINT " OMME=";OMME;"-O&M MECH EQUIP (% CAP COST)   V=";V;"-AVERAGE WIND SPEED (M/SEC)"
43585 PRINT " OMNME=";OMNME;"-O&M NON-MECH EQUIP (% CAP)  WATTS=";WATTS;"-POWER INPUT TO HP (WATTS)"
43595 PRINT " HRPUMP=";HRPUMP;" - HOURS OF PUMPING TIME     *SOLARPVC=";SOLARPVC;"-COST OF PV ARRAYS ($)"
43610 PRINT " DSLEFF=";DSLEFF;" -DIESEL EFFICEINCY (%)    AHPW=";AHPW;"ATTENDANT HOURS PER WEEK"
43620 PRINT " CAPSUB=";CAPSUB;"-CAPITAL SUBSIDY(0=FULL,1=NO) EXRATIO=";EXRATIO;"-NET BEN RATIO (OPTION 8)"
43630 PRINT " OTPCB=";OTPCB;" -OTHER PER CAPITA BENEFITS ($/CAP/YEAR)"
43640 PRINT
43645 PRINT "                        (*) NORMALLY CALCULATED BUT CAN BE SET"
43650 PRINT
43660 RETURN
45375 REM THIS SECTION IS FOR SELECTING AND SETTING THE CHOSEN VARIABLES
45376 REM
45380 IF SET$="POP" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR POP?";POP:POPFLAG = 1:GOTO 45020
45390 IF SET$="VT" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR VT PRINT";VT:VTFLAG = 1:GOTO 45020
45400 IF SET$="HD" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR HD?";HD:HDFLAG = 1:GOTO 45020
45402 IF SET$="FSIZE" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR FSIZE";FSIZE:FSIZEFLAG = 1:GOTO 45020
45420 IF SET$="LIFT" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR LIFT?";LIFT:LIFTFLAG = 1:GOTO 45020
45430 IF SET$="I" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR I?";I:IFLAG = 1:GOTO 45020
45440 IF SET$="LPCD" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR LPCD";LPCD:LET LPCDFLAG = 1:GOTO 45020
45442 IF SET$="OTPCB" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR OTPCB";OTPCB:OTPCBFLAG = 1:GOTO 45020
45450 IF SET$="LIFEME" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR LIFEME";LIFEME:LIFEMEFLAG = 1:GOTO 45020
45452 IF SET$="LIFENME" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR LIFENME";LIFENME:LIFENMEFLAG = 1:GOTO 45020
45470 IF SET$="HRPUMP" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR HRPUMP";HRPUMP:HRPUMPFLAG = 1:GOTO 45020
45490 IF SET$="V" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR V";V:VFLAG = 1:GOTO 45020
45500 IF SET$="QUEHP" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR QUEHP";QUEHP:QUEFLAG = 1:GOTO 45020
45505 IF SET$="QUESP" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR QUESP";QUESP:QUEFLAG = 1:GOTO 45020
45510 IF SET$="ELPOWERC" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR ELPOWERC";ELPOWERC:ELPOWERCFLAG = 1:GOTO 45020
45530 IF SET$="DIESELC" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR DIESELC";DIESELC:DIESELCFLAG = 1:GOTO 45020
45532 IF SET$="DELHP" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR DELHP";DELHP:DELFLAG= 1:GOTO 45020
45533 IF SET$="DELSP" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR DELSP";DELSP:DELFLAG= 1:GOTO 45020
45534 IF SET$="OMME" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR OMME";OMME:OMMEFLAG = 1:GOTO 45020
45540 IF SET$="CPHP" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR CPHP";CPHP:CPHPFLAG = 1:GOTO 45020
45542 IF SET$="CPSP" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR CPSP";CPSP:CPSPFLAG = 1:GOTO 45020
