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NATIONAL RURAL WATER SUPPLY PROGRAMMES

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PART I RURAL WATER SUPPLIES: INTRODUCTION

"There is no single measure that can so improve the health and well-being of the rural dweller as the provision of an ample supply of safe water."

This statement sounds a provocative one: it is intended to be so. It is the experience of the WHO Community Water Supply Unit, based upon 10 years' work in this field, and supported by the frequently expressed opinion of others whose work embraces village conditions in developing countries, that not only is the water supply the most important factor in the health and social life of the community, but it is appreciated as such by the villagers themselves. This experience has been quoted before on numerous occasions: we are still waiting for it to be challenged.

The most obvious benefit to be derived from a safe water supply is the improved health of all consumers. Other benefits, perhaps less obvious, follow in the social and economic fields. It may be useful to recapitulate some of these effects.

Rural Water Supplies and Health

At the last World Health Assembly (1969),[1] the representative of one Asian Government stated that water-borne disease accounts for 60 per cent of all morbidity and 40 per cent of all mortality in his country. He estimated that 90 per cent of the rural population (or about 72 per cent of the total population) suffer from intestinal parasitic infestation, and added that less than 10 per cent of the total inhabitants of the country have access to piped water supplies.

It is difficult to judge how typical this example is, or how comparable with developing countries in Africa. It is feared that, if the full facts were known, many similar examples could be quoted. Statistics, however, are difficult to come by; one reason for this is that in many areas where water-borne diseases are endemic - particularly those caused by parasites - infection has been accepted as a fact of life, so common as not to warrant medical treatment even if this were available.

Diseases in the transmission of which water plays a role may be divided into four categories. The first - "water associated diseases" - though important are outside the scope of this paper. They comprise such infections as malaria and onchocerciasis (river blindness) of which the vectors breed in water. Although it is possible for badly designed or operated water supply works to increase the incidence of these, they are not normally transmitted through community water supplies directly.

Water-borne Diseases form the second class; these are the killing infections responsible for innumerable cases of sickness and death annually. Typhoid and cholera fall into this group, flaring up periodically into spectacular epidemics, but also steadily and continuously taking their toll of lives. Enteric infections, caused by bacteria, viruses and amoeba, are water-borne; they include a variety of dysenteries, and infantile diarrhoea which is responsible for the deaths of so many young children. The border line between water-borne and food-borne infections is often indeterminable, food being contaminated by water containing pathogens and in its turn serving as a vehicle for infection. The lack of sufficient water to clean cooking and eating utensils can obviously play its part in spreading disease by this means.

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[1] Official Records of WHO, 177, p.371

Parasitic Diseases conveyed by water are usually debilitating rather than fatal. Not only do they cause widespread misery and sickness, but by lowering the resistance of the sufferers they render them more liable to succumb to other infections. A common and painful example is dracontiasis (guinea worm), very widespread in many parts of Africa. This disease, to which reference will be made later, is entirely eradicable through one single measure - the provision of drinking water free from copepods.

Schistosomiasis (bilharziasis) is another parasitic disease common in many countries in Africa and elsewhere, but it would be misleading to suggest that the provision of safe water would eliminate this over a wide area. There is, however, evidence that the supply of an ample quantity of water in a convenient manner within a village can indirectly reduce its incidence among the inhabitants of that village. Schistosomiasis is almost always contracted by contact with water containing cercariae - rarely by drinking - and although it is impracticable to prevent boatmen or workers on irrigated farms from making this contact, and nearly as difficult to prevent small boys from swimming in an infested river or canal, it is possible to render it unnecessary for women to enter such a river to wash clothes or obtain drinking water. Coupled with health education, the provision of water and washing slabs can at least protect the women of the village: complete protection of all classes can only be given by expensive and continuing campaigns of mollusc eradication.

The fourth class of diseases that can be materially reduced by the provision of water can be described as the diseases of filth, including trachoma, scabies and louse-borne typhus. These diseases, which particularly affect children, are especially prevalent in the absence of ample supplies of safe water for bathing, clothes washing and domestic hygiene, and of other environmental health measures such as the sanitary disposal of excreta, waste water and domestic refuse.

Trachoma, which is responsible for so much permanent blindness, can be reduced by two measures - regular bathing of the infected eyes, and the control of flies. The incidence of yaws has been shown to decrease markedly with the improvement of environmental conditions, particularly water supply.

Lest there should be any doubt as to the effect upon individual and public health of adequate water supplies, a number of typical experiences from different countries have been quoted in Appendix I to this paper. These may be regarded as samples of a large literature on the subject, and are set down merely to give an idea of the kind of evidence available.

Before leaving the subject of rural water supplies and health, it may be relevant to refer to the relationship between water supply and nutrition.

Water is not in itself a nutrient, although it acts as a vehicle for conveying nutrition to the digestive organs of the body. That it can also serve as a vehicle for the transmission of disease-causing germs and parasites has already been referred to earlier.

One of the symptoms common to most water-born diseases is diarrhoea, particularly among children. In infants, diarrhoea is often not only a symptom but an actual cause of death. Even in those cases which do not prove fatal, its effects are frequently severe and long lasting.

One of the ways in which diarrhoea affects children is by preventing the nutritive value of the food from being utilized by the body. Where the child is already malnourished, it reduces still further the benefits obtainable from the already inadequate food source, and attempts to improve the value of the child's feeding can be completely counteracted by recurring bouts of diarrhoea. The condition is aggravated by the traditional practice, common in many countries, of putting the child on to a starvation diet and giving strong purges as a supposed cure for diarrhoea.

The process is self-multiplying since the undernourishment itself weakens the body's resistance to further infection. In addition, the severe dehydration and electrolyte imbalance makes treatment more difficult, and it is these conditions which often prove fatal. In some developing countries, deaths from diarrhoea account for one-fourth of all fatalities among infants.

Further agents which can thwart attempts to improve nutrition among children are the intestinal parasites, which thrive under insanitary conditions. Adults, as well as children, suffer from a variety of these and a medical observer[1] quotes the case of a certain semi-tropical country where the worms infesting the people "metabolize more of the produce of that country than do the inhabitants. Half the work of a sick peasantry, therefore, goes into the cultivation of food for the worms that make them sick".

The relationship between diarrhoeal diseases and parasites on the one hand, and the lack of clean water and sanitary means of excreta disposal on the other, has already been shown. It necessarily follows that the improvement of the environment will have a direct effect upon the nutrition of those benefited.

Rural Water Supplies and the Local Economy

The improvement of health consequent upon the provision of ample and safe water benefits the economy of the community served in a number of ways.

Some of these are obvious: the demand on scarce health services is reduced, thus freeing hospital beds and the services of doctors and nurses for other areas or for the treatment of other ailments. The improved output of the healthier labourer leads to improved food yields. The release of women from the task of carrying water over long distances permits them to engage in other, more productive, tasks.

Other public health measures such as "maternal and child health" and "nutrition" cannot really bear fruit without provision of safe water. The effects of better nutrition can never be felt if children suffer constantly from water-born diseases.

Cleanliness will remain merely a foreign concept if the health visitor has to use a blackboard to show how to bathe a baby because no clean water is available in the village.

The World Health Organization places the greatest importance on the humanitarian aspects of the reduction of death and disease, but it is realized that the miseries of sickness and the distress of mothers who lose their new-born children through infantile diarrhoea cannot be measured in terms of money.

It is, however, well established that the death of any individual prior to or during his age of productivity represents a definite economic loss to the community. An even greater loss is represented by those who go blind through trachoma; not only can they not contribute to the productivity of the community, but they represent an actual debit in that they must be fed and maintained during their lifetime.

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[1] Hyde, H. van Zile (1951) Amer. J. publ. Hlth., 41, 1.

Much money is rightly being expended in many countries upon education. If children are absent from school through their own sickness, or that of their parents, that proportion of the education expenditure is wasted. Equally, if the child is present at school, but unreceptive to teaching because an infection of parasites makes him unresponsive and lethargic, the money spent in trying to educate him could be put to better use. The total effect of these factors has never, to our knowledge, been assessed, but in sum the loss of education funds must be very considerable.

In order to increase agricultural productivity, as well as to halt the drift to the towns with its attendant problems of uncontrolled urbanization, many countries have programmes for the development of rural economy. A good example of such a programme is that formulated by the Town Planning Department of the Ministry of Lands and Settlement in Kenya. The key feature of this programme is the establishment of an infrastructure of "local", "market" and "rural" centres to provide social services and market facilities to scattered rural communities. It is significant that the common requirement for all these centres is a public water supply, without which hospitals, schools, administrative and commercial undertakings, hotels and similar developments are considered virtually impossible.

In the same way, the establishment of village industries, particularly those in which food and other agricultural crops are processed in the vicinity of the place where they are grown, is usually dependent upon the existence of a suitable community water supply.

The provision of water supplies for domestic use has, in several areas, permitted the utilization of uncultivated land by enabling communities to exist where, before, habitation was not possible. Settlement of nomadic tribes and the opening up of cattle routes have also been made feasible by this same measure.

A further economic factor to be considered is the employment created by the construction and operation of the water supplies themselves. Provided that construction is planned with this factor in mind, labour will be used not only on actual construction (e.g., well sinkers, dam builders) but secondary employment will also be created in cement manufacture and other manufacturing industries, in transport and ancillary services. The employment capacity of waterworks operation will depend too upon the original planning, for example slow sand filtration calls for unskilled labour for cleaning and maintenance, while rapid gravity filtration needs smaller number of more highly skilled operators.

