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Estimating costs of small scale water supply interventions

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INTRODUCTION

Within the scope of this Guide, the main objective of this chapter is to explain a basic approach to estimating financial costs of installing, maintaining and operating a small scale drinking water supply. After assigning shadow prices to certain costs as appropriate, the outcome of such an estimate can then be used, with the estimates of the total benefits derived from water improvements, to select the best improvement or intervention for a given target group in the context of their livelihood patterns, by comparing rates of return.

Costing is one step in the economic assessment of water supply projects and an economic assessment is one part of the full set of information (economic, environmental, health, social, technical assessments and feasibility studies) likely to be used by decision makers in selecting the specifications of the system to implement. In the context of this chapter, the costing method proposed is not intended to provide guidance on full economic valuation of the costs, but rather to provide a financial input into a cost-effectiveness or social cost-benefit analysis of small scale water supply improvements. In a broader sense, costing is an essential element of any economic analysis that may involve modifying financial costs through the assignment of shadow prices to reflect true economic value.

At this point in the process, the aim is to identify the *financial* costs. The description of the costing method in this chapter therefore aims at providing an incremental price in present-day monetary terms (year zero) of water supply technology providing water to a community against which the derived benefits could be measured, so that informed decisions can be made. Information on full economic costing can be found in the WHO publication, *Costing Improved Water Supply Systems for Low-income Communities, A Practical Manual*, developed by the Department of Econometrics (DE), Faculty of Economic and Social Sciences, University of Geneva (UNIGE) (Carlevaro and Gonzalez 2008).

The present Guide is describes the method of social cost-benefit analysis for use at a national level (though sensitive to local livelihood patterns), with the intention that it can be used by non-specialists and specialists alike. So to keep the presentation accessible to all readers, costing of items that are incurred for activities at national level or are indirect outcomes at national or local level are not dealt with in this chapter. These are costs such as *external environmental costs,* which arise out of local environmental damage or protection, *opportunity costs* which value the forgone benefits of diverting raw water from productive activities like agriculture (both with significant livelihood implications), to non-productive ones like *basic domestic uses*, and *depletion premiums* which value the loss of water supplies from difficult-to-replenish sources, or a *share of overhead costs* that are needed to run national regulatory and laboratory facilities.

The approach followed in this chapter to estimate the *use costs* of a water supply intervention such as costs for construction, operation, maintenance, direct administration and overheads. It provides an insight into simple and effective costing that a specialist would use and which a non-specialist at national as well as local level would understand. In practice, costing preferably should be done at the service provider level e.g., a regional water management body or at lower levels, a district authority. The costing could, depending on local capabilities, also be done by the end-user target group or a local NGO.

Costing a system locally implies that a water service provider i.e. a district authority, or a local user group, decides to invest in improved infrastructure (i.e., storage and treatment facilities and a distribution network). After constructing and activating the system, the service provider then continues to spend money on the system for operation, maintenance, future rehabilitation, administration, training, promotion and education (e.g. energy and chemicals use), and has to make sure that these expenses are covered by some form of income (standing charges, consumption rates or subsidy). The main objective of the service provider might not be to make a profit, but to provide an economically efficient water service that can also provide benefits in improving the target group's livelihoods. The purpose of a cost estimate in this situation is therefore to assist decision makers responsible for the provision of services with a reliable financial value for providing improved drinking water supply technologies.

Chapter 6 describes the differences in quantities or quality of services that characterize small water system technologies. A useful characteristic of small systems is that they can allow for incremental improvement as the target group's needs change over time, perhaps as a result of population growth or move from standpipe to in-house provision. This may lead to a decision to initially choose the most affordable system (least-cost system) with the intention to incrementally adapt the system's capacity to fit the needs or financial capabilities of a growing population. A practical costing approach must allow for this incremental costing as well.

This chapter discusses the methods and procedures for costing a small water system in three sections. Firstly, the implications of installing a small water system intervention are addressed, be it in the form of putting in a system where there wasn't one before, or upgrading an existing system. Secondly, a brief discussion follows on the various types of financial costs that will be encountered in the process of costing a small water system, and lastly a simplified costing approach is presented to reliably estimate a pattern of costs of systems that allows for costing across time should a system be incrementally adapted.

