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

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 consumption). 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 employing 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
include 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
subsides 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 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, groundwater 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 in multiples of about 2500ℓ or 5000ℓ up to about 20000ℓ. 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/floculation, 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

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

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$.

**BIBLIOGRAPHY**

The chapter is based on work of a similar nature described in the following literature:


