Development of rural water supplies in Tanzania

J. M. HOLLOWAY

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For Tanzania to provide her 12.25 million people, 95% of whom live in the rural areas, with an adequate water supply would involve the expenditure of £2.25 m every year for 40 years at present day prices and without allowance for population growth.

56. Expenditure of such sums, which are large in relation to national revenue, inevitably requires justification. Unfortunately services such as rural water supplies do not lend themselves to economic analysis and the production of cost-benefit ratios. Some research work has been done on the problem; one team has been looking into the amount of energy the average woman expends daily in carrying water, converting that energy into food consumed and thus deriving a figure for the cost of the water fetched. The time the women would save in not having to make a long journey for water could be used for more profitable pursuits such as the increased cultivation of a cash crop, and the value of this secondary benefit assessed.

57. Again, the problem has been looked at from the health point of view, and the cost of providing curative medicine for the diseases caused by impure water can be taken as the cost of not providing a clean water supply. But none of these approaches helps very much, the fact is that no satisfactory method has yet been devised for evaluating, in terms of cash, development of this nature, and they have to be looked upon as essential development in-puts, something in the nature of a catalyst, which will generate further economic growth.

58. In this respect it is essential that proposed supplies should be planned and programmed in close co-ordination with other development in-puts; health services, feeder roads, agricultural development, education services, etc. but it is becoming apparent that the first essential in making the other developments viable is the provision of a relatively satisfactory source of domestic water.

Miss M. Lindley, Senior Engineer, Messrs Rofe, Kennard & Lapworth

The Paper is very interesting to those who have had experience of similar areas and have seen the size of the problem.

60. The Author brought out the question of obtaining a good grass cover on embankments before erosion started: if the grass is not well established at an early stage that which has been started is almost certainly going to be lost; washed away by very intense rainfall after the long dry season, leaving a gullied bank within a year. We experienced similar trouble with erosion of spillways and, on occasions, placed topsoil on the spillway as a base for the grass. Did the Author have any success with this method or were the spillways left bare?

61. Were problems encountered with heavy siltation in the dam basins and the gathering areas of the charcos? In some areas in which we worked, silt was a definite problem due to the high intensity of rainfall following long dry periods. In one case we lost 18% of the capacity of a dam in the first wet season in an area having two wet seasons per year. Although it was an abnormally wet year, we could not afford such losses.

62. I would also like to ask whether there was much trouble with vandalism at the installations. I noticed that the Author could safely leave the well head outside

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the pumphouse: in some of our areas the belt would have been cut. We had to enclose both well head and pump, building the gantry into the structure. The Author also showed *normal taps*. How did he persuade Tanzanians to turn them off? We found open taps a cause of serious waste.

63. The Author states that in circular masonry tanks he placed the reinforcement between the courses. We found that this led to considerable cracking and leakage, and modified our method of building by putting up a blockwork or single brick skin, wrapping it with normal fencing wire as a type of prestressing, and plastering or building a further protective brick skin around that. The masons apparently much preferred this method, which was quicker and easier. Did the Author use it? I think he was fortunate in having so much suitable natural stone for masonry tanks. Much of our local stone, although suitable for buildings, could not be used in water-retaining structures.

Mr J. Waterhouse, National College of Agricultural Engineering

I enjoyed the Paper, having been for some time associated with East Africa, including Tanzania and I have one or two questions on technical details.

65. The pipeline at Seronera is noted for its low cost per mile, which is very good. At the same time the cost of the water provided by this pipeline works out at something a little less than £1 per thousand gallons, say 18s. The question as far as Seronera is concerned is what alternative sources were available which might also have been suitable, for example, if the brackish water in the region had been desalted or if water from boreholes with high fluoride content had been treated to reduce the fluoride.

66. The second question concerns evaporation from the reservoirs constructed for the rural schemes in Tanzania. Has any experimental work been carried out concerning evaporation control knowing that tremendous losses do occur through evaporation in what would be an expensive scheme?

67. The third question also concerns storage reservoirs. Were any troubles experienced with bilharzia and what control or treatment periods were adopted to prevent its spread through water supplies?

Mr M. J. H. West, Binnie & Partners

I would like to thank the Author for describing a field of engineering which is less sophisticated than most, but very satisfying in the benefits which flow from it, and to add a few thoughts on the philosophy behind building small earth dams in Tanzania.

69. In § 11 the Author states that dams were only built as a last resort, mainly owing to the pollution problems. Although pollution is a problem with open reservoirs, I do not think that was the main reason in Tanzania at that time for more dams not being built. In the late 1950s and early 1960s the main effort of the Department was in the building of dams, both in terms of money spent and men occupied. I think the shift in emphasis was due to several reasons in addition to pollution. The first was financial. Soon after independence most of the money for the rural water supplies came from external aid. The donor countries required programmes in advance and usually preferred schemes with a high proportion of materials costs rather than schemes such as earth dams, whose costs are mainly in plant hire charges and are not so easily controlled or accounted for.

70. The second reason was in the difficulty, mentioned in the Paper, of getting skilled staff for construction, and for maintenance of the plant, either by direct labour or by contractors.