45544 IF SET$="CPYT" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR CPYT";CPYT:CPYTFLAG = 1:GOTO 45020
45546 IF SET$="INS" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR INS";INS:INSFLAG = 1:GOTO 45020
45550 IF SET$="OMNME" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR OMNME";OMNME:OMNMEFLAG = 1:GOTO 45020
45560 IF SET$="DISTO" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR DISTO";DISTO:DISTOFLAG = 1:GOTO 45020
45570 IF SET$="WATTS" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR WATTS";WATTS:LET WATTSFLAG = 1:GOTO 45020
45580 IF SET$="DISTHP" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR DISTHP";DISTHP:LET DISTFLAG =1:GOTO 45020
45582 IF SET$="DISTSP" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR DISTSP";DISTSP:LET DISTFLAG =1:GOTO 45020
45592 IF SET$="NHP" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR NHP";NHPSET:LET NHPSETFLAG = 1:LET NHP=NHPSET:GOTO 45020
45594 IF SET$="NSP" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR NSP";NSPSET:LET NSPSETFLAG = 1:LET NSP=NSPSET:GOTO 45020
45595 IF SET$="EXRATIO" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR EXRATIO";EXRATIO:EXRATIOFLAG = 1:GOTO 45020
45600 IF SET$="CAPSUB" THEN INPUT "PLEASE ENTER THE NEW VALUE FOR CAPSUB";CAPSUB:CAPSUBFLAG = 1:GOTO 45020
45682 IF SET$="BCSTORAGE" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR BCSTORAGE";BCSTORAGE:BCSTORAGEFLAG = 1:GOTO 45020
45684 IF SET$="CPPWATT" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR CPPWATT";CPPWATT:CPPWATTFLAG = 1:GOTO 45020
45685 IF SET$="WMILLC" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR WMILLC";WMILLC:WMILLCFLAG = 1:GO TO 45020
45686 IF SET$="CPMLAT" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR CPMLAT";CPMLAT:CPMLATFLAG = 1:GOTO 45020
45688 IF SET$="CPMPIPE" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR CPMPIPE";CPMPIPE:CPMPIPEFLAG = 1:GOTO 45020
45690 IF SET$="STORLIFT" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR FRICTION LOSS + STORAGE LIFT";STORLIFT:STORLIFTFLAG=1:GOTO 45020
45691 IF SET$="STORAGE" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR STORAGE (STORAGE VOLUME/Q)";STORAGE:STORAGEFLAG=1:GOTO 45020
45692 IF SET$="DSLEFF" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR DSLEFF (DIESEL EFFIC)";DSLEFF:DSLEFFFLAG=1:GOTO 45020
45693 IF SET$="AHPW" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR AHPW (ATTENDANT HOURS PER WEEK)";AHPW:AHPWFLAG=1:GOTO 45020
45694 IF SET$="TYT" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR TYT (TIME AT YARD TAP)";TYT:TYTFLAG=1:GOTO 45020
45695 IF SET$="LPCDO" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR LPCDO (OLD SOURCE LPCD)";LPCDO:LPCDOFLAG=1:GOTO 45020
```

```
45698 IF SET$="SOLARPVC" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR FRICTION LOSS + STORAGE LIFT";SOLARPVC:SOLARPVCFLAG=1:GOTO 45020
45699 IF SET$="LPIPE" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR FRICTION LOSS + STORAGE LIFT";LPIPE:LPIPEFLAG=1:GOTO 45020
45700 IF SET$="STORC" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR FRICTION LOSS + STORAGE LIFT";STORC:STORCFLAG=1:GOTO 45020
