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Appropriate Water Supply Systems for Disaster Relief

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1. Concept and Development

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INTRODUCTION

For many years Oxfam and other agencies involved in relief, medical aid and development work in many parts of the world have been acutely aware of the health problems created by an inadequate water supply. Oxfam, in its relief work overseas, has repeatedly been called upon to initiate or assist with water supply schemes to alleviate human privation and suffering. Experience in these types of operation has led to the consideration of what preplanning and preparation of equipment and materials is needed to provide water supplies *urgently* in a variety of situations. The successful application by Oxfam of packaged sanitation units to communities in acute need has added incentive to finding a water supply equivalent.

In 1980 the clear need for a planned water supply system, emanating jointly from Oxfam and the Ross Institute (London School of Hygiene and Tropical Medicine), was taken up as an exploratory project by the Public Health Engineering Section of the Department of Civil Engineering, Imperial College. The ultimate objective of the project was to provide Oxfam with a flexible and rapid response to the urgent need for a water supply system (e.g. for refugee communities). It was concluded that this response should comprise a simple decision process for sorting stock-piled modular equipment packages into an appropriate and working system. The collection of packages would necessarily need to be few in number, yet wide ranging in their application in the field. Generally, the packages would logically make up two distinct flow schemes which would be: (i) a surface water source (typically polluted) with treatment, and (ii) a ground water source with storage.

It was readily realized that this approach to providing a water supply was very limited and that the variety of local conditions would in many cases show the equipment packages to be less than fully appropriate or ideal. Nevertheless, it was felt that the proposed equipment would provide a basis for the necessary development and refinements to be made by local operators to suit the local circumstances. In addition, the stocking and use of standard equipment packages would encourage the training and familiarization of relief agency operatives with the recommended equipment, and this, it was hoped, would help to reduce the difficulties of installation and operation in the field.

During 1980 and 1981 a number of essential equipment packages were selected and an exhaustive collection of relevant information was gathered of currently available equipment. For each module such information (e.g. nature of unit, operating performance, cost, reliability) was assembled for approximately three or four alternative units so that a rational and final decision could be made. Emphasis was placed on actual field information and operators' experience as the best measures of the relative merits of each item of equipment. Most of the equipment packages have now been finalized and operators' manuals have been prepared for two complete packages.

GENERAL REQUIREMENTS

The water quantity-quality dilemma for those designing water supply systems within tight monetary constraints is well understood. Setting a per caput consumption value is unavoidably arbitrary, but field experience supported the adoption of 5 gallons per day as a sensible per caput allocation. The design population for the constituent equipment packages was fixed at 5000, so that larger populations could be served by multiples of these basic package units. Having thus decided the scale of the system (25 000 gpd) and adopting a guide-line system cost of £2 per caput, the magnitude of the resources available for improving water quality was apparent. Since storage for one day's demand prior to distribution was essential, adequate disinfection of the water, irrespective of its general quality, was considered to be feasible.

It was taken as axiomatic that the final equipment packages should be chosen largely by the merits of reliability, simplicity in operation, ease and speed of fabrication and installation, cheapness, and low energy consumption. Relative ease of transportation and use of local materials were additional important considerations.

CATEGORIZATION OF RAW WATER

Devising a low-cost water supply system that has the capability to translate any natural raw water into a potable form is inherently difficult. For example, there is a considerable quality difference between surface and ground water and a variety of ways in which such sources can be exploited. An indication of the high degree of variation in water quality in bacterial terms, depending on its source, is illustrated in Table 1.

Of the possible raw water sources, it is well established that direct rainfall interception is impracticable and unreliable. If urban water supplies are available within close proximity to the particular community water can justifiably be brought by tankers, provided the volumes taken do not give rise to an unacceptable demand on the urban network. More usually, though, water is provided from local natural sources. If there are alternative sources in a given situation the choice of raw water source depends on water quality, quantity and reliability. A possible decision framework for source selection based on water quality may be the flow diagram shown in Figure 1.