71. Another disadvantage of earth dams was the fact that construction could be delayed during the rains, and in the unusually wet season of 1961–62 several of our teams were completely marooned for several months at a time and access to them was on foot. We had to pay them by wading through rivers with their wages on our heads.

72. Another factor which counted against earth dams was the damage suffered by spillways in that wet season, when rainfall was 50% in excess of average and dams spilled abnormally. Most dams had natural unlined spillways which suffered erosion, starting not on the surface of the spillway but at the downstream end. A deep gully would start where the water ran back to the river, even if there was a good grass cover. This gully cut back into the reservoir and emptied it; hence no amount of grass or other natural cover on the spillway itself would have prevented this happening. The only solution would have been a drop structure of some kind somewhere on the spillway.

73. For this reason we tried when designing a dam to make the capacity of the reservoir equal to at least one year's average annual run-off. It was often cheaper to do this than protecting spillways to take prolonged flows. This usually involved only a few thousand extra cubic yards of fill at 2s or 3s per cubic yard, but increased the capacity of the reservoir to the extent where flows over the spillway rarely occurred. Erosion was rare until 1961-62 when record flows occurred.

74. The method of construction of the spillways, in that the material was all used in the embankments, meant that they were very cheap and that we could easily afford to build them big enough to allow a large margin of safety as far as floods were concerned. Apart from one near miss we have not had any overtopping of a dam.

75. Designing the spillways required the estimation of the peak, for which we had various rational formulae and charts based mainly on local experience. None of these methods gave the volume of the run-off or the shape of the hydrograph. This proved difficult and we usually had to estimate this from local experience and information and casual observations from local people. Having estimated the dimensions of the hydrograph we routed it through the reservoir. We used a simple formula for finding the extent to which the flood peak would be reduced, based on the obvious assumption that the area between inflow and outflow hydrographs represents storage going into the reservoir.

76. From this assumption we derived the simple formula:⁵

$$Q_o = Q_i - \frac{24V - Q_i t}{T}$$

where Q_i is the peak inflow in cusecs, Q_o the peak outflow in cusecs, t the duration of Q_i in hours, T the base of flood hydrograph in hours, and V the storage increase, in acre/ft. These approximate methods of flood routing were commensurate with the general accuracy of the data we had to work with.

77. In the construction of the dam, the control we could exercise over the excavation and the placing of fill rarely justified carrying out slope analyses and we standardized at a slope of one in three upstream and one in two downstream. This was justified by past experience and also by the experience of the United States Soil Conservation Service on similar problems. As far as I know, using these criteria we never had a slope failure.

78. The embankments were usually built with the material from the spillway and nearby borrow pits, being homogenous or zoned, according to the types of soils available. We even used black cotton clay successfully. In the dry season, when it had dried out, the clay was very hard and dense. Its dry density may be greater than that corresponding to the Proctor optimum moisture content. It comes from the borrow area in very hard lumps, unless care is taken to grind it up, which we were usually unable to afford. Hence, if water is added up to optimum moisture content, the effect is to produce hard nodules in a matrix of wet mud; better compaction was obtained with only a little water.

79. We never really tried to reduce evaporation on any of the large reservoirs. This was beyond the scope of our activities, but we experimented with ponds and small tanks, by placing over them various types of covers. We found that a rigid roof produced about 30% reduction in evaporation provided it was wind-proof to a

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reasonable extent, but the cost was uneconomic. We tried also suspending plastic sheets over the surface, but generally these would not stay in place and deteriorated quickly. We tried floating rubber or plastic balls on the surface of the water, but we found that the surface tension tended to bring the water up to where it could be evaporated anyway. We also tried acetyl alcohol, but even on undisturbed surfaces we found it difficult to maintain the cover, and we got reductions of only 30%.

80. I have described a few methods which may seem crude, but which provided water at costs as low as £6 per million gallons and represented the best use of available funds. These dams played an important part in opening up the arid areas where there were no other sources of water and where the hardships of the local people were the greatest. One of the advantages of dams and reservoirs, compared with pipelines and boreholes and pumped supplies and other mechanical devices, is psychological. The unsophisticated villager is reassured to have all his water in sight. This was an important factor when persuading people to move into newly developed areas.

Mr M. J. Featherstone, Wye River Authority

There are two points I wish to make regarding the East Kilimanjaro trunk main. First, if the long term annual isohyets are added to Fig. 3, the redistribution of water carried out by the trunk main becomes readily apparent, as shown in Fig. 5. The isohyets used in Fig. 5 were prepared by the Chief Meteorological Officer, Dar es Salaam, and were obtained from a report on the Pangani Basin by Sir William Halcrow and Partners.

82. The second point concerns the 1 000 000 gal storage tank; just after the tank was filled for testing there was a minor earth tremor. I would be interested to know if any schemes for water development, carried out by the Government, were designed against these occurrences, particularly in the region of Kilimanjaro, where there is continuing activity.

Mr G. H. Bateman, Intermediate Technological Development Survey

Intermediate Technology has been concerned in Botswana, and to a lesser extent in the Sudan, with the introduction of small tanks of 10 000–15 000 gal. These are rainwater catchment tanks, lined with layers of polythene and mud and, as a final protection, with what we called sausages, tubes of polythene filled with a weak cement-sand mix. The advantages are that the materials are cheap and local labour can be employed, often through self-help schemes: they can, therefore, make an important contribution to the economy of an area. I would like to hear the Author's comments on the place of such small catchment tanks in development in Tanzania, bearing in mind that one person who is familiar with the construction of such tanks could look after the construction of perhaps 15 or 20 of them at any one time.