45701 IF SET$="LLAT" THEN INPUT "PLEASE INPUT THE NEW VALUE FOR FRICTION LOSS + STORAGE LIFT";LLAT:LLATFLAG=1:GOTO 45020
45710 REM
45720 CLS:PRINT:PRINT:PRINT "UNABLE TO FIND YOUR VARIABLE, PLEASE TRY AGAIN."
45730 PRINT CHR$(7):GOTO 45035
50170 REM
50200 REM THIS SUBROUTINE IS FOR CHOOSING THE THE TYPE OF LOOPING
50202 REM SELECT NO LOOPING, PRIMARY LOOPING, OR SECONDARY LOOPING
50205 PRINT:PRINT
50207 CLS
50208 PRINT:PRINT
50210 PRINT "SELECT THE TYPE OF LOOPING YOU WISH"
50215 PRINT:PRINT
50230 PRINT "0----------------NO LOOPING"
50240 PRINT "1----------------SINGLE LOOPING"
50260 PRINT "2----------------DOUBLE LOOPING"
50262 PRINT:PRINT
50270 INPUT "SELECT  0, 1, OR 2: ";looop
50275 IF looop=0 THEN RETURN
50280 IF (looop>0) AND (looop <3) THEN GOTO 50500 ELSE PRINT "INVALID INPUT PLEASE TRY AGAIN":GOTO 50270
50500 REM "SPECIFY THE PRIMARY LOOPING VARIABLE"
50510 CLS
50515 PRINT "THIS IS A LIST OF THE VARIABLES FOR LOOPING AND THEIR CURRENT VALUES"
50516 GOSUB 43000 'DISPLAY FIRST SCREEN OF VARIABLES
50630 PRINT
50650 INPUT "SELECT ONE OF THE ABOVE VARIABLES FOR PRIMARY LOOP: ";PLVAR$
50652 IF PLVAR$="OTHER" THEN GOSUB 43500 ELSE GO TO 50660
50654 INPUT "SELECT ONE OF THE ABOVE VARIABLES FOR PRIMARY LOOP: ";PLVAR$
50660 INPUT "SELECT LOWER LIMIT: ";PLLL
50670 INPUT "SELECT UPPER LIMIT: ";PLUL
50680 INPUT "SELECT INCREMENT:   ";PLINC
50690 IF looop=1 THEN RETURN
51500 REM "SPECIFY THE SECONDARY LOOPING VARIABLE"
51510 CLS
51515 PRINT "THIS IS A LIST OF THE VARIABLES FOR LOOPING AND THEIR CURRENT VALUES"
51520 GOSUB 43000 ' DISPLAY THE FIRST SCREEN OF VARIABLES
51530 PRINT
51558 INPUT "SELECT ONE OF THE ABOVE VARIABLES FOR SECONDARY LOOP: ";SLVAR$
51652 IF SLVAR$ = PLVAR$ THEN PRINT "SECONDARY LOOP MUST BE DIFFERENT THAN PRIMARY LOOP PLEASE TRY AGAIN": GOTO 51558
51154 IF SLVAR$="OTHER" THEN GOSUB 43500 ELSE GO TO 51660
51156 INPUT "SELECT ONE OF THE ABOVE VARIABLES FOR SECONDARY LOOP: ";SLVAR$
51660 INPUT "SELECT LOWER LIMIT: ";SLLL
51670 INPUT "SELECT UPPER LIMIT: ";SLUL
51680 INPUT "SELECT INCREMENT:   ";SLINC
51690 RETURN
52000 IF PLVAR$ = "POP" THEN POP = PL:POPFLAG = 1:RETURN
52010 IF PLVAR$ = "VT" THEN VT = PL:VTFLAG = 1:RETURN
52020 IF PLVAR$ = "HD" THEN HD = PL:HDFLAG = 1:RETURN
52022 IF PLVAR$ = "FSIZE" THEN FSIZE = PL: FSIZEFLAG = 1:RETURN
52040 IF PLVAR$ = "LIFT" THEN LIFT = PL:LIFTFLAG = 1:RETURN
52050 IF PLVAR$ = "I" THEN I = PL:LET I = I/100:IFLAG=1:RETURN
52060 IF PLVAR$ = "LPCD" THEN LPCD = PL:LET LPCDFLAG = 1:RETURN