TABLE 1

Some reported concentrations of faecal bacteria in untreated domestic water sources in developing countries (Adapted from ref. 2)

Raw water source	Faecal coliforms per 100 ml	Faecal streptococci per 100 ml
Springs (unprotected)	0–2000	0–1700
Springs (protected)	0–200	0–250
Open hand-dug wells	200–580 (may be up to 100 000)	180–630
Protected wells	7	33
Water holes	11–860	up to 1610
Boreholes	0–60	0–10
Ponds	1300–1900	1300–3900
Streams	0–5000	0–4100
Large rivers	10–100 000	10–10 000

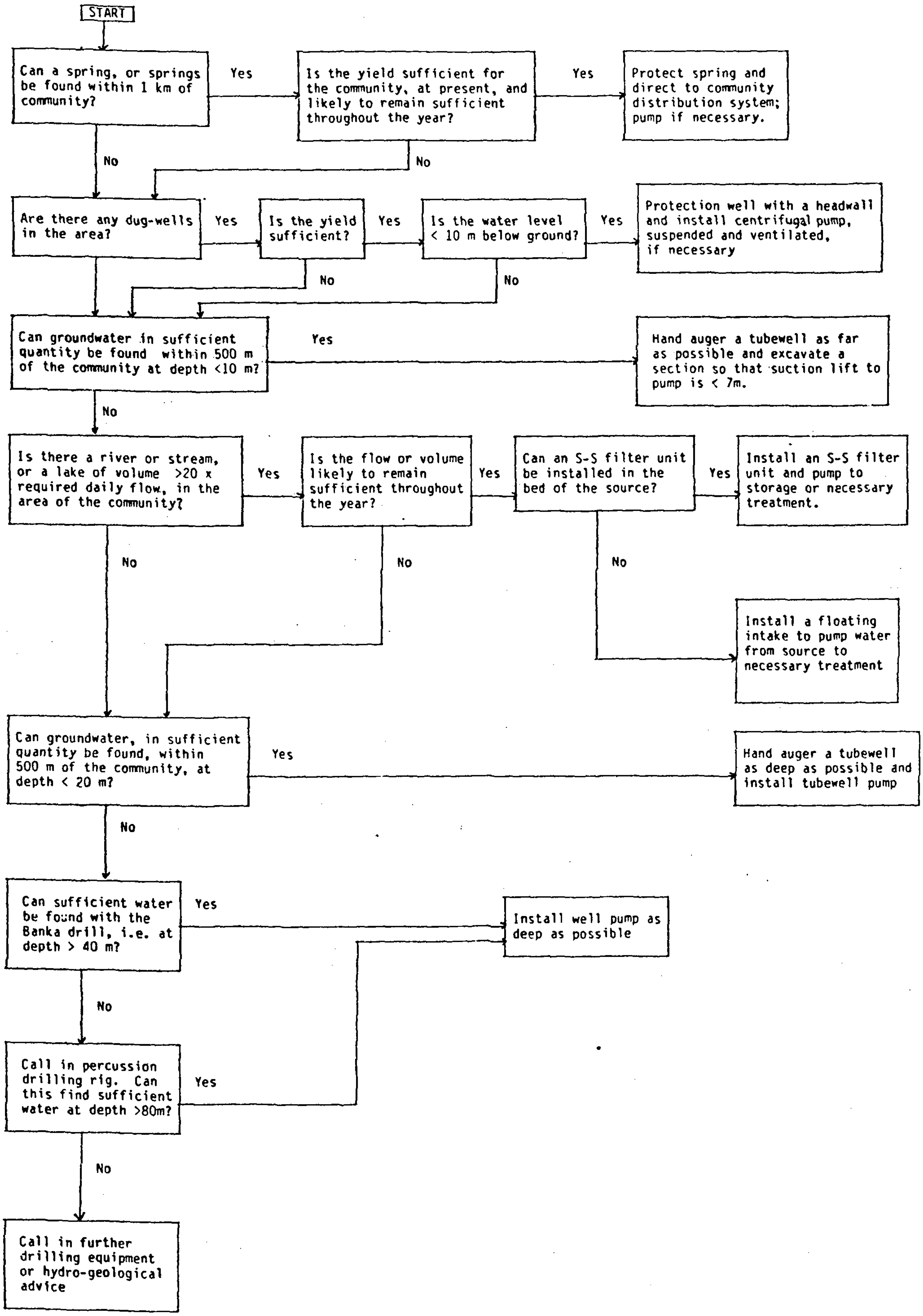

Figure 1. Suggested flow diagram for source selection and exploitation. (Adapted from ref. (3)).

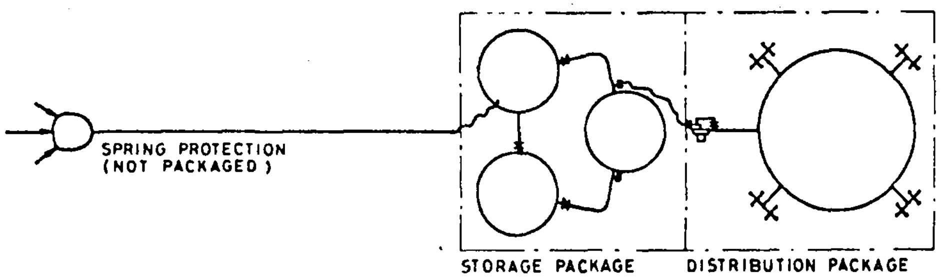

Figure 2. System 1. Spring source.

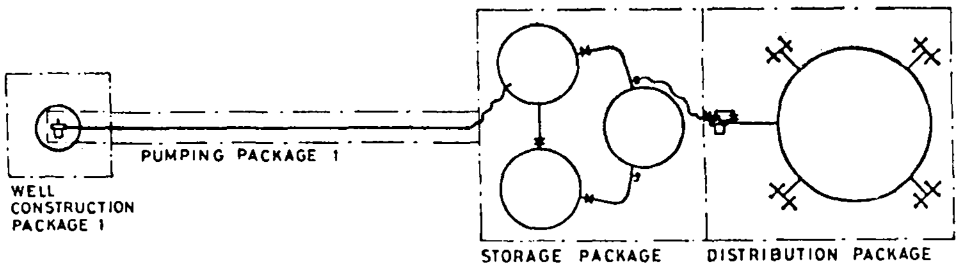

Figure 3. System 2. Shallow dug well (to 10 m).

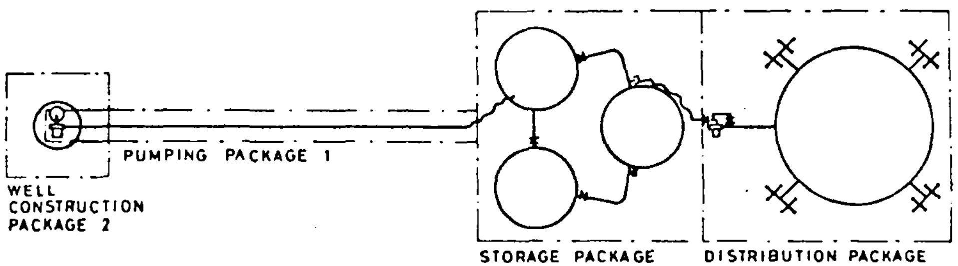

Figure 4. System 3. Shallow tube well (to 10 m).

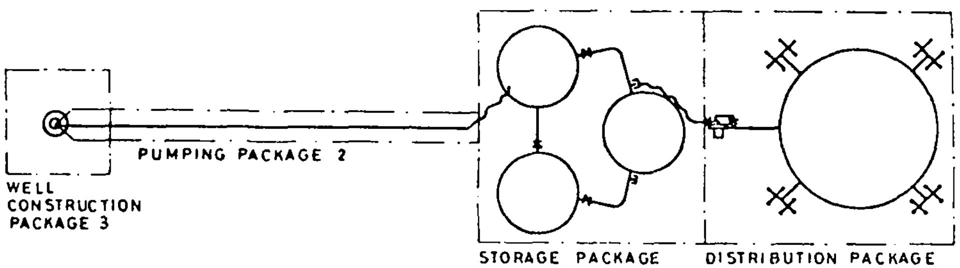

Figure 5. System 4. Medium depth tube well (10-20 m).

