IDRC-MR127e

International Development Research Centre

MANUSCRIPT REPORT

Rainwater Catchment

Status and Research Priorities in the Southeastern Asian Region

Proceedings of the Regional Seminar and Workshop held in Khon Kaen, Thailand, 29 November to 3 December 1983

April 1986

IDRC Manuscript Report

This series includes meeting documents, internal reports, and preliminary technical documents that may later form the basis of a formal publication. A Manuscript Report is given a small distribution to a highly specialized audience.

RAINWATER CATCHMENT

Status and Research Priorities in the Southeast Asian Region

Proceedings of the Regional Seminar and Workshop held in
Khon Kaen, Thailand, 29 November to 3 December 1983

Sponsored and Organized by
Khon Kaen University, Thailand
and
The International Development Research Centre, Canada

CONTENTS

A NOTE FROM THE EDITORS

The lack of adequate safe drinking water in nearly one third of the world's population has prompted the United Nations to label 1980-1990 as the Decade for Water Supply and Sanitation. The problem is especially critical in developing countries where barely 13% of the population has piped water connections. However, an age-old method which is not widely practised in present times is Rainwater Catchment and Storage (or Rain Water Cistern System usage). This system which does not involve large capital outlay (a major problem in developing countries) is applicable to conditions where the normal sources of water are not feasible, such as when the terrain is hilly or where the water is brackish.

The realization of the potential for Rainwater Catchment culminated in the organization of the First International Conference on Rainwater Cistern Systems which was held in Honolulu, Hawaii, in June 1982. The Conference dealt with various aspects of Rainwater Catchment, but with heavy emphasis on hydrology and rainfall patterns, engineering designs and materials for construction. However, it was evident from the conference that several critical areas required further studies, such as water quality and socio-economic issues, and those that influence applications of this system on a larger scale at the village level, such as community mobilization and organization, and operation and maintenance of the system.

The objectives of this seminar and workshop were to provide the participants with first-hand information on existing Rainwater Catchment programs in the region; review the status of Rainwater Catchment in Southeast Asia; and identify research priorities for investigation of the above issues and develop a common approach to improve existing programs or introduce this system to those communities in the region which are not using it.

Accordingly, papers presented are arranged in the following categories:

Session I: Presentation of on-going Rainwater Catchment projects in Khon Kaen and Sierra Leone

Session II: Review of the status of existing programs in Southeast Asia

Session III: Research priorities for Rainwater Catchment studies in Southeast Asia

Session IV: Workshop on research ideas for improving and introducing this system to the region

It is to be noted that the background and experience of the participants who presented the papers are varied, such as practising engineers and economists, university researchers involved in material testing and engineering designs, government officials in charge of rural water supply programs, and community development workers who worked closely with the villagers. This broad spectrum of participants accounts for the variability of the papers in terms of depth and emphasis. It is suggested therefore that these Proceedings which outline the state-of-the-art and priorities for research in Rainwater Catchment in the region should be read in their totality.

Interesting spin-offs following the workshop sessions include research undertaken and completed in Thailand concerning water quality and use of mortar blocks and indigenous materials, such as bamboo-reinforcement. Several research projects on Rainwater Catchment from the region which will be considered by IDRC for funding support are being developed. They are focusing on the use of this system in the region with emphasis on the socio-cultural acceptance of this system, the use of local construction materials, getting the community to be involved in the financing, construction and maintenance of the system, and investigating water quality aspects related to the storage of water over a long period. A network of monitoring stations will be included in this regional study to establish the relationship between rainfall patterns, storage volumes, and roof areas and to investigate water quality and appropriate construction materials. The results from this regional study will be crucial for any attempt to expand this method of water supply on a larger scale within the region.

Adhityan Appan*
Lee Kam Wing**
Brian Latham***

Editorial Note: The articles presented in this manuscript have been edited to improve their readability. The editors and IDRC do not take responsibility for the technical accuracy of the articles. Enquiries of a technical nature should be directed to the authors concerned.

* Nanyang Technological Institute, Singapore
** IDRC, Singapore
*** Ottawa, Ontario

SESSION I: ON-GOING RAINWATER CATCHMENT PROJECTS IN KHON KAEN, THAILAND AND SIERRA LEONE

FERROCEMENT WATER TANK

Chayatit Vadhanavikkit
Faculty of Engineering
Khon Kaen University
Thailand

SYNOPSIS

A ferrocement tank has been designed for use in rural areas. The design is based on the properties and the availability of materials as well as the acceptability by villagers of both construction techniques and cost. The cylindrical tank is 2.50 m in diameter and 2.50 m in height. Its behaviour and the construction procedures are presented and discussed.

INTRODUCTION

Ferrocement as a structural material is not new. Since its introduction by Professor P. L. Nervi in 1943, ferrocement has been used worldwide for structures and structural members in walls, roofs, boats, low cost houses, water storage, etc. However, ferrocement is still probably the least exploited of such materials, especially in Thailand. There are varieties of reasons as to why ferrocement has not gained popularity here. One reason is that ferrocement is often regarded with suspicion. This may be the result of the missing link between research carried out at universities and practical use. Ferrocement fabrication is also mistaken as a high skilled work. In fact, most of the labour in ferrocement construction is, by contrast, at a low skill level - using rods and mesh, tying them, compacting the reinforcing panel, etc. Ferrocement construction is also labour-intensive and all construction materials used are available locally.

In this paper, a ferrocement water tank constructed without the aid of a framework is described. The design, based on the properties and the availability of local materials as well as the acceptability by villagers of both construction techniques and cost, is presented and discussed.

MATERIALS

The properties and costs of construction materials for ferrocement, i.e., cement, sand and wire mesh available in Khon Kaen were investigated and described below. Note: ASTM = American Standards for Testing and Materials.

Cement

Three types of cement are available:

1) Normal portland cement (ASTM type I)
2) Silica cement (Type I + 25% finely ground sand)
3) High-early-strength cement (ASTM type III)

Only the normal portland cement and silica cement were considered, since there is no need for early strength gain for tank construction. Silica cement, from the engineering point of view, is not suitable for the construction of load carrying members because of its low strength. From the manufacturer's certificate as well as test results, the ratio of strength of silica cement to strength of normal portland cement is less than 7 to 10, while the price ratio is 8 to 10. Thus, normal portland cement is cheaper.

However, villagers have been using silica cement in all their concrete construction because of its lower price, and its slower setting time. Normal portland cement sets quickly, hence it is difficult to handle when concrete mixing is manually performed. It is thus decided that the silica cement be used in tank construction and is the type considered in the design.

Sand

Sands from all local suppliers in Khon Kaen were tested. Their properties varied greatly and none of these sands meets all the requirements of the ASTM standards (C33-80). The price range is between 110-180 baht/m^3.

In order to find the strength of mortar for designing the tank, mortar specimens were made from these local sands. The ratio of cement : sand is 1:3 by volume (at SSD) and water : cement ratio is 0.45 by weight (recommended w : c is 0.4 but the 0.45 was tested to allow for the variation in the degree of control in the field). The strength of the mortar varied remarkably as follows:

Tensile strength at 28 days (direct tension test ASTM C190)	17 - 30 kg/cm^2
Compressive strength at 28 days (2" cube ASTM C109)	150 - 250 kg/cm^2

The lower strengths of the mortar are used in the design.

Wire Mesh

The most common wire meshes used for ferrocement are hexagonal wire mesh, square welded mesh and woven mesh. Woven mesh is available only with heavy gauge wires. Therefore only hexagonal mesh and square welded mesh were considered. Their description, mechanical properties and prices are summarized in Tables 1 and 2 respectively.

Comparing the strength of the mesh wires, it is seen that wires from square welded mesh have higher strength than those from hexagonal mesh. Furthermore, the price per kilogram of square welded mesh is approximately half that of hexagonal mesh. The two mesh types, however, have distinctive properties. Hexagonal mesh is flexible and is suitable for structures with many corners and changes in contour whereas square welded mesh is stiff and is suitable for structures where strength and stiffness are required.

TABLE 1. DESCRIPTION, PROPERTIES AND PRICES OF HEXAGONAL WIRE MESHES.

- ultimate strength 3740 kg/cm^2 - yield strength 2100 kg/cm^2 - modulus of elasticity 93.75 x 10^4 kg/cm^2					
mesh size	wire diameter	roll size	Price (baht)* per		
mm (inch)	(mm)	m (feet)	roll	m^2	kg
25 (1)	0.5	.91x45.7 (3x150)	400	8.8	64.1
19 (3/4)	0.5	.91x45.7 .(3x150)	480	10.6	54.3
12.5(1/2)	0.5	.91x45.7 (3x150)	610	13.5	48.1

Note: The actual length of mesh in a roll is only 42.6 m (140 ft).

TABLE 2. DESCRIPTION, PROPERTIES AND PRICE OF SQUARE WELDED MESHES.

Mechanical properties gauge no. 16 wire (diameter = 1.4 mm) - ultimate strength 8450 kg/cm^2 - yield strength 4500 kg/cm^2 - modulus of elasticity 19.4 x 10^5 kg/cm^2 gauge no. 20 wire (diameter = 0.8 mm) - ultimate strength 4850 kg/cm^2 - yield strength 3650 kg/cm^2 - modulus of elasticity 17.9 x 10^5 kg/cm^2							
grid size mm (inches)	wire diameter (mm)	roll size m	(feet)	Price (baht)* per			
				roll	m^2	kg	
25 (1)	1.4	.91x30.5	(3x100)	750	23.2	27.2	
25 (1)	1.4	1.22x30.5	(3x100)	1100	25.5	29.9	
12.5 (1/2)	0.8	.91x30.5	(3x100)	750	23.2	38.0	

* Conversion rate (1983) $1 US = 23 baht

For water tanks constructed without the aid of a framework, the tank reinforcement must be strong enough to hold the weight of mortar applied on it and must also be stiff enough to prevent slumping of mortar during plastering. Hence the square welded mesh of grid size 25 mm (.91 x 30.5 m roll size) was chosen because of its stiffness and cost advantage.

ANALYSIS

Analyses of a cylindrical tank based on thin shell theory are presented in several publications (ref. 1, 2, 3, 4) and will not be described here.

Tank dimensions

diameter	= 2.50 m
height	= 2.50 m
wall thickness	= 40 mm
capacity	= 12 m^3

The maximum hoop stresses obtained from an analysis of fixed and hinged type connections between the wall and the base are 6.64 kg/cm^2 and 7.18 kg/cm^2 respectively. The maximum bending moment at the base of the wall is 34.20 kg-cm/cm width, which creates a maximum fibre stress of 12.83 kg/cm^2 if the wall is not reinforced.

DESIGN

The stresses occurring in the tank are small and do not exceed even the tensile strength of unreinforced mortar (17 kg/cm^2). Hence, in this case, the design of the tank is controlled partly by construction techniques and the sizes of materials available. For ease in construction the tank reinforcement chosen consists of 9 mm skeletal steel rods sandwiched between two layers of 25 mm square welded mesh. The distance between the mesh layers is approximately 20 mm.

For this reinforcement arrangement, hoop wires alone produce resisting tensile strength at yield point of 12.12 kg/cm^2 which is more than 40% higher than the induced stress. Ultimate moment capacity of the section is 52.8 kg-cm/cm width, when a 0.75 capacity reduction factor is applied.

Details of tank dimensions are given in Fig. 1. A list of construction materials is presented in Table 3. Cutting of wire meshes and steel bars are illustrated in Table 4. It should be noted that wire meshes and steel bars are efficiently used. Unplanned cutting will result in more materials and waste.

TABLE 3. MATERIALS AND COST.

No.	Materials	Quantity	Price (baht)*
1	Silica Cement	19 bags	1330
2	Sand	2 m^3	340
3	Stones 19 mm (3/4")	0.7 m^3	161
4	9 mm steel bars	11 bars	385
5	Square welded mesh 25 mm grid, (.91 x 30.5 m roll size)	2 rolls	1500
6	Tying wires	2 kg	30
7	Pipes and fittings etc.		160
			3906

* Conversion rate (1983) $1 US = 23 baht

CONSTRUCTION TECHNIQUES

The construction stages of ferrocement water tanks are as follows:

Preparation of Skeletal and Mesh Reinforcement

Although the stiffness of square welded mesh is very necessary in this type of construction, it is difficult to apply this type of mesh on to the skeletal steel. To overcome this difficulty, the mesh and

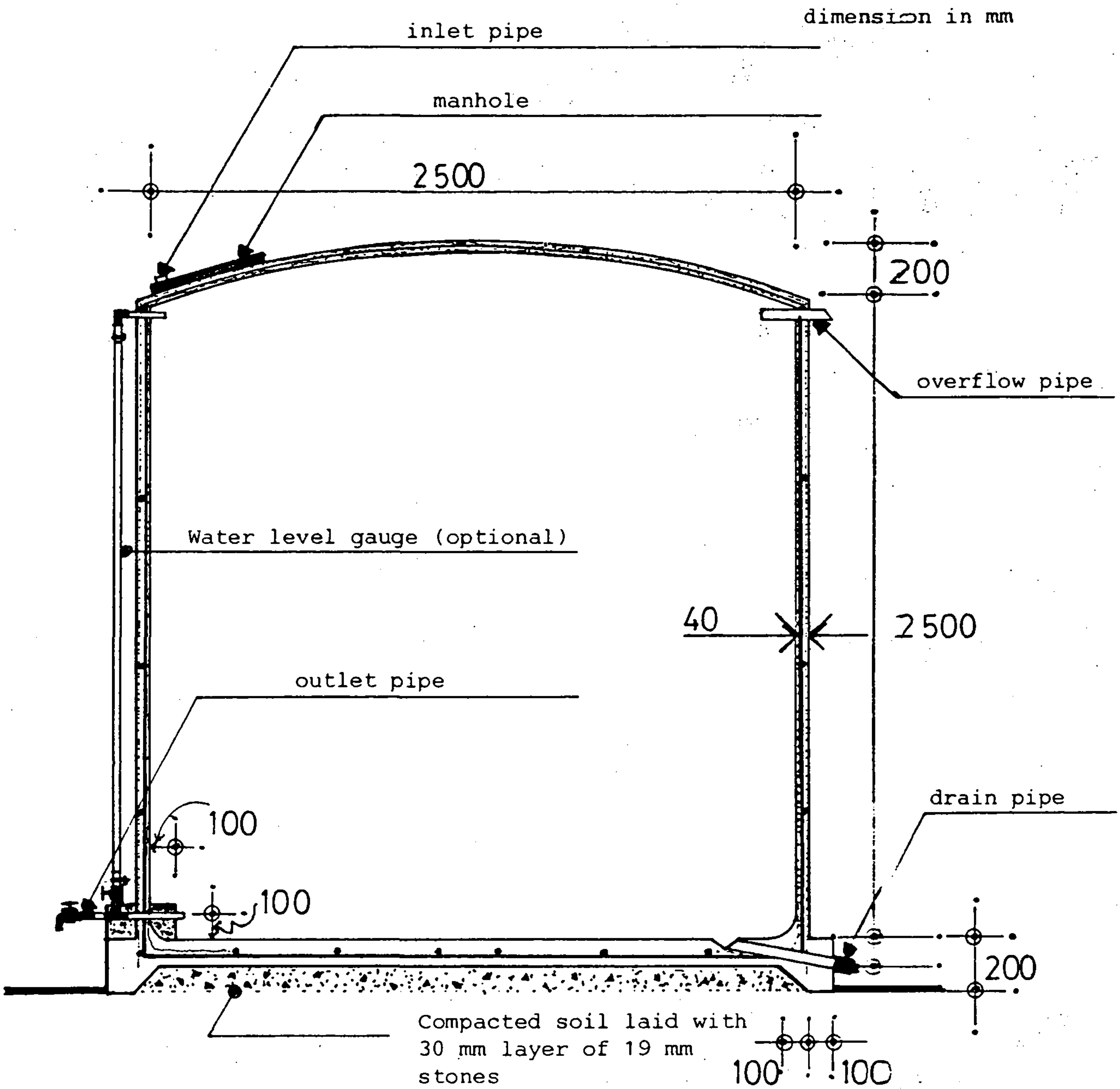
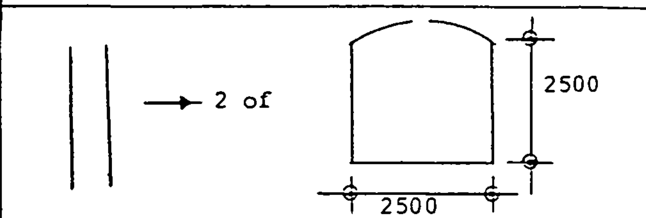
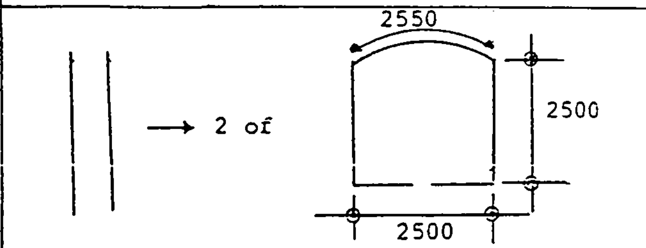
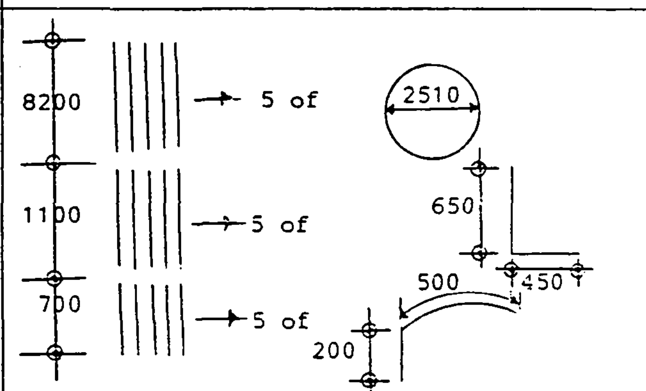
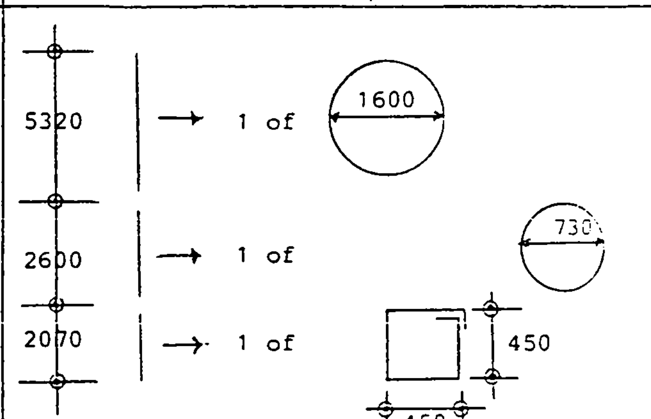
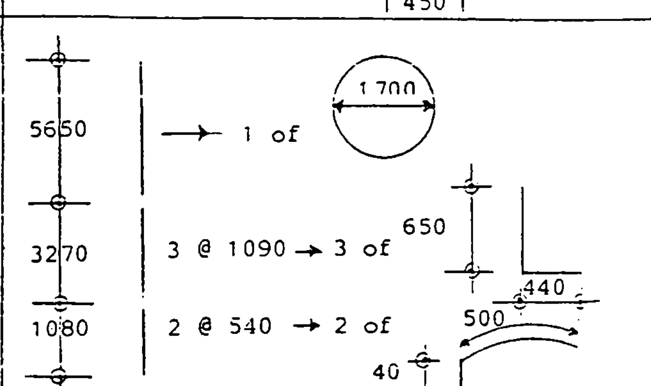


Figure 1. Details and Dimensions of Ferrocement Tank

TABLE 4. DETAILS OF BAR CUTTING AND CONFIGURATION.