52062 IF PLVAR$ = "OTPCB" THEN OTPCB = PL:OTPCBFLAG = 1:RETURN
52070 IF PLVAR$ = "LIFEME" THEN LIFEME = PL:LIFEMEFLAG = 1:RETURN
52072 IF PLVAR$ = "LIFENME" THEN LIFENME = PL:LIFENMEFLAG = 1:RETURN
52090 IF PLVAR$ = "HRPUMP" THEN HRPUMP = PL:HRPUMPFLAG = 1:RETURN
52110 IF PLVAR$ = "V" THEN V = PL:VFLAG = 1:RETURN
52120 IF PLVAR$ = "QUEHP" THEN QUEHP = PL:LET QUEFLAG = 1:RETURN
52130 IF PLVAR$ = "ELPOWERC" THEN ELPOWERC = PL:ELPOWERCFLAG = 1:RETURN
52140 IF PLVAR$ = "QUESP" THEN QUESP = PL:LET QUEFLAG =1:RETURN
52150 IF PLVAR$ = "DIESELC" THEN DIESELC = PL:DIESELCFLAG = 1:RETURN
52160 IF PLVAR$ = "DISTHP" THEN DISTHP = PL:LET DISTFLAG = 1:RETURN
```

```
52155 IF PLVAR$ = "C[illegible]" THEN C[illegible] = PL:C[illegible]FL[illegible] = 1:[illegible]
52157 IF PLVAR$ = "CPSP" THEN CPSP = PL:CPSPFLAG = 1:RETURN
52159 IF PLVAR$ = "CPYT" THEN CPYT = PL:CPYTFLAG = 1:RETURN
52170 IF PLVAR$ = "OMNME" THEN OMNME = PL:LET OMNME = OMNME/100:OMNMEFLAG = 1:RETURN
52172 IF PLVAR$ = "OMME" THEN OMME = PL:LET OMME = OMME/100:OMMEFLAG = 1:RETURN
52180 IF PLVAR$ = "DISTO" THEN DISTO = PL:DISTOFLAG = 1:RETURN
52182 IF PLVAR$ = "WATTS" THEN WATTS = PL:LET WATTSFLAG = 1:RETURN
52187 IF PLVAR$ = "NHP" THEN NHPSET = PL:LET NHPSETFLAG = 1:RETURN
52188 IF PLVAR$ = "NSP" THEN NSPSET = PL:LET NSPSETFLAG = 1:RETURN
52189 IF PLVAR$ = "CAPSUB" THEN LET CAPSUB = PL:CAPSUBFLAG = 1:RETURN
52190 IF PLVAR$ = "EXRATIO" THEN EXRATIO = PL:EXRATIOFLAG = 1:RETURN
52195 IF PLVAR$ = "CPMLAT" THEN CPMLAT = PL:CPMLATFLAG = 1:RETURN
52200 IF PLVAR$ = "CPMPIPE" THEN CPMPIPE = PL:CPMPIPEFLAG= 1:RETURN
52210 IF PLVAR$ = "BCSTORAGE" THEN BCSTORAGE = PL:BCSTORAGEFLAG = 1:RETURN
52220 IF PLVAR$ = "CPPWATT" THEN CPPWATT = PL:CPPWATTFLAG = 1:RETURN
52230 IF PLVAR$ = "WMILLC" THEN WMILLC = PL: WMILLCFLAG = 1:RETURN
52235 IF PLVAR$ = "INS" THEN INS = PL: INSFLAG = 1: RETURN
52240 IF PLVAR$ = "STORLIFT" THEN STORLIFT = PL: STORLIFTFLAG = 1:RETURN
52241 IF PLVAR$ = "STORAGE" THEN STORAGE = PL: STORAGEFLAG = 1:RETURN
52242 IF PLVAR$ = "DSLEFF" THEN DSLEFF = PL: DSLEFFFLAG = 1:RETURN
52243 IF PLVAR$ = "AHPW" THEN AHPW = PL: AHPWFLAG = 1:RETURN
52244 IF PLVAR$ = "TYT" THEN TYT = PL: TYTFLAG = 1:RETURN
52245 IF PLVAR$ = "LPCDO" THEN LPCDO = PL: LPCDOFLAG = 1:RETURN
52246 IF PLVAR$ = "WELLC" THEN WELLC = PL: WELLCFLAG = 1:RETURN
52247 IF PLVAR$ = "PUMPC" THEN PUMPC = PL: PUMPCFLAG = 1:RETURN
52248 IF PLVAR$ = "STORC" THEN STORC = PL: STORCFLAG = 1:RETURN