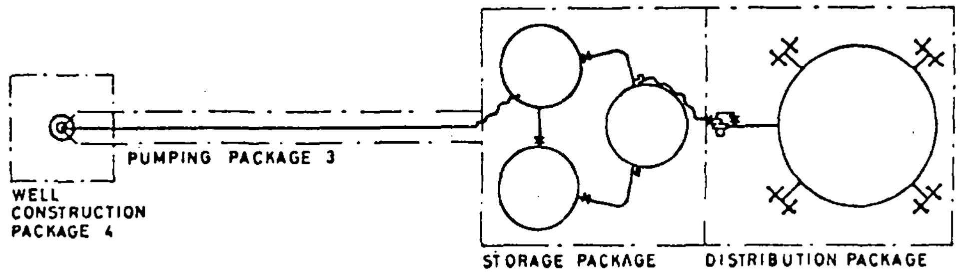

Figure 6. System 5. Deep tube well (20-40 m).

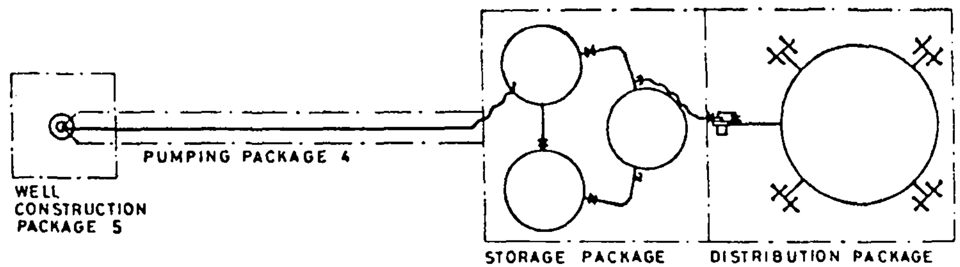

Figure 7. System 6. Borehole (>40 m).

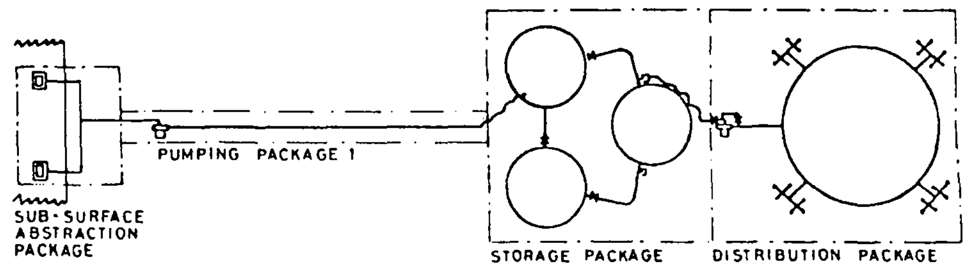

Figure 8. System 7. Surface source.

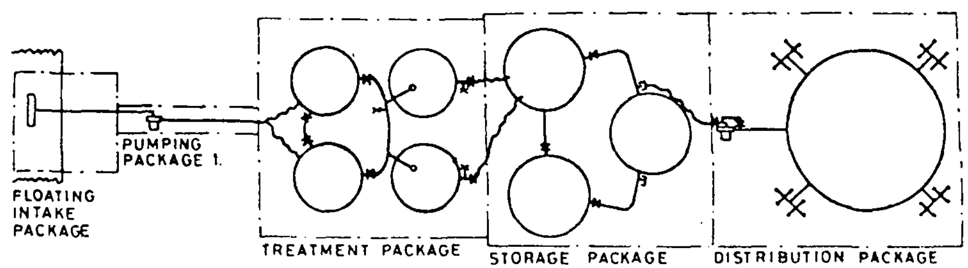

Figure 9. System 8. Surface source.

Given such a range of raw water sources and possible means of exploitation, eight distinct water supply systems have been established that relate to the nature of the water source, as follows:

1. *Spring source*. This is the only souu source. This is the only source likely to allow the system to work entirely by gravity. All others would require pumping at some point.
2. *Shallow dug well*, to 10 m depth.
3. *Shallow tube well*, to 10 m depth.
4. *Medium depth tube well*, 10-20 m depth.
5. *Deep tube well*, 20-40 m depth.
6. *Borehole*, for depths greater than 40 m.
7. *Surface source*, river or lake with sub-surface abstraction.
8. *Surface source*, with surface abstraction.