Bar designation	No. of bars required	No. of 9 mm bars used	Details of bar cuttings and configuration (dimension in mm)
A	2	2	
B	2	2	
C	5		
D	5	5	
E	5		
F	1		
G	1	1	
H	1		
I	1		
D	3	1	
E	2		

skeletal steel are built up together by using the mesh as a guide instead of forcing the stiff mesh onto the skeletal steel.

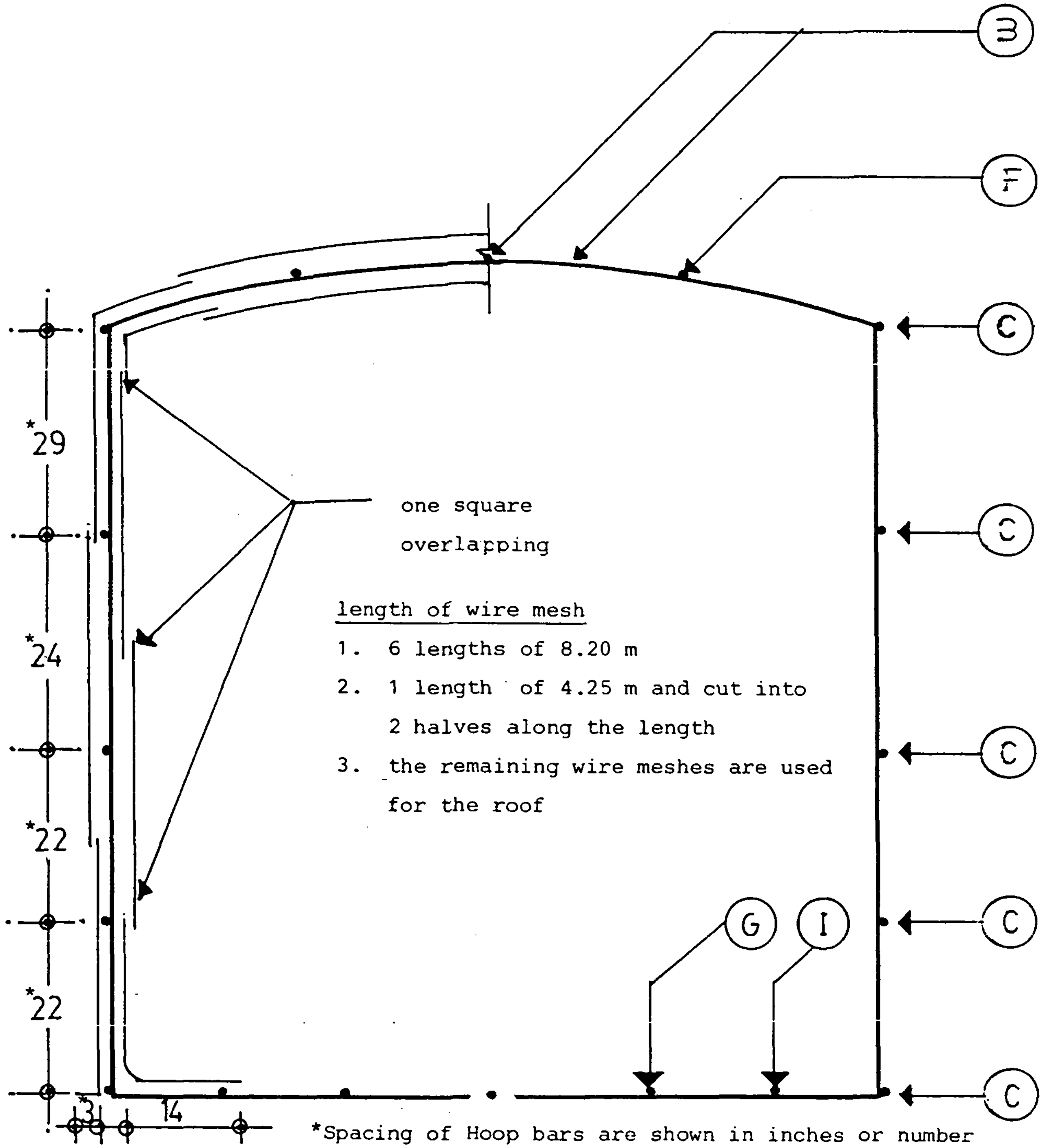
Figs. 2, 3 and 4 show the arrangement of skeletal steel and the mesh. In building up the steel form, first the outer layer mesh at the bottom is formed together with the two hoop bars. The verticality and the constant diameter of the tank are achieved by keeping the wires in the mesh aligned at the overlap. Each steel bar is tied along a mesh wire, and is adjusted to fit with the mesh if unconformity is found. All vertical bars, base reinforcement and the inner layer mesh at the bottom are then put into place. The steel form is gradually built up in the same manner until it is completed. The distance between the inner and outer meshes is kept at approximately 20 mm. This distance will increase markedly due to the pressure applied and the weight of mortar during the mortar plastering process. To guard against this increase, the meshes are tied together at intervals of approximately 200 mm to prevent any further separation. All ends of tying wires should be pushed inside the meshes for ease and comfort in mortar plastering. It is also advisable to arrange the location of mesh overlaps both inside and outside so that an access can be achieved through the wall.

Base Concreting

Concrete having a mixture of cement : sand : stone of 1 : 2 : 4 by volume is used for the base. The base thickness of 100 mm is cast in two layers. The first 50 mm is laid and the steel form is put into place (Fig 5) then the other 50 mm of concrete is poured on top. The compaction of concrete is done by stepping on it. The base surface is finished with a thin layer of cement paste for water tightness.

Plastering of Mortar

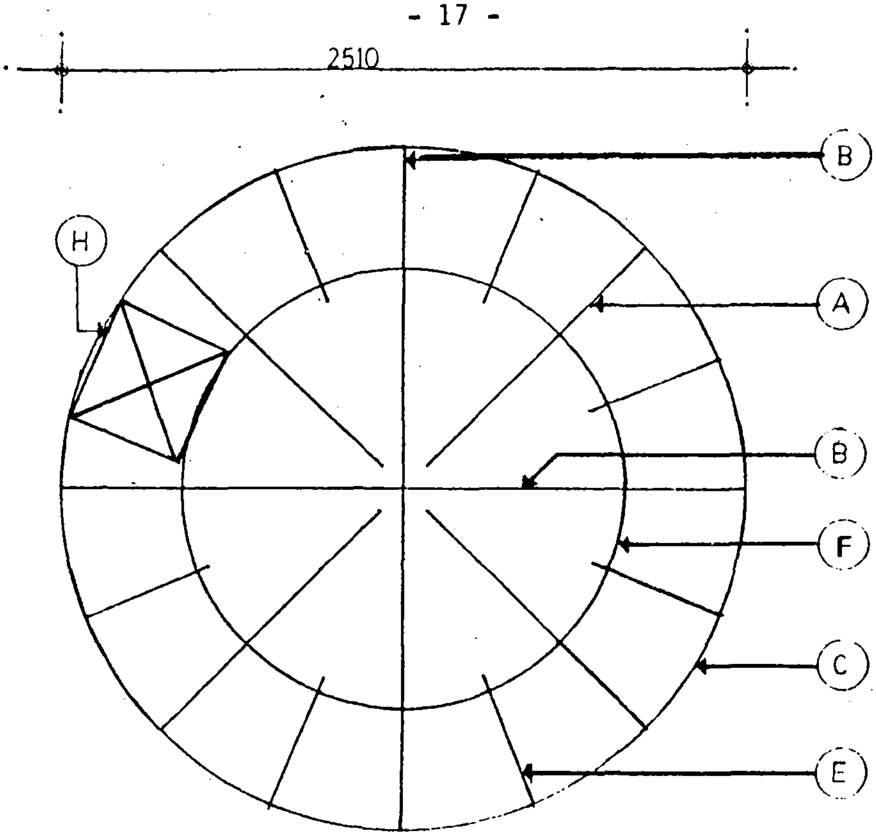
Mortar having a cement : sand ratio of 1 : 3 by volume, and the water : cement ratio of 0.4 by weight, is recommended. Mortar is applied by hand and plastic bags are used for hand protection. One man stands outside the tank and pushes a handful of mortar through the reinforcement



*Spacing of Hoop bars are shown in inches or number of square opening in wire mesh

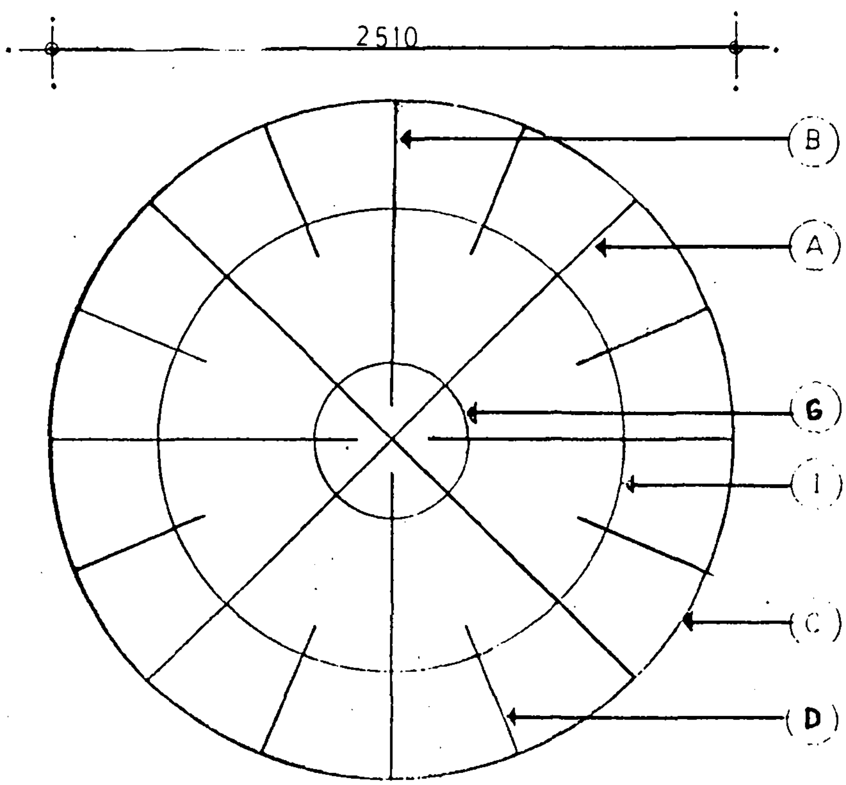
Circled letters are Bar Designations as per Table 4

Figure 2. Cross Section of Steel Reinforcement



Circled letters are Bar Designations as per Table 4

Figure 3. Details of Skeletal Steel for Roof



Circled letters are Bar Designations as per Table 4

Figure 4. Details of Skeletal Steel for Base

Figure 5. Tank reinforcement is being put into place.

Figure 6. Plastering of mortar core

in a sweep motion to another man standing on the inside of the tank who also moves his hand in the same manner (see Fig. 6). The mortar core is given a day to harden and 5-10 mm thick layers of mortar are trowelled onto both the outside and the inside of the tank (see Fig. 7). A thin layer of cement paste is then trowelled on the inside surface for a smooth finish and an increase in water tightness. Plastering of the roof is carried out in a similar manner. Since water tightness is not required in the roof, plastering is carried out quickly. A piece of thin board such as 4 mm plywood board is used on the inside to receive the mortar. Thick cement slurry is applied to all construction joints such as the joint between the base and the wall or the connection between the concrete and the pipes to ensure a good watertight bond.

Curing of the Tank

Curing of the tank can be achieved by several methods, such as water sprinkling, covering with wet sacks, etc. However, it is found that the methods that need a lot of water are not suitable in rural situations where water is difficult to get. Curing the tank by covering it with thin PVC sheets is found to be most appropriate (Fig.8) since no further attention is required during the curing period (14 days). The PVC sheets are reusable.

BEHAVIOUR OF THE TANK

Four ferrocement tanks were constructed, one in the laboratory and three in villages. All of these tanks are in constant use. To date no seepage has been found.

CONCLUSION

For each tank, materials cost is 3906 baht (326 baht/m^3). The construction duration is four days and the labour cost is 1500 baht.

Tank construction can be carried out solely by unskilled labour if good finishing plastering is not required. Water tightness quality of

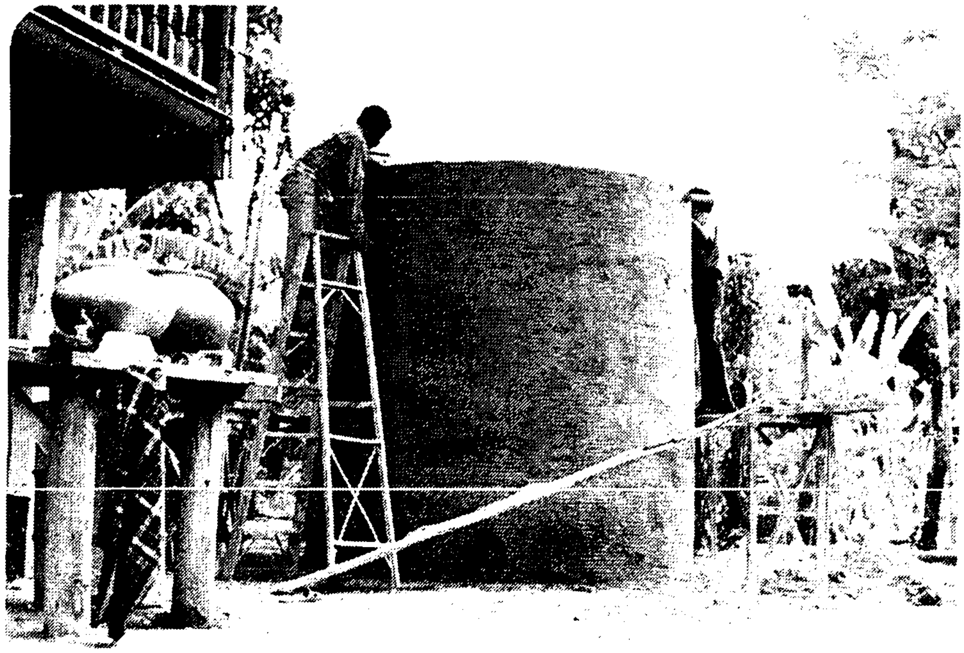


Figure 7. Mortar core prior to finishing plastering

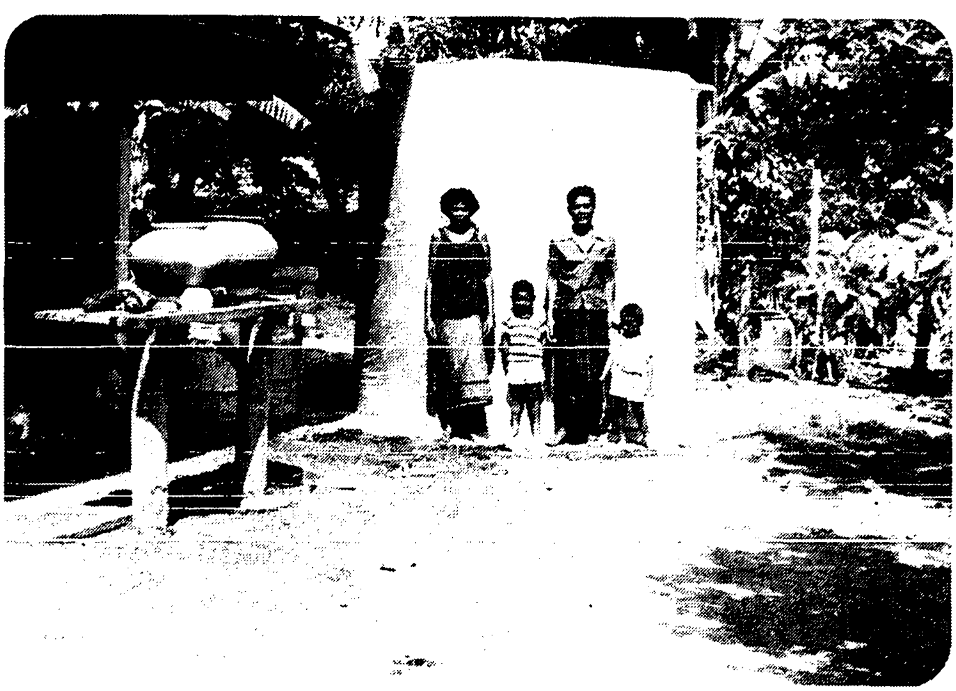


Figure 8. Water tank is being cured in PVC sheet.

the tank is excellent. There is no seepage and no waterline which is normally visible in a concrete tank when it is first filled with water. Villagers are at first sceptical because of the thinness of the walls of the tank. This reaction, however, changes when the tank shows its remarkable strength.

REFERENCES

1. Manning, G.P. Reservoirs and Tanks. Concrete Publication Limited, London, 1967.

2. Timoshenko, S. and Woinowsky-Krieger, S. Theory of Plate and Shell. McGraw-Hill, 1959.

3. Ghali, A. Circular Storage Tanks and Silos. E. & F.N. Spon Ltd., London, 1979.

4. Portland Cement Association, Circular Concrete Tanks Without Prestressing. Concrete Information, 1969.

5. Watt, S.B. Ferrocement Water Tanks and Their Construction. Intermediate Technology Publications Ltd., London, 1978.

6. Lee, S.L., Raisinghani M., and Pama R.P. "Mechanical Properties of Ferrocement", FAO Investigates Ferrocement Fishing Craft. Edited by Fyson J.F. Fishing News (Books) Ltd., 1974.

BRICK WATER TANK

Chayatit Vadhanavikkit
Suthiphol Viwathanathepa
Faculty of Engineering
Khon Kaen University
Thailand

SYNOPSIS

A brick water tank has been designed for use in rural areas. It consists of a cylindrical shaped brick wall, wound around by galvanized wires during mortar plastering. The inside surface of the tank is lined with hexagonal wire mesh prior to plastering. Tanks of two sizes were constructed, both 2.5 m diameter, and with heights of 2.5 m (12 m^3) and 3 m (14.5 m^3). Their behaviour and construction procedures are presented and discussed.

INTRODUCTION

Bricks are among the most commonly used materials for water storage construction. Brick tank construction does not require any formwork and so tank sizes and shapes can be varied. The main drawbacks of the use of bricks in water tanks are their low tensile strength and their high shrinkage, which result in leakage and a short working life of the tanks. Thus, the size of an unreinforced brick water tank has been limited to only a small size range where induced stresses are small.

In this paper, circular water tanks with reinforcement of galvanized wires and hexagonal wire mesh are designed. Two sizes of the tanks were constructed both with 2.5 m diameter, and with the heights of 2.5 m (12 m^3) and 3 m (14.5 m^3). Five tanks were constructed: one in the laboratory and four in three villages. Several methods of construction were tried. Their behaviour and construction procedures are presented and discussed.

DESIGN OF WATER TANK

General features of the tank are illustrated in Fig. 1. The base is made of reinforced concrete and the wall is built up with bricks and mortar. Galvanized steel wires wound around the outside surface of the tank wall are designed to take up all the hoop stresses induced in the wall. The inside surface of the tank is lined with 12.5 mm hexagonal wire mesh to prevent cracking in the mortar due to shrinkage stresses. The roof is made of ferrocement where the main steel reinforcement is sandwiched between hexagonal wire meshes. Details of roof and base reinforcement are presented in Figs. 2 and 3. Bar cutting and bar configuration are shown in Table 1.

CONSTRUCTION TECHNIQUES

The construction stages of brick water tanks are as follows:

Base Concreting

Concrete having a mixture of cement : sand : stones of 1 : 2 : 4 by volume is used for the base. The base thickness of 100 mm is cast from the centre of the base and spread radially outwards. The centre of the tank is marked by a piece of tying wire which is tied to the steel bars. This wire should protrude from the concrete for at least 50 mm. When the diameter of the laid concrete is large enough to draw a circle of 2.30 m diameter, the circle is drawn and 24 galvanized wires of 1.5 m length are placed around the perimeter with equal spacing of 300 mm. These wires are buried in the concrete in a radial direction with an anchorage length of 300 mm (Fig. 4). The compaction of concrete is done by stepping on it.

Building of the Brick Wall

Thick mortar slurry is applied at the connection between the base and the wall prior to the wall construction. A circular brick wall with inside diameter of 2.5 m is built up with mortar having a cement : sand

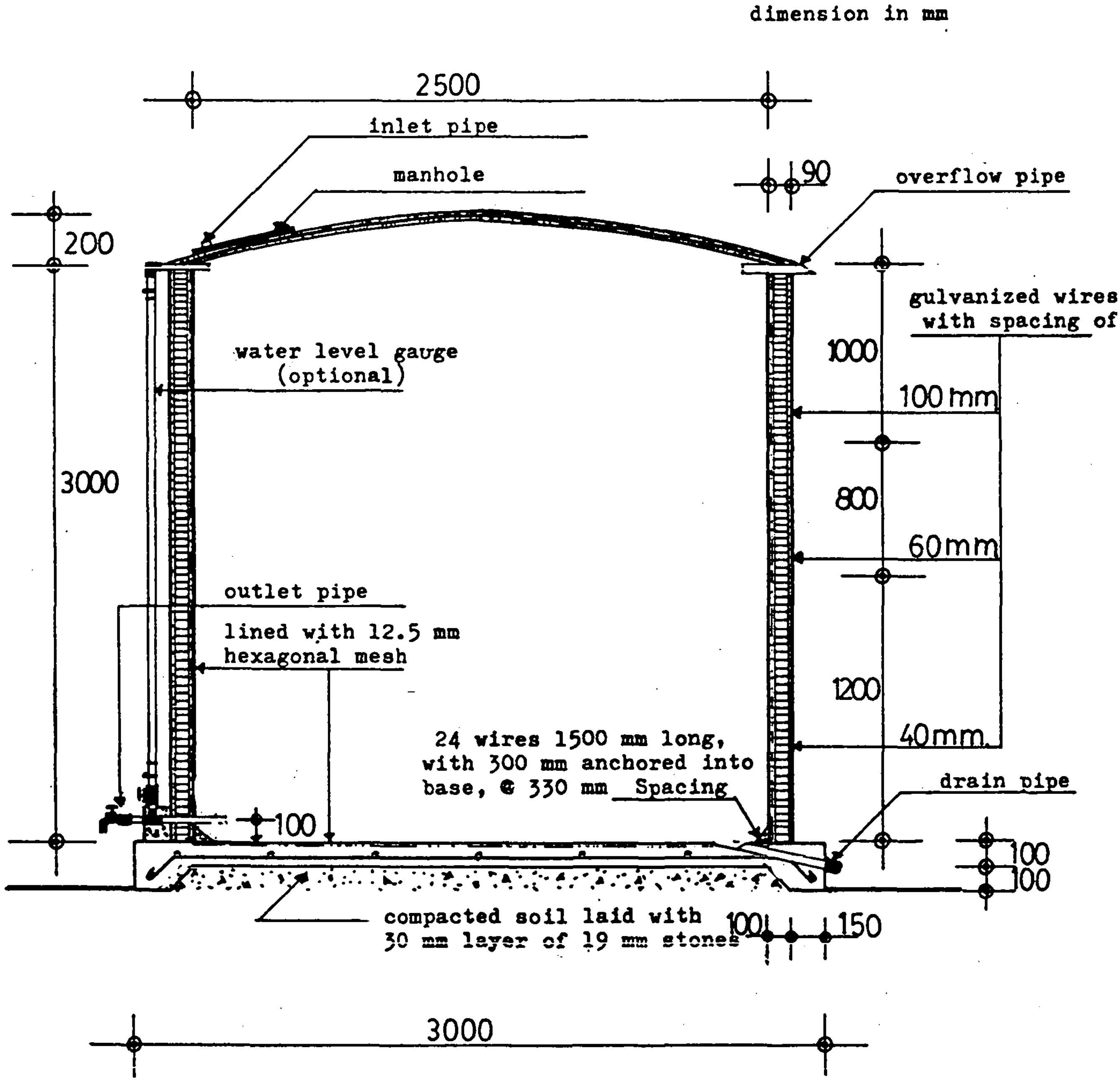
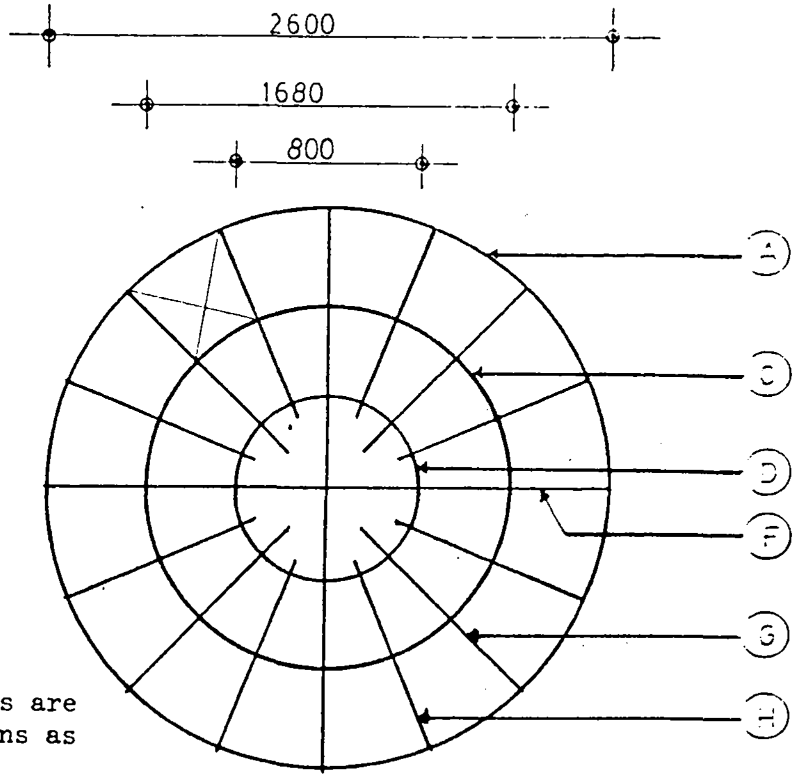
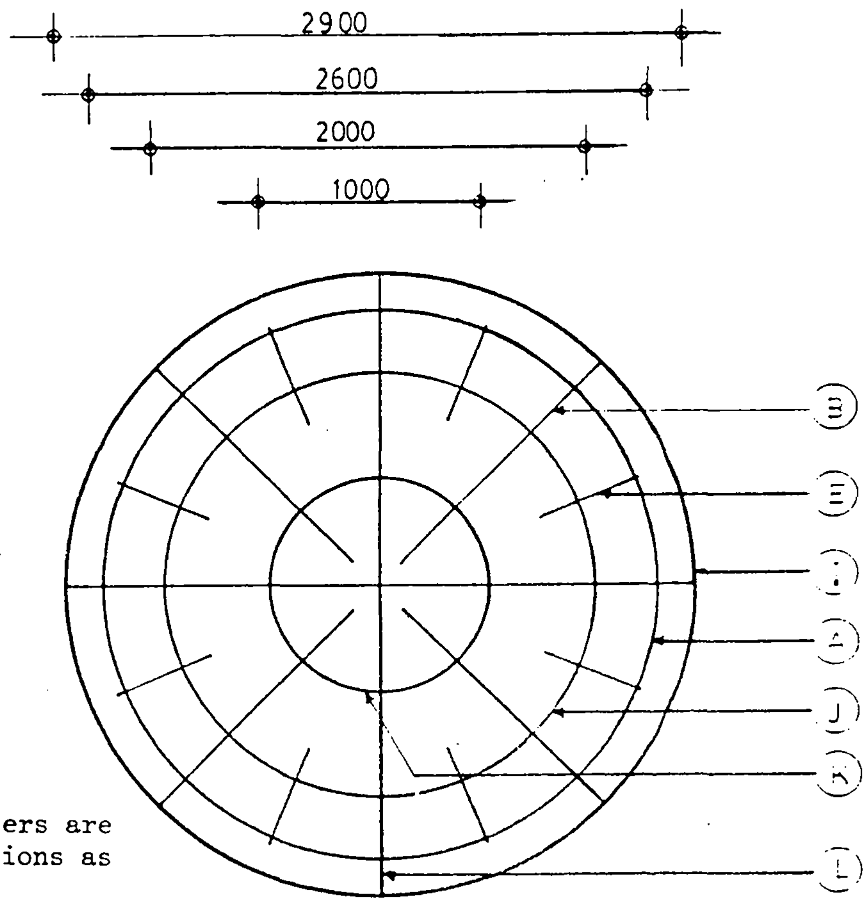


Figure 1. General description of brick water tank



Circled letters are
Bar Designations as
per Table 1

Figure 2. Reinforcement for roof



Circled letters are
Bar Designations as
per Table 1

Figure 3. Reinforcement for base

TABLE 1. DETAILS OF BAR CUTTING AND CONFIGURATION.

Bar designation	No. of bars required	No. of 9 mm bars used	Details of bar cutting and Configuration (dimension in mm)
A	2	2	8500 → 2 of [2600]
B	2		1500 → 2 of [150, 1150, 100]
C	1	1	5600 → 1 of [1680]
D	1		2850 → 1 of [800]
E	3		1550 3 @ 510 → 3 of [450]
F	2	1	5500 2 @ 2750 → 1 of [2600, 200]
G	4		4500 4 @ 1120 → 4 of [1070]
E	4	1	1900 4 @ 470 → 4 of [400]
H	8		8100 8 @ 1010 → 8 of [9500]
I	1	1	9400 → 1 of [2900]
E	1		600 → 1 of [540]
J	1	1	6600 → 1 of [2000]
K	1		3400 → 1 of [1000]
L	1	1	6100 2 @ 3050 → 2 of [150, 2900, 100]
B	2		3900 2 @ 1950 → 2 of [150, 1150, 100]

Figure 4. Construction of base

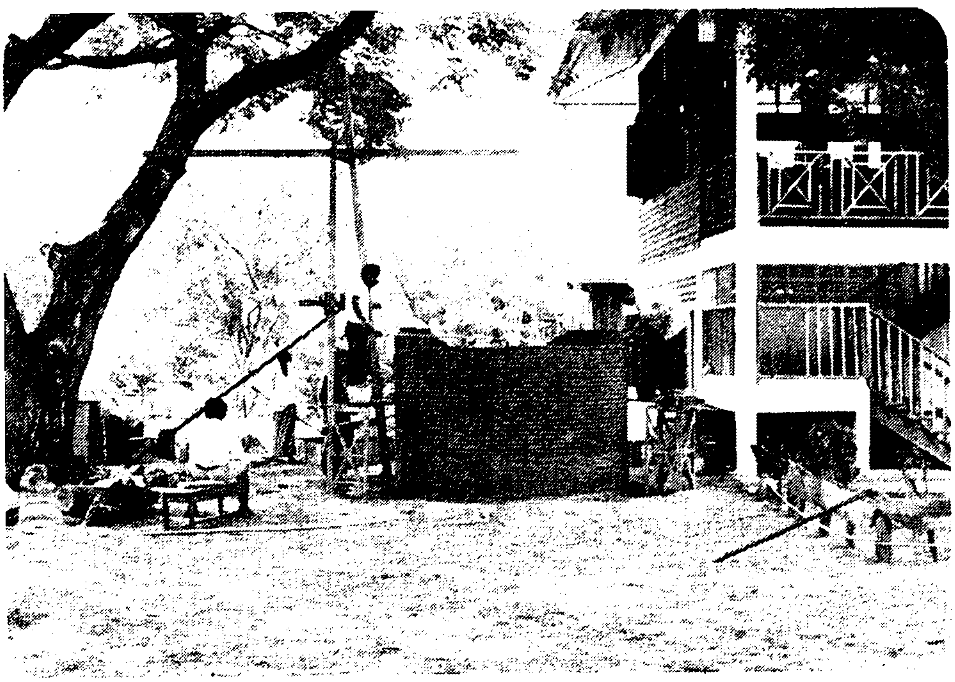


Figure 5. Construction of brick wall

ratio of 1 : 4 by volume. The wall can be built immediately after the base is completed, but the wall should not be too high. A maximum of 800 mm was constructed and no ill effects were found. Unlike normal brick laying, the joints between bricks must be fully filled with mortar to ensure good watertightness. Two bricklayers lay this brick wall at a rate of 350 mm height per hour. Hence, construction of the base and wall can be carried out in two days. Several methods were tried to keep the wall shape circular and vertical. It is found that using the vertical line which is tied to the wire at the base centre as a guide, and periodically checking the distance between the wall and the line by means of a stick are simple and adequate methods (see Fig. 5).

Plastering of Outer Surface of the Wall

Mortar having a mixture of cement : sand of 1 : 3 by volume is used for wall plastering. Prior to plastering, the base around the outside of the wall must be cleaned, and any unsound hardened mortar must be taken off. Thick cement slurry is then applied at the base for a good watertight bond between mortar and base. Quick rough plastering is applied and then galvanized wires are wound around the tank with three rounds at the bottom. The spacing of the wires begins at 40 mm and increases to 60 mm and 100 mm when the respective heights of 1.2 m and 2.0 m are reached. Two rounds are finished off at the top. The wires must be pulled tightly and embedded in mortar. To achieve this, mortar plastering and wire winding can be carried out either at the same time or alternately. In either way, mortar plastering should not be too far ahead, because the mortar will stiffen and the wires will not be able to penetrate into it. It is found that a plastering height of 500 mm at a time is suitable.

Unwinding wires from a coil can be troublesome if it is not done correctly. Wires must be unwound smoothly, without twists and knots. It is found that unwinding by rolling out wires from a coil around the tank is satisfactory. The coil should not be too heavy (10 kg is the maximum) and joining of wires by tying knots is recommended.

When wire winding is completed (Fig. 6), finishing by plastering 10 mm thick is carried out.

Plastering of Inner Surface of the Wall

The bottom of the tank is cleaned and unsound mortar is taken off. Wires which are anchored to the base are nailed to the brick wall. The inner surface of the wall is then lined with 9 pieces of hexagonal wire mesh, each with a length of 3.5 mm. These meshes are placed in a vertical direction with 30 mm overlapping (see Fig. 7). Meshes are closely fixed to the wall by short flathead nails at intervals of not more than 200 mm. The bottom is also lined with two 3 m length meshes. The entire surface is plastered and a thin layer of cement paste is applied for a smooth finish and watertightness.

Construction of the Roof

The roof is constructed using a ferrocement technique. The reinforcement consists of 9 mm steel bars sandwiched between two layers of hexagonal mesh. These meshes are tied together and to steel bars at intervals of not more than 200 mm. The roof reinforcement is placed on top of the tank and adjustment may be necessary if the roof shape does not fit the tank. More than often, it is found that adjustments are necessary. Thus, it is advisable that the roof skeletal steel should be tailor-made on the tank.

Mortar with a mixture of cement : sand ratio of 1 : 3 by volume and water : cement ratio of 0.4 by weight is used for the roof. Plastering of mortar is performed by hand (see Fig. 8).

Curing of the Tank

The tank is cured using thin PVC sheets (see Fig. 9) which are suitable for rural areas where water is scarce. This method is very effective and no further attention is needed during the curing period (14 days). The PVC sheets are reusable.

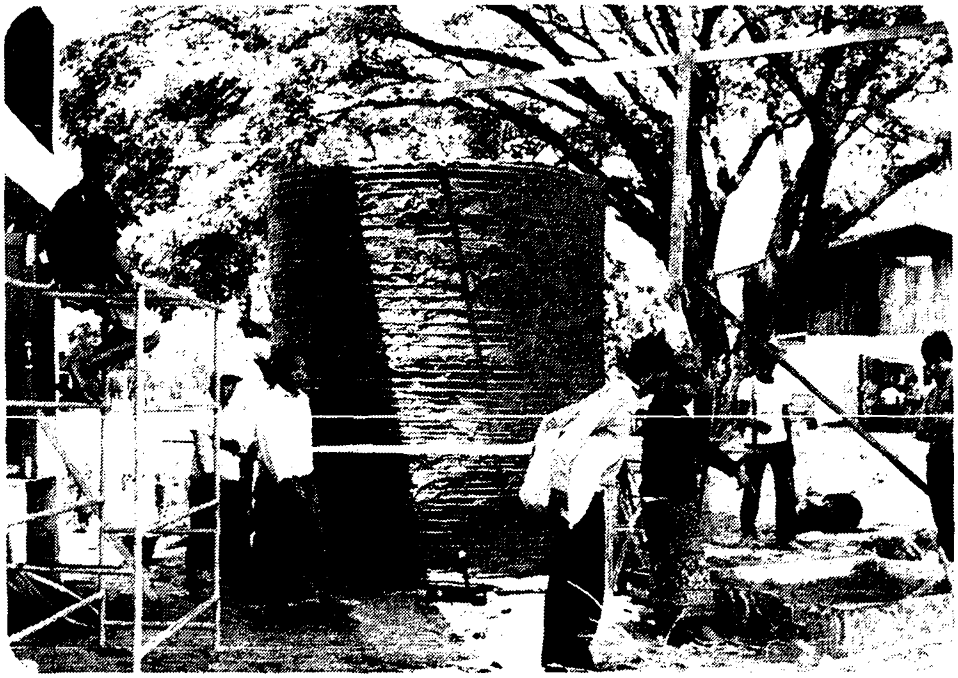


Figure 6. Hoop reinforcement of water tank

Figure 7. Lining of wire mesh

Figure 8. Plastering of roof

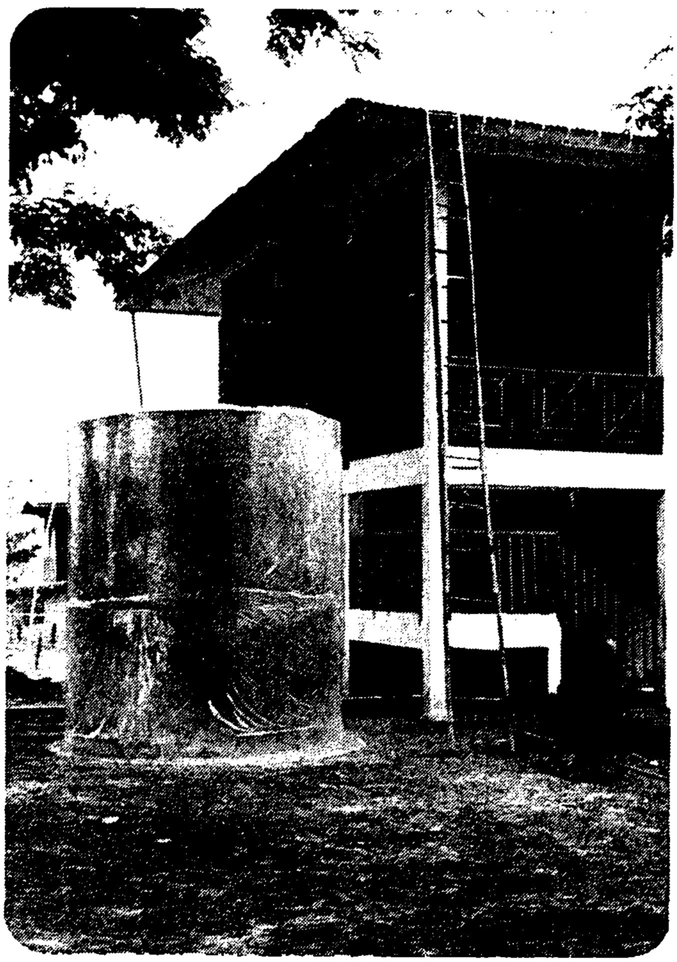


Figure 9. Curing of water tank

BEHAVIOUR OF THE TANKS

Five tanks were constructed, and are in constant use. Very minor seepage on the tank wall was noticed but it sealed itself within a few days. The long term behaviour of these tanks will be observed and compared with tanks of other types.