Case History - Zaina, KENYA

To prove statistically the effectiveness of safe water supplies and sanitation in improving rural health and social conditions would require a thorough canvas, medical examination and laboratory tests on a significant sample of the inhabitants of the communities helped, and a repetition of this survey after a number of years of living with the improved facilities. This substantial effort is not likely to be made as a normal routine, nor should it be necessary with the tremendous background of environmental health accomplishment in developed countries.

However, for those who may be sceptical of the results obtained from applying sanitary engineering principles in primitive rural environments, there is fortunately within the present WHO/UNICEF programme a well documented case history.

A simple water supply system was installed in the Zaina area in the Central Province of Kenya, with the help of UNICEF and WHO, in 1961. This system is fed by gravity from a high level surface source of good physical quality and provides chlorinated piped water to 588 farms and four villages which had a total population of 3850 in 1961. By 1965, the system had been extended to supply water to 5800 persons. Prior to 1961, the source of water for domestic use and the considerable farm animal population was the Zaina River which flows in a gorge about 100 metres below the inhabited areas. Carrying water up the steep incline consumed a major portion of the time of the women.

When the new system was installed in 1961, a complete survey of the health and social aspects of the area was made under the supervision of the Provincial Medical Officer. The survey collected detailed information on the incidence of illnesses and infections, housing conditions and general living standards. A similar study was made of a control area located eight kilometres from Zaina and comparable to it in practically all characteristics except that it lacked an adequate community water supply. In 1965, after four years of operation of the Zaina water system, a resurvey was made of both areas.

It was found that the Zaina community was in better health than four years earlier in terms of both total number of illnesses and duration of each illness. Using the same basis of comparison, the people of the control area were found to be in poorer health. A dramatic difference was found in the stool examination of children for ascariasis, the most common helminth infection in the area. The 1965 survey showed a decline of the disease in Zaina and an increase in the control area giving the latter a prevalence of six times that found in Zaina. The studies also showed that Zaina had made a greater economic advance than the control area. The easy availability of piped water and the release of women's energies for better housekeeping, care of children and vegetable gardening, has been the principal factor in the improvement of both health and well-being in Zaina.

The installation of the water supply system was the only basic public improvement made in Zaina during the four-year period, but there was, in addition, considerable private activity in the construction of latrines to individual houses.

PART II PLANNING OF RURAL WATER SUPPLY PROGRAMMES

There are two fallacies in connexion with rural water supplies that have impeded progress and will continue to do so if not corrected.

Fallacy 1. A rural water supply programme is a collection of scaled-down urban supplies, each designed on an ad hoc basis to suit the community to be served.

Fallacy 2. Because the individual supplies are small, there is less engineering skill and ingenuity required than is called for in designing urban systems.

It cannot be too strongly emphasized that a rural water supply programme (as distinct from an individual project for a single village) requires a special approach and a high degree of competence and experience. Difficulties of logistics, a wide variety of sources and physical conditions, construction with inadequate supervision and little mechanical assistance, community participation, and (almost invariably) a shortage of funds have to be overcome. Devices such as unit planning, standardization of equipment, formation and training of "single-operation" work teams, utilization of indigenous skills and locally available materials must be adopted as circumstances warrant to deal with those difficulties. Engineering and economic comparisons of grouped supplies versus individual source works must be made, and continual decisions reached as to comparisons between the "desirable" and the "possible".

Rural water supplies begin with the programme which, in its turn, depends upon the organization available to execute the programme. The strength of the national organization, and its ability to solve the country's problems, will depend upon many obvious factors - its budget, legal powers, staff establishment - but probably the most decisive factor of all will be the presence of an energetic, imaginative and experienced engineer in charge of its operations.

Definition of Rural Water Supplies

One of the first considerations in setting up an organization to deal with rural water supplies is to define the scope of its activities, and this will depend to a great extent on the definition given to the term "rural". This apparently trivial point has proved a difficulty in a number of countries since there is no generally accepted common practice in this matter, and there are wide variations in the way in which urban and rural projects are differentiated.

Some countries make no difference in their approach, having a single organization to deal with community supplies of all sizes. Although this arrangement may work satisfactorily under certain circumstances, there will often be serious objections from an administrative point of view; these may be overcome by having two distinct sections within a single organization. One of the weaknesses of a single organization is the over-emphasis given to urban communities at the expense of the rural. This, in practice, is extremely common, and results from many causes; the greater danger of epidemic in a large, closely knit, population; the degree of articulation - and hence political pressure - that can be exerted by an urban community; the more favourable results, in terms of numbers of people served, that can be achieved by a given technical staff when designing and constructing a single large project; the simpler problems of finance, communication and logistics; the reluctance of technical staffs to work in remote rural areas when there are alternative opportunities in the city.

It is not suggested that urban problems are any less urgent than those of rural areas - indeed, the contrary may be true. It is most desirable that both types of community should be served as rapidly as possible, but in parallel rather than in sequence. In any case, the technical problems of the two types of supply are so different that a completely different approach is needed; hence the advantage of administrative separation.

In some countries this is achieved by adopting a criterion based upon population figures; an arbitrary upper limit is chosen (5000, 10 000 or even 20 000 are known examples) below which the community is considered rural. This ignores two considerations - the pattern and characteristics of the community to be served. For examples, a group of villages, scattered and rural in character, may be capable of being economically supplied from a single source and treatment works, the water being transmitted by relatively long pipe lines. The total population served may be well above the limit for a rural community, but conditions are obviously not urban. On the other hand, a relatively small community serving, say, an isolated industrial development may be essentially urban in pattern but classified as rural because of its numbers.

Another difficulty can arise if the population criterion is rigidly adhered to, when a community is just below the upper limit, and may even reach that limit between planning and construction stages. This may mean its transfer from one organization's responsibility to that of another during the course of a project.

In other countries, the differentiation is made according to the occupation of the inhabitants irrespective of the size of the community, being considered rural if the majority of the people are agricultural workers or fishermen. This often works well, but creates borderline cases, particularly if rural service facilities or agricultural industry are sited within the community.

When, as is often successfully practised, the same organization is responsible for construction and for maintenance and operation of rural water supplies, this fact will influence the initial "grading" of the community as rural. Another factor worthy of consideration is the financial viability of a waterworks; in some instances, this may in fact be the determining one.

In general, an urban project should be financially viable in that consumer charges can be made that will at least pay for operation and maintenance and possibly also repay capital costs over a period. It is only in rare cases that a rural water supply can become financially self supporting in this way, although it is usually considered desirable that those supplied should contribute at least a part of the recurrent charges. Hence, the financing of both construction and operation of these two types of supply will differ considerably, and this may be one solution to the definition problem i.e., a rural supply is one the construction of which has to be financed wholly by government or state funds, and maintained and operated largely from a similar source, while an urban supply is one in which the consumers pay for operation and maintenance and contribute towards the construction cost. Borderline cases will obviously arise, but these are, in some countries, dealt with by means of a transition stage described as "semi-urban", with clearly defined financial arrangements leading towards the goal of eventual viability.

A further consideration determining the difference between urban and rural may be the status of the existing local authority - whether the local organization is capable of the financial and technical management of the water supply when completed, or whether this must continue to be the responsibility of the central rural water supply organization for some time to come.

A country, then, when setting up its rural water supply organization, should choose its own criteria as to which communities shall be included, but should spell these out clearly so that the organization's responsibilities are in no doubt.

Basic Programme Requirements

A rural water supply programme consists basically of two parts:

(a) An identification of needs (sometimes referred to as a "sector" study)

(b) Proposals to satisfy those needs.

The first of these is an essential preliminary to the second; this fact, though apparently obvious, is stressed because it is all too often neglected. Because of the urgency of improving the most pressing conditions, programmes are often conceived in a haphazard ad hoc manner which may reduce their effectiveness and lead to wasted effort and expenditure.

It is, however, possible - and usually desirable - to divide the "needs" study into two parts; the first consisting of a general, nation-wide, long-term survey to identify the areas requiring most urgent attention, and the second a more detailed short-term study of these particular areas.

The nation-wide survey will consider such questions as incidence of water-borne disease, areas of water shortage, demographic distribution, national economic planning which may affect population trends, areas of special economic importance, adequacy of present supplies, other health programmes with which rural water supplies should be co-ordinated. From this over-all picture priority areas will be selected and the more detailed needs in terms of present and future demands worked out.

On the basis of this "needs" study, the programme of operations can be worked out. First, having established the extent of the problem within the country, it will be necessary to establish a policy decision as to a long-term timetable, including target dates by which the most urgent and the less immediate requirements are to be satisfied. This will then have to be compared with the financial and staff resources that will be required year by year to achieve these target dates.

Planning for the future in this way will, of course, be based on future population requirements, and in itself is a salutary exercise. In several instances, it has been found that an apparently ambitious rural water supply programme was insufficient even to keep pace with population growth, so that despite construction activities the situation gradually deteriorated rather than improved. In the report of a WHO Expert Committee on Community Water Supply held in 1969,[1] it was noted that in many developing countries the present rate of progress in improving rural water supplies is so slow that it will take more than 100 years to reach a satisfactory level. Few governments would wish to accept this situation, but without the "needs" survey and the preparation of a realistic timetable, they may be unaware of the true facts. Properly presented, such a timetable may be a powerful tool in obtaining adequate financial support for the programme.

At the same time, future staff requirements will also be identified, and training programmes can be initiated to ensure that qualified men become available in the future as they are needed.

While on the subject of "target planning", it may be of interest to describe what has been achieved in Latin America as a result of such planning.