Since there are various common elements to the exploitation of these eight water sources, an interchangeable package approach to the description and selection of equipment was considered possible and desirable. Figures 2 to 9 show the constituent equipment packages and their respective configurations for each of the eight systems. The packages referred to are:

1. Well Construction Packages.
   There are five of these covering the following situations:
   Well Construction Package 1 – Shallow dug well to 10 m.
   W.C.P.2 – Shallow tube well to 10 m.
   W.C.P.3 – Medium depth tube well 10 to 20 m.
   W.C.P.4 – Deep tube well 20 to 40 m.
   W.C.P.5 – Borehole for depths greater than 40 m.
2. Pumping Packages.
   There are four of these which, used in conjunction with the other packages, cover all sources of water as follows:
   Pumping Package 1 – Surface source, shallow dug well, shallow tube well.
   P.P.2 – Medium depth well.
   P.P.3 – Deep tube well.
   P.P.4 – Borehole.
3. Storage Package.
   One design only of this package is used in all eight systems.
4. Floating Intake Package.
   Occurs on raw water source 8.
5. Sub-surface Abstraction Package.
   Occurs in sources 1, 7 and 8 where required.
6. Treatment Package.
   Occurs in one system only.
7. Distribution Package.
   One design only used in all eight systems.

PRINCIPAL EQUIPMENT PACKAGES

The design and specifications of the principal packages were carried out in an order of preference that would facilitate their immediate field application. Thus, the Distribution Package first, followed by the Storage Package, have been fully specified and have already been installed in refugee communities. The Treatment Package is at near completion and may be applied in the very near future. The remaining ground water packages will soon be under consideration.

Distribution Package

Although this package is common to all systems, it is nevertheless capable of being used in conjunction with any suitable storage facility. It is therefore available separately if a distribution system is all that is lacking in a particular situation. The package is versatile in the way in which it can be assembled to suit the site conditions and is complete in its entirety, ready for immediate installation and use, although certain preparatory work is recommended and described in the package manual.

The package includes a pump and diesel engine for pumping directly into a 90 mm plastic pipe distribution system. Direct pumping was adopted instead of a system incorporating a high-level gravity feed, since the construction of a large elevated storage tank was felt to impose additional and substantial cost, installation and supervision requirements. In addition, the possible availability of elevated ground in the area of the proposed water supply system, it was felt, could not be generally assumed. However, it is possible and preferable for the package to work without the pump if sufficient head can be obtained at the input to the supply main.

The distribution includes four water collection points spaced equally within the network. The network should be arranged preferably as a closed loop to lower friction losses and maintain a uniform pressure at all collection points, but other arrangements are possible if the particular situation demands it.

Each collection point has six self-closing delivery valves, designed to conserve water, which are fed by 32 mm plastic draw-off pipes. The valves close automatically after about 1½ minutes, having delivered about 10 litres of water, and each valve serves a nominal population of 208 people. Facilities for network venting and draining are included and operate by means of self-tapping ferrule/strap assemblies.

To simplify pipe transportation the 90 mm plastic pipe will be supplied in 6 m straight lengths and the 32 mm pipe will be cut from 50 m coils.

Storage Package

Some water storage is essential in most water supply schemes serving moderately-sized communities. In this Oxfam/Imperial College scheme, the Storage Package is a requirement for all the various systems if no alternative facility is locally available. Like the Distribution Package, the Storage Package is available separately should there be a need to provide storage to an existing distribution system. Circular membrane storage tanks were chosen for their advantages of cost, ease of construction, and avoidance of any requirements for foundations or special site preparation. The tanks consist of a rigid shell of corrugated steel sheets bolted together to provide the strength to support a flexible butyl rubber liner which holds the water (Figure 10). The package comprises three tanks, each 7 m diameter and 1.2 m high, which provide a total storage of one day's demand. Link pipework has been designed to give as much flexibility as possible in the way in which the tanks can be positioned relative to each other so as to reduce problems imposed by site conditions.

The tanks can be covered to lessen contamination by means of a plastic cover sheet supported by eight plastic trusses (Figure 10). The cover sheet is profiled by the seams in it to form a series of ridges and valleys. This enables the sheet to be adequately secured to the tank and encourages the draining of rain water. Disinfection of the water is carried out by adding chlorine, either by means of tablets or hypochlorite drip feed, to the first tank in the series of three; the three-tank sequence ensures an adequate contact time. The package includes a portable colour comparator for chlorine residual measurement.

Treatment Package

Where improvements in water quality are required the Treatment Package provides raw water storage (hence partial settlement of suspended solids) and slow sand filtration. The raw water storage facility permits short duration, intermittent, daily pumping of raw water into storage and the maintenance of a continuous and uniform flow through the filter. Both the storage and the slow sand filter are membrane tanks identical to those of the storage package. These tanks are designed to be constructed in vertical stages with successive 1.2 m steel sheets bolted on

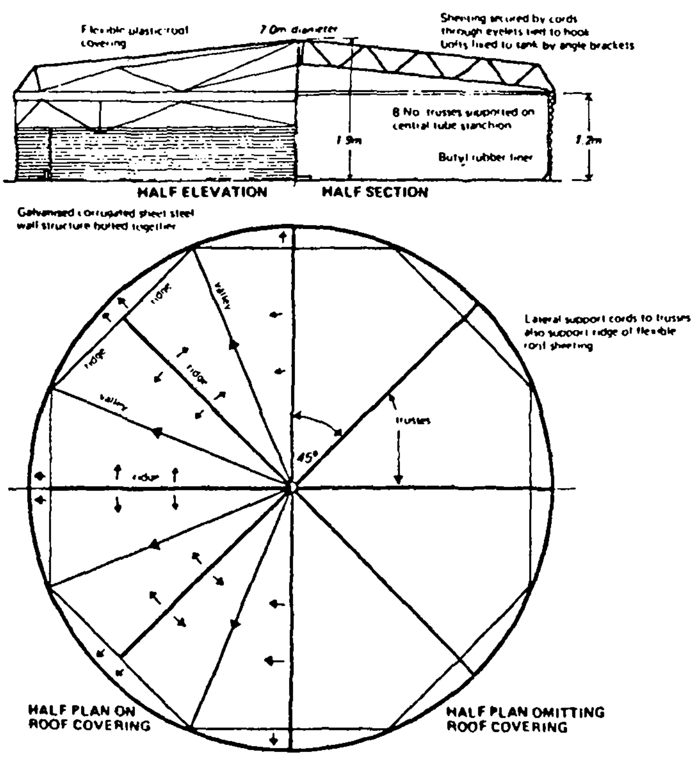

Figure 10. Oxfam water supply project: details of tanks to storage package, March 1982.

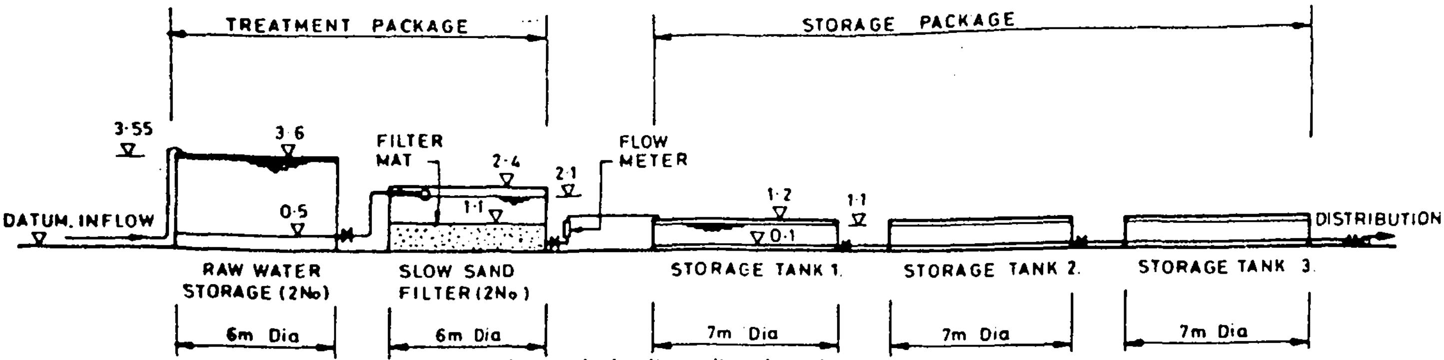

Figure 11. Section showing hydraulic gradient through treatment and storage system.

to the stage beneath. For hydraulic advantages, the height and diameter of the raw water storage and filter tanks were designed as shown in Figures 11 and 12. The filter outlet connection is set at a level just above the filter media so that there is no possibility of a temporary drawdown of water from the filter which would be detrimental to the treatment process.

The package has been designed to give two parallel streams of raw water storage and filtration so that filter cleaning can be alternated with one stream always in operation. The package is complete and ready for immediate installation with the exception of the sand and shingle which has to be obtained locally and washed and graded; washing and grading can be carried out by a simple backwashing process in a small tank unit provided in the Treatment Package.

The raw water storage tanks have a net storage capacity equivalent to two-thirds of the daily demand, with an elevated outlet to be above the settled solids layer; the accumulated settled solids can be removed via a drain valve. Link pipework within the package has been designed to give as much flexibility as possible to the positioning of tanks on the site and also to take advantage of any natural slopes that would benefit the hydraulic gradient through the system. Pipe connections through the butyl rubber liner were minimized to preserve its strength.

To simplify and improve the process of filter cleaning an artificial fabric layer is placed as a mat on the sand surface to act as the filter "schmutzdecke". The periodic removal of the matting in rolls for washing avoids having to skim, wash and replace layers of sand. The results of full-scale tests to study the treatment performance of the fabric layer are discussed subsequently by Lloyd et al[1].

Normally, raw water will be drawn through a floating intake and pumped into the raw water storage tanks. Experience from full-scale trials has shown that filter run times can be considerably increased by abstracting the raw water through a sub-surface filter unit. It is recommended that for highly contaminated raw waters some form of physical pretreatment, such as a sub-surface filter or fabric strainer, should be used at the point of abstraction.

Remaining Packages

The principal remaining packages relate to the abstraction of ground water and these are summarized here. An arbitrary upper limit on water depth has been taken as 80 metres since it is considered that the type of drilling equipment necessary for greater depths could be of a sophistication far outside the objectives of this scheme. Tube-well construction and borehole drilling for a range of water depths in different ground conditions will be covered by the following equipment, although it is appreciated that strict categorization of equipment according to depth is unrealistic since drilling performance is so dependent on the local ground conditions.

i) A lightweight manual auger set, for drilling to depths not exceeding 20 metres.
ii) A heavyweight man-powered auger set, complete for drilling to a depth of 40 metres.
iii) A lightweight, friction-winch percussion drilling rig, for boreholes finished at 100 mm bore and a maximum depth of 80 metres.

The individual packages will contain appropriate well screens and casing materials, and suitable linings will also be included for hand-dug wells.

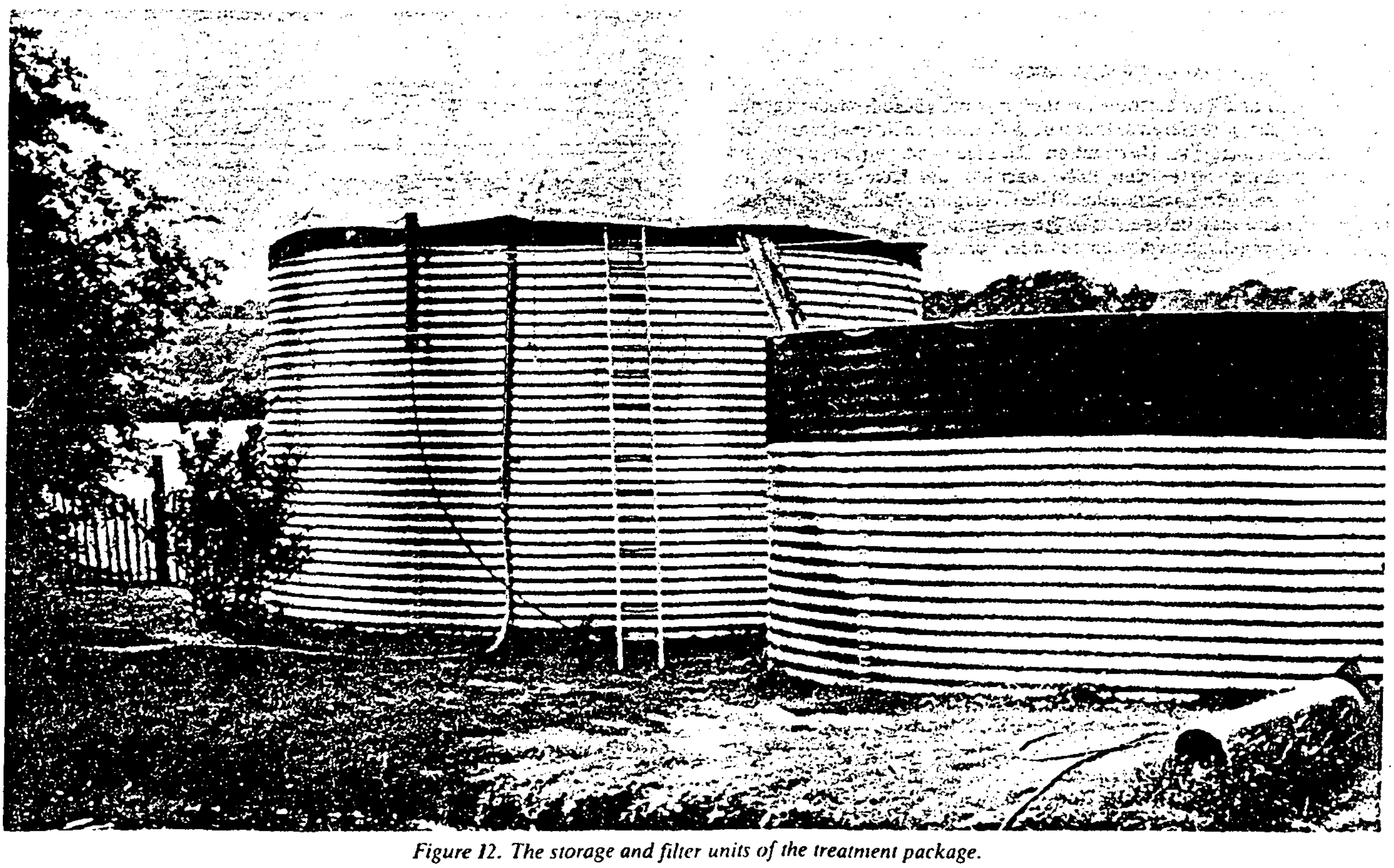

Figure 12. The storage and filter units of the treatment package.

CLOSURE

Summary of Costs

The project requirement was that a given water supply system should have an approximate per caput provision cost of £2, or £10 000 per system. A summary of the approximate costs for the eight distinct systems is given Table 2. These costs include all the necessary ancillary equipment and tools, but not running costs. It can be seen that three systems exceed the cost requirement (systems 5, 6 and 8). However for the two systems requiring major well constructions, the means of well construction will be used many times (or on loan/hired) and this particular cost can realistically be deducted. This gives the total system costs as £10 000 and £10 800 respectively for systems 5 and 6.

TABLE 2

Approximate Package and System Costs

System	Package	Package Cost, £	Total System Cost, £
1	S	3900	
	D	3100	
			7000
2	W.C.1	1150	
	P.1	500	
	S	3900	
	D	3100	
			8650
3	W.C.2	2000	
	P.1	500	
	S	3900	
	D	3100	
			9500
4	W.C.3	1400	
	P.2	2500	
	S	3900	
	D	3100	
			10 900
5	W.C.4	5700	
	P.3	2750	
	S	3900	
	D	3100	
			15 450
6	W.C.5	11 300	
	P.4	3300	
	S	3900	
	D	3100	
			21 600
7	S-S.A.	650	
	P.1	500	
	S	3900	
	D	3100	
			8150
8	F.I.	160	
	P.1	500	
	T	7500	
	S	3900	
	D	3100	
			15 160

Key: S—Storage, D—Distribution, W.C.—Well Construction, P—Pumping, S-S Sub-surface, F.I.—Floating Intake, T—Treatment.

Figure 13. Standpipe package as recently installed in Honduras.

Future Work

Currently, the field trials and equipment manual for the Treatment Package are nearing completion. Following this the preparation of equipment manuals will begin for the remaining Pumping and Well Construction Packages. In the longer term all of the manuals and selected equipment may need some reconsideration once their performance in the field has been properly evaluated.

The application of these packages and systems for rural, non-emergency water supply schemes will also receive urgent consideration since the project represents a potentially important contribution to the current UN Water Decade Programme.

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