52249 IF PLVAR$ = "SOLARPVC" THEN SOLARPVC = PL: SOLARPVCFLAG = 1:RETURN
52250 IF PLVAR$ = "LPIPE" THEN LPIPE = PL: LPIPEFLAG = 1:RETURN
52251 IF PLVAR$ = "LLAT" THEN LLAT = PL: LLATFLAG = 1:RETURN
52252 PRINT "MATCHING VARIABLE FOR PRIMARY LOOP NOT FOUND":GOTO 411
52300 RETURN
53000 IF SLVAR$ = "PDP" THEN PDP = SL:PDPFLAT = 1:RETURN
53010 IF SLVAR$ = "VT" THEN VT = SL:VTFLAG = 1:RETURN
53020 IF SLVAR$ = "HD" THEN HD = SL:HDFLAG = 1:RETURN
53022 IF SLVAR$ = "FSIZE" THEN FSIZE = SL:FSIZEFLAG = 1:RETURN
53040 IF SLVAR$ = "LIFT" THEN LIFT = SL:LIFTFLAG = 1:RETURN
53050 IF SLVAR$ = "I" THEN I = SL:LET I = I/100:IFLAG=1:RETURN
53060 IF SLVAR$ = "LPCD" THEN LPCD = SL:LET LPCDFLAG = 1:RETURN
53062 IF SLVAR$ = "OTPCB" THEN OTPCB = SL:OTPCBFLAG = 1:RETURN
53070 IF SLVAR$ = "LIFEME" THEN LIFEME = SL:LIFEMEFLAG = 1:RETURN
53072 IF SLVAR$ = "LIFENME" THEN LIFENME = SL:LIFENMEFLAG = 1:RETURN
53090 IF SLVAR$ = "HRPUMP" THEN HRPUMP = SL:HRPUMPFLAG = 1:RETURN
53110 IF SLVAR$ = "V" THEN V = SL:VFLAG = 1:RETURN
53120 IF SLVAR$ = "QUEHP" THEN QUEHP = SL:LET QUEFLAG = 1:RETURN
53130 IF SLVAR$ = "ELPOWERC" THEN ELPOWERC = SL:ELPOWERCFLAG = 1:RETURN
53140 IF SLVAR$ = "QUESP" THEN QUESP = SL:LET QUEFLAG =1:RETURN
53150 IF SLVAR$ = "DIESELC" THEN DIESELC = SL:DIESELCFLAG = 1:RETURN
53155 IF SLVAR$ = "CPHP" THEN CPHP = SL:CPHPFLAG = 1:RETURN
53157 IF SLVAR$ = "CPSP" THEN CPSP = SL:CPSPFLAG = 1:RETURN
53159 IF SLVAR$ = "CPYT" THEN CPYT = SL:CPYTFLAG = 1:RETURN
53160 IF SLVAR$ = "DISTHP" THEN DISTHP = SL:LET DISTFLAG = 1:RETURN
53165 IF SLVAR$ = "DISTSP" THEN DISTSP = SL:LET DISTFLAG = 1:RETURN
53170 IF SLVAR$ = "OMNME" THEN OMNME = SL:LET OMNME = OMNME/100:OMNMEFLAG = 1:RETURN
53172 IF SLVAR$ = "OMME" THEN OMME = SL:LET OMME = OMME/100:OMMEFLAG = 1:RETURN
53180 IF SLVAR$ = "DISTO" THEN DISTO = SL:DISTOFLAG = 1:RETURN
53182 IF SLVAR$ = "WATTS" THEN WATTS = SL:LET WATTSFLAG = 1:RETURN
53187 IF SLVAR$ = "NHP" THEN NHPSET = SL:LET NHPSETFLAG = 1:RETURN
53188 IF SLVAR$ = "NSP" THEN NSPSET = SL:LET NSPSETFLAG = 1:RETURN
53189 IF SLVAR$ = "CAPSUB" THEN LET CAPSUB = SL:CAPSUBFLAG = 1:RETURN
53190 IF SLVAR$ = "EXRATIO" THEN EXRATIO = SL:EXRATIOFLAG = 1:RETURN
53195 IF SLVAR$ = "CPMLAT" THEN CPMLAT = SL:CPMLATFLAG = 1:RETURN
53200 IF SLVAR$ = "CPMPIPE" THEN CPMPIPE = SL:CPMPIPEFLAG= 1:RETURN
53210 IF SLVAR$ = "BCSTORAGE" THEN BCSTORAGE = SL:BCSTORAGEFLAG = 1:RETURN
53220 IF SLVAR$ = "CPPWATT" THEN CPPWATT = SL:CPPWATTFLAG = 1:RETURN
53230 IF SLVAR$ = "WMILLC" THEN WMILLC = SL: WMILLCFLAG = 1:RETURN
```