Charter of Punta del Este

In 1961 the Chiefs of State of 19 Latin American countries signed the Charter of Punta del Este, which established general objectives in health for the decade beginning in 1962.

[1] WHO Technical Report Series No. 420, p.6.

Among the problems considered were those of water supplies, and a target was set whereby each country aimed at supplying potable water to at least 70 per cent of its urban, and 50 per cent of its rural population.

Prompt action was taken by the Governments concerned, a high priority was awarded by each to works of water supply and to other environmental health measures, and, with the assistance of WHO and PAHO, full national programmes were drawn up and implemented in each country.

As a result, it was reported at a special meeting of Ministers of Health in October 1968, at which 26 Latin American countries were represented, that 18 of these had already achieved their urban water supply goal and that the others were relatively close to this.

Rural water supplies had not achieved the same rate of progress, but at the same meeting it was reported that 16 per cent of the 124 million rural inhabitants had water services - about one third of the target. It is understood that, with the filling of the urban need, emphasis is being switched to the rural problems, and that - although it now seems unlikely that the 50 per cent provision will be reached by 1971 - it is expected that a substantial proportion of the proposed works will be completed by that date, and the target reached soon afterwards.

It is not suggested that conditions in the region are necessarily comparable with those in other parts of the world, but it is worth noting that the population of South and Central America was estimated at 267 million in 1968, with an annual increase of 2.9 per cent. Urbanization is rapid, and it is expected that by 1980 almost half the population will be living in towns of 20 000 and more inhabitants. The average economic growth rate was 5.0 per cent in 1967, 4.3 in 1966; the per capita growth rate was 1.8 per cent during the same periods and the per capita annual income varied between $409 and $344 in different countries. Population density is low, except for the Caribbean Islands, and no mainland country has a density as high as 25 per square kilometre. The economy is predominantly agricultural, though with a gradual shift to trade and services. It is estimated that in 1950, 54 per cent of the labour force was in agriculture, and that this will reduce to 44 per cent in 1970.

The over-all purpose of the Punta del Este Charter was a health plan which would raise the life expectancy of every individual at birth by five years within the decade, and would also improve the health, and the learning and producing capacity of each. Although the water supply aspects have been stressed, these were by no means the only provisions, and it is probable that the co-ordination of water supply programmes with those of other basic health services, nutrition and the eradication of malaria and other diseases has contributed to its undoubted achievements, even if the total objectives have not been reached.

Other success factors include the financial assistance provided by international and bilateral loan agencies, though it should be pointed out that by far the greater part of the expenditure has in each case been borne by the countries themselves. Various financial devices, such as the setting up of revolving funds, have helped rural water schemes particularly, but probably the most important impetus to the programme stemmed from the concerted nature of the attack upon the problem, the priorities and determination of the Governments concerned, and the efforts of a dedicated and active body of engineers and other Government servants in each country. Their reward is the knowledge that in less than eight years 65.5 million people benefited from their activities.

Planning for an Immediate Programme

A long-term programme must obviously comprise a series of short-term programmes prepared successively, but the emphasis of these will gradually change as the organization strengthens, the technical staff gains experience, working methods are established and basic information collected. Hence, for a given input of finance and manpower, it is not to be expected that in the first one or two years the same output in terms of population served will be achieved as may be anticipated in the later stages of the long-term programme when unit costs should reduce steadily and the capacity of the supervising staff increase.

For this reason, the first stages of a programme are usually planned to be to a large extent demonstrational in nature, with a considerable element of training, research, collection of data and production of standard designs. The results of these early years should not be judged in terms of physical results; their real value will become apparent in succeeding programmes. The assistance provided by UNICEF and WHO (which is referred to later) is specifically intended to cover this transitional period. Nevertheless, the demonstrational work will be of benefit to the communities served, and the areas in which it is to be carried out should be selected with two purposes in mind: the need of the consumer (based upon health requirements, water shortage and similar factors), and the training element, for which latter purpose accessibility, variety of physical conditions and the possibility of grouping construction operations are important.

Having identified, within the long-term programme, the areas to be the subject of the first short-term phase, and having assessed the extent of work capable of being carried out during this phase within the limits of funds and staff available, technical details of the short-term proposals can be worked out. These will be based upon physical surveys of individual projects; identification of water sources; treatment, pumping, storage and distribution facilities to be provided, after which detailed cost estimates and lists of equipment and materials can be prepared. However, there are certain decisions regarding technical principles that must be made as early as possible, since these will affect the design and construction programme. These include such matters as the degree of distribution within a village (single point, scattered standpipes or services within compounds), degree of treatment to be given, consumption and other criteria (e.g., amount of storage to be provided), arrangements for operation and maintenance, whether or not standby facilities are to be provieded, and similar considerations.

The following notes deal with some of these technical aspects.

Maintenance and Operation

Paradoxically one of the first considerations in planning a programme will be the last stage in its implementation, i.e., operation and maintenance. How this is to be carried out eventually will affect not only the pattern of construction, but even the design and specification of equipment to be installed. It is almost always the position that surveillance, supervision, maintenance and skilled operation staffs for rural water supplies are likely to be minimal in numbers and of lower technical capability than similar personnel available in city or large urban undertakings. In addition, the funds available for the payment of salaries on rural projects are usually insufficient to attract the best men from the city into the country.

For these reasons, it will often be found that the only effective way of managing village supplies (especially those dependent on mechanical pumping and equipment) is by organizing a number of these within a particular area in such a way that they can be serviced from a single maintenance centre, from which a small staff can manage, supervise and maintain the individual works, each of which can then be operated by a relatively unskilled attendant.

By designing all works within the group with interchangeable pumps, engines, and other fittings, construction can be simplified, storekeeping kept to a minimum, and considerable savings in initial cost can be made by reducing the necessity of stand-by plant. The maintenance centre would be equipped with transport, replacement units and a skilled mechanic who could immediately upon receiving new of a breakdown, substitute a reconditioned unit and return the defective equipment to the centre for overhaul under supervised conditions.

Construction of a group of supplies of this nature can be planned more economically than can a similar number of widely dispersed projects; obvious savings will be made in supervisory staff, building machinery (e.g., concrete mixers) and in the ability to use teams of construction labour trained in a particular task. As an example, it is possible to train a team of practically unskilled men to construct, say, an overhead tank of a particular height and capacity without plans or drawings, and with simple tools, measuring devices and formwork which are carried with them from site to site.

Standby Plant

Closely allied with the question of maintenance is that of standby equipment and the degree to which this will be provided. A general policy decision on this subject is necessary as it will materially affect planning and programming.

Ideally, complete standby facilities should be provided for every part of a water supply which is liable to breakdown or failure; in practice, to supply standby equipment to this extent would result in reducing the number of supplies provided within a given budget by nearly half.

In practice, the factors determining whether standby equipment shall be provided, and their extent, include the following:

(a) The accessibility of the site, upon which will depend the speed with which repairs to defective plant can be made. A remote village in a water-short area, dependent upon a single borehole for its supply is particularly vulnerable, and a pump breakdown could be a major catastrophe. In such a case, an alternative source should always be provided.

(b) The existence of "special" consumers (e.g., a hospital or small industry) which might cease to function in the event of the water supply failing. Standby plant or alternative sources will again be necessary here.

(c) The efficiency of the maintenance organization. Where supplies are grouped around a maintenance unit (as referred to in the preceding section) so organized as to be capable of carrying out rapid repairs or replacement, it may be possible to dispense with standby equipment altogether, especially if sufficient storage is provided to enable service to be maintained (at a reduced rate) during the period of an emergency.

(d) The extent to which duplication has been incorporated into the design. Two small pumps may cost more to install and operate than a single pump twice the size, but the breakdown of one of these will enable service to be maintained at half level (or even fully by working longer hours) while repairs are carried out.

(e) The reliability of the power supply when electricity is used. Adequate water storage is the simplest (though not necessarily the least expensive) method of protection against short power failures; standby internal combustion engines either driving the pumps directly or operating a generator are the only complete protection against longer cessations of the electricity supply.

In general, while it may be necessary to sacrifice the convenience of the consumer during an emergency. the safety of the supply should continue to be ensured. It is permissible to provide, say, a handpump as a temporary substitute for a mechanically driven one, but the position should not be allowed to arise where villagers are forced to use a contaminated source through lack of an alternative. Where a high risk of this nature occurs, e.g., where a number of villages are in close proximity to a polluted irrigation canal system which would be the natural choice of alternative source, the desirability of having a portable pumping and treatment plant available at the central maintenance workshop should be considered.

The higher the degree of standardization of equipment and materials the easier will replacement be, and hence the necessity of standby capacity will be correspondingly reduced. If, for some particular technical reason, special equipment has to be installed on a supply, spares must obviously be held for its maintenance; the greater the number of items of this type the more complicated will storekeeping become.

To summarize: standby capacity is necessary for the maintenance of continuity of supply until defective plant can be repaired or replaced. The quicker such repairs or replacements can be effective, the less need for standby. The cost of an efficient maintenance organization may be offset to a considerable extent by the savings on reduced standby requirements. The relative advantages and disadvantages of speedy maintenance capacity versus adequate standby must be compared and decided upon at the planning stage, and these factors must be taken into consideration before designing commences.

Choice of Water Source

This is obviously one of the first and most important decisions to be made for any water supply project. Groundwater (deep or shallow) or surface sources (stream, river or lake) may be used, or springs, which combine some aspects of each.