IMPLICATIONS OF COSTING A SMALL WATER SYSTEM INTERVENTION

The local costing an intervention system may be done for a new system or for upgrading an existing water supply system to a more sophisticated system. Costing a *new system* for an area where there is none at first might be quite complicated as it takes place in the early planning stages before the actual construction begins to take shape. Especially costing of the initial stage of a project to install a water system will potentially have large inaccuracies. One reason for this is that relatively little is known during the initial stage (configuration of the treatment scheme, specific construction demands, and local conditions). Another reason is that many things can and will change during subsequent designs. This all requires great understanding and integration of three critical aspects i.e. the service provider must have a good idea of what *type of intervention* (i.e. system) might potentially be installed e.g. the intervention types in Chapter 6 will provide a good idea.

With this in mind, the *layout* of the system must be determined (relative positions and elevations of source, storage and pipe network configuration) and then the elements of the potential system must be *sized.* Only then can the costing of the intended system commence. While costing can be done in great detail to cover for these uncertainties, this will require a high level of collaboration between service providers and engineering planners. It should therefore preferably be done by such specialists.

For detailed information, including comprehensive checklists, reference is made to the Practical Manual by Carlevaro and Gonzalez (2008).

Costing an *upgrading* of an existing system is more readily attempted by specialists or non-specialists alike because of the fewer degrees of freedom (or uncertainty).

After following these preceding steps described above, estimating the approximate cost of a small water supply system can start, usually with estimating the investment or *capital* costs. However, the service provider should look at the complete picture and costing therefore has to be extended to include *recurrent* (operation and maintenance) costs. This second component is absolutely vital to predicting what the *sustainable operation* of the system is going to cost the service provider once the system is built. If this is neglected, the intervention will be short lived and the benefits often negated before they were accrued. This will be discussed further in the next section.

Cost estimation necessarily requires a large number of inputs. In order to simplify the data collection and preparation steps, a three-tier data structure is required. The first data category captures the *engineering* parameters, which would typically include technical specifications such as pump and motor efficiencies, as well as pipe friction coefficients, which are not likely to vary significantly anywhere in the world. Data for these parameters should only be measured by those with an engineering background with the capacity to provide a sound technical judgement based on experience. The second data category captures the *monetary* parameters, which would typically include the cost of pumps, pipes, holding tanks, fuel and electricity, as well as the ratio between the costs of labour and materials for system construction. These parameters will be fairly constant for any particular economic zone. Once these parameters have been calibrated for a particular region, they can be left unchanged while different water supply systems within the region are analysed. The third data category captures the *system* parameters, which will typically include pipe types, diameters and lengths, storage tank volumes and the number of standpipes. These parameters are unique to each water supply system, and have to be determined on site or from engineering drawings.

TYPES OF COSTING

Costs by definition consist of all resources required to put in place and maintain the intervention. These include capital costs (investment in planning, preparing, construction, purchase of hardware) and recurrent costs (operation, maintenance and monitoring). The cost of a small water supply system usually includes capital as well as recurrent costs in each of the usual activities of a water supply i.e. source, treatment, pumping, storage and distribution. The costing method must be robust and it will need to provide reliable estimates by aggregating collections of physical parts of a water supply activity into single units of cost. An example is the estimation of the initial costs of water treatment for a new / improved system. To get started, cost-functions can be used that are based on previously completed projects for which there must be several examples in any country. Often in such functions, the design capacity is typically included as a variable e.g. cost per m^3 of treated water and this will give the planner a good estimate of the cost of water treatment for a village of X number of people consuming Y litres of water per person per day (ℓ/c/d).

While this example is simplistic and robust, the costing model at the end of the chapter is more refined but is still based on this approach.