Mr G. F. Albany-Ward, Sir M. MacDonald & Partners

I enjoyed the Paper, having had some part to play in the development of rural water supplies in the Sudan. I want to add to Mr Bateman's comments about small catchment tanks. We have been doing some work in Darfur Province on a project financed jointly by the Ministry of Overseas Development and the Sudan Rural Water Development Corporation, and this has included some experimental work both on small catchment tanks and on lining open reservoirs of the charco type to reduce seepage losses.

85. The work on the small catchment tanks is a direct follow-up of the work referred to as having been started by the Intermediate Technology Development Group which was conducted in western Sudan, in the adjacent province of Kordofan. Our work is not yet concluded. The experimental tanks which we have built were completed July 1969 and filled in the 1969 wet season. Their performance is currently

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suitable for use in Darfur in view of the difficulty of getting large quantities of water which would be needed for making the clay linings. Our costings have come out at £0.427 Sudanese/m² for the completed lining, using a sandwich type of polythene lining with insecticidal protection to guard against termite attack, which is quite a problem in the Sudan. The termites seem to attack any type of membrane to get through to the moisture in the reservoir.

88. The insecticidal protection is applied in two ways. It is given as an impregnation to the base surface of the reservoir and then the first and thinner membrane is applied; a 250 gauge polythene has been used for this. This is followed by a mud slurry with insecticide, which is placed on top of the 250 gauge, and then the top membrane of 1000 gauge polythene on which is placed 0.5 m of backfill.

89. During our first season of operation we carried out surveys and site investigations for full sized charco types of reservoir, ranging from 20 000 to 30 000 m³ gross capacity. The average costs were estimated at about £0.800 Sudanese/m³ of useful capacity if we used the linings I have described. The average costs for unlined reservoirs were estimated at about £0.600 Sudanese/m³ of useful capacity, so the cost difference between the larger reservoirs as compared with the small catchment tanks is considerable.

90. There is one situation where the small catchment tanks may be applicable and this is in heavy sand country, which is quite extensive in western Sudan, where there is no surface run-off and it is not possible to site a lined reservoir and where there is no ground water potential. In the Sudan, as in Tanzania, ground water is always given first preference for rural water supplies.

Mr R. W. Horner, Department of Public Health Engineering

I came across a similar problem during the war when I had to construct a water supply system for a division training in southern India, in the Deccan, an area not altogether a desert but certainly under-populated. For this reason I well appreciate the Author's problems and I found the Paper most interesting.

Fig. 6. Elevated storage tank

92. I was intrigued with the 20 000 gal reservoir and the idea of keeping reinforcement to the minimum. Are the walls of the circular section reinforced or are they cavity walls? I had the problem of providing elevated storage tanks for filling a normal 150 gal water trailer and as there was no reinforcement available, we evolved a design of an elevated tank requiring no reinforcement, using local granite which was available in sections, 12 in. by 6 in. and 4 ft long.

93. I wondered whether to build such a tank, but having got the moral courage to go ahead with this I decided on the design given in Fig. 6.

94. Three walls were built, each about 2 ft thick, up to the required height, in granite masonry. On top we put lintels forming a continuous floor. The side walls were carried up to a sufficient height to supply the storage capacity as gravity walls.

95. We paved this over with concrete and rendered the walls. These tanks were quite satisfactory and not unduly expensive because local materials were cheap. They were rather monumental structures, but one was able to do the job with a single piece of reinforcement.

Mr W. P. Steele, H. A. Simons Ltd, Vancouver, Canada

With reference to § 20, would the Author please indicate that what is today known as the Usagaran system is the same as that formerly classified in geological surveys of the country as Lower basement complex, which is a formation widely distributed in Tanzania. The term Usagaran occurs again in § 35.

97. Referring to § 26, it is interesting to note that an arrangement for borehole pumping installations devised in the early 1950s has continued to be successfully employed, one improvement being the shortening of the centres between engine and pump by the use of V-belt drive. A flat belt was used to keep the installation repairable by even the most inept mechanic.

98. Turning to § 28, it appears that this refers to the Makonde water supply system, wherein a private company, entirely African owned, borrowed the required capital from a bank to finance the capital cost. This was, in the mid 1950s, quite a financial adventure. It would be interesting to hear from the Author whether this, in the light of subsequent operations, has proved a feasible experiment from the banker's standpoint, and how the maintenance problem with such high lifts has worked out.

99. The East Kilimanjaro trunk main development is a very sensible improvement on the rather piecemeal gravity supplies installed for the Chagga, in the early 1950s, and it appears that the pipelines through Mahida and Mgoyoni should open up some wide grazing areas previously inaccessible through lack of water. At one time, consideration was given to pumping out of Laka Chala for this purpose, although the precipitous rock sides of the lake would render accessibility extremely difficult and expensive. However a similar access problem was overcome at the Makonde supply. It would be interesting to know whether Lake Chala has yet been used for any pumped supply, either by Tanzania or Kenya, since it lies astride the border.

100. Prior to 1954, most low dam construction was carried out by the Water Development and Irrigation Department using reconditioned crawler type earth moving units, but in the face of considerable opposition, I succeeded in securing two teams of rubber-tired equipment for this purpose which would not only prove more mobile over East African terrain, but would effect a far better embankment compaction. Could the Author indicate whether this type of equipment is universally used by the Division today?

101. Could the Author state which design of clarifier is used today for rural urban supplies? For some years a shallow circular spiral-flow tank was found economical and effective, but as a trial, a pyramidal upward-flow sludge blanket type was installed at Kiserawe and it would be interesting to learn the success of this type.

102. While I would agree with the statement made in § 45, I have found that attracting capital from outside sources on humanitarian grounds alone can be

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extremely difficult, largely because of the prodigal use which is made of the water by the consumers. This is true for rural water supplies not only in Africa but also in South America. Where at one time water was a dire necessity, once a rural supply is installed, taps are left running endlessly to waste, and even the installation of a spring-closing tap is frustrated by the attachment of a heavy stone. In South America it has inevitably been found that the consumers most wasteful of water are such institutions as are provided with a free supply. When one seeks capital from such a body as the International Development Bank, a sound assurance has to be provided of payment proportional to consumption before any investment is forthcoming. Has East Africa yet found an answer to this problem?

103. One final query I would like to make is that of the question of controlling the spread of waterborne parasites, particularly of schistosoma. Copper sulphate blocks placed at intervals around a reservoir have been found to control the bullidus snails which harbour the schistosoma, but this is not only expensive to put into practice but can also result in poisoning. Twenty-four hour storage eliminates the cercariae, but new water supplies always seem to end in a greater spread of the infestation.

104. It would appear that education, possibly at the village schoolmaster level, in cleaner use of water is the only answer, and even that can be short circuited when irrigation is introduced as has been found in Egypt and the Sudan.

Mr S. Gunaratnam, Ghana Water & Sewerage Corp., Accra

In Ghana about 75% of the population live in rural areas. Since 1968 there has been an increased effort towards the supply of good drinking water to rural localities.

106. To have a successful programme of providing drinking water to rural areas, it is necessary that criteria for development and a target to be achieved at the end of a period should be formulated at a national level.

107. For example in Ghana, as far as the provision of drinking water is concerned, localities with population below 10 000 each are taken as rural, and localities with population over 10 000 as urban. Also, unless due to exceptional reasons, localities with population below 2000 are provided with non-pipe borne water supplies; and localities with population over 2000 are provided with pipe-borne water supplies. Using these criteria it is possible to work out a programme, say for a ten year period, in terms of the annual demand from the Central Government budget and of the targets that are hoped to be achieved at the end of the period.

108. The economic benefits of providing water to rural areas have been considered together with the optimum number of gallons per head per day that should be supplied to achieve a maximum benefit-cost ratio. The benefits to the economy include the reduction of water-borne diseases and the saving of time spent in walking long distances for water, both of which in turn increase productivity which could be quantified. (Quantifying these benefits has been attempted very approximately and a *b/c* ratio of 1.4 for rural water supply arrived at. But it is necessary that research at postgraduate level be taken up in various developing countries on this subject. If this is done and a *b/c* ratio of greater than unity is proved, it be easier to persuade planning ministries of central governments to allocate funds for these projects.)

109. Given costs, the *b/c* ratio starts rising as the number of gallons per head per day supplied is increased from zero, and reaches a point beyond which the marginal economic benefit is less than the marginal cost. Beyond this level of consumption, water has to be sold on a commercial basis to justify the scheme, the consumer paying for the capital cost, a reasonable rate of return on capital, and operation and maintenance cost. It is the general opinion that this consumption limit varies from 2.5 gal/head per day to 4-5 gal/head per day. This is a subject on which research should be done in various countries. It is suggested that this limit is taken as 6 gal/head per day, and allowing for system losses, rural schemes designed to cater for 8 gal/head per day, the design period being 10-15 years.

110. Referring to the Author's remarks on boiling all drinking water, I am of the opinion that water supplied through pipes should be of good quality; the impurities should not exceed the maximum allowed limits as stated by WHO International drinking water standards. If we are to get the desirable economic benefits this quality should be maintained. It is also necessary to limit the maximum distance each householder has to carry water from a public standpipe to a maximum of about 600 yd. The Author mentions 0.5–1 mile.

111. It may be mentioned here that during the period 1968–1970, the Ghana Water and Sewerage Corporation carried out projects in rural areas to the value of about £4 m and provided pipe-borne water to about 350 000 people.

Mr I. L. Ward, formerly Commissioner for Water Development and Irrigation, Tanzania

The Author has had long and intimate experience of Tanzania's water problems and his present Paper on rural water supplies will be of great value to others engaged upon similar work elsewhere. A reliable supply of water is one of the greatest needs of the rural population of many developing countries.

113. A problem which may be of growing importance in regard to water supplies of the type described in the Paper is that of operation and maintenance, particularly the latter. This problem is touched upon in §§ 5, 8 and 50, and its size in Tanzania is indicated by the facts that rural water supply works are now valued at more than £6 m and they are increasing in value and number every year.

114. Design and construction of such schemes can usually be attended to without too much difficulty by a concentrated effort on the part of the relatively few senior and experienced water supply engineers of the Central Government. Maintenance, however, is different and perhaps more difficult because it requires continuous on the spot attention not easily provided by a limited technical staff in a country where rural water supplies are usually in remote places.

115. Minor repairs to a small waterworks, resulting from flood damage, may cause major problems if they are not carried out quickly, and prolonged neglect might sometimes lead to total failure.

116. In Tanzania the district councils, whose many responsibilities are wide and varied, have been found unsuitable to run the rural water supplies and the Central Government through its Water Development and Irrigation Department, is taking them over (§ 50). With its greater technical and other resources it should be in a better position to act effectively. However, I cannot help feeling that where there is a settled population who are regular users of a rural waterworks they themselves should be called upon to accept the chief share of responsibility for operation and maintenance.

117. When I was in Tanzania in 1959–1962 I found that the users of a rural water supply usually regarded the works as government property towards which they as individuals had little responsibility. Therefore, they were not particularly disturbed when works were damaged by flood or neglect, feeling that in good time repairs would be effected by some representative of the Government.

118. I frequently compared conditions in Tanzania with those in Cyprus where I had previously worked. In the latter country somewhat similar rural water supplies are owned and operated by village water commissions comprised chiefly of the local inhabitants who also attend to maintenance. Only in the event of major difficulty is the Government Water Development Department asked for assistance, which is then given with the village water commission paying part or all of the cost.

119. The above arrangement works very well in Cyprus and I do not see why it should not also be successful in parts of Tanzania, particularly in places where there is a settled population, as around the slopes of Kilimanjaro. If the local inhabitants could prove themselves capable of managing their own water supplies then of course

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the Government would be saved the cost in staff and worry of attending to a relatively simple but time-consuming task.

120. Perhaps the Author, with his close understanding of local conditions, will be kind enough to give his views on the practical possibility of running the Tanzanian rural water supplies through a village water committee comprised, as in Cyprus, chiefly of the users of the water. His opinions on the subject will, I am sure, be of considerable value in other countries with similar problems.

Mr P. A. Oluwande, University College Hospital, Ibadan, Nigeria

The Paper is very important and useful for engineers in charge of water schemes in developing countries. However, the approach to the solution of the problem in Tanzania will have to be modified to suit conditions in other developing countries.

122. In Tanzania, the majority of the people live permanently in scattered small communities. This enables the Government to focus attention on the water supply problems of the people. In the Western State of Nigeria and other countries of the developing world, it is difficult for the governments to tackle the problems of rural water supply. The people have permanent houses in towns and cities, but they spend more than 75% of their lives in small villages, only going into town on special occasions. The governments of such countries provide pipe-borne potable water in the big towns. Water supply in the villages, however, is either totally neglected or left to local councils which are ill-equipped both in manpower and materials for the job. At the present level of development of the countries concerned, it will be more than the economy can sustain if schemes as expensive as those in Tanzania are planned for the villages.

123. Cheaper and simpler schemes are necessary. In Ibarapa division of Western State of Nigeria, I have been able to provide well water for guinea worm infested villages of populations between 50 and 200 at costs ranging between £80 and £300. The wells are of 4 ft dia. and 20–30 ft deep. In the smallest villages, the people use buckets and ropes to obtain water from the wells. In the larger villages, semi-rotary hand operated pumps are used to raise well water into overhead metal tanks. The free ends of the ropes attached to the buckets are fixed to the wells to prevent the buckets from being carried away.

124. The Author stated that the criteria adopted for rural water supply qualities were based on the assumption that the people are expected to boil their drinking water. I think it is wrong and dangerous from the health point of view to pipe low quality water to the people and expect them to boil it before drinking, many people will not do this. Boiling is not a practical process of disinfecting water for the people. Chlorine or other chemical disinfection is more reliable.

125. From the figures captioned 'Water drawing point in village' (page 652) and 'Rural domestic water supply point' (page 653), I notice that there are two different types of taps. It appears that for the water drawing point in village, non-self stopping taps are used whereas the self-stopping taps are used for the rural domestic water supply points. I should have thought that self-stopping taps would have been used for all the public taps to reduce water wastage. May I know if the Author has reasons for selecting different taps for almost identical conditions?

126. Finally, I would like the Author to give a breakdown of the capital cost of a scheme consisting of 8 ft dia., 30 ft deep wells in alluvial porous beds with regard to:

- (a) well construction
- (b) 10 000 ft distribution pipes
- (c) 30 000 gal block work tank on 25 ft high raiser
- (d) pump and fittings.

I am also interested in the annual operational cost of such a scheme.

Mr L. H. Robertson, Department of Community Development, Malawi

I was interested to read about the development of rural water supplies in Tanzania, and about gravity pipe systems in particular.

128. Our efforts in Malawi have been very modest by comparison, and our largest rural project so far has been 180 000 gal/day which covers a population of 30 000 people. This was done with rigid PVC pipe class B-D, sizes ranging from 4-0.5 in.

129. The feature that may be of interest is that all our pipes were laid by the villagers themselves, as a community development project. The technique required in the solvent cement jointing system is very similar to that of mending a puncture in a bicycle tube, a thing which almost every villager can do.

130. This has three very great advantages. The cost of the project is little more than the cost of the piping, and was £1/head of population for 6 gal/day. Maintenance is carried out by the people; having installed the pipe they are then able to mend any breakages themselves. Also they look after the taps and sediment tanks. The community, having organized itself to do one project, is then in a position to carry on with other development.

131. For supervision we have one qualified engineer, who is responsible for the project; and a number of community development assistants who check the digging and supervise the laying and help to organize the local committees. The pipe is buried at a depth of 2.5 ft (a depth that can be dug with the local hoe), and we also mark the line by planting *nostatum paspalum* grass, a drought resistant grass.

132. Where water has to be carried home, 3 gal/head per day is usually sufficient. A feature of our design is that the pipe sizes are reduced progressively so that when all the taps are open each will get approximately the same amount of water. When the village wants to improve its facilities for washing clothes and bathing, it can do so very easily by building an overnight storage tank, and thus double its supply.

133. In the larger mountain rivers we find it is not necessary to build a dam at all. The steel pipe is simply laid in the V of a small waterfall into the pool above. This eliminates the need for skilled construction of intake works. In the small streams where the flow is limited, a small weir is built, but a scour pipe is placed near the bottom, from which the plug is removed during the wet season so that there is no silting behind the weir wall.

134. In conclusion I would like to emphasize three points which the Author made in the Paper. First, in remote areas, where skilled manpower is in short supply, the over-riding consideration is simplicity of design, construction and maintenance.

135. Second, domestic rural water supplies are vital to the future of many developing countries in Africa: not only on humanitarian and health grounds, but because the building of a national economy is based on developing the rural economy; and the rural economy will not develop, if life in the rural areas is simply a struggle for subsistence.

136. Third, the responsibility for financing these larger projects lies with the central government. But at the same time, new governments with expanding budgets find it very hard to provide extra money for projects. If there were outside assistance available there would be no better use for it than literally to 'prime the pump' of the rural economy.

Mr R. N. Balmer, formerly with Water Development Department, Uganda Government

The Paper will be most useful to engineers working in the developing countries of the world. The Author has rightly pointed out that a different design philosophy is needed when projects are small and both human and material resources are very limited.

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138. Perhaps the omission was intended, but the Author has not mentioned that where a people are not highly educated it is necessary to design specifically against what we would term vandalism or theft, which arises because the value of machinery or an installation cannot be fully appreciated. In Uganda I found that shiny fittings, or covers that could be used as containers, for example, should be avoided at all costs. Even so, on one occasion, five 3 ft dia. concrete culvert rings placed vertically to form a shallow 15 ft deep well, were later found as five piles of chippings, the reinforcement removed, presumably to make spear heads.

139. There are many sand rivers in Uganda and, I believe, in Tanzania. A sand river is a seasonal river where heavy sediment loads are carried down in the rainy season. The sand builds up to a semi-permanent level with some scour and subsequent deposition each year. The depth of sand varies but is commonly in excess of 6 ft, and normally overlies rock. It was proposed in Uganda to cut trenches across such rivers down to the rock and backfill them with impermeable soil up to the top of the sand thus forming a sub-surface dam, and a reservoir which could be tapped by a horizontal drainage gallery behind the dam. The reservoir would be largely free from evaporation losses which often amounted in Uganda to 9 in. per month. If experiments were made on these 'sub-surface' dams in Tanzania, the Author's comments on the experience gained would be most useful.

Mr Holloway

Miss Lindley stressed the importance of a good grass cover on embankments. That is something we are all agreed upon. As to grass cover in spillways, Mr West has effectively answered that for me in § 72. It was our experience that a grass cover often did establish itself in a spillway, but it was never purposefully established; vegetation of one sort or another frequently established itself on spillways but this has little effect in retarding tail erosion once it has started. We were often more concerned about the growth of thorn bush and other vegetation cutting down the effective area of a spillway.

141. In certain areas siltation of dams was a problem although not as great as one might expect, particularly on the larger reservoirs. Among the smaller dams rapid silting has been experienced with one example completely filling in ten years but here again the deposit was more of a sand than a silt and the voids contained a considerable amount of water which could still be extracted.

142. The problem of vandalism at mechanical installations was largely overcome by employing a pump attendant housed close to the installation. All pipelines are vulnerable to piercing by spears if a water drawing point is not easily at hand. This is a difficulty one has to bear but judicious siting of domestic and cattle watering points reduces the risk. I do not think that anyone has, as yet, devised a tap which will stand up to the treatment given by a people not accustomed to mechanical devices. There are some fairly good taps on the market, the robust 'waste not' self-closing stop cock takes a lot of breaking but it can be broken. If someone really wants to break something he can usually find a way of doing it. Vandalism is however an individual problem and is not, I am sure, confined to developing nations.

143. Both Mr Horner and Miss Lindley referred to the reinforcement of block-work storage tanks. The reinforcement was placed in a preformed recess in the concrete blocks and packed with mortar as shown in Fig. 7. These have, to date, proved extremely effective. The inside of the tank is of course lined with a water-proof cement rendering. The leakage has been negligible and many of these tanks have been in use now for upwards of eight years and show no signs of deterioration.