CONCLUSION

Brick water tank construction is simple. The techniques are known to villagers. Although a certain degree of skill in brick laying is required, there is no shortage of the skills in the three villages where tanks are constructed. Lists of materials used are presented in Table 2.

TABLE 2. CONSTRUCTION MATERIALS.

No.	Materials	12 m^3		14.5 m^3	
		quantity	cost* (B)	quantity	cost* (B)
1.	silica cement	22 bags	1540	24 bags	1680
2.	bricks	2500	625	3000	750
3.	stones 19 mm (3/4")	1 m^3	230	1 m^3	230
4.	sand	2.5 m^3	425	3 m^3	510
5.	steel bars 9 mm	8 bars	280	8 bars	280
6.	hexagonal wire mesh	1 roll	610	1 roll	610
7.	galvanized wires				
	no. 12 (0=2.7 mm)	17 kg	221		
	no. 11 (0=3.3 mm)			25 kg	325
8.	flathead nails	0.5 kg	10	0.5 kg	10
9.	tying wires	0.5 kg	8	0.5 kg	8
10.	pipes and fittings etc.	-	160	-	160
			4109		4563

* Conversion rate (1983) $1 US = 23 baht

Note: Roll size of hexagonal wire mesh is .91 m x 45.7 m (3 feet x 150 feet).

For a tank of 2.5 m in diameter and 3 m in height (14.5 m^3), the cost of materials is 4600 baht (317 baht/m^3). The construction period is 5 days and labour cost is 1750 baht.

For a tank of 2.5 m in diameter and 2.5 m in height (12 m^3), the cost of material is 4100 baht (342 baht/m^3). The construction period is 4 days and labour cost is 1400 baht.

REFERENCES

1. Manning, G.P. Reservoirs and Tanks. Concrete Publication Limited, London, 1967.

2. Timoshenko, S. and Woinowsky-Krieger, S. Theory of Plate and Shell. McGraw-Hill, 1959.

3. Leangpibul, K., Tanakarn, R. and Panyapradit, B. "Brick Water Tanks", Project Report No. C 84-4, Faculty of Engineering, Khon Kaen University, 1983.

INTERLOCKING MORTAR-BLOCK WATER TANK

Chayatit Vadhanavikkit
Suthiphol Viwatanathepa
Faculty of Engineering
Khon Kaen University
Thailand

SYNOPSIS

A circular water tank constructed from mortar blocks is being developed for use in rural areas. Mortar blocks which form the tank wall are made from dry-mix mortar which is compacted into a form by hand tamping. These blocks are designed to have such a shape that they interlock. Thus weaknesses at the joints are avoided. Four tanks with the capacity of 9 m^3 and 12 m^3 (2 of each) were constructed and tested. Their behaviour and construction procedures are presented and discussed.

INTRODUCTION

Mortar and concrete blocks are popular for wall construction because of their low cost and construction simplicity. So far, however, the application of mortar blocks to water tank construction is limited because of weaknesses at the joints between blocks. In most domestic water tanks, the induced stresses are small. If mortar blocks can be made (with sufficient reliability) so that their strength is several times higher than the induced stresses, reinforcement may not be necessary.

This paper describes the design of unreinforced mortar block water tanks. These blocks are designed to have such a shape that they interlock and weaknesses at the joints are avoided. Four tanks of 9 m^3 and 12 m^3 were constructed and tested. Their behaviour and construction procedures are presented and discussed.

ANALYSIS AND DESIGN

Several shapes of interlocking blocks were considered and a dog-bone shape illustrated in Fig. 1 was chosen. The shear strength of mortar is more than five times its tensile strength. Hence, to ensure full interlocking action, the area of the shear plane (A) must be more than 1/5 of the area of the tension plane (B).

A cylindrical water tank of 2.5 m in diameter and 2.5 m in height was designed. The flat shaped block was used instead of the curved one for its simplicity in block making. Determination of the block's dimensions is illustrated in Fig. 2. The dimensions of these blocks are presented in Fig. 3. A clearance of 3 mm for joints between blocks is allowed. Block type A is for the bottom and top layers of the tank wall while block type B is for those layers in between.

If the connection between base and wall is assumed to be fixed or hinged, the maximum hoop stresses are 4.23 kg/cm^2 and 4.63 kg/cm^2 respectively. The maximum bending moment at the base of the wall is 50.16 kg-cm/cm width which creates a maximum fibre stress of 8.36 kg/cm^2.

The strength of the mortar varies remarkably depending on types of sand used. The price of sand in Khon Kaen ranges from 110 $baht/m^3$ to 180 $baht/m^3$ and none of them meet all the requirements of ASTM standards (C-33). With these types of sand, using a mortar having a cement : sand ratio of 1:3 by volume and a water : cement ratio of 0.45 by weight, the tensile strength ranges from 17 kg/cm^2 to 30 kg/cm^2 (note: though a water : cement ratio of 0.4 is recommended, 0.45 is used in the tests to allow for varying degrees of control in the field).

Cement paste is used to bind mortar blocks together and it is found that the strength at the joints is stronger than the blocks themselves. Hence, tensile strength of the tank wall is at least four times the induced hoop stress and is twice the bending stress.

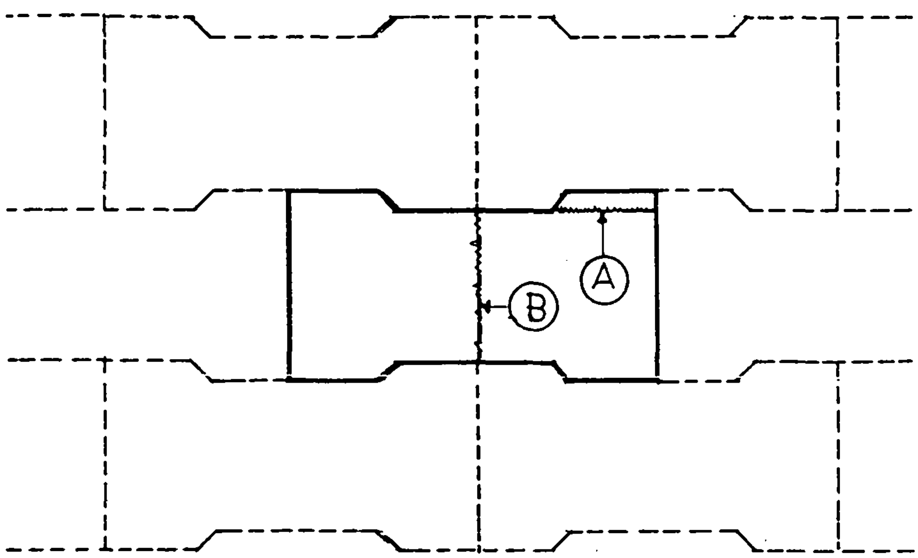


Figure 1. Shape of interlocking blocks

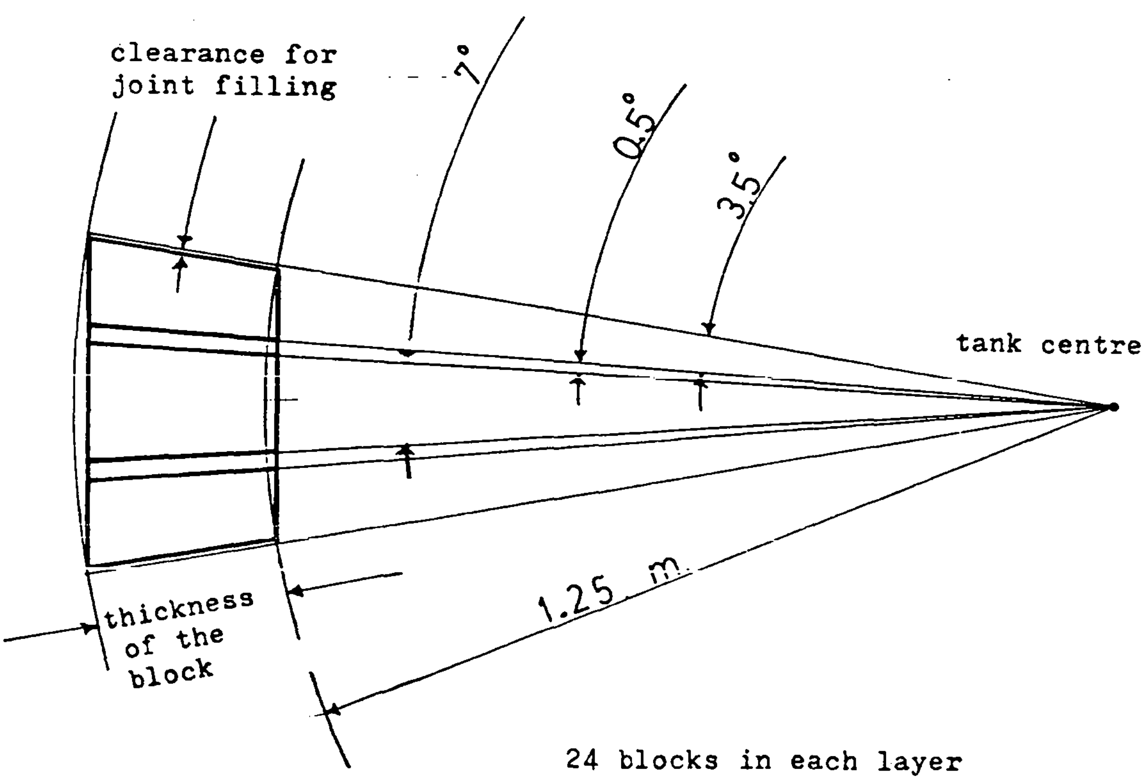


Figure 2. Determination of block size

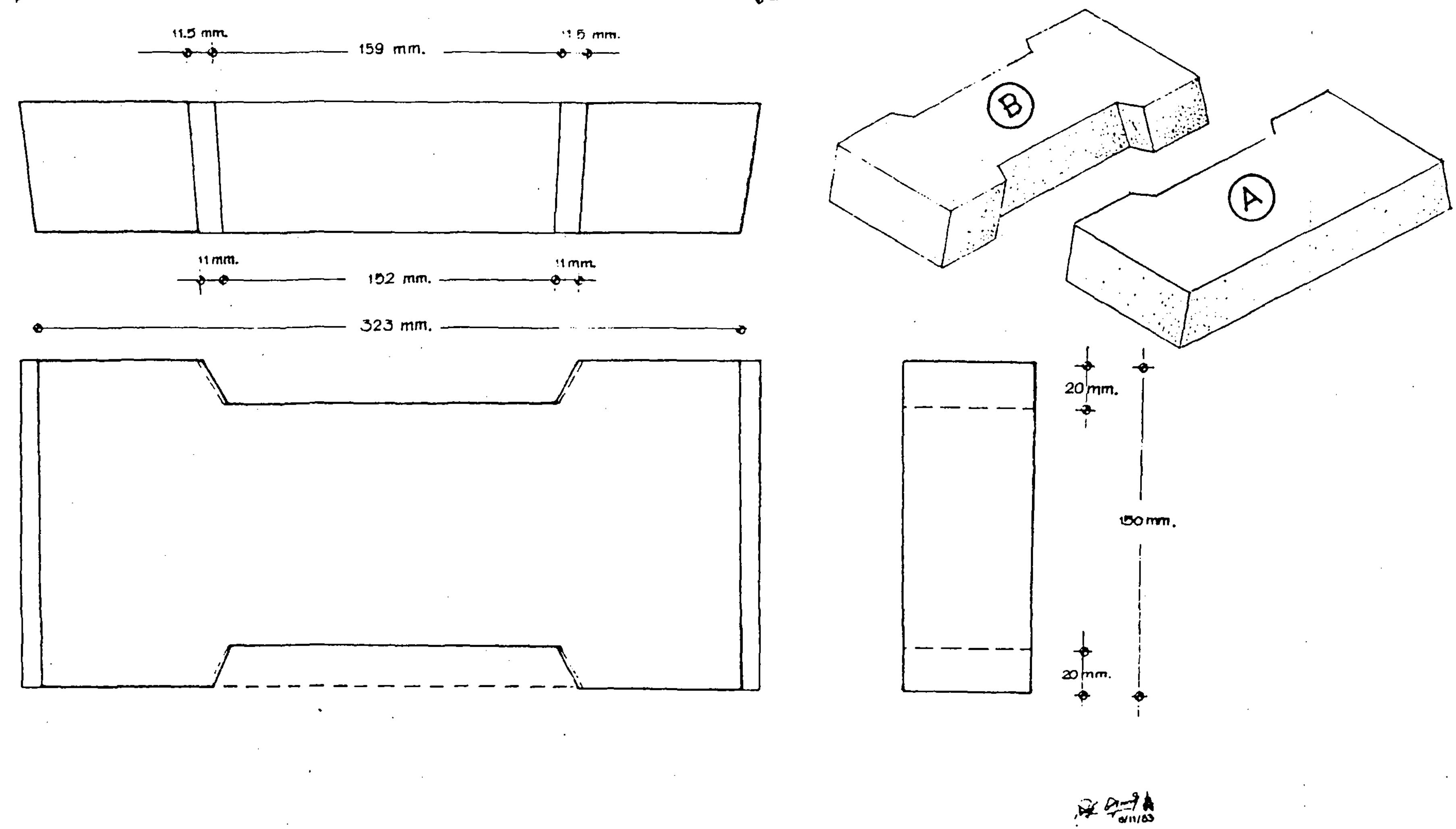


Figure 3. Dimensions of interlocking blocks

The general appearance of an interlocking mortar block water tank is as illustrated in Fig. 4. It is also found that tanks with diameters ranging from 2 to 3 m can be constructed from the same blocks (shown in Fig. 3). If the diameters are outside this range, laying the blocks is difficult. However, it is not recommended to use these blocks to construct tanks which are larger than that designed for, unless appropriate modifications of the blocks, such as an increase in thickness or strength, is made.

CONSTRUCTION TECHNIQUES

Steel reinforcement for roof and base is presented in Figs. 5 and 6 respectively. Bar cutting is illustrated in Table 1 and a list of construction materials is presented in Table 2.

The construction procedures for interlocking mortar-block water tanks are as follows:

Mortar-Block Making

Mortar having a cement : sand ratio of 1:3 by volume and a water : cement ratio of 0.4 by weight is used. Mortar must be well mixed and compaction is carried out by hand tamping. Compacting must be done on a flat hard floor which is covered by PVC sheets to prevent the blocks from sticking to the floor. Material wastage is practically nil as excess mortar from the previous block is collected and used for making other blocks (Fig. 7).

Under most conditions water content in the mortar mix is usually controlled by eye during mixing. The amount of water added is affected by the presence of moisture in the sand, which can vary considerably between the top and bottom layers of the sand stockpile. However, from tests in the laboratory, it is noticed that when mortar having a water : cement ratio of 0.4 is compacted into the mould, a small amount of water (1-2 cc) is squeezed out and can be seen around the edges of the blocks.