Capital costs

Formally defined, capital goods is the stock of goods which are man-made and used in production (as opposed to consumtion). Fixed capital goods (durable goods such as buildings and machinery) are usually distinguished from circulating capital goods (stocks of raw materials and semi-finished goods which are rapidly used up). Capital costs are the costs incurred by emplying capital goods. In accounting conventions, capital goods are usually taken as those with a life of more than one year, such as land, buildings and equipment.

In the context of developing and installing a small water system the capital costs represent, therefore, the total costs that are not expected to recur for significant periods of time. These are costs for the preparation and construction of the system through to the moment that the system becomes operational. From that moment on, the system must be operated and maintained towards the optimal benefit expected from the intervention i.e. the O&M costs. Capital costs can also occur during the operational lifetime of the system. Examples include expansion of the system and replacement of major (high-cost) parts.

Capital costs usually include those costs related to the *construction* and *equipment* activities of installing the new system. These costs flow from the *preliminary studies,* which are conducted during the pre-investment (e.g. planning) stage and involve the study of the technical, economical, social, environmental and health aspects in the construction project.

A drinking water system consists of a variety of *fixed (constructed) installations* like filter units, clear water reservoirs, pipes etc. Depending on the size of the system, these construction activities might include office and sanitary facilities for the staff of the new treatment facility and / or a workshop and maybe a small laboratory with facilities for the maintenance personnel. Besides these costs, the furnishing of staff facilities, workshop and a laboratory is part of the capital costs. The project requires *equipment,* which will be a capital cost in items such as pumps and power systems. *Materials* are needed to complete the construction including materials bought or acquired by the community or the municipality in the local markets of the country as well as imported materials.

The *workforce* for the construction can be specialists such as engineers, constructors, technical staff, and social science professionals. It will also include non-qualified workers that work in excavation, cleaning, etc. These can be the people from the local community. Lastly, semi-qualified workers will be required - generally a type of worker between qualified and non-qualified. This will depend on the work activity.

Other capital costs will be related to management of the project, administration, direction, coordination, logistic, transportation, communications, office costs, private executors and control of quality, and any other unassigned cost of the project. *Contingency* costs are an amount or percentage of the total capital costs included in a project account to allow for adverse conditions that will add to the basic costs.

A cost which will often be encountered that should be seen as part of the capital costs will be the *acquisition of land* that might be required for components of the system e.g. the site for the treatment facility, land covered by water when a surface source such as a stream or river is impounded.

Provision must also be made for *overheads and supervision*. Once all the *capital* investment costs have been estimated, their sum will reflect the *net construction cost*. A contractor, be it the villagers themselves or outsiders, might add a surcharge to allow for site establishment, site clearing, supervision, profit, etc, which are all allowed for by adding an additional percentage to the net construction cost. (A typical surcharge for contracts in rural South Africa is 25%.) This then add up to form the *total contract cost*. For a new water supply system, the client has to also bear the costs of planning, surveying, soil investigation, possibly exploratory drilling, contract management, quality control, etc. These design and supervision costs, paid to consulting engineers or borne by the client's own design staff, amount to an additional surcharge (about 25% over and above the total contract value) to finally determine the *total project cost*.

Recurrent costs

These costs comprise all expenditures (staff, parts and materials) that are required to keep a system *operational* and in good condition (*maintenance*) after its installation was completed, including certain *fixed costs*, which, depending on the finance policy of the service provider, need to be provided for on an annual basis. An example of this is the creation of a replacement fund through annual depreciation levies. Monitoring of the system can be an operational function or could be a regulatory function to ensure the quality of the water supply to the community. It has a cost that can become part of the recurrent costs as a separate item or part of O&M costs, depending on the need and the extent of the system. This illustrates a very important point in the context of costing. For small systems management it is often the case that maintenance costs are budgeted for annually at the service provider level, which is usually a tier above local community level. Operational costs are usually budgeted for at the local level.

The *maintenance costs* contain all costs for the repair and replacement of parts of installations (e.g. pumps or repairing wells) within the predicted lifetime of the small water supply system, as far as these are not included in the operational cost. Effective maintenance is the key to sustainability of a system but is often neglected in terms of its effective execution, rendering many small systems ineffective not long after their inception.