144. Mr Waterhouse referred to the cost of the Seronera pipeline. In terms of capital outlay to volume of water delivered, I agree that it is high. On the other hand, the operating costs and the recurrent expenditure on the scheme are low. This was something of a special situation in that a research centre had been sited at the

Fig. 7

point most suitable for the study of wild life and the ecology of the Serengeti National Park; it was also an ideal centre for tourism and a hotel was to be constructed there. A water supply had to be provided that would satisfactorily meet both these requirements. The possibility of a supply from boreholes was examined. Trial boreholes around Seronera yielded water which had a high fluoride content and gave a yield of the order of 200 gallons per hour. A large number of boreholes would have been required to provide the necessary quantity of water, defluoridation on a large scale is very expensive particularly in respect of recurrent costs, and the supply could not have been guaranteed.

145. A possibly satisfactory borehole was obtained about ten miles away from Seronera which would have involved two-stage pumping. Time did not allow for the additional exploratory drilling and long term pumping which would have been necessary before the supply could have been guaranteed to the satisfaction of the

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people putting up the finance for the hotel, and a further complication was that the promising borehole was located in a valley which had a very heavy tsetse fly infestation. Two of the crew of the drilling rig died of sleeping sickness. To develop boreholes in the valley would have meant doing a lot of clearing around the area, which the National Park Authorities were reluctant to contemplate because of disturbance to the ecology of the area, and also running the risk of bringing in infected fly into a tourist centre. The capital cost would have been lower but the recurrent costs would have been considerably higher. The borehole prospect was therefore abandoned.

146. Mr Waterhouse inquired about evaporation control. I am grateful to Mr West for effectively answering that point in § 79. It was appropriate that he should do so because he did most of the research work on the subject.

147. The question of bilharzia and the treatment provided for the water supplies was mentioned. This is a widespread problem in East Africa wherever there is permanent moving water and it is one to which there is no easy solution. To some extent bilharzia can be looked upon as being endemic and its eradication is primarily a matter of education. An opinion reiterated by Mr Steele in § 104. If people can be trained not to foul water supplies, then bilharzia can be eradicated.

148. Little work has been done on treatment of supplies although latterly consideration was being given to the provision of 24 hour storage and chlorination of water supply where a large area was to be served. Some of the schemes now being contemplated are going to distribute two to three million gallons a day and on that scale the expense of bilharzia control can be justified. One method which appears to offer a satisfactory solution is to provide 24 hour storage and chlorination; medical opinion seems, although not unanimous, to be coming to the view that if water is stored or kept still for about 24 hours and a liberal dose of chlorine is added the bilharzia carariae are destroyed.

149. Mr West's remarks infer that I have given the impression that I was against small dams; that was not my intention. In fact there is and always will be a place for dams as a source of water in the arid countries of Africa. They have their problems, which are more evident now that more sophisticated supplies are being demanded. A group of people will accept turbid water for a few years and they are very grateful to have it because it is far better and more easily obtained than anything they have had before. But in time they naturally want something better, and the problems of purification are considerable. The reason why purification has largely been abandoned was experience; a number of small schemes were provided with simple flocculating settling tanks and slow sand filters but invariably after a short period they broke down through inadequate maintenance.

150. Until such time as an efficient maintenance and operational organization can be set up, simplicity has to be the keynote. If good quality ground water is obtainable it is preferable to surface water.

151. I am grateful to Mr West for outlining methods of determining the run-off from catchments, and for amplifying some of the design considerations adopted for dams.

152. Mr Featherstone helped to make the value of the East Kilimanjaro trunk main more explicit by indicating the rainfall pattern on Mount Kilimanjaro. The question of earth tremors and effect on storage tanks was varied; by and large the answer is 'no'. Special precautions have not been taken and although minor tremors are experienced they have on the whole been very small and with one exception I do not know of any damage to storage tanks.

153. Mr Bateman outlined the method of construction employed in Botswana for small catchment tanks. I am firmly convinced that works of this nature should be encouraged where there are sufficient enthusiastic people to do it. The same applies to well construction, which is an even more pertinent occupation for self-help. For instance, a lightweight drilling rig can easily locate a large number of sites suitable

for shallow wells, if such exist; the local authority can then provide well rings and the local people can then sink a shallow well. I believe, however, that professional departments should confine their involvement to technical guidance, the execution of such works should be left in the hands of community development officials; reserving the professional expertise of engineering departments to the execution of those works, and solution of problems outside the competence of other agencies.

154. **Mr Albany-Ward** made some interesting comments on linings for small catchment tanks, and the details make a valuable contribution to the subject. At the time of my departure for Tanzania results from trial polythene linings in working models had not been analysed. Butyl sheeting was being tried for lining two full-scale working catchment tanks. As in the Sudan, the cost was found to be very high, and except where there is no alternative this solution is not practicable.

155. Mr Horner indicated a method adopted in the Deccan to construct tanks out of large granite slabs and in many ways that solution was not unlike the gravity masonry tanks adopted in Tanzania, although we did not have the courage to put them up on raisers.