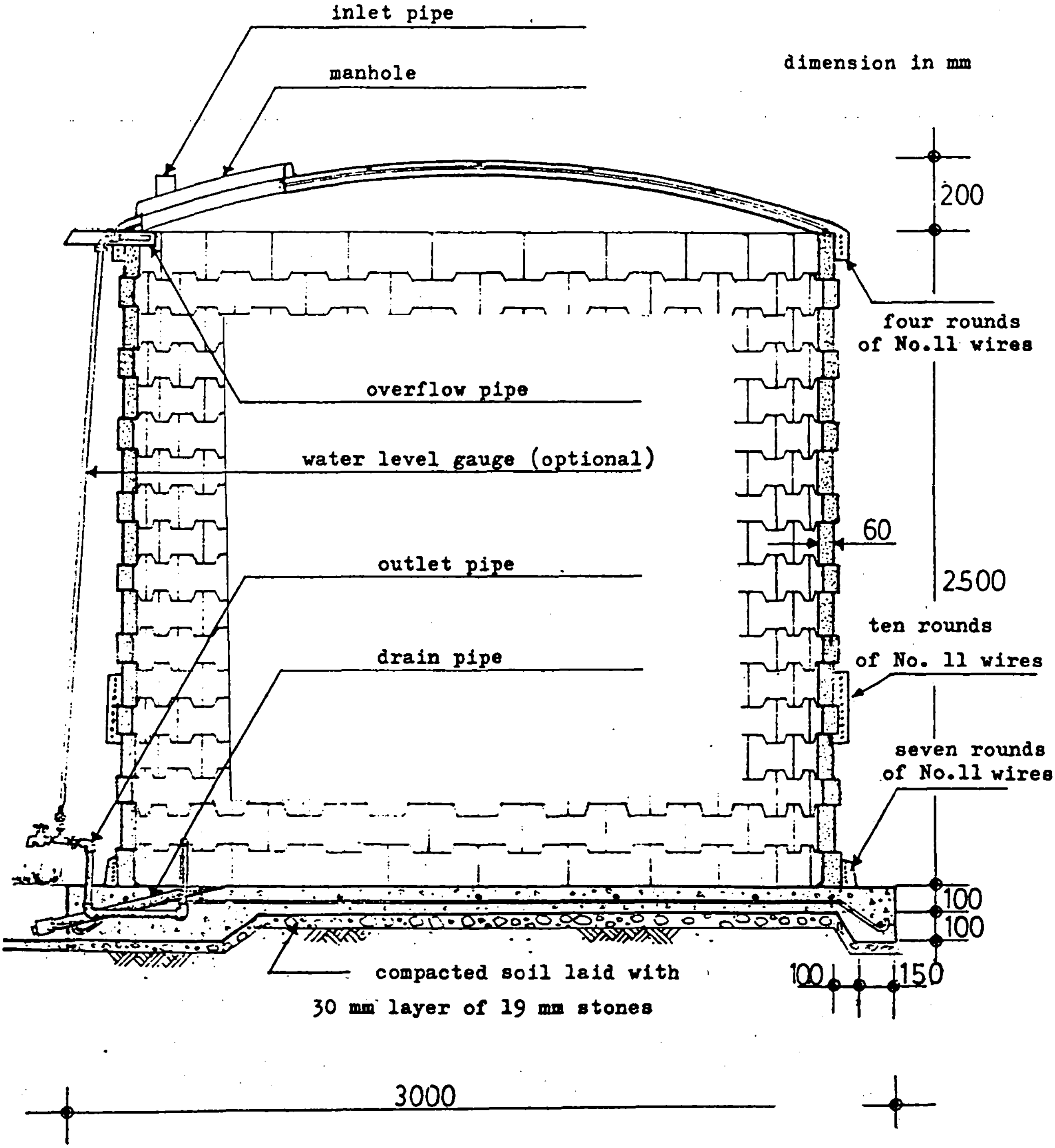


Figure 4. General description of interlocking mortar-block water tank

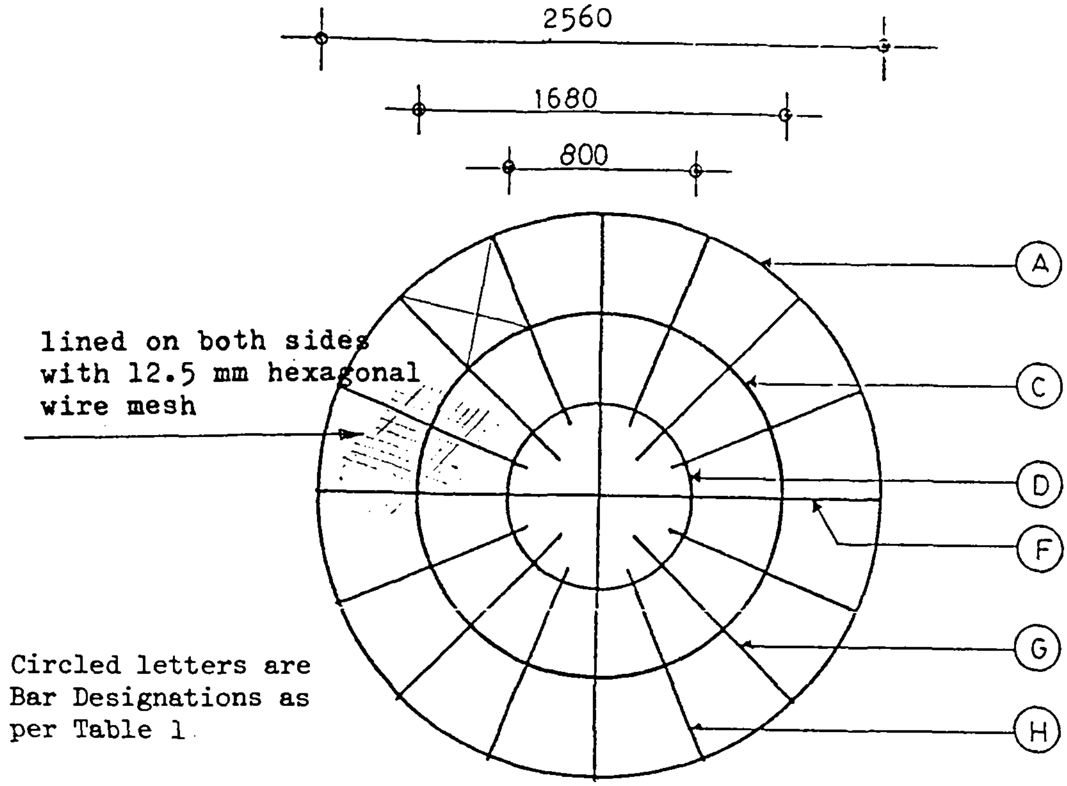


Figure 5. Reinforcement for roof

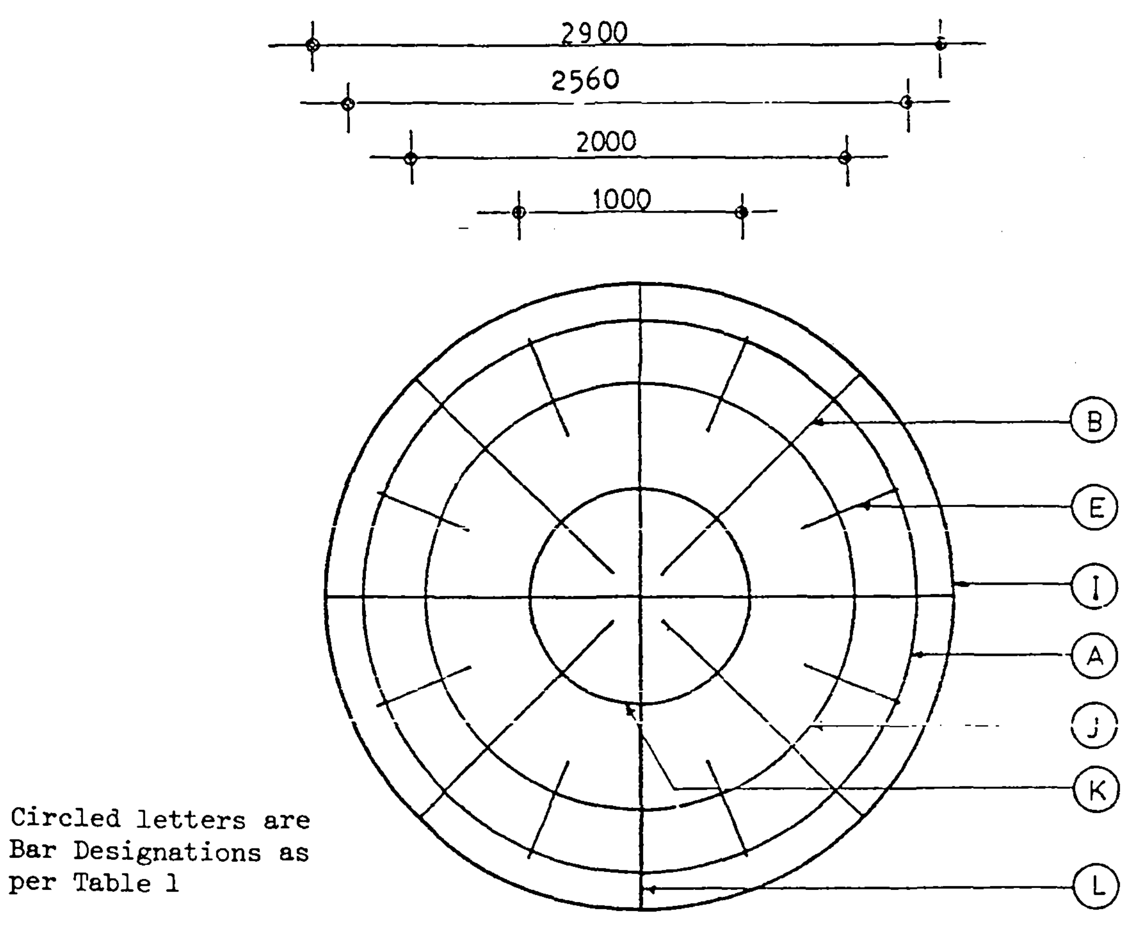


Figure 6. Reinforcement for base

TABLE 1. DETAILS OF BAR CUTTING AND CONFIGURATION.

Bar designation	No. of bars required	No. of 9 mm bars used	Details of bar cutting and Configuration (dimension in mm)
A	2	2	8500 → 2 of 2560
B	2		1500 → 2 of 150, 1150, 100
C	1	1	5600 → 1 of 1680
D	1		2850 → 1 of 800
E	3		1550 3 @ 510 → 3 of 450
F	2	1	5500 2 @ 2750 → 1 of 2560, 200
G	4		4500 4 @ 1120 → 4 of 1070
E	4	1	1900 4 @ 470 → 4 of 400
H	8		8100 8 @ 1010 → 8 of 9500
I	1	1	9400 → 1 of 2900
E	1		600 → 1 of 540
J	1	1	6600 → 1 of 2000
K	1		3400 → 1 of 1000
L	1	1	6100 2 @ 3050 → 2 of 150, 2900, 100
B	2		3900 2 @ 1950 → 2 of 150, 1150, 100

TABLE 2. CONSTRUCTION MATERIALS.

No.	Materials	12 m^3		9 m^3	
		quantity	cost (B)*	quantity	cost (B)*
1	cement	25 bags	1750	20 bags	1400
2	sand	2.5 m^3	425	2.0 m^3	340
3	stone 19 mm (3/4")	1 m^3	230	0.7 m^3	161
4	steel bars 19 mm	8 bars	280	7 bars	245
5	hexagonal wire mesh 12.5 mm, .91 m (3') wide	14 m	210	13 m	195
6	galvanized wires No. 11	200 m (12 kg)	156	150 m (9 kg)	117
7	tying wires	0.5 kg	8	0.5 kg	8
8	pipes and fittings etc.		180		180
			3239		2646

* Conversion rate (1983) $1 US = 23 baht (B)

But for mortar with a water : cement ratio of 0.35, no trace of excess water is seen, and for mortar with a water : cement ratio of 0.45, a considerable amount of excess water is noticed. This excess water indication has been used successfully for construction in the field. Total cement content per brick is 1.5 kg for Type A and 1.3 kg for Type B. For the 12 m^3 tank, 47 Type A and 385 Type B blocks are required and for the 9 m^3 tank, 43 of Type A and 309 Type B.

Base Concreting

Concrete having a mixture of cement : sand : stone of 1 : 2 : 4 by volume is used for the base. The base is 100 mm thick and concrete compaction is carried out by stepping on it. The concrete surface is finished with a thin layer of cement paste to increase its watertightness.

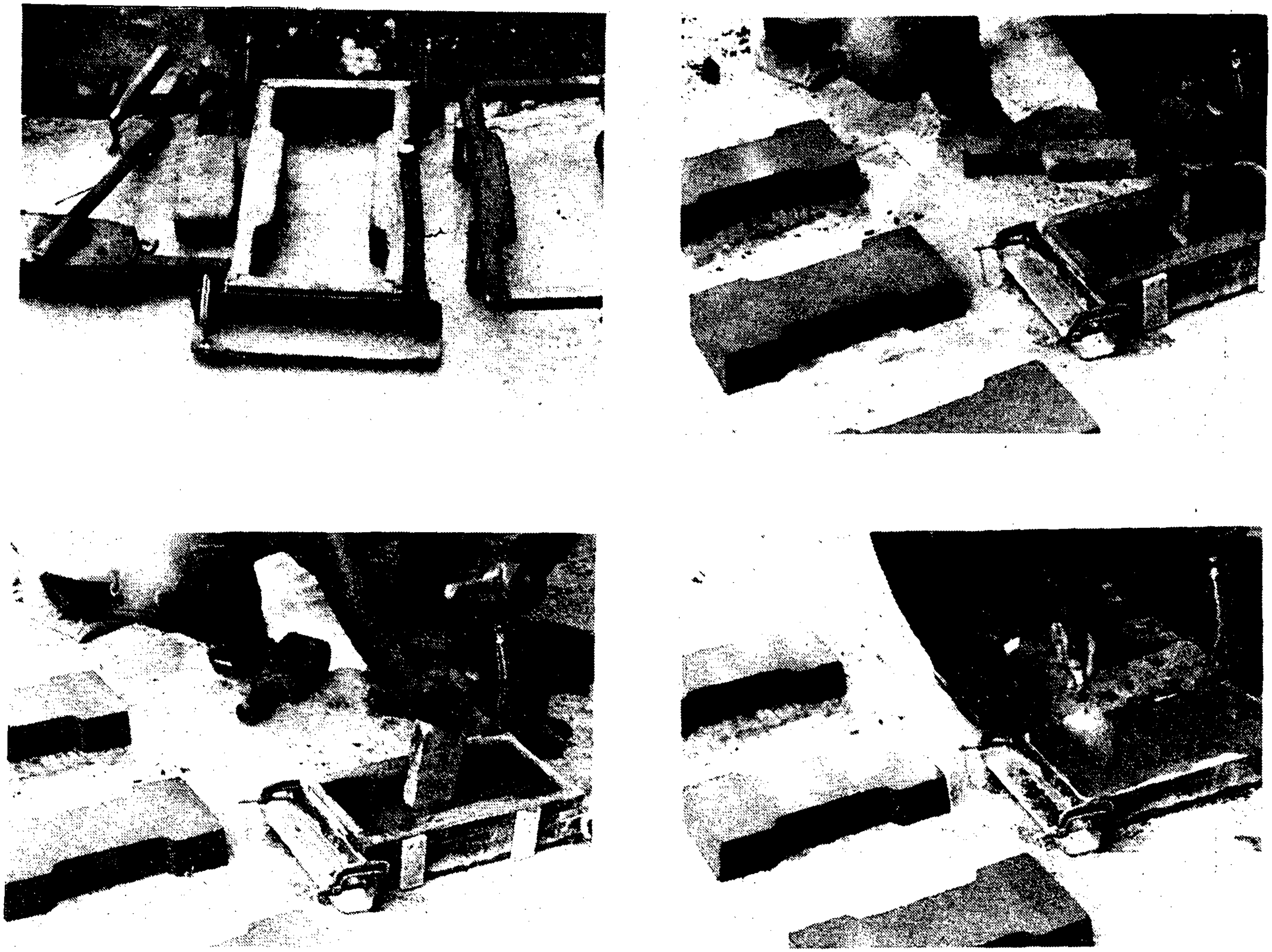


Figure 7. Making of interlocking blocks

Construction of Tank Wall

The concrete base is given a day to harden. A circle of tank diameter (2.5 m for 12 m^3 tank and 2.29 m for 9 m^3 tank) is drawn on the concrete base. Blocks type A are placed on the perimeter of the circle and are arranged so that gaps between blocks are approximately 1 to 3 mm. Blocks are laid one layer at a time (Fig. 8). The numbers of blocks in each layer are 24 and 22 for 12 m^3 and 9 m^3 tanks respectively. Cement paste (water : cement ratio between 0.3 to 0.35) is used to bind the blocks together.

Before bonding, it is important that all blocks and the concrete base are damp so that they do not absorb water from the cement paste. It is advisable that the blocks be submerged in water for at least 15 minutes prior to bonding. Water content in the cement paste is kept low in order to minimize the risks of shrinkage cracks at the joints. The cement paste is rather stiff and does not flow easily when it is squeezed from the joints. Furthermore, stiff cement paste does not bind well with the mortar block surfaces. To overcome these problems, a cement slurry (water : cement ratio between 0.5 to 0.55) is applied on all surfaces before applying cement paste. The cement slurry eases the flow of cement paste and improves the bond strength.

Since only a small clearance is allowed at the joints, block laying may be difficult at times. However, one way to avoid the difficulty is to try laying all blocks in the whole layer on their locations and any non-uniformity is adjusted prior to the actual bonding process.

Cement slurry is applied by using an old paint brush or something similar. Then cement paste is applied on the surfaces and the blocks are laid in such a manner that as much cement paste as possible can be squeezed from the joints. Then the excess paste is removed. It is important that the joints are fully filled. The inside of the tank wall is coated with cement slurry to increase its watertightness.

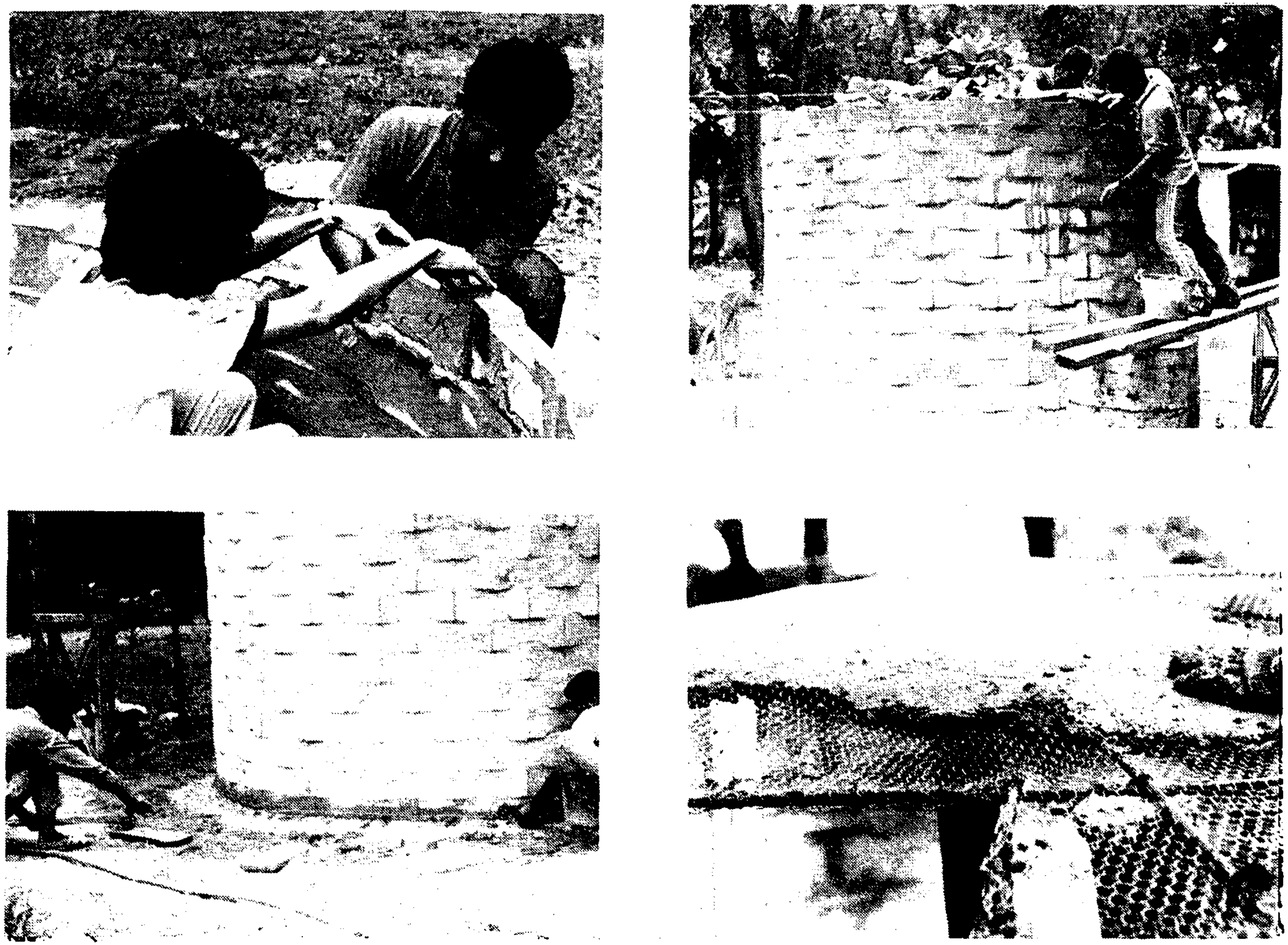


Figure 8. Construction of water tank

Construction of the Roof

The roof is made using the ferrocement construction technique. The reinforcement consists of 9 mm steel bars sandwiched between two layers of hexagonal meshes. These meshes are tied together and to steel bars at an interval of not more than 200 mm. The steel reinforcement of the roof is placed on the tank and is adjusted to conform with the contour of the tank.

Mortar having a cement : sand ratio of 1 : 3 by volume and water : cement ratio of 0.4 by weight is used and plastering is performed by hand.

Plastering of Wire Belts

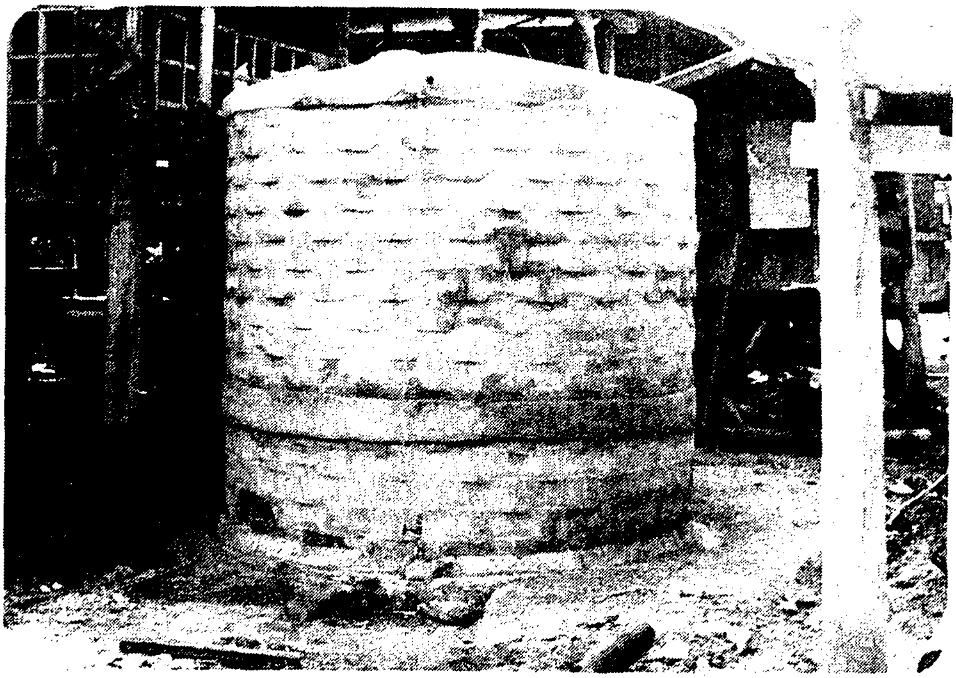
Three wire belts, one at the top, one at the bottom and the third one at a level between 0.2 to 0.3 of the height, are designed for tank safety. The tank surface where the wire belts are to be installed must have a layer of cement slurry prior to mortar plastering for good bonding. Galvanized wire is then wound around the tank at a spacing of 40 mm. The wire must be pulled tightly and embedded in the mortar. The two ends of the wire must be tied together to avoid slipping of the wire. The wire is then covered with finishing mortar 10 to 15 mm thick.

Curing of the Tank

Water to an approximate height of 100 mm is stored in the tank for curing. Since all blocks are already cured, curing of the outside surface of the tank wall may not be essential (Fig. 9).

BEHAVIOUR OF THE TANKS

Two tanks of 9 m^3 and two tanks of 12 m^3 were constructed. One tank (12 m^3) was constructed in the laboratory and the middle wire belt was omitted. Some minor seepages were noticed when these tanks were first filled with water. Two types of seepages were found - seepage at the



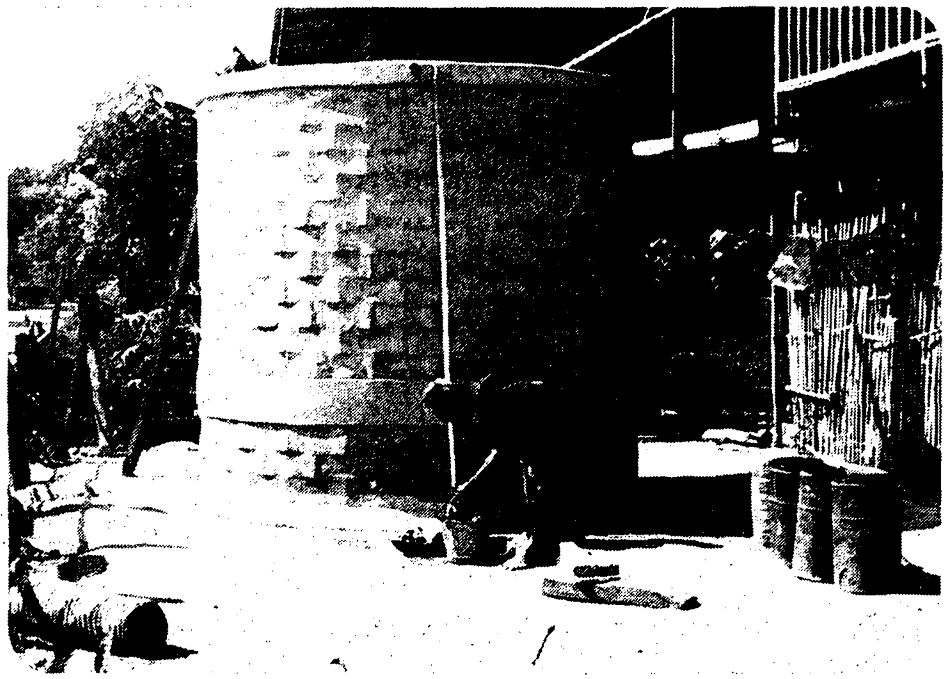


Figure 9. Completed water tanks

joints and seepage through the blocks. Seepage at the joints ceased within a few days. Most seepage through the blocks ceased within the week. One block was found seeping after two weeks. The tank was drained and cement slurry was painted on the blocks. This action was found to be effective.

After 4 months of storing water, a single vertical crack was found in the tank where the middle wire belt was omitted. The crack width was between 1 to 2 mm and ran from the top of the bottom belt to the bottom of the top belt. The crack was discovered when only half of the water remained in the tank. An investigation was undertaken and blocks left over from the construction were tested. It was found that the compressive strength of mortar cut from the blocks varied remarkably from as low as 70 kg/cm^2 up to 200 kg/cm^2 which is equivalent to the tensile strength of approximately from 7 kg/cm^2 to 20 kg/cm^2. At this strength level, the mortar will not be able to sustain the induced stresses (including thermal and shrinkage stresses).

On the cut surfaces of weak blocks there were smooth dark grey spots of cement paste scattered on the surfaces. It is then obvious that the weakness of the blocks is the result of inadequate mixing. Another factor which is believed to be a major contributor to an uneven mixed mortar is wet sand. It is very difficult to disperse cement in wet sand because cement absorbs moisture in the sand and forms small tablets. For a mix with a high water : cement ratio these tablets will be softened and broken down during further mixing. For a low water : cement ratio of 0.4 and 0.45, unless vigorous mixing methods are employed, only some of cement tablets are broken down. It is advisable that only dry sand be used. Cement and sand must be well mixed before any water is added.

An encouraging feature of failure is that the tank did not collapse or disintegrate: hence the failure is not dangerous. It is proposed to have the tank repaired and the omitted wire belt installed. The tank will be refilled and its long term behaviour will be further investigated.

CONCLUSION

The construction of interlocking mortar-blocks is simple and straightforward. The number of men involved is small and so it can be managed by members of a single family. It takes 3 men 4 days and 5 days to construct a 9 m^3 tank and a 12 m^3 tank respectively. Block making can be carried out in one's own time and pace. Wasting of materials is minimal. The strength and the thickness of the blocks can be varied to match the varying stresses in the tank (i.e. thicker or stronger blocks for the lower layers).

Blocks can be mass produced and transported to the construction sites. Hence, there is an industrial implication on both village and town levels.

Cost of materials for 9 m^3 and 12 m^3 tanks are 2646 baht (294 baht/m^3) and 3239 baht (270 baht/m^3) respectively. The cost of the roof is approximately 700 baht which is about 22% of the total cost of the tank. The hexagonal wire mesh is used for ease in roof construction. The cost reduction of approximately 200 baht will be achieved if wire mesh is omitted.

REFERENCES

1. Manning, G.P. Reservoirs and Tanks. Concrete Publication Limited, London, 1967.

2. Timoshenko, S. and Woinowsky-Krieger, S. Theory of Plate and Shell. McGraw-Hill, 1959.

3. Sae Tang, S., Klungbunkrong, P. and Wongchaipume, P. "Interlocking Mortar-Block Water Tanks". Project Report No.C 84-23, Faculty of Engineering, Khon Kaen University, 1983.

BAMBOO REINFORCED CONCRETE WATER TANKS

Nipon Thiensiripipat
Faculty of Engineering
Khon Kaen University
Khon Kaen, Thailand

SUMMARY

This paper presents the results of a project on "Bamboo Reinforced Concrete Water Tanks". The objectives of the project were to design and construct safe and economical bamboo reinforced concrete water tanks for the use of Thai villagers, who lack clean water during dry seasons. Tanks of four sizes having diameters of 1.5 m, 2.0 m, 2.5 m, and 3.0 m and a height of 3 m were designed. Three demonstration tanks of diameters 3 m and a height of 3 m approximately were constructed and functioned satisfactorily. The construction technique for these tanks has been described. It was found that bamboo reinforced concrete tanks are economical compared with other conventional tanks.

INTRODUCTION

Water shortage during dry seasons is a major problem for many villagers in the rural areas of Thailand. This problem will be alleviated if the villagers have large tanks to store rainwater for their use during the dry periods. The costs of the tanks should be low because most villagers are poor. In order to reduce the costs of concrete tanks, bamboo is used as reinforcement instead of steel.

Bamboo reinforced concrete tanks of 1.5 m and 2.0 m diameters, and 3.0 m height, with a capacity of 5 m^3 and 9 m^3, were introduced about a decade ago and have been promoted by the Public Sanitary Centre, Region 4. Most of these tanks still function satisfactorily, but some developed cracks or have broken. These tanks were designed and built on a trial and error basis, as knowledge about bamboo reinforced concrete was still limited.

A study was made in order to investigate in more detail the analysis, design, and construction of these tanks, especially those of larger diameters. It was expected that such tanks would be used increasingly and with more confidence. Furthermore, water scarcity and illness due to the use of dirty water would be reduced.

TANK SIZES

The size of a tank that is suitable for a family depends on the water requirements of the family and the amount of rainwater available.

The water requirement of a family throughout a dry period may be estimated from the product of family size, the amount of water each member requires per day, and the number of days of the dry period. According to a governmental survey, water requirements for drinking are four litres per capita per day, and a villager's total domestic water requirements for one day, which include water for drinking, cooking, bathing, and washing clothes, are approximately 55 litres.

If a dry period of six months (from November to April) or 180 days is assumed, the required capacity of the tank for drinking only is 180 x 4 = 720 litres/capita or 0.72 m^3/capita. Similarly, for full domestic use, the water requirement for the dry period is 180 x 55 = 9900 litres/capita or 9.90 m^3/capita. For a family of four, the tank size required for drinking is 0.72 x 4 = 2.88 m^3, and that for full domestic use is 9.90 x 4 = 39.60 m^3, assuming the collection area can supply the full demand.

The amount of rainwater available during a wet season is usually enough for the requirement of a family. For example, the average annual rainfall of Khon Kaen province located at the centre of the northeastern region, is 120 cm. This amount of rainfall on one square metre of roof area is enough for the drinking requirement of a villager for 300 days.

With a significantly large roof area, he can have enough rainwater for drinking and other purposes for the whole family and store enough for a dry period of six months.

TANK DESIGN

Structurally, there are two important considerations in the design of bamboo reinforced concrete water tanks. First, the thickness of the concrete wall must be large enough to prevent cracking. Second, in case of cracking, the bamboo hoops must be able to carry all tensile hoop stresses safely.

Different forces in the wall approximately relate to various parameters as follows. Hoop tension varies with the product of height and radius, shear varies with height squared, and moment varies with height cubed. Thus, the height of the tank should not be too large.

For a given height, large diameter tanks are more economical than small diameter tanks because the amount of construction material approximately varies with diameter but the capacity varies with diameter squared.

In order to facilitate the design and reduce the amount of formwork for the tanks, four tank sizes were considered. They have a diameter of 1.5 m, 2.0 m, 2.5 m, and 3.0 m, each having a height of 3.0 m. Their capacity is 5 m^3, 9 m^3, 15 m^3, and 21 m^3, respectively. Fig. 1 shows a design drawing of these tanks.

The tanks were designed using results of tests on bamboo reinforced concrete conducted at Khon Kaen University (3).

For practical purposes, the thickness of the tank wall is kept at 10 cm and a height of 3.0 m is used. For ease of construction, the bamboo used has a cross-sectional area of 2 cm^2 (e.g. 2-cm wide and 1-cm thick) and a spacing of 20 cm on centres.

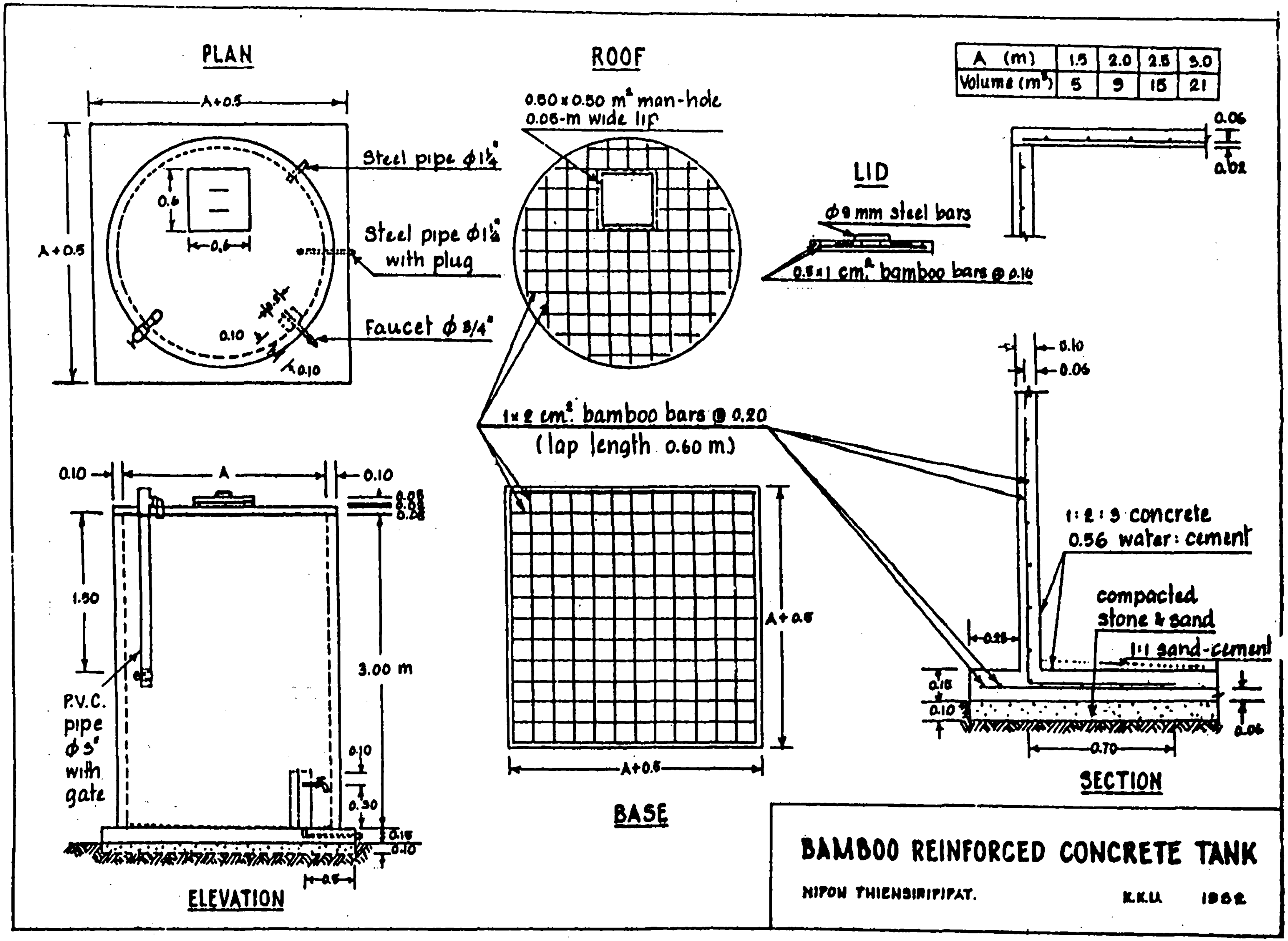

PLAN
A+0.5
A+0.5
0.6
0.6
Steel pipe ϕ1¼"
Steel pipe ϕ1½" with plug
Faucet ϕ 3/4"
0.10
0.10
ROOF
0.50 x 0.50 m² man-hole
0.05-m wide lip
LID
ϕ 9 mm steel bars
0.5x1 cm² bamboo bars @ 0.10
A (m) | 1.5 | 2.0 | 2.5 | 3.0
Volume (m³) | 5 | 9 | 15 | 21
0.06
0.02
1x2 cm². bamboo bars @ 0.20
(lap length 0.60 m)
0.10
0.06
1:2:3 concrete
0.56 water : cement
compacted stone & sand
1:1 sand-cement
0.15
0.10
0.06
0.70
SECTION
0.10
A
0.10
1.50
3.00 m
P.V.C. pipe ϕ3" with gate
0.10
0.30
0.15
0.10
0.5
ELEVATION
A+0.5
A+0.5
BASE
BAMBOO REINFORCED CONCRETE TANK
NIPON THIENSIRIPIPAT.
K.K.U 1982

Figure 1

If bamboo is replaced by steel reinforcement, 9-mm diameter bars may be spaced as follows:

- 17 cm both ways, for base slab;
- 25 cm, for vertical wall bars;
- 15 cm, for horizontal wall bars;
- 25 cm, for roof slab bars

CONSTRUCTION MATERIALS

Table 1 gives a list of materials required for the construction of bamboo reinforced concrete tanks of an inside diameter of 1.5 m, 2.0 m, 2.5 m, or 3.0 m, with a height of 3.0 m and a wall thickness of 10 cm.

TABLE 1. LIST OF CONSTRUCTION MATERIALS.

No.	Materials*	Tank Diameter (m)			
		1.5	2.0	2.5	3.0
1	Crushed stone or broken brick for foundation	1 m^3	1 m^3	1 m^3	1 m^3
2	Crushed stone or gravel, size no.1(3/4"max. size)	2 m^3	3 m^3	4 m^3	5 m^3
3	Coarse sand	2 m^3	3 m^3	4 m^3	5 m^3
4	Portland cement (50 kg/bag)	15 bags	22 bags	28 bags	35 bags
5	Bong or Ban or See Suk Bamboo (over 2-year old and 6-m long with diameter over 5 cm)	7 units	11 units	13 units	15 units
6	1¼" steel pipe with both ends threaded, for drainage	50 cm	50 cm	50 cm	50 cm
7	1¼" steel pipe, for overflow	20 cm	20 cm	20 cm	20 cm
8	3/4" steel pipe with one end threaded	30 cm	30 cm	30 cm	30 cm

* 1" = 2.54 cm

TABLE 1. LIST OF CONSTRUCTION MATERIALS. (con't)

No.	Materials*	Tank diameter (m)			
		1.5	2.0	2.5	3.0
9	3/4" steel pipe elbow for drainage pipe	1 unit	1 unit	1 unit	1 unit
10	1¼" steel plug, for drainage pipe	1 unit	1 unit	1 unit	1unit
11	1¼" steel connector	1 unit	1 unit	1 unit	1 unit
12	3/4" steel pipe connector, for outlet faucet				
13	3/4" faucet	1 unit	1 unit	1 unit	1 unit
14	Tie wire	1 kg	1 kg	2 kg	2 kg
15	Used motor oil	5 litres	5 litres	5 litres	5 litres
16	2" nails	1 kg	1 kg	1 kg	1 kg
17	3" PVC pipe	1.5 m	1.5 m	1.5 m	1.5 m
18	3" PVC elbow	1 unit	1 unit	1 unit	1 unit
19	3" PVC tee	1 unit	1 unit	1 unit	1 unit
20	3" PVC pipe	15 cm	15 cm	15 cm	15 cm
21	3" PVC outside connector	1 unit	1 unit	1 unit	1 unit
22	3" gate	1 unit	1 unit	1 unit	1 unit
23	PVC glue	1 tin	1 tin	1 tin	1 tin

Note: Item nos. 17 to 23, for a sediment trap, are optional.

* 1" = 2.54 cm

In addition to the materials listed in Table 1, other materials and tools which are required and may be reused are as follows:

1. Tank forms. These are made of steel. Each set of forms consists of eight pieces of circular arch with a height of 60 cm. For readers in Thailand, tank forms of 1.5 m and 2.0 m diameters may be borrowed by contacting the author.

2. Used lumber for formwork. Some used lumber is needed for the formwork of the base slab and roof slab. Some timber or bamboo are also needed for scaffolding.

3. Concrete construction tools. These include:

   - buckets for carrying and measuring materials,
   - shovels,
   - a saw,
   - a hammer,
   - pliers,
   - etc.

CONSTRUCTION TECHNIQUE

The following technique is recommended for the construction of bamboo reinforced concrete tanks of diameter 3 m and height 3 m. This technique may also be used for other tank sizes but certain dimensions should be adjusted accordingly.

Preparation of Bamboo

The bamboo used should be straight and at least 2 to 3 years old. Cut the bamboo longitudinally so that each piece has a cross sectional area of approximately 2 cm^2 - for example, 2 cm wide and 1 cm thick. Where sharp bending of bamboo is required, low heat may be applied at the end. When the bamboo is too short an overlap of at least 60 cm should be provided. If possible, the bamboo should be coated with dammar or other suitable sealing material so that the bond strength between bamboo and concrete may be increased.

Base Slab Construction (Fig. 2)

At the selected construction site, usually near a corner of the building, excavate a hole 10 cm deep and 3.55 m wide and 3.55 m long.

Compact the excavated area thoroughly by pounding it with a heavy piece of wood. Lay a 10 cm bed of crushed stones or broken bricks in this area. Add a layer of sand to fill in the voids and even off the top surface. Compact to get a level surface and firm base. Place four pieces of used lumber (1" x 7") along the four edges. Secure them properly.

On the excavated area, weave a mat of bamboo (3.40 m long, 3.40 m wide and bamboo at 20 cm spacings). Place the inner form centrally on the bamboo mat. Tie a ring of bamboo to the bamboo mat and around the form so that the ring lies in the centre of the tank wall. Remove the form.