Where alternatives exist, choice is likely to depend upon reliability, safety and economy in that order. Reliability - the ability to deliver sufficient quantities 365 days in the year - is placed first because it is in periods of water shortage that consumers are driven to other, unsafe sources, thereby counteracting the advantages of their safe supply during the remainder of the year.

Safety of the source is an important factor, as well as safety of the delivered water. A good groundwater needing no treatment is to be preferred to a treated surface water source - in the former case, there is no risk inherent in the breakdown of treatment or non-delivery of disinfecting chemicals.

While it is understandable that some relaxation of quality standards may be unavoidable in very small supplies, particularly in such matters as physical characteristics (e.g., colour or taste), or in non-toxic chemical constituents (e.g., iron or chlorides), it is most important that the water delivered should be safe as regards biological or toxic chemical contamination. Merely to improve convenience, i.e., to bring the existing unsafe source nearer to the consumer without improving its quality, is not sufficient. It may be argued that increasing the quantity available has in itself a beneficial effect, but no rural supply that delivers potentially dangerous water at any time can be considered successful, even if this is an improvement on what the consumers had before.

Economic considerations must give way to reliability and safety. An upland stream that can be piped by gravity to a village supply may be most attractive financially, but only if the quantity is certain and the quality can be guaranteed free from pollution - a difficult assurance to give in most cases.

Similarly, the financial advantage of pumping from a shallow rather than a deep groundwater source may be outweighed by the risk of pollution of the former unless it is possible to site the wells in such a position that there is no potential source of contamination of the shallower aquifer.

Extraction of Ground Water

Wells for the extraction of ground water may be divided loosely into two classes - hand dug wells and boreholes. Hand dug wells (in the construction of which a greater or lesser degree of mechanical assistance may be employed) are of such a diameter that a man may enter the excavation or the completed well, while boreholes are of small diameter and may be sunk by a variety of methods - e.g. drilling, jetting, thrusting, etc.

It is a great mistake to underestimate the potentialities of a properly constructed, sanitary, hand dug well. In Africa particularly, in the very large areas of sedimentary rocks which can be found in almost every country of the continent, such wells are the chief supply of a large proportion of the existing rural populations, and local well sinkers can be found almost every where. There is obviously a great difference between the crude, dangerous hole-in-the-ground, which has been the traditional source for centuries, and the sanitary, soundly constructed, hand dug well incorporating modern design and materials. Methods of construction, improvement and adaptation are described in considerable detail in the WHO monograph on "Water Supply for Rural Areas and Small Communities"[1] based upon practical experience in West Africa. At the time of publication it is known that fourteen thousand sanitary wells had been sunk by the methods described by the Government of Northern Nigeria alone, and that the water supply to some five million villagers had been improved in this way.

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[1] Wagner E.G. and Lanoix J.N. WHO Monograph Series No. 42, 1959

Particularly striking results in the control of dracontiasis (guinea worm) were observed as a result of the well sinking programme in Bornu province of Northern Nigeria. Almost the whole of this province consists of flat, arid, sandy country with a small and short rainy season. Wells have, from time immemorial, constituted the sole water supply for the bulk of the population; these wells consisted of a simple unlined excavation with an average depth of about one hundred feet. They were dangerous to construct - the chances of a well sinker being buried alive by collapse were high - and dangerous to use due both to the periodic caving in to which they were subject, and to the incidence of parasites and pathogens contained in the water. Guinea worm was endemic to such an extent that it is safe to say that no single individual achieved adulthood without being infected at some time by this loathsome parasite. On reaching maturity the worm emerged from an ulcer (usually on the leg or arm of the sufferer), dropping its eggs, and when this occurred in the vicinity of the well these eggs were washed back into the water, swallowed by a small water copepod (cyclops) and in due course drunk by another villager to set up reinfection. Following the construction of concrete lined wells with sanitary, drained aprons and curb walls, the chain of infection was broken, and, as a result, dracontiasis virtually disappeared from the area concerned, and is now a rare occurrence in the province.

There is a tendency to regard hand dug wells as outdated, having been superseded by boreholes; this is definitely not so. Under the appropriate physical conditions they are inexpensive, reliable, require the minimum of skilled labour and supervision for their construction, can be sunk with little mechanical equipment and with locally produced tools and materials and hence do not call for a large capital outlay for equipment and transport, little foreign exchange is needed for imported materials, and often the nucleus of skilled labour - i.e. the traditional well sinkers - are available to be trained in the new methods required.

A further advantage is that where weak aquifers are concerned, yielding only small quantitites of water, the storage within the body of the well itself allows the water collected during the night to be available for use during the hours of peak draw-off next day.

The chief objection to hand sinking is the slowness of construction. This, as regards the individual well, is a valid point, but is largely offset by the large number of wells that can be constructed simultaneously. As an example, in Northern Nigeria, to which reference has already been made, twelve hundred wells were reported completed in a single year at an average depth of eighty feet - a result unobtainable in any other way.

There are, on the other hand, areas where hand dug wells are impracticable because of geological or other conditions, where hard rock has to be penetrated, where water lies at a great depth, or where speedy construction on individual projects is essential. In such cases the drilling of boreholes is the only solution.

Within the scope of this paper it is obviously impossible to go into all the considerations of embarking upon a drilling programme. Suffice it to say that the subject is far from simple, and is not merely a matter of purchasing equipment and drilling holes. There are many types of drilling rigs (e.g. percussion, rotary, air-hammer) each with its own field of usefulness and its own limitations. To keep a rig operating needs a support organization and considerable ancillary services (transport, fuel and water bowsers, bit dressing, fishing tools, stores of casing and screens) a trained and experienced staff, and follow-up operations of test pumping and pump setting for which additional equipment is required.

Before initiating a drilling programme or making major extensions to existing activities it is worth while obtaining expert and impartial advice as to all these factors to ensure that the maximum and most efficient use is made of the expensive equipment involved. WHO is assisting countries in many parts of the world by the provision of consultants to study local conditions and make recommendations on the organization, training and budgetting necessary for this purpose.

There is a third method of extracting ground water from small sources, usually known as a "tubewell". The difference between a "tubewell" and a "borehole" is that the latter consists of a lined (or, sometimes, unlined) hole into which a pump and rising main is inserted, while in the former the casing of the hole itself acts as the rising main, to the top of which a hand or mechanically-operated pump is attached. This type of extraction is particularly useful for drawing water from saturated sands along the banks of a potentially polluted river or canal, making use of the filtration properties of the soil itself to produce water of a better quality than can be obtained from the open source. Various ways of installing tubewlls of this nature are described in the WHO monograph referred to earlier.

Extraction of Surface Water

Surface water sources must always be regarded as suspect in respect of quality; frequently they are also doubtfully reliable as to quantity in the dry season.

If quantity is in doubt hydrological investigations are necessary, and these, to be of practical use, must be conducted over a period, preferably several years. Many instances are known of failure of sources of water supplies in which considerable capital has been invested, solely on account of over-optimistic estimates of available water based upon inadequate preliminary investigation.

It is therefore wise in any programme to identify future projects which will draw upon small surface water sources, and to initiate basic hydrological observations well in advance. Thus ample warning will be given of the necessity for impoundment, raw water storage or other device that may prove necessary later to ensure continuity of supply in periods of low flow.

Quality of the delivered water can only be guaranteed by adequate treatment, and this will depend upon raw water quality, which in turn will vary according to season, rate of flow and other factors. Advance sampling at various times throughout at least a year may prevent costly mistakes later.

Certain devices to stabilize raw water quality, and thus reduce the degree of treatment necessary, may be incorporated, e.g., the use of tubewells in the bank as described in the foregoing section, the use of infiltration galleries or sand-screened intakes below river bed level. Impoundment of a stream, or simple raw water storage lagoons may be effective in settling out seasonal turbidity and reduction of bacterial content of the water.

Surface sources do not lend themselves to the use of type design for intakes as do ground water sources. In addition to streams and rivers, various unconventional intakes will tax the ingenuity of the engineer - rock catchments, hafirs and tapkis, small dams and barrages, protected springs are all possibilities to be encountered. The only general rule is to prevent contamination of the source to the greatest extent possible, and then still treat the raw water as suspect.

Pumping Equipment and Pump Houses

Unnecessary expenditure on elaborate pumphouses is an all too common fault in the design of rural supplies, often resulting in the necessity for economizing in more vital parts of the project.

The question should first be asked as to whether a building is really essential. For a small extra cost electric and internal combustion motors can be obtained "weatherproofed" - i.e. proof against all but extreme conditions of sun and rain. Where conditions are likely to be really severe a simple open-sided roof covering just the essential machinery, switchgear, etc. may be adequate. Hedging or fencing may be necessary against animals or children, but it has been found by experience in many places that adequate education of the villagers, instilling them with a realization of the value to them of the supply together with a pride of local ownership, is an even more effective safeguard against damage. Instances are known of pumping equipment, brightly painted, in the open in the centre of a village, surrounded by well kept garden plots, and regarded as a village feature.

If it is necessary to have a pumphouse this should be as simple as possible, should provide easy access to machinery for maintenance or replacement and should be capable of good ventilation when men are working inside. Such obvious errors in design as doorways too narrow to allow a pump to enter, or the enclosure of a borehole under a roof which prevents pump rods being pulled are not unknown. Protection of moving parts, e.g. belts, is particularly important in areas where local garments are loose and flowing. Other points to watch include sloping floors that can be washed without draining into the well or underground tank, and the provision of hoisting points over heavy items of equipment. Fuel tanks and material stores should be sited outside the pumphouse, and if chlorination equipment is necessary this is better housed in a lean-to building.