In general *operational costs* are considered to be mostly costs for acquiring and administering *consumables* such as energy, process water and chemicals, as well as disposing of waste. These consumables do not include general maintenance materials such as paint, lubricating oil, and tools as these should included in the maintenance costs.

Fixed costs are costs incurred by obligations towards the financing and replacement aspects of the system. It includes interest, depreciation and replacement, rents, assurances and taxes. Depreciation is a particularly important aspect of fixed costs for this approach can allow for the build-up of funds to replace especially larger pieces of equipment and parts in the system i.e. pipes. Depreciation is way to earn back, from annual income, costs incurred on the system during construction. Depreciation periods for a water system are relatively long. On one hand, the technical facilities should last a relatively long time (buildings and pipes); on the other hand, incomes from water sales and subsidies should be realised during the entire depreciation period. While the depreciation period preferably equals the expected actual technical life time of the system, the depreciation periods are not necessarily equal for all the components of the system. Buildings, machines, distribution network, inventories all have different life times. Therefore, the costs for funding the replacement reserves have to be determined separately for each component.

Lastly, *monitoring, surveillance* and *training* are also mainly operational costs. These activities are required to continuously assess and maintain the quality of the water of the source as well as during and after treatment and distribution. They require skilled human resources, laboratory facilities and training facilities, vehicles and sampling equipment. Some of these activities might require an initial *capital* investment such as on-site monitoring systems. A significant cost component of all these activities can be travel costs. Travel might be required to and from monitoring points, remote training sessions and facilities. While not conventional, costs for monitoring and assessing the process of livelihood changes attributable to the intervention i.e. social behavioural change, education and promotion, might also be incurred. A cost component that might occur is the cost of *water corruption*. This activity is where people illegally gain access to the distribution of the water supply such as illegal and unmetered connections or inequity in distribution.

ESTIMATING COSTS FOR A SMALL WATER SYSTEM

Three costing types exist for small water supply interventions. A service provider might want to 1) do a direct costing, or 2) estimate the costs as part of a cost-effectiveness analysis. This chapter is about 3) estimating the costs as part of a social cost-benefit analysis.

For guidance on direct costing, a detailed process of costing can be found in the WHO publication, *Costing Improved Water Supply Systems for Low-income Communities, A Practical Manual* (Carlevaro and Gonzalez, 2008).

The approach by Clasen et al. (2007) on *The cost-effectiveness of water quality interventions for preventing diarrhoeal disease in developing countries* can be followed to estimate intervention costs for a cost effectiveness analysis.

Estimates for cost-benefit analyses need not be as detailed as the former. They can be simple *unit costs* as shown in Table 1 later on. The unit cost approach provides flexibility when a service provider wishes to estimate whether costs to install a new or upgrade an existing system are cost-beneficial.

Unit costs are robust cost estimations of a system that include *capital costs* as well as *recurrent* costs. Data can be obtained from local sources, in particular from country-specific cost summaries of previously installed schemes.

This section has three parts. Firstly, the costs incurred by *preliminary* requirements to developing and installing a system. Then, costs of each *activity* usually included in a small system are discussed. Lastly, a tabled summary (Table 1) of unit costs is provided and the calculation of unit costs briefly discussed. This section therefore aims at informing the reader about the full costing process that eventually allows for a unit cost (e.g. cost per volume unit) to be estimated.

Preliminary requirements

Costing can only begin after the physical system details are known (refer to the earlier section on the implications for costing). For planned systems, an inventory has to be developed to the point where specific system components have been clearly identified, e.g. pipe lengths and diameter, storage tank positions and sizes, etc.. For existing systems, the convenient option would be to find the original technical drawings and specifications to which the system had been built. This option, however, is often not available. For example, the drawings might be deposited in some remote archive from where it is difficult, if not impossible, to retrieve them. Even if they are retrieved, special attention must be given to details of the original planning and those of the actual system, to establish whether it had not already been adapted or changed since the original construction.