Tie vertical bamboo bars so that their horizontal toes of 70 cm are on the bamboo mats and their bends are just outside the bamboo ring and their short ends point toward the centre. Their spacings are 20 cm on centres. Tie the top ends together.

Use stones to support the bottom of the bamboo mat 6 cm above the ground.

Attach the 1¼" steel elbow to one end of the drainage pipe and attach the steel plug to the other end. Place the drainage pipe on the bamboo mat, with the elbow toward the centre and the plug just outside a cut in the wooden form of the base slab. Tie the pipe to the bamboo mat with steel wires. Plug the elbow end temporarily with a piece of paper.

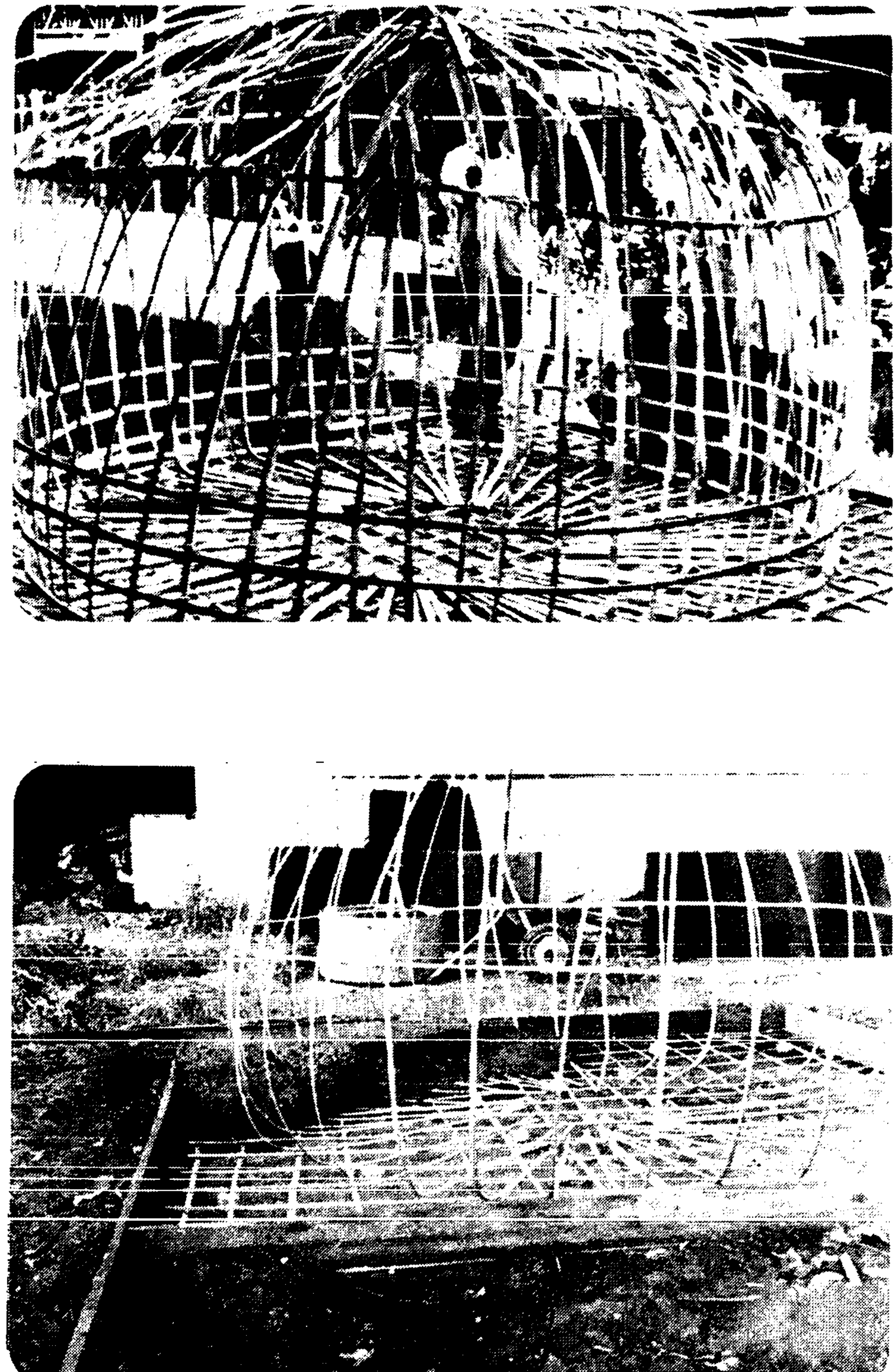


Figure 2. Base slab construction

Wet the excavated area thoroughly.

Pour a 15 cm thick concrete base slab using a mixture of 1 : 2 : 3 (cement : sand : stone) with a water : cement ratio of about 0.56 (e.g. cement 1 can, water 0.56 can). Leave the concrete to set for 24 hours.

Wall Construction (Fig. 3)

Tie three rings of horizontal bamboo reinforcements at 20 cm spacings to the inner faces of the vertical bars, starting at a level of 10 cm above the base slab. The horizontal bamboo bars should be placed at the centre line of the tank wall. A lap of 60 cm between bamboo ends should be provided and tied together.

Oil the steel forms and install them on the concrete floor, leaving some space around the bamboo bars. Check the level of the top of the form.

Moisten the floor thoroughly. Spread two buckets of water-cement mortar between the two forms. Pour the first ring of concrete using a 1 : 2 : 3 mix. Use rods to tamp the concrete thoroughly while it is poured.

Let the concrete set for 24 hours. Then strip the forms - be sure to strip the inner form first to prevent cracking.

Make a hole at a distance 30 cm above the base slab and install the 3/4" diameter outlet pipe with a faucet connected and protruding 10 cm outside the tank. Pour a block of concrete of size 40 cm x 20 cm x 10 cm on the inside face of the tank to enclose the pipe.

The next four rings of concrete walls may be constructed in a similar manner as for the first ring. To prevent leakage of fresh concrete, the steel forms may have to overlap a previously poured concrete ring by about 2 cm. To facilitate the roof construction, the concrete for the fifth ring may be poured to a level 8 cm below the top

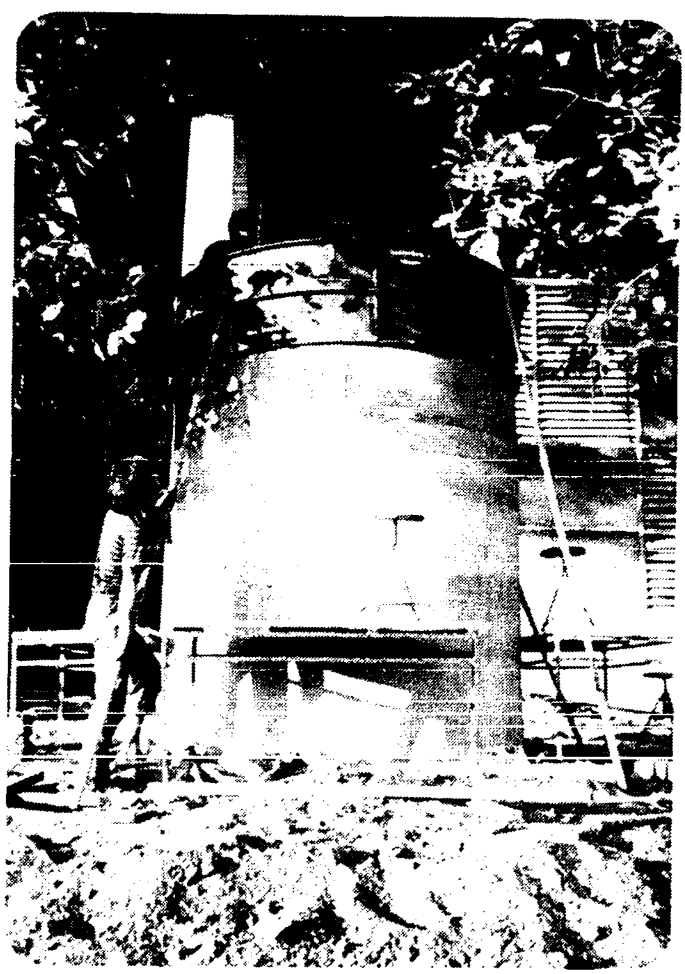


Figure 3. Wall construction

of the forms, so that the roof top may be poured without adjusting the outer forms.

To prevent cracking and to obtain high strength, it is very important to cure concrete after it has set for 24 hours. This is done by keeping the concrete moist for at least seven days by spraying or wrapping with moist burlap.

Roof Construction (Fig. 4)

Strip the inner form 24 hours after the fifth ring has been poured. The outer form is left and used as formwork for the roof. Construct a platform for pouring the roof by placing used lumber which fits snugly against the top of the inside wall of the tank. The lumber is supported by bamboo or wooden columns placed within the tank. The platform has an opening of 50 cm x 50 cm in the middle for a manhole. Cover the platform with tin roofing material or cement paper bags.

Weave a mat of bamboo (2.0 cm wide and 1.0 cm thick) having 20 cm spacings both ways. Each bar should have a 5 cm support on the wall and have a 5 cm side cover. Place the mat 2 cm above the platform. Pour the roof 8 cm thick using a 1 : 2 : 3 mix. Let it harden for at least three days before removing the columns, platform and tin roofing material.

Twenty-four hours after pouring the roof concrete, pour a 2 cm high and 5 cm wide lip of 1 : 2 (cement : sand) mortar around the edge of the manhole.

To make a cover for the manhole, prepare a bamboo mat of 0.5 x 1 cm cross sectional area with 10 cm spacings, in a form of size 60 cm x 60 cm x 5 cm, and pour a 1 : 2 : 3 concrete into the form.

If a PVC sediment trap is to be used, it may be attached to the outside of the tank by using a 1 : 1 (cement : sand) mortar for its entire length.

Figure 4. Roof construction

Finishing

Wet the concrete and use a 1 : 1 (cement : sand) mortar to patch any holes in the concrete and level the joints between successive rings and first ring and the floor. Use this mix to form a sloping surface on the base slab to the drainage pipe.

Use a cement-water paste to cover the inside of the tank three times and the outside two times.

After the concrete surface is dry, apply two coats of plastic paint to the outside of the tank, if desired.

DEMONSTRATION TANKS (Fig. 5)

In order to prove the validity of the design, appreciate the construction problems and demonstrate construction techniques, three bamboo reinforced concrete tanks with an outside diameter of 3.0 m and

Figure 5. A demonstration tank

a height of about 3 m were constructed. The first one was located at Wat Pah Samukkee Thamma, a temple at Jorakae district, Khon Kaen. The second tank was constructed at Ban Pone Sawang school, Jorakae district, Khon Kaen. The third one was built at Surin Teachers' College, Surin.

Tanks of diameter 3 m were chosen for the demonstration because they were more severely stressed than smaller ones, which had previously been built and functioned satisfactorily.

The construction of a typical tank takes about eight days: one day for the base, five days for five rings, one day for the roof, and one day for finishing. A crew of five workers is required. If enough forms are available, three tanks may be built simultaneously, using the same crew and finishing within the same period of time.

The tanks have functioned satisfactorily. At first there may be a small quantity of seepage at the joints between rings, but this soon disappears.

The construction of these tanks presented no problems, even for village artisans under little supervision. They learned how to build the tanks quickly and could do the job by themselves. Some of them were employed to construct many more tanks for other villages. This provides them with a source of extra income.

Tanks of large diameters are very suitable for public buildings. The 3-m diameter tank built at Ban Pone Sawang school, for instance, has provided clean water for a few hundred students to drink. Formerly, the school spent over 100 baht each day to buy dug-well water for the students to drink. The amount of money spent for buying water for about five months may enable the school to pay for a bamboo reinforced concrete tank of 3 m diameter and 3 m height. Having such a tank, the school will not have to buy drinking water for a hundred students anymore.

TANK COSTS

Table 2 shows approximate material costs of tanks of different size estimated using 1983 prices. It can be seen that large bamboo reinforced concrete tanks have lower unit material costs than smaller ones. Also, bamboo reinforced concrete tanks are relatively cheap.

TABLE 2. APPROXIMATE MATERIAL COSTS OF TANKS (1983)

No.	Tank	Volumes, m^3	Material costs, baht	Material cost/unit vol. baht/m^3
1	BRC 1.5 m x 3 m	5	2454	491
2	BRC 2.0 m x 3 m	9	3418	380
3	BRC 2.5 m x 3 m	15	4287	286
4	BRC 3.0 m x 3 m	21	5211	248
5	Plastic	1	2700	2700
6	Steel	1.5	2100	1400
7	Sand - cement	1.2	700	580

Note : 1. BRC = bamboo reinforced concrete,

2. BRC tank costs do not include painting cost, the cost of a PVC sediment trap (about 300 to 600 baht each), labour cost of five workers for eight days (about 8 x 250 = 2000 baht)

3. 1 US$ = 23 baht (approximately)

Using bamboo as reinforcement (instead of steel) for concrete tanks may result in a saving of approximately 2000 to 4000 baht for each tank.

CONCLUSIONS

The following conclusions may be made:

1) A shortage of clean water in rural areas of Thailand may be decreased by providing large water tanks to store rainwater.

2) Large water tanks made of bamboo reinforced concrete are suitable because they are economical.

3) A large diameter tank (3 m), is more economical than a small diameter tank. Thus the former should be promoted.

RECOMMENDATION

It is recommended that a long term study of the behaviour of bamboo reinforced concrete water tanks should be made.

ACKNOWLEDGEMENT

This project on Bamboo Reinforced Concrete Water Tanks was sponsored by the International Development Research Centre (IDRC), the United Nations Educational, Scientific and Cultural Organization (UNESCO), and Khon Kaen University.

REFERENCES

1. Vazirani, V.N. and Ratwani, M.M., Concrete Structures, Khanna Publishers, 9th Ed., 1980.

2. Portland Cement Association, Circular Concrete Tanks without Prestressing, Concrete Information, 1969.

3. Chaisuwanarak, S., Tangjitdamrongrat, C., Thamrongteerakul, T., Intarakamhaeng, N., and Thiensiripipat, N., "Bamboo Reinforced Concrete Slabs", Proceedings of a conference on Technology for Rural Development, held at the Faculty of Engineering, Khon Kaen University, 18-19 February, 1983.

4. Manning, G.P., Reservoirs and Tanks. Concrete Publication Ltd., 1967.

5. Winter, G. and Nilson, A.H., Design of Concrete Structures, McGraw-Hill Kogakusha, Ltd., 9th Ed., 1979.

6. Civil Engineering Committee 1970-71, "Standards for Reinforced Concrete Buildings", Standards of the Engineering Institute of Thailand 1001-16, 1979.

7. Grover P., "Ban Lan Rain Water Storage Tank Construction Project", Progress Report, Community-Based Appropriate Technology and Development Services, June 1980.

8. Division of Sanitation, "Concrete Water Tank Construction", Public Health Department, 1977.

9. Sanitary Section 1, Sanitary Centre, Region 4, "Rain Water Storage Tanks", Additional Handbook for a Small Water Resource Development, Faculty of Engineering, Khon Kaen University, 1981.

10. Sae Koew P., Sanukool S., and Chaimontree S., "Bamboo Reinforced Concrete Water Tanks", Project Report No 81-5, Faculty of Engineering, Khon Kaen University, 1981.

11. Thiensiripipat, N. "Bamboo Reinforced Concrete Water Tanks". Final Report, Faculty of Engineering, Khon Kaen University, May 1983.

POPULATION AND COMMUNITY DEVELOPMENT ASSOCIATION RAINWATER COLLECTION AND STORAGE PROJECT (TUNGNAM III)

Jonathan Hayssen
Water Resources Development Unit
Community-Based Appropriate Technology Services
and Development Bureau
Population & Community Development Association

INTRODUCTION

The Population & Community Development Association, a non-profit development organization, was founded in 1974 with the initial goal of establishing a network of family planning service providers in rural and selected urban areas of Thailand, to complement the existing services of the Royal Thai Government. A community-based implementation strategy was adopted, whereby respected members of local villages were recruited and trained to give counselling and distribute contraceptives at the village level. By 1978 PDA established its network in 16,118 villages of 158 districts in 48 provinces.

The success in family planning activities encouraged PDA to expand into other areas of development, aiming at improving the standard of living and upgrading the quality of life of the rural people.

Sensing the critical need to develop alternative drinking water resources for villagers in Northeastern Thailand, the poorest and driest region of the country, PDA undertook a pilot project in rainwater collection and storage tank construction in 1980. The pilot project was successful - successful because villagers showed their willingness to participate in the development project for their own betterment.

To expand the scope of the rainwater collection and storage tank construction programme, PDA entered into an agreement of co-operation with German Agro-Action of West Germany to assist villagers in the construction of additional tanks. PDA also received financial support from the German Relief Association and the New Zealand Embassy for tank construction. With the financial support from these sources and through PDA's revolving fund, PDA was able to construct a cumulative total of 2,772 water catchment tanks by April 1983.

RATIONALE

PDA's activities relating to the Rainwater Collection and Storage Project are centered in Northeastern Thailand, which is the driest, poorest, most populous and largest region in Thailand. This project is to supplement the government's water resources development programme. PDA staff and technicians work in cooperation with local government officials.

OBJECTIVES

PDA's long and short term objectives in implementing this project are as follows:

1. To find suitable sources of water supply.
2. To provide adequate water for rural people.
3. To develop and to improve drinking water resources with the co-operation of the rural people.
4. To promote clean water storage facilities.
5. To promote small-scale water resource development activities.
6. To assist villagers in establishing revolving funds for development activities.
7. To disseminate educational materials relating to water usage and health.

TANK CONSTRUCTION TARGET

During this implementing year (May 1983-April 1984) PDA will construct 2,700 rainwater catchment tanks in 11 districts and 2 sub-districts in Mahasarakham, Khon Kaen and Buriram provinces. Below are the project locations:

District	Province
1. Muang	Mahasarakham
2. Borabu	Mahasarakham
3. Phayakkhaphum Phisai	Mahasarakham
4. Na Doon	Mahasarakham
5. Na Chuak	Mahasarakham
6. Ban Pai	Khon Kaen
7. Chonabot	Khon Kaen
8. Nam Phong	Khon Kaen
9. Putthaisong	Buriram
10. Ku Muang	Buriram
11. Satuk	Buriram

Sub-district	Province
12. Kae Dam	Mahasarakham
13. Na Poh	Buriram

APPROACH ADOPTED

Before entering the villages, the Water Resources Development Unit (WRU) staff will consult government officials at provincial, district and local levels. WRU staff will also co-operate with government officials in the selection of target villages and of villagers who will be taking part in this project. With the revolving fund allocated by PDA Headquarters, WRU staff will purchase equipment, materials and tools. The staff will also train voluntary village technicians to assist in tank construction. The staff explains loan repayment to the villagers.

IMPLEMENTATION OF PROJECT

Preparation

PDA Headquarters staff will contact relevant government departments to notify them of the existence of this project, and will make necessary arrangements in matters regarding the selection of target villages. PDA Headquarters staff will also prepare all the operation plans and budget.

After consulting PDA Headquarters staff, WRU staff at project sites will make the necessary contact with local level government officials and village headmen. A survey is then made in order to determine the target villages. The WRU staff will prepare all the operation plans.

Operation

Activities to be carried out are as follows:

- Selection of target villages
- Selection of participants
- Selecting and training of village volunteer technicians to assist in construction
- Informing the villagers of the tank construction technique.
- Purchase of construction materials, usually in bulk.
- Informing the villagers of the loan repayment procedures.
- Establishing a Village Development Committee.

Follow-up

After tanks have been constructed, WRU staff will visit the participants of this project regularly in order to:

- inspect the conditions of the tanks
- make repairs as necessary at no charge
- see how participants maintain the tanks
- check the repayments of loans

- see the operation of the Village Development Committee
- follow up the relevant activities of the participants and other villagers

Evaluation

The WRU staff and PDA headquarters staff will evaluate the impact of this project on the participants and on the target villages. At the same time the staff will try to trace any discrepancy with the intention of putting it right.