Pumps and motors should be rugged and standardized for ease of maintenance and replacement. There is a great deal to be said for reciprocating pumps, both for ground and surface water supplies. Though less efficient for a particular duty than a turbine specifically chosen for the job, reciprocating pumps can cover a wide range of duties, last longer on account of their slower operating speeds, and need less skill in servicing. Normally the only repairs necessary are the occasional replacement of bucket washers and of gland packing-items which in a well designed installation can be easily performed with minimum skills.

Where a good electricity supply is assured submersible pumps, arranged so as to be easily and quickly removed and replaced, have much to commend them provided that a mechanic at the central service depot has been properly trained in the dismantling and reconditioning of this type of pump. Two difficulties should be borne in mind when standardizing on this type of equipment: the excessive wear when the pumped water contains abrasive sand, and the possibility of motors burning out if the supply voltage fluctuates considerably.

Controls for all types of pumping equipment should be as simple as possible, and reliance on automatic devices avoided unless absolutely necessary. Remote controls are a constant source of trouble unless regular maintenance by a skilled instrument mechanic can be arranged.

Hand pumps will for many years be the obvious choice for a large number of small installations. It is worth conducting trials to ascertain the type most suitable and acceptable to the users before embarking on a large programme - in some areas a rotary motion is preferable to an up-and-down handle for instance. In the Philippines and elsewhere considerable success has been experienced with wooden beam handles; although these may not be as durable as metal, they can be repaired locally in the event of breakage and are, in any case, cheaper in first cost.

Standardization is as important with hand pumps as with mechanically driven ones, and the training of a relatively unskilled team to instal and replace these, using minimum equipment, should present little difficulty provided that a single type is adhered to.

In appropriate weather conditions windmills may be a valuable device, but preliminary studies are necessary to ensure that the wind is adequate when it is most needed, and also to select the best height of tower, diameter of sails, etc. Storage or a standby motor should be provided to tide over periods of feeble winds. A careful study of all factors before embarking on an installation programme will amply repay the cost and effort by avoiding costly failures later.

Water Treatment

Treatment for rural supplies should be as simple as possible, and within the capacity of the available local skills to operate. As a general rule protected groundwater sources will not require treatment, while filtration will be the basis for treatment of surface waters, except in those relatively few instances where the surface source is known to be dangerously polluted and no alternative source is available.

Slow sand filtration has many advantages in both construction and operation over rapid gravity or pressure filters for small projects particularly. The advantages and limitations of this process are discussed in some detail in WHO document WHO/CWS/RD/70.1[1].

Where sources are periodically very turbid, preliminary storage of the rain water, either by impoundment or in open lagoons, will assist the operation of filters considerably. The use of chemicals for coagulation should be avoided if possible in small installations.

Chlorination, using chloride of lime or hypochlorite, and dosed from a solution tank by drip feed or other non-mechanical method, may be added as an additional safeguard, but should not be regarded as a substitute for filtration. Reliance upon chlorination alone, dependent as it is upon regular deliveries and proper storage of the disinfectant material, upon possible human errors on the part of unskilled operators, and upon the necessity of regular surveillance, is dangerous. It should only be practised in cases where the raw water quality is reasonably reliable - e.g. in an upland stream, and free from turbidity or organic matter that will interfere with the disinfection action.

In certain areas where the water contains excessive quantities of iron a simple aeration cascade and subsequent sedimentation has proved useful prior to filtration.

[1]WHO Background Paper: Biological or Slow Sand Filters, 1970

Storage

The amount of storage to be provided, in terms of the number of hours (or days) of demand, is a matter of policy to be decided according to circumstances. Storage serves three purposes; to deal with periods of fluctuating demand, to tide over periods of breakdown and to permit pumping to take place during part of the day only. Factors to be considered include accessibility of site, speed with which repairs can be carried out, the degree of inconvenience to the consumer in the event of interruption of the supply, the existence of alternative sources of supply. A further factor in larger installations will be fire protection, which will be less applicable in village supplies where no fire fighting equipment is available.

Excessive storage may be an expensive luxury; inadequate provision an inconvenience, more or less serious according to circumstance. Storage for immediate needs, capable of being extended or duplicated in the future as demand grows, is a commonly adopted practice.

Storage tanks, both ground level and elevated, lend themselves readily to type designing, and to the adaptation of locally available skills and materials. The avoidance of complicated pipework, the use of thin block or masonry skin walls filled between with mass concrete in lieu of traditional reinforced concrete design, the restriction of the number of types and sizes to a minimum (even if this involves over-capacity in some instances) are possible ways of economising on imported materials and on design and construction staffs. Steel tanks have advantages in speed of construction, but need regular painting and do not last so long as concrete; these and similar economic conditions must be balanced.

Pipes

The use of polyethylene and polyvinyl chloride pipes, particularly in smaller sizes, enables considerable economies to be made on rural supplies. If programming has been done well into the future, and it is possible to guarantee purchases in the years ahead, manufacturers may be sufficiently interested to carry out the extrusion of these pipes within the country, thus saving foreign exchange.

Asbestos cement pipes will usually be found most economical for larger diameter mains. The important thing is to standardize on certain materials and makes, particularly of joints and specials, and to reduce the number of sizes and types to a minimum, so as to ensure interchangeability, simplify storekeeping, and minimize the training necessary to enable workmen to lay, repair and replace damaged pipes anywhere in the country.

Criteria

Here again is a subject upon which a policy should be established according to experience and local conditions, as basic criteria will influence the design and cost of installations built under the programme.

As an example the number of gallons (or litres) provided per head per day will be one factor in determining the total output of a supply. Under-design will result in the works becoming quickly overloaded as population increases or consumption rises; on the other hand over-design will mean wasted expenditure. In many cases the biggest part of the output of a village supply will be taken by women from a central watering point and carried home. It is worthwhile considering that 10 gallons per head per day (a common design criterion) means that a family of five will consume 50 gallons, or 500 lbs. of water daily - i.e. that the women of the household will have to carry almost one quarter of a ton daily. In some places this may be realistic, in others the figure will never be reached in practice; obviously distance through which the water is to be carried will be a consideration.

The fixing of such basic design criteria is always a compromise between what is desirable and what will be achieved in practice, frequently resulting in "immediate" and "future" standards which will enable a small supply to be given now with provision for augmentation as demand grows and as more money and manpower become available.

The foregoing ten sections have touched briefly upon some of the technical aspects of programme planning, and are intended only to illustrate some types of consideration that must be worked out in advance. The engineer engaged upon detailed planning and design will be well aware from his training, text books and experience of the hundreds of points left unmentioned. Before closing this paper, reference will be made to a few general subjects of relevance to rural water supply programming.

Financing

As an appendix to this paper appears a short summary on the financing of rural water supplies, including some details of international assistance available, particularly the joint WHO/UNICEF programme of assistance. This was prepared for a recent WHO seminar on the subject in Thailand, and is given here exactly as presented on that occasion.

Health Education in Rural Water Supply Programmes

Health education still conjures up in many minds only visions of a doctor in white coat with a microscope demonstrating pathogens which cause disease, or a health visitor showing a film in a village. Whilst these examples have their application, a properly conceived health education programme involves very much more. The objective in the present case is to motivate people to want a better water supply and to be ready at least to accept the responsibility of operating and maintaining the water supply system satisfactorily. Such an objective cannot be reached without the authorities being aware of the existing conditions of water supply in the community and the needs as felt by the community itself. Even where the causal relationship between polluted water and water borne diseases is understood, this may not, in itself, be sufficient stimulation for the villagers to want a proper, protected water supply; they are more likely to be impressed by considerations of convenience and, possibly, economics. Efforts to secure community participation would have a much greater chance of success in the light of practical examples of how an adjacent community with similar conditions has solved its problem - such demonstration has far greater impact than discussions. Practical improvement measures should therefore be carried out simultaneously with health education programmes, which cannot function in a vacuum.

Professional health educators will be able to give valuable assistance in obtaining acceptance of rural water supply programmes. It must, however, be realised that every worker in the rural water supply field, such as the engineer, the construction crew, the sanitarian, etc. should have a "health education" approach when dealing with the public. The coordination between health education authorities and those responsible for rural water supply, established from the very beginning of the programme, should be continued so that problems arising during and after programme implementation can be analysed and solutions found. Such collaboration cannot fail to be mutually beneficial.

Water supply and excreta disposal

It is highly desirable that water supply and excreta disposal should be undertaken simultaneously in each community, thus obtaining the maximum effect from the environmental improvements. This ideal is, however, sometimes found to be unattainable in practice.

The need for a good water supply is an obvious one, and in almost every case villagers without such a supply are anxious to obtain it and very willing to co-operate in its installation. The equal need for sanitary disposal of excreta may not be so immediately apparent to them, and some persuasion may be necessary to gain their support for this measure.

Attempts to force acceptance of both improvements by stipulating "both or neither" have met with, at best, a grudging acquiescence - an unfortunate attitude toward measures which can so greatly improve their health and that of their children.

On the other hand, experience shows that the general rise in environmental standards brought about by the provision of safe water supplies, coupled with the example and education provided by the health workers, leads to a later, but more enthusiastic, acceptance of an excreta disposal programme.

The installation of water supplies also frequently brings an unforeseen (unforeseen by the villagers, that is) problem of the disposal of waste water, which is most acute in compact, densely populated villages built upon impervious soil. This can present a particular health hazard in the form of filariasis, the mosquito carrier of which breeds in dirty or soapy pools.