It is highly recommended that costing is preceded by thorough fieldwork, in close collaboration with the local community. In the absence of engineering drawings, the most feasible way is to locate and map the system components (increasingly convenient with GPS technology), to locate the pipe routes and water connections, and also to assess the quality of the system in terms of maintenance and its reliability.

Activity cost estimation

Developing the source

Small water systems are often supplied from groundwater or from perennial protected springs. Because of its inherent characteristics, ground water in rural areas is quite often considered as safe enough to be provided directly without treatment i.e. with a handpump. Costs are relatively lower than with other forms of supply, which makes it a popular choice with service providers.

Where there is no other option than to use surface water, construction of impoundments in rivers and streams is mostly required (Chapter 6) to provide a continuous supply of raw water throughout the year for treatment and distribution. The costs of creating an impoundment in a small water supply system can be a considerable proportion of the whole system cost.

The *capital* cost of groundwater sourcing are two-fold; the direct costs of gaining access to an aquifer either by drilling a borehole or digging as well, and the cost of lining such a borehole or well where the well has to penetrate soft material in the earth. A good estimate of drill-well costs can be made, for example, by using unit rates for linear metres of hole drilled and lined, respectively. The unit cost here is usually capital cost per meter drilled including the final finishing of the well such as casing and concrete surface collar - depending on the extent of the service rendered by the drilling company. The final capital cost will therefore depend on the depth of the drill-well.

The *maintenance* cost will be a percentage of the civil structure as shown in the relevant section later on. *Operation* costs will be minimal on the well itself if the well was properly installed. Operation costs around pumping will be dealt with in a following section.

Costs to surface water sourcing will mostly be incurred by the creation of an impoundment, as well as by securing the land that the impounded water might cover and the land required for the sourcing activity such as a pumping station and often the treatment facility. Capital costs can be estimated as cost of m^3 of concrete in the dam wall, per running meter of the dam wall or per m^3 of water stored. The latter would usually be used if the activity required purchasing of land. *Maintenance* cost will be required for ensuring the integrity of the impoundment wall, as well as for whatever sluices / valves and other mechanical water outlets there might be. Maintenance cost will be a percentage civil structure costs. *Operation* costs will be incurred by running the above and will often comprise only personnel costs.

Storage

After sourcing, water usually needs to be stored, either for direct distribution or pre- and post-treatment distribution. These activities require a storage tank, which is usually a *capital* cost item. Three common storage tank types are in use for small water supply systems. The smallest systems generally use prefabricated glass-fibre tanks if and where these are available. These tanks are available is in multiples of about 2 500ℓ or 5 000ℓ up to about 20 000ℓ. For tanks from about 20 m^3 or larger, tanks of reinforced concrete might be used. Tanks assembled from prefabricated panels of galvanised steel are also popular due their ease of construction and are available in similar volume sizes as the plastic tanks.

Treatment

When water is obtained from a surface (and sometimes a ground) water source, treatment is required. Depending on the quality of the source, simple chlorination can be sufficient. When water is polluted with suspended solids and pathogenic micro-organisms more advanced treatment is necessary, including coagulation/flocculation, and filtration as well. Most of the treatment items are usually *capital costs* to firstly install the treatment system. These costs depend on degree of pollution of the source, the number and type of treatment steps and the scale of the treatment. The larger the scale of the treatment is, the lower the costs per m^2 building area. Unit costs for different treatment steps can be obtained from projects that are realised earlier in similar settings. Part of the capital costs at the treatment site is the installation of a small laboratory for water quality analysis, storage of chemicals, pumping stations and reservoirs. Although the capital costs of treatment are normally not high compared to the capital costs of transport and distribution, treatment requires considerable operation and maintenance. *O&M costs* consist mainly of salaries for operators and laboratory personnel and the costs of chemicals (such as aluminium sulphate and chlorine) to be dosed during treatment. Water will be lost during cleaning and backwashing of filters and disposal of the resultant sludge must be organised. The loss of water (which can be up to 5-10% of the produced water) represents an economic value and the sludge must be treated before disposal, which represents an economic and environmental value. These costs must thus be included in the O&M costs.