SOCIAL PREPARATION

Selection of Target Villages

The selection of a target village is based on the following factors:

a. There is a real shortage of drinking water.
b. The village comes under the government development programme.
c. The residents of the village have given co-operation in village development.
d. There are family planning service acceptors in the village.

Selection of Participants

The selection of appropriate and qualified villagers to benefit from this project is based on the following factors:

a. The villager is willing to have his/her own water catchment tank.
b. The villager used to take part in development programmes.
c. The villager has the intention of developing his/her village.
d. The villager has the capability to repay the cost of construction materials in instalments.
e. The villager should be a family planning acceptor.

Repayment of Loans

As for repayment terms, PDA has introduced special concessions as follows:

a. Those who make payment in full upon completion of tank construction will be granted a 5% reduction.

b. Those who are able to introduce 6 persons to participate in family planning programme for 6 consecutive months will be allowed 25 Baht reduction.

c. Those who are able to introduce women to a sterilization programme will be allowed 25 Baht reduction per woman sterilized.

d. Those who are able to introduce men to a vasectomy programme will be granted 50 Baht reduction per man vasectomized.

CONCLUSION

As water supply is a complex social amenity which may potentially confer many kinds of benefits on its users, PDA hopes to be able to play its role to meet this basic human need - WATER.

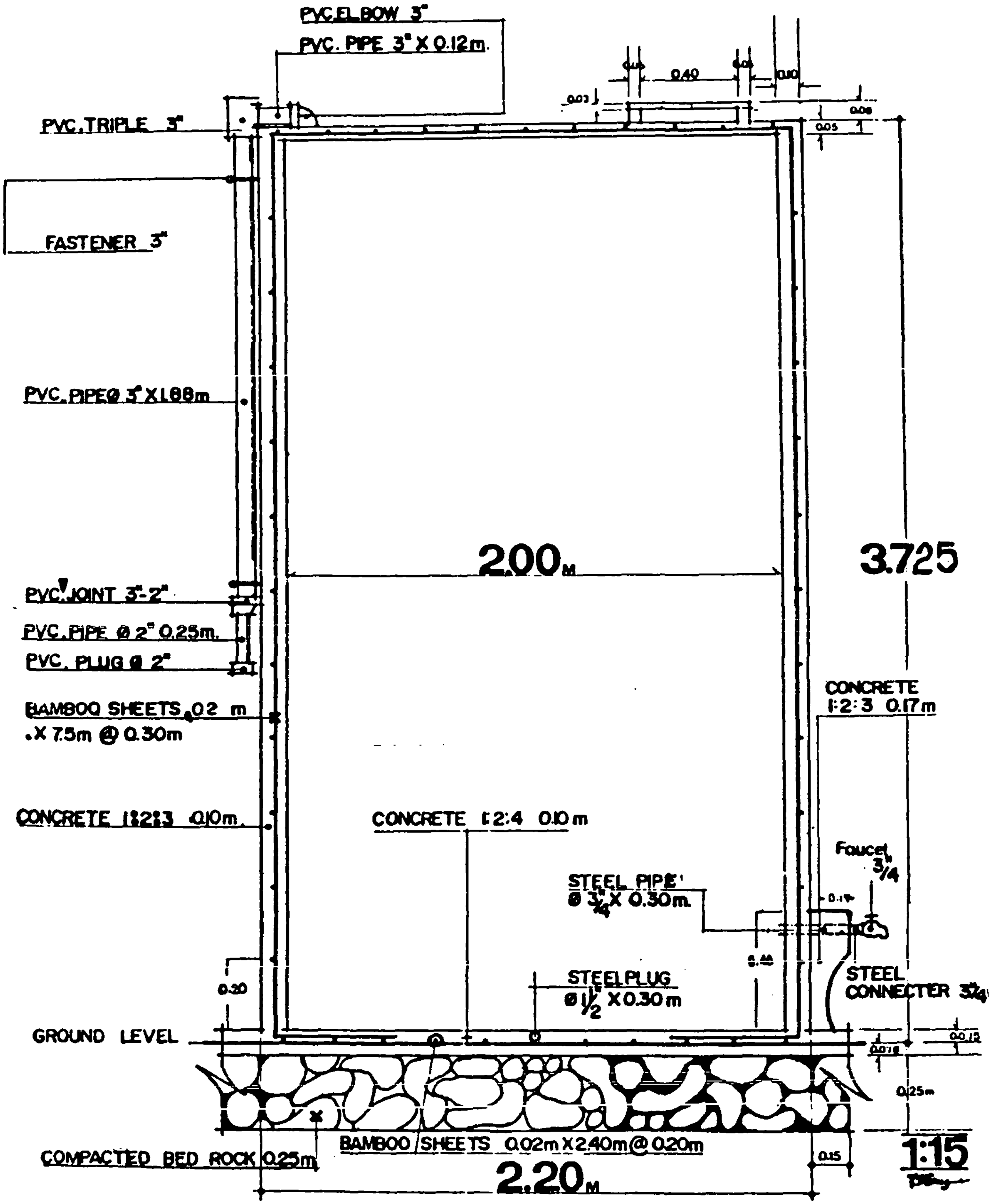


Figure 1. PDA Rainwater Catchment Tank

RAINWATER CATCHMENT TANK - BAMBOO REINFORCED CONCRETE

Pakorn Sriruenthong
Population and Community
Development Association

INTRODUCTION

One of our important necessities of life is water. Although it is very useful, it can also be harmful as drinking water can be a carrier of disease if it is not clean enough. Rainwater, the natural drinking water for which a purifying process is unnecessary, is widely used in the rural areas. Cumulative rainfall in most areas of Thailand is more than 1,000 millimetres per year.

Rainwater is usually kept in jars, a metal tank or a reinforced concrete tank. Many groups, such as Mr. Boonma Piradej from Ban Nong Wang, Borabu District, Mahasarakham Province, have developed bamboo-reinforced concrete tanks which have been durable for 10 years. The Sanitation Center Region 4 in Khon Kaen Province has promoted the bamboo-reinforced concrete tank for a long time. Research conducted by many engineering institutes indicates that bamboo reinforced concrete tanks have the necessary capacity to support the weight of water. Thus, bamboo reinforced concrete tanks have been widely used.

CONCRETE MIX

Concrete is the mix of cement, sand, rock and water. Each element will help reinforce the concrete tank. Thus quality of these ingredients should be well-considered.

- Cement. It should be in a good condition and should not have been kept for a long time. (As there are many brands of cement, choose the most economical having good quality control).

- Sand. Do not use seasand. It should be rough sand, clean and without any organic material mixed with it.

- Rock. Either mountain rock or river rock can be used in sizes of 3/4 to 1 inch. Clean rock will be preferred. If the rock is very dirty, it should be rinsed before mixing.

- Water. It should not be muddy or be too acidic or alkaline.

To construct the tank, there are two separate mixes to be prepared:

1. For the base of the tank, the mixing ratio of 1 : 2 : 4 (cement, sand, rock).

2. For the other parts use a mix ratio of 1 : 2 : 3.

Do not use too much water, because the tank will be less durable.

CONSTRUCTION EQUIPMENT

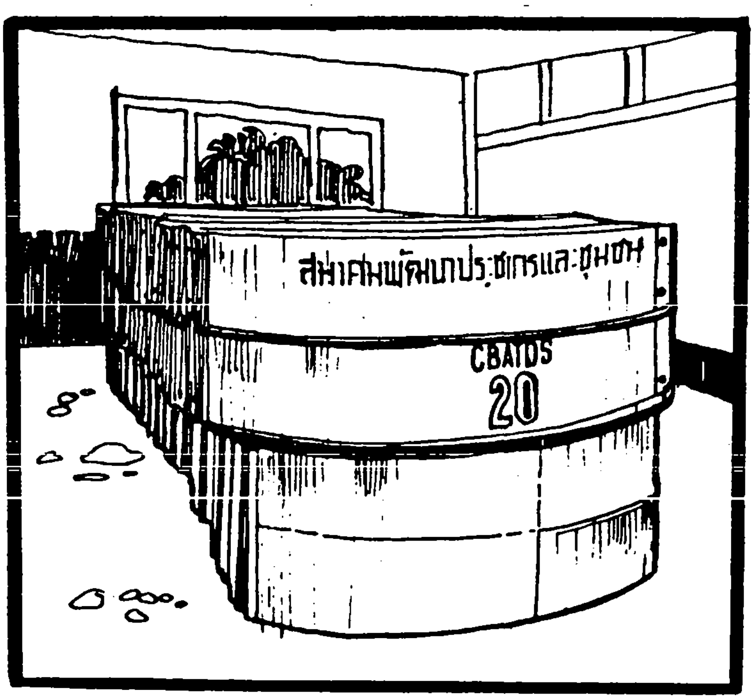


Figure 1

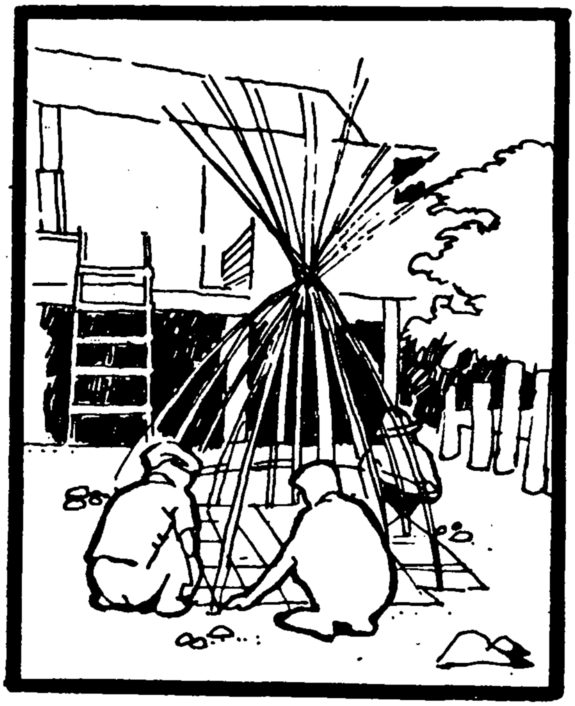
1. The steel forms for the diameter 1.5 m or 2 m tank.
2. Buckets for containing the mixed concrete.
3. Water hose for leveling.
4. Hammer.
5. Shovel and pick axe.
6. Container for concrete mixing.

CONSTRUCTION MATERIAL

1. Crushed rock, crushed brick or crushed and powdered laterite
2. 3/4" - 1" selected rock
3. Rough sand
4. Cement
5. Dry bamboo (at least 3 years old)
6. Tie wire
7. Used motor oil
8. Faucet
9. Drainage pipe
10. A bypass filter (PVC drainage pipe)

PREPARATION OF BAMBOO

Select dry bamboo at least 3 years old, since green bamboo will shrink with time and will cause the cracking of concrete. Cut bamboo bars 2 cm wide and smooth the bamboo.



Bamboo Base Weave a mat of bamboo allowing 15 cm-20 cm spacing between bars in both directions. Use tie wire to fasten the bars.

Figure 2

Vertical Reinforcement

Bend the bars into an L shape with the joint occurring 40 cm from the end of the bar. Space the 20 vertical bars evenly around a circle of diameter 2.12 cm for the tank of diameter 2 m and 1.58 cm for the tank of diameter 1.5 m.

Horizontal Reinforcement

The first ring should be 25 cm from the floor mat. Allow 30 cm spacing between bars.

CONSTRUCTION

Site

Choose a suitable site to build the tank based on the following criteria:

- It should not obstruct the expansion of the house in the future.
- The house should have a corrugated iron or brick roof.
- The site should not be far from the eaves, so that a short pipe can be used.
- It should not be on low-lying land and should be on soil that is firm enough.

In case the soil condition is not firm and the site cannot be changed, obtain details of concrete reinforcement for the base from the District Sanitation Center or Official Engineering Division in that region. Normally, in the North and Northeast of Thailand, the tank can be constructed without any foundation reinforcement of the base.

Compact the Base

Excavate an area of 2-2.5 meters square and 25 cm deep. Compact the excavated area thoroughly by pounding it with a heavy piece of wood. Lay

5 cm of crushed rock or crushed brick in the excavated area. Sprinkle some water to make each layer more compacted. Fill the excavated area up to 20 cm, then add a layer of sand or powdered laterite to the top surface. Compact and smooth the surface. Make a square wood form by using 4 pieces of lumber. Place the form at the excavated area, then place the floor mat. Pour a 15 cm thick concrete floor using a mix ratio of 1:2:4. Try to adjust the floor mat into the middle of the concrete. To make sure that the floor mat will be placed between the concrete, first, pour a 5 cm thick concrete using a mix ratio of 1:2:4, place the floor mat, then pour 15 cm of concrete using a mix ratio of 1:2:3. Place a drainage pipe on the top concrete layer on a slope. Grade the concrete base with an inclination to the drainage pipe so that the water can flow easily. Let the floor set for 24 hours.

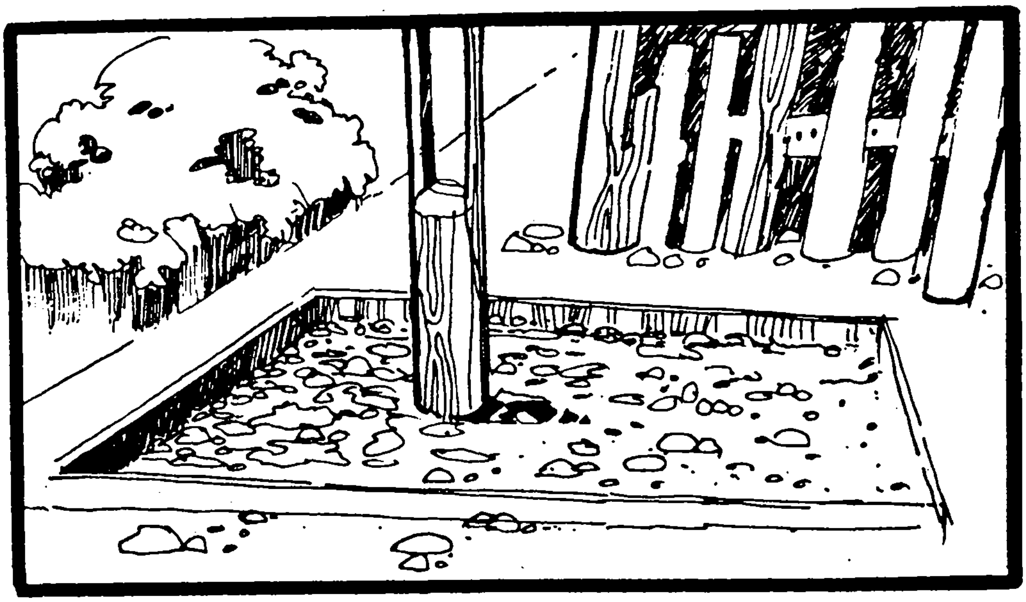


Figure 3

Figure 4

Sidewalls and Roof

Oil the steel forms and place them on the top of the concrete floor. There is an inner and outer form: the spacing between both forms must be 10 cm. The forms must be located in the middle of the floor with the 20 vertical bars rising between the 2 forms. Allow a 20 cm spacing between the first horizontal bamboo ring and the floor mat, and 25 cm between the first, second and third rings. The spacing between the remaining rings should be 30 cm.

Use the water hose to check the elevations of the top of the forms and ensure they are placed level. If there is any space between the forms and the floor, use sand to close the space.

Pour cement slurry for joining the floor and the tank. Afterwards, pour the first ring of concrete using a 1:2:3 mix ratio (use 4 buckets of water : 1 bag of cement). Be sure to tamp the concrete thoroughly as it is being poured. The bamboo reinforcement should be in the middle between the inner and outer form. Leave an opening 40 cm. from the floor to attach the faucet.

Removal of the Forms

After each ring has been poured, allow 24 hours for the concrete to harden and then strip the forms. It will be easier to remove the inner

Figure 5

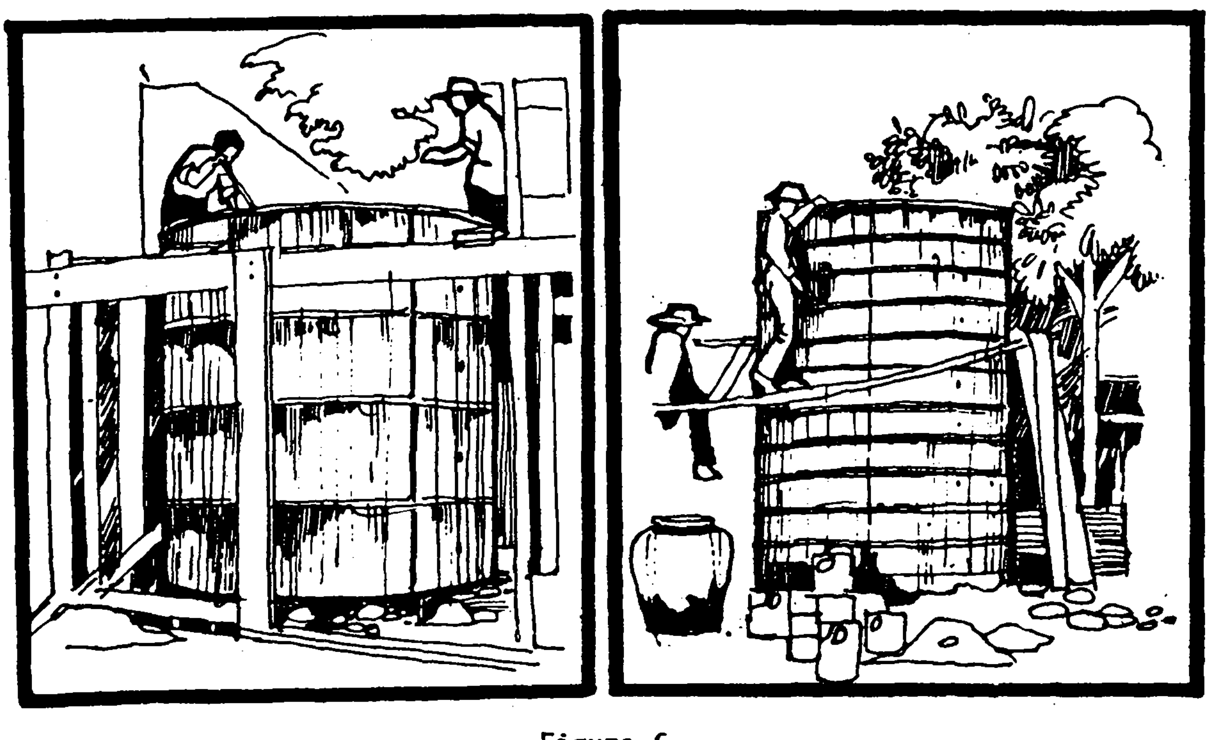


Figure 6

form first. If it is difficult to remove the outer form pound it carefully with a hammer but be sure not to crack the tank.

If pouring the concrete ring by ring, wedge spaces should be made between the rings and each ring will be jointed to the other by pouring cement slurry in these spaces.

If there are many forms and the concrete will be poured at one time, the leveling should be done accurately before placing each ring. Clean the forms every time they are removed.

For the tank of diameter 2 metres, the height should not be more than 3.6 metres (or 6 rings) and for the tank of diameter 1.5 metres, the height should not be more than 3 metres (or 5 rings).

Surface Finishing

Use 1:2 cement mortar to patch any holes in the concrete on the inside or outside of the tank. Use one layer of a cement/water paste 3:1 (with no sand) to reduce seepage through the wall and improve the tank's general appearance.

Tank's Roof

To construct a roof for the tank, remove the inner form 24 hours after the sixth ring has been poured. Raise the outer form as if a seventh ring is to be poured. Construct a platform for pouring the roof by placing scraps of used lumber across the top of the tank. The lumber must be supported by 4 beams with 40 cm spacing between