It is, therefore, felt that every effort should be made to obtain acceptance of the simultaneous installation of water supply and excreta disposal but this should not be insisted upon. Where there is a reluctance, for any reason, the water supply alone should be proceeded with, and preparation made for the introduction of the other improvements at as early a date as possible after the provision of water. Where applicable the problem of waste water drainage should also be considered.

In any case, where there are schools, health centres or buildings of communal use (including markets) the full range of sanitary improvements should be installed from the start. Apart from the obvious health implications for groups of people congregated together, these installations in themselves will assist toward the acceptance of sanitary facilities by the villagers, and encourage them in their wise use and in hygienic habits.

Legal Provisions

To be successful any national rural water supply programme should be supported by adequate legal powers the extent of which, of course, must be decided upon within the country concerned. However some of the points which experience in many areas has shown to require a firm legal basis are the ownership of water resources, existing water rights, the prevention of pollution of surface and underground sources, prevention of overpumping, control of abstraction by industry and private users, and the acquisition of land and wayleaves to construct waterworks.

Having secured the agreement of a community to participate in construction of the water supply wherever possible, and to operate and maintain the same after construction, it has been found useful in a number of instances to have this agreement recorded so that the village community is legally bound to take charge of the water supply on completion of construction.

Laboratories and Quality Surveillance

A national programme of rural water supplies will almost certainly require its own laboratory to test raw water quality in order to determine treatment necessary. In addition, if dams or "hafirs" are to be constructed, facilities will be necessary for soil testing, while hydrological investigations may call for tests on evaporation, run off coefficients and the like.

Surveillance of quality of delivered water is essential, but frequently this will be found to be more practical on a decentralized basis. The use of portable chemical and bacteriological test kits at, say, district maintenance depots may take the load off central laboratory services. Ideally every works of any appreciable size should be able to make simple tests of water quality, but it is most unlikely that the standard of expertise amongst operators of small works will permit this.

The ultimate responsibility for quality surveillance rests, in almost every instance, with the health authorities; a close coordination between the water and health departments (when these are separate) will go far toward ensuring the safety of the consumer.

Livestock watering and other village uses

Whilst it is generally accepted that water for domestic purposes is the highest priority use in any supply there are nevertheless many areas in Africa and elsewhere where the villager himself will give almost equal priority to the watering of his cattle and domestic animals.

This fact must be recognised in any rural water supply programme; if there is a single watering point only no amount of instruction or surveillance will prevent it being equally used for humans and for cattle. Consequently allowance must be made for this extra demand when calculating the capacity of the system and, in addition, it is desirable to construct troughs or other animal watering devices in such a way as to protect the supply for human consumption against animal contamination.

The design of animal watering points in arid areas on a large scale is a different problem, and dangers of erosion, overgrazing and disease transmission have to be considered. Close coordination with the appropriate department (e.g. Agriculture or Animal Husbandry) will be necessary if a rural water supply programme is to include works of this kind.

Similar remarks apply when there is a likelihood that a village supply will be used for, say, the watering of garden plots. Irrigation works of any size are outside the terms of this paper.

Recruitment and Training

The subject of recruitment and training has been left to the end of the paper, not because it is less important than the other subjects referred to - the exact contrary is true - but because its complexity would warrant a paper on its own, and only a few general remarks can be made here.

Firstly, recruitment. It is always difficult to obtain staff to work on rural projects; the work is arduous, living conditions are usually less attractive than in the cities, and young men are understandably more likely to be interested in the larger and more spectacular works associated with big urban supplies. Recruitment at the village level for all but the most simple operative tasks is usually hampered by the lack of candidates with a suitable educational background.

As a result it is often found that top-grade men are reluctant to enter the field of rural water supplies. This is a great pity since there is hardly any other activity that can have such a profound effect upon the health and well being of the majority of a country's population, and hence benefit the national interest. In addition the work has a particular satisfaction of its own; the gratitude of those benefited, the continual exercise of ingenuity in the solution of fresh problems, and the ability to see positive results from personal efforts are attractions in themselves to the right type of recruit.

Probably the most important single factor in the success of any programme is the presence of a keen, energetic and experienced man in the key position. Such a man will attract a team of first-class subordinates and communicate, through them, his enthusiasm throughout the department. He must be able to offer the inducements of reasonable salary scales, promotion prospects and living conditions which are likely to be amply repaid in efficiency and output.

Secondly, training; training of professionals, subprofessionals, clerical and administrative staff, artizans, mechanics, operators. All the multifarious staff who work together within the department, where the inefficiency of one can affect the efforts of many, need training ranging from the university course for the professional engineer to the in-service instruction of the village pump operator. Such training should be accompanied by a recognition of skills acquired, and an inducement for the promising trainee to continue improving his skills with the prospect of rising in the service. By so doing the future of the service will be assured.

It is perhaps unnecessary to emphasize that the best time for training is before responsibilities are undertaken. This can only be ensured by a proper assessment of needs for personnel of different grades now and in the future. Each project completed requires operation and supervision - the time to prepare staff to do this is before and during construction, not after the job is finished.

Training is not a once-for-all operation, it is a continuing process as staff wastage and programme expansion calls for new and replacement staff. Improving methods of working, experience in programme organization, demand for better water treatment will all call for refresher training of the personnel concerned.

In a programme of any size it will usually be found desirable to appoint an officer whose sole duty is to ensure that all staff are appropriately trained. He himself should be trained to do this. He will have to deal with such questions as the setting up of a school or schools for artizans, organization of training courses, mobile demonstration teams, in-service training, the preparation of course materials and instructions to lower-grade personnel, possibly in their own languages where these differ within the country. He will also be responsible for setting standards for certification of various skilled grades.

The three requirements of any water supply project are a suitable water source, finance for construction and operation, and skilled staff to build, maintain, supervise, operate and manage it. These three are equally essential, the third is only too often neglected to the prejudice of the whole programme.

Conclusion

An attempt has been made in the foregoing paper to show the importance of rural water supplies as a basic necessity for the health and well being of the people and as an investment in the economy of the country, to describe the planning of a country-wide programme, and to refer briefly to a number of factors that must be considered within such a programme.

Within the limits of a paper of this kind there must obviously be many omissions. In any case it is virtually impossible in a single document to cover all the varying types of administration, social, legal and historical background, physical and hydrological conditions met in different countries. Each national programme has to be individually tailored to the needs of the particular country; the important thing is that preliminary study and careful preparation to ensure that the programme adequately covers those needs is well worth while. Changes at a late stage are always more difficult than sound initial planning.

WHO has been, and is, assisting many countries throughout the world to carry out this planning. This is done in many ways: by the posting of staff and consultants; by advice on organization, management, legal and financial aspects, training, as well as upon the technical problems involved; by research and development, including the search for locally available materials and the adaptation of traditional skills and techniques; by the exchange of information between countries, so that newly initiated programmes may avoid the mistakes which others have made; by publications; by the organizing of conferences and seminars; by the award of fellowships; and by other forms of assistance requested by member governments.

Successive meetings of the World Health Assembly have stressed the concern of the Organization with rural water supplies. To conclude, therefore, the opening statement of the paper is repeated:

"There is no single measure that can so improve the health and well-being of the rural dweller as the provision of an ample supply of safe water".

World Health Organization
CWS Unit
May 1970

APPENDIX I

WATER SUPPLIES AND HEALTH

Some experiences from different countries

The entire philosophy of the WHO programme for the improvement of environmental sanitation is based upon the premise that the provision of ample supplies of safe water and the sanitary disposal of excreta have a direct and far reaching effect upon the health and well-being of rural populations. Indeed, it is believed that no other single measure can make a comparable contribution to the improvement of their health and standard of living. The effect is particularly marked upon women and children; upon women because it is to them that the drudgery of carrying water over long distances falls, and upon children because of the greatest number of preventable fatalities and sickness attributable to lack of sanitation occur among infants and young children.

While it is difficult to produce from any individual project statistical proof of this premise, there is an overwhelming mass of evidence from all parts of the world in support of its validity. A number of references are given, which may be regarded as merely typical of a large literature on the subject; the quotations which follow give an idea of the kind of evidence available.

A survey, carried out in Japan, in 1962, of 30 rural areas showed that after installation of safe water supplies the number of cases of communicable intestinal diseases was reduced by 71.5 per cent., and that of trachoma by 64 per cent., while the death rate for infants and young children fell by 51.7 per cent.[1]

In the Amazon valley of Brazil, the incidence of typhoid fever and other water-borne diseases was extremely high, as was the infant mortality rate and intestinal parasite infection rate. Construction of safe public water supplies was undertaken in smaller communities (ranging in size from 500 to 10 000 inhabitants). In one of these where there had been 20-30 cases of typhoid fever each year, not a single case occurred after the installation of a small and economical water supply.[2]

The report of the WHO Diarrhoeal Diseases Advisory Team on a study carried out in Venezuela in 1964-1965 includes the finding that "Diarrhoea seemed to be caused by defective sanitation and more especially by the lack of water and washing facilities. Water and washing facilities proved to have a considerable impact on incidence of diarrhoea (from all causes), incidence of Shigella and Balantidium coli, two recognized causes of diarrhoea."[3]

In replies to a WHO questionnaire in 1962, Japan, Cuba, Peru, Colombia, Pakistan, Ceylon, Madagascar, Kuwait and India reported that the incidence of water-borne diseases had markedly declined since the improvement of water supply conditions.[4]

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[1] World Health Organization, Public Health Paper No. 23, 20

[2] United States Department of State (1950) Point four: co-operative programme for aid in the development of economically underdeveloped areas, Washington, D.C. (Publication 3719, Economic Co-operation Series 24)

[3] Report of WHO Diarrhoeal Diseases Advisory Team, WHO/EMT/66.7, 151

[4] World Health Organization, Public Health Paper No. 23, 20

United States Government Public Health Monograph No. 54, which deals with the relationship of environmental factors to enteric diseases, ends with the sentence "It is concluded that specific environmental improvements, based on a knowledge of local deficiencies, will invariably effect significant reduction in enteric disease."[1]

A study on the influence of water availability on Shigella prevalence in children of farm labour families in California, United States of America, may be summed up in a quotation from the report: "The finding implies that the control of Shigella infections may be significantly improved through a single practical modification of the environment - provision of easily accessible water for personal hygiene."[2]

Special mention should be made of communicable diseases of the eye, particularly trachoma, and attention is drawn to a survey carried out by the Government of Taiwan with UNICEF and WHO assistance in 1960-1961, preparatory to the initiation of a trachoma control programme. Among the facts which emerged from this study, which involved the examination of more than 33 000 children, was a direct relationship between the incidence of the disease and the distance of the home from a tap or other source of water. Where water was available in or adjacent to the house, the incidence was 19.1 per cent.; as the distance between house and tap increased, so did the prevalence of trachoma, until where the source was more than 500 metres distant, the incidence was as high as 29.5 per cent.