Distribution

Costing a distribution system is discussed in this section in the context of costing mainly three diverse systems. Water can be distributed through 1) a pipeline, 2) mobile units such as tanker trucks and other forms of mobile vending i.e. animal drawn carts and 3) containers that people in communities use to move water from the supply point and store at home.

Pipelines are usually *capital* cost items. The cost components of a pipeline consist of the costs of pipes, couplings and shut-off valves. There are also the earthworks needed to excavate pipe trenches, bedding for laying the pipes on, backfilling the pipeline trench after laying the pipe and labour. For the smaller diameters of pipes used in small systems, the capital costs are about constant and mostly independent of the pipe diameter. *Maintenance* costs are normally incurred to maintain valves. *Operational* costs will be incurred to fix major (breaks) and minor leaks in pipelines.

Mobile distribution might also require considerable *capital* investment depending on the type of system. For example, it may require investment in the truck or cart and the animals. The *maintenance* cost will be keeping the vehicles and tanks in a good mechanical state. Animals of course have to be kept in a healthy state physiologically, which will incur a cost. *Operationally*, the vehicles / animals have to be fuelled / fed.

A container-based distribution system requires purchasing of the containers (a *capital* cost), and keeping the containers free from dirt and biofilm (a *recurrent* cost item). These costs can be considerable for a poor household and should be considered when attempting a cost-benefit analysis. The idea is that an intervention must be optimally effective at a minimum cost..

Costs that is often overlooked when assessing a small system will be those related to the inevitable water losses though especially the distribution part. These can be seen as operational or *other* costs once the loss-characteristics of a system are established.

Pumping

Pumping is an integral part of many small systems across the globe. Whether water is pumped from the source to the treatment works or to the system, pumps have certain characteristics which will enable the costing of the pumping component of a small system intervention. These characteristics are best determined with the help of a technician or engineer with specific knowledge in this field.

Pump suppliers can provide an estimation of the capital as well as the recurrent costs if they can be provided with information on the net power delivered by the pump. This is derived from the static head, an estimate of the friction head as well as the pumping rate if it is known. The pumping rate can be estimated from the pipe diameter and assuming a pipe flow velocity (typically between 0.6 and 1.0 m/s for small diameter pipelines). From this the size of the motor to drive the pump can be derived. Such a motor can be electric but would in rural areas usually be a fuel-powered motor, which has implications for the recurrent costs.

Public source points (taps on standposts)

The community sources its supply from the taps at the end of standpipes, which are connected to the distribution pipeline. The *capital* investment goes towards the taps, pipework and connecting fittings, which can have a nominal size of either 15mm, 20mm (the most common) or 25mm, the latter being much sturdier, of course. To facilitate the filling and lifting of containers, most taps are installed as part of a small concrete platform with the vertical pipe encased in some form of concrete pedestal. The *maintenance* of the taps has proven to be a substantial *recurrent* cost in that the taps are often not designed for the many times it is opened per day and also other abuses.

General remarks on estimating maintenance cost

A longer-lifetime project often results in the replacement of more parts of the installation within this period and, thus, higher maintenance costs. The planning (and concurrent costing) of maintenance should identify all the activities involved and the activity levels for implementation such as hours of work by activity, replacement parts, repairs procedures, inputs, etc. These activities and activity levels that typically would be encountered during maintenance can evolve over time, making it possible to estimate an annual cost for maintenance as an annual constant cost equivalent to the present value of the changing maintenance costs over the use-life of the equipment. A more straightforward and more generic method is to estimate the maintenance costs per year as a percentage of the construction costs. The civil, mechanical and electrical parts require maintenance to different extents, requiring different percentages. For the specific parts the percentage has to be estimated as accurately as possible together with the depreciation period. Generally, the following average percentages for structures and installation costs are used to determine the annual maintenance costs for the total treatment plant i.e. civil structures – X%; mechanical installations – Y%; electrical installations – Z% and furnishings – AA%.