156. Mr Steele made reference to the Makonde Water Corporation and wondered whether it was the supply outlined in § 26. The supply described was in fact in the Karagua District of West Lake Region. Financially the Makonde water supply was not a success; sufficient water, at an economic price, could not be sold to cover the costs, the Corporation was wound up, and the scheme was taken over by the Government and water supplied at subsidized rates. The engineering aspects of the scheme were quite satisfactory and there is considerable demand for extensions to the distribution system to take in the whole of the Makonde Plateau, which with the resulting increased consumption would make the scheme more economically justified. In the Kilimanjaro Region the waters of Lake Chala have not, as yet, been tapped by either Kenya or Tanzania, although very successful boreholes have been sunk near the Crater Lake.

157. Rubber-tired earth moving equipment has certainly made a valuable contribution to dam building by its increased mobility; experience showed, however, that in most cases a crawler tractor with a bulldozer blade was required to push-load scraper units, and for this reason rubber-tired construction units still have to be provided with transporters for tracked equipment.

158. In general, rural supplies are not treated and if possible coagulants are avoided, but where clarifiers were installed the shallow circular spiral floor tank was probably marginally more satisfactory.

159. Preventing waste at domestic points is a very real problem and self-closing taps can be damaged. Automatic dispensers discharging 4 gal of water on payment of amounts varying between 1 cent and 5 cents (100 cents = 1 s) were tried, but these did not prove very successful and required considerable maintenance. Manned kiosks, the only foolproof method, represent very high running costs. Current policy in Tanzania is that all domestic water obtained from public supply points is free and a charge on the exchequer. A policy of free domestic water for a developing nation is, I am convinced, correct; to try and charge an economic rate for domestic fetched water negates the very objective of putting water into rural areas by rendering it a luxury many cannot afford. Proper use of water and a responsible attitude towards waste must be a matter of social education.

160. **Mr Gunaratnam's** experience with cost-benefit ratios is noted with interest, but I am not convinced that the value of such a basic development input can be adequately quantified, a view more fully expressed in §§ 56 and 57.

161. The WHO International drinking water standards are certainly a desirable target, and the distance which water has to be carried should be a minimum. But a balance between cost and maximum benefit has to be struck, and this is the aim in Tanzania; it is significant that the cost of supplies constructed in Ghana during the period 1968-70 averaged £11 8s 0d per person supplied, the cost of projects

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constructed in the period 1965–70 in accord with the Tanzania standards averaged £7 9s 0d per person supplied.

162. **Mr Ward** raised the very important problem of maintenance and put forward the suggestion that village water committees on the Cyprus pattern might be made responsible for maintenance and operation of supplies. Where the supply is a simple gravity pipeline there is scope for local responsibility. But the current lack of readily available mechanical skills in many rural areas would present most committees with problems beyond their resources, and I believe that whereas in Cyprus it was only in the face of major difficulties that recourse was made to the Water Development Department, in Tanzania in its present state of development the frequency of calls for help would amount to the virtual provision of a maintenance service. There are certain areas where the level of skill is high, but in general the rural scene in Tanzania is still very short of technical skills.

163. The essential pre-requisites for placing the responsibility in local hands would seem to be: a strongly developed sense of community responsibility for services covering a wider area than one's own immediate neighbourhood (applicable where long distribution systems are involved); increased mechanical talent in the local community, something which will come in time with the advent of mechanical maize grinders, tractors and transport; and an increased level of wealth to allow local communities to shoulder at least part of the financial burden of water supplies. The provision of development generators such as rural water supplies will, in time, bring about the changes which will pave the way to rural communities shouldering responsibilities in a similar manner to the Cyprus villagers.

164. **Mr Oluwande** contrasts the mode of life of the Nigerian rural population with Tanzania's. One of the problems facing the developing nations is the drift of the rural population to the cities and towns, where adequate employment is seldom available. If living conditions in the rural areas can be improved the attractions of the towns diminish; a population spending 75% of its time in rural areas would be considered a rural community and encouraged to remain as such. Water supplies obviously must be as cheap as possible and where shallow wells will serve a community they are recommended. (Due consideration in siting in relation to pit latrines must be given.) However, as stated in § 4, the easiest of solutions is frequently not applicable.

165. Treatment of supplies must be related to reliability. If a community becomes accustomed to a bacteriologically pure supply which in due course breaks down through poor maintenance, the probability of infection is far greater because the earlier natural resistance to infection will have declined; therefore unless continuous treatment can be guaranteed it is better omitted.

166. Various types of domestic water taps have been tried and the different types depicted in the photographs on pp. 652 and 653 simply reflect this fact.

167. The breakdown of costs for the scheme described in § 27 are in round figures and from memory:

Well	£1 500
Distribution	£2 900
Storage tank	£3 000
Pumping installations	£1 200
Overheads	£1 700
	<hr/>
	£10 300

Operation costs for pumped supplies average about 2s 6d per 1000 gallons (excluding capital charges and amortization).

168. **Mr Robertson's** Malawi experience with self-help is a useful demonstration of the benefits many developing countries, including Tanzania, gain from harnessing the voluntary efforts of the people.

169. **Mr Balmer** described proposals for sub-surface dams in sand rivers, an idea canvassed in Tanzania and tried with only moderate success. Water losses from the banks and around the clay cut-off are large in relation to the quantity stored and to some extent defeat the object of the dam. Direct pumping from the sand bed by a well point system appears to offer better prospects.

Reference

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