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[1] Schliessman, M.S.S.E., et al. (1958) USPHS Monograph 54, 33

[2] Hollister, A.C., et al. (1955) Amer. J. publ. Hlth, 45, 362

APPENDIX II

FINANCING OF RURAL WATER SUPPLIES[1]

In connexion with the second United Nations Development Decade proposals, an estimate was prepared of the cost of a global programme of rural water supply. A target was first selected as being reasonably attainable in the ten years 1971-1980, and the cost of its implementation was calculated.

On the basis of available information, it was assessed that in 1970 approximately 10 per cent. of the rural populations of the world have access to reasonable good and safe water, and the target set for the Decade was to raise this figure to 20 per cent., allowing for the population increase in the interim.

The cost of providing the additional supplies required under this programme was estimated at the equivalent of $ 1 600 million, of which 60 per cent. ($ 960 million) would be required in Asia, 25 per cent. ($ 400 million) in Latin America, and 15 per cent. ($ 240 million) in Africa.

While it is hoped and expected that the maximum possible assistance will be given by international, regional and bilateral financing agencies in the implementation of the programme, it is obvious that reliance cannot be placed upon such agencies to provide the whole of the capital required, particularly as rural water supplies comprise only one item out of many planned in the Decade proposals for the raising of health, social and economic standards in the developing countries. Provisional estimates have, therefore, assumed that about one quarter of the capital costs involved will be obtainable from external services; this is approximately the proportion of the outlay on an average rural water supply project represented by the value of materials that require to be imported into the country.

On the assumption that external loans will be forthcoming for one quarter of the total construction costs, it necessarily follows that the other 75 per cent. will have to be provided from sources within the country. This figure can again be broken into two roughly equal parts - that which can be provided at village level, e.g. labour, sand and gravel, and that which can best be provided by government or state organizations, e.g. cement, other materials available within the country, transport, etc.

Global figures of this nature must obviously be treated as very rough approximations only, intended to show the magnitude of the problem. Unit costs vary very widely, as will be seen from the attached table of construction costs per head in six countries having differing conditions; further variations will result from the degree of service provided, and can range from less than $ 1 per caput (a shallow tube well and hand pump serving a small community) to more than $ 16 (a deep well or treated surface source distributed through house connexions).

The assumptions made in the United Nations Development Decade proposals were that 200 million people would require to be served at an average cost of $ 8 each, and that of this amount $ 2 would represent external costs to be financed with international or bilateral assistance, $ 3 would be met at village level and $ 3 from other national resources. Similar figures may be found useful for the first approximations when gauging the extent of national programmes.

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[1] Paper presented by CWS unit at a WHO Seminar on Rural Water Supplies, held in Thailand, March 1970.

Paying for Water

Before considering the financing of a national programme, certain basic policy decisions must be made. One of these will be the degree to which the individual consumer himself will pay for the water received.

In some countries there is a long standing tradition that water should be provided free to all who need it. This "free water" concept has its roots in religious and cultural customs ingrained in the people, but its application to a community water supply is founded upon a serious fallacy, i.e. that naturally occurring water, God-given from rainfall, is what is proposed to be sold.

It may be taken as a general rule that the objective of a rural water supply programme is to improve the quality, quantity or convenience of the water service rather than to "provide" water. Where a community exists, there must already be some water or the people could not live. It may be inadequate, unsafe or far away (sometimes all three), and the costs involved are required for the purpose of remedying these deficiencies. Provided that this point of view is adequately put over to the villagers, it will usually be found that the rooted objection to making any payment for their supply will be overcome. In any case, it will often be found that there is a parallel custom of paying for the carriage of water when brought by hand or by animal from a distant source - the argument that similar payment is incurred when water is conveyed by pipe is often accepted.

On the other hand, those who will benefit from a rural water supply are usually among the lowest income group of the country, and to charge them the true cost for their improved service would be beyond their capacity to pay. Hence, while maintaining the principle that the consumers should make some contribution toward the cost of their water, most governments find it necessary to subsidize to some extent at least the cost of new construction. The division of costs referred to earlier may be a convenient basis for this purpose, permitting the local contribution of labour, sand, gravel, etc. to be made in kind by the community, thus avoiding the collection of cash by government.

After completion of a village project, there will be recurrent costs to be paid. In the case of a simple well or piped spring catchment, these will be very small, but nevertheless no installation lasts for ever, and the principle of setting aside an annual amount for repairs and renewals is a good one. Where a more elaborate system is installed, with mechanical pumping or chlorination, operation costs must be provided for, including labour, fuel, chemicals and periodic maintenance. These will usually be charged to the consumers; the collection of the appropriate amount may be made in a number of ways, e.g., a community charge based upon actual costing, a flat rate per caput, a charge for actual water consumed.

In some countries, governments require that communities, in addition to paying for these recurrent outgoings, shall contribute over a period to the repayment of the initial subsidy toward the construction costs - in other words, that these costs should be regarded (in whole or in part) as a loan rather than as a grant, repayable by the community benefited.

The amount of capital and recurrent charges to be borne by consumers and the method of collection are matters to be decided by each government for itself, bearing in mind the circumstances in each case. The obvious simplification of accounting possibly by pooling income and expenditure into a national or state fund for the purpose, so that all rural consumers pay a flat rate, will no doubt be considered. The obvious drawback is that this method will lose its simplicity if account has to be taken of different degrees of service, e.g., one village is served by a single hand pump, while another has water delivered to convenient standpipes.

The important point is that the policy of whether or not, and how, to charge consumers should be decided and clearly defined before the commencement of the programme. To supply water first, and to fix charges later, has proved to be a cause of trouble in almost every instance known.

Some methods of construction financing are now considered, under the three headings referred to earlier.

External Financing

The foreign exchange component of construction costs, required mainly for materials and equipment that cannot be produced within the country itself, is usually the most difficult problem in rural water supply financing. This fact is recognized by certain of the international and bilateral financing agencies, from whom it is often possible to obtain assistance in the form of loans or extended credits. However, certain safeguards are usually required by the lender when assistance of this kind is sought.

At this point, an important difference between the financing of urban and rural projects should be noted. Properly planned and managed, an urban supply can often be shown to be a "bankable" proposition, a generator of income that will not only cover all recurrent costs but also capital loan repayments. Furthermore, the construction of such a project will create an asset which in itself will form the security for the financial outlay. A loan made for an urban supply is usually specific to that project alone; such a loan, although made to and serviced by a government is, in its turn, guaranteed to the government as to its repayment by the municipality or undertaking operating it.

Rural supplies, on the other hand, are rarely financed on an individual basis; they cannot be made "bankable", will rely on continual government subventions, and the assets are less readily identifiable. As a consequence, the government when applying for a loan for this purpose will have to use other national assets as a security for repayment, and will usually also have to show the existence of a national programme and organization capable of administering and utilizing efficiently the loan for the purpose provided.

In Latin America, the Inter-American Development Bank has been one of the factors contributing to the success of rural water supply programmes in a number of countries by granting loans to governments; it is hoped that the more newly-formed Asian and African Development Banks may become equally active within their respective areas. The Agency for International Development in Latin America, and other bilateral agencies in other parts of the world, have also contributed towards the successful financing of rural water supply projects, and the International Bank for Reconstruction and Development is another source from which loans for programmes of this kind may be sought.

Probably the international agency most active in this field is the United Nations Children's Fund (UNICEF) which, in collaboration with WHO, is assisting rural water supplies in more than 70 countries. UNICEF's assistance, however, except in certain special cases, is confined to the initial stages of a programme. The purpose of their activities is to set up pilot or demonstrational projects in order to allow governments and their staffs to gain experience that will lead to national programmes being carried out with greatly reduced reliance upon external assistance.

UNICEF-WHO assistance operates in the following way. Following the preparation of a Request by government (in the formulation of which WHO staff may be of help), UNICEF provide (in kind) the imported materials and equipment required, free of charge to the recipient government, who in turn provide locally available materials, and arrange for the villagers to provide the necessary labour force.

WHO staff work with and assist the national organization in the planning, programming and supervision of construction, concentrating on the training of national staffs at all levels to enable them to take an increasing share of the responsibility, and eventually to become completely independent of outside assistance.