The one important element that can make it difficult for a service provider to use such straightforward approaches as described above may be the growth of the population around a new system – especially in the developing world. This would require constant upgrade without an incremental upgrade necessarily being required. To keep an eye on effective and sustainable maintenance the service provider would use a monitoring tool such as *water demand*.

The total demand to be met by a water system is a critical parameter which, in a way, drives the entire cost estimate but is especially important in planning and costing maintenance. In an existing system this can be directly measured from a bulk flow meter (which is seldom present or working) and this value should then take precedence. When this is not possible, it may be possible to determine the pumping rate (by volumetric measurement of how rapidly the storage tank is filled, or simply by reading the information plate on pump) and determining for how many hours a day the supply pump would typically work. Failing this, the water production has to be estimated from the consumer end by multiplying the per capita water demand with the population. The per capita demand can be estimated by counting the containers filled at a typical standpipe and the population either from census data (where available) or by counting the households and estimating the average occupancy per household on some demographic basis.

To the water demand estimated in the previous paragraph must be added the water lost through leaks in the pipes and at the connections. This is measurable by checking the night flow, but this is less than reliable when standpipes are left open during the night for irrigation or other purposes. A first estimate can be made by assuming the IWA benchmark values for leakage from *Loss in Water Distribution Networks* by Farley and Trow (2003). However small it may seem at first sight, it is important to allow for some leakage – for spread-out rural systems with low demand it may be a significant contribution.

General remarks on estimating operational costs

In general, operation costs are constants over the time if the prices of inputs e.g. \$/KWh, and activity level or output e.g. m^3 of drinkable water delivered, remains constant. In this case, operation costs can be estimated as a constant annuity over the use-life of the equipment. If this is achievable, an annual constant equivalent cost could be estimated, in the same way as for maintenance costs. Parts of the operation costs are normally those required for consumables such as electricity, treatment chemicals and liquid fuel for pumping stations. The projected consumption of these items, as well as their prices are readily estimated.

Much more difficult is the estimation of the cost of personnel, as they are often only partially utilised in a small water supply system. Small systems may only require one hour of operation per day (to stop and start a pump). Often a specific person will be tasked with other community duties such as waste collection. In other instances, one person will be tasked with the operation of more than one small system, to which must be added the extra cost and time of moving between these system. It is clear that no single algorithm could capture all these permutations. There is no option but to estimate the personnel costs from first principles.

The same arguments hold for the cost of equipment required for monitoring and maintenance. A certain minimum of laboratory equipment, for example, is required for monitoring, whether hundreds of only a few samples have to be analysed per week. Often, the monitoring will be performed by a better equipped regional laboratory to obtain some economy of scale, but at the expense of transporting samples.

Estimating unit costs

Unit costs will vary between countries and will depend on the initial investment (capital) costs, the recurrent costs, the life time of the system and the water demand i.e. the water requirements per person per calculation period. Table 1 contains figures (derived from literature) for these cost components. It is assumed that the various costs as discussed in the previous sections are included wherever required within these figures. The unit cost for discussion in this section will be expressed in US$ per cubic metre (m^3) of supply water per year.

Table 1: Information to calculate unit costs for rural water supply systems

	Capital investment ($ per person)	Recurrent (% annual cost)	System lifetime (years)	Water demand (Lppd)
House connection	92-144	20-40	30-50	80-120
Standpost	31-64	0-10	10-30	50-80
Handpump on drill well	17-55	0-10	10-30	20-30
Dug well	21-48	0-10	10-30	20-30
Rainwater	34-49	5-15	10-30	20-30

If *house connections* are used as example, then the following serves as a demonstration:

A capital cost of $120 is assumed (from Table 1). The depreciation is linear at 2.5%. The system lifetime is 40 years. Assuming an interest rate of 7.5%, the fixed costs for a house connection in a small rural water system will be (2.5+7.5) = 10% of $120, which is $12 per person per year. The recurrent costs will be approximately 30% of $12, which is $3.6 per person per year, amounting to an annual cost of $15.6 per person. Assuming a demand of 100 litres per person per day (Lppd) the total annual demand is 36,500 litres which is 36.5m^3. The unit cost will then be $0.43 per m^3.

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