This system has proved very successful in a number of countries, but, it is repeated, it is not intended as a method of financing rural supply construction on a large scale. One of the conditions of UNICEF-WHO assistance of this nature is an indication of government's intention to undertake a national programme, using other sources of finance, upon completion of the demonstrational projects.

Another potential source of external finance is the United Nations Development Programme (Special Fund) but, like UNICEF assistance, this is not intended to provide construction capital on a large scale. The type of project considered most likely to be accepted by this fund would comprise the setting up of a national organization for rural water supplies, carrying out sectoral or physical studies in selected areas, demonstrational projects and staff training.

National Financing

When referring earlier to the proportion of the cost of rural water supply construction that will have to be financed by government, no account was taken of the cost of the administrative organization to plan, design, build, maintain and operate these supplies. This was a deliberate omission, because to attempt to relate these organizational costs to individual projects or to the number of population served can be very misleading, especially at the early stages of a programme. For the first few years, the organization's staff will be developing standard designs and methods and formulating long-term plans, the advantages of which will be more apparent as the programme gets under way than in the results of the first few years' work. It should also be remembered that the organization and its staff will, at this time, be acquiring experience of local problems and conditions, and that consequently their output will gradually increase as this experience is gained.

The cost of setting up and maintaining the national rural water supply organization is, therefore, the first of the charges to be borne by government, and will be irrespective of the number of projects actually constructed. Note: in this section, the word "government" is used somewhat loosely - referring either to the national government, or to state or regional governments according to the political administration of the country concerned.

Apart from these organizational costs, the portion of construction costs of projects that will have to be financed from government funds consists of those materials available within the country which cannot be provided at the village level, together with the costs of their procurement, storage and transport to site, and such other items as tools, equipment and the provision of skilled labour and supervision for construction, where such skills are not available locally.

In the global approximations quoted earlier, the percentage of the total construction costs represented by this portion of the work was taken as 37½; according to circumstances, a more accurate figure may be anywhere between 25 and 50 per cent.

The mechanism whereby this is provided will vary from country to country, depending upon such factors as the nature of the rural water supply organization, and whether it is intended that any part of the amount shall be recovered from the benefited community.

Perhaps the simplest form of financing procedure occurs when the organization consists of a corporation with a self contained accounting procedure, but it is more usual to find that the responsibility for rural water supplies lies in a branch of a department or ministry. In such case, normal budgetary procedures will be observed; it is, however, important that the system should be sufficiently flexible to enable construction work to proceed steadily and as part of a plan covering several years, with consequent economy of purchasing, design and supervision.

When a cash return is planned from the local authorities, communities or individuals, the advantages of a revolving fund should be considered, receipts being added to the amounts provided by government to enable the programme to accelerate in the future. Whatever the mechanism, it is important that the amounts provided for rural water supplies should be kept separate and identifiable.

Local Contributions

The principle of local contribution, in cash or in kind, is one that has proved valuable in almost every instance where it has been practised. Apart from the financial consideration, it has been found that the participation of villagers in the construction of their own water supply has resulted in a sense of partnership with government and an improved attitude toward the maintenance and protection of the works in the future.

The degree to which the local population will contribute toward the construction of their water supply will depend on three factors especially. Firstly, the condition of their existing supply as to quantity and physical properties. It is easier to promote participation in water short areas, in places where long distances have to be covered to reach the source, or where the only source is highly coloured or bitter in taste than when an ample, but unsafe, source is close by. Health considerations are notoriously difficult to put over to villagers whose families have been drinking the same water for generations, and who can see no connexion between the diseases from which they suffer and the water they drink. Improved convenience and appearance are likely to carry more weight; an actual shortage (continually or periodically) is the most persuasive factor of all.

The second point is the relation between personal income and the proposed charges to be made. Arrangements to spread payment over a period will often ease the burden of the individual, but it must be remembered that there may be charges for operation and maintenance to be levied in addition to capital contributions. Participation in kind - by providing labour for trench digging and the collection of sand and gravel - is likely to be more acceptable to the poorer peasantry.

A third factor is the preparatory public relations groundwork, which is so necessary to obtain local support, and to kindle a spirit of partnership in the undertaking. If the consumers themselves really want the project, and can be made to feel that they are instrumental in obtaining it rather than the recipients of something decreed by a distant government, then their co-operation and contribution will be more readily forthcoming.

The degree of support experienced in actual practice has been surprisingly good in many places. Instances abound, in Latin America particularly, of communities - apparently among the poorest in the country - where co-operative effort and the use of such devices as lotteries or fiestas have raised the entire capital cost of their water supplies.

General

The foregoing notes on rural water supply financing consist mainly of generalities that may be of little value in particular cases. Economic conditions, financial procedures as well as physical conditions vary from country to country and must be taken into account to find the system most suited to the national needs. Bond issues, national lotteries, local investment by banks and insurance companies, revolving funds have all been successfully used on occasion. Encouragement to local industry to manufacture such items as hand pumps has helped to reduce costs and, more importantly, to reduce the proportion of foreign exchange required.

WHO has assisted countries to find the most appropriate solution to their particular problems by providing, upon request, the services of economist consultants experienced in water supply financing.

In summary, rural water supply programmes require a great deal of capital for their implementation, and the bulk of this expenditure will have to be raised within the countries concerned. Financially, it is unlikely that the smaller installations can ever be made self supporting. Economically, there is little doubt that the expenditure is worth while, and will result in long-term benefits greatly in excess of the outlay. From the social and health aspects, there is no measure that can produce a greater benefit to so many people throughout their whole lives as the provision of an ample and convenient supply of safe water.

CONSTRUCTION COSTS PER CAPUT OF POPULATION SERVED OF DIFFERENT TYPES OF WATER SUPPLY SYSTEMS IN SIX COUNTRIES*

Type of Water Supply System	Unit Construction Cost per caput (Range) in US$
Sanitary dug wells with hand pumps	1.50 to 3.30
Reconditioned wells with concrete cover, apron and hand pump (Malaysia)	0.68
Dug wells, mechanical power pumps, chlorination, storage, piped distribution, some standposts, some house connexions	5.00 to 10.70
Shallow tube wells with hand pumps (East Pakistan)	0.58
Tube well, deep well turbine pumps, with and without chlorination, storage, piped distribution, some standposts, some house connexions	4.20 to 16.40
Tube well, deep well turbine pumps, with and without chlorination, storage, piped distribution, some standposts, some house connexions, with iron and/or manganese removal (Taiwan)	4.90 to 7.00
Spring, chlorinated, gravity piped supply, some standposts, some house connexions	3.35 to 10.40 15.40 in very hilly areas
Spring, no treatment, mechanical pumps, piped supply, standposts and house connexions	1.90 to 6.10
Small concrete dam on stream, gravity feed (Malaysia)	2.33 to 2.80
Stream, chlorinated, gravity piped supply, standposts and some house connexions	3.25 to 10.50
Stream, infiltration gallery, chlorination, turbine pump piped supply, standposts and house connexions	4.30 to 16.00
Stream, lake, mechanical pump, filtration, chlorination, storage, piped supply, standposts, some house connexions	3.18 to 12.47

* China (Taiwan), India, Kenya, Malaysia, Pakistan, Thailand

Specimen only

Operation, Maintenance and Renewals for Rural Water Supply Project
Bansaniba Village, Ruritania

Description of project:

Present population 1800
Water consumption/head/day 75 litres
Hours of pumping per day - 9
Quantity pumped per hour - 15 000 litres
Maximum head (including friction) - 80 feet
Pumping plant: 2 x 6 hp diesel motors driving 2 x 3 inch diameter reciprocating pumps (including standby)
Reservoir: concrete, 50 cubic metres capacity
Source: stream intake
Transmission and distribution: 3000 feet x 3 inch diameter asbestos cement pipe, 10 standpipe faucets
Treatment: chlorination (chloride of lime)

Capital cost of project: $ 11 000 comprising:

	$
Pumping plant and motors (2 sets)	2 500
Intake and access	1 000
Pumphouse and oil store	1 500
Reservoir	1 000
Standpipes with wastenot valves and drainage sumps	1 000
Piping and fittings	3 200
Concrete to aprons, chlorine dosing tank, etc.	800

Renewals contribution:

	Estimated life		$ per annum
Pumping plant	(10 years)	(1 set)	125
Pumphouse and intake	(30 years)		80
Reservoir	(40 years)		25
Piping	(20 years)		160
Concrete	(30 years)		27
Standpipes	(5 years)		200
Total renewals, per annum			617

Operation:

		$
Labour	1 pumping attendant	600
	Relief and casual labour	500
Fuel	(Consumption 0.3 gals/hour, 2.7 gals/day)	
	1000 gals/annum	500
Oil	70 gals/annum	100
Chemicals	160 lbs chloride of lime (assume dosing 0.5 ppm)	20
Miscellaneous	Grease, cleaning materials, tools, transport	40
	Total: Operation	1 760

Maintenance:	Contribution to maintenance workship, based upon 4 visits per annum, including transport	50
	Spares and replacements	50
	Maintenance of buildings, and distribution repairs	50
	Total: Maintenance	150

Total running cost (excluding capital repayments) per annum:

Renewals	617	($ 0.33 per caput)
Operation	1 760	($ 0.99 per caput)
Maintenance	150	($ 0.08 per caput)
	2 527	

Cost per head of population per annum $ 1.40

Capital cost $ 11 000 equals $ 6.1 per caput of present population. If useful life of over-all project is taken as 20 years, then capital cost per year of life is $ 550, or approximately 30 cents per head of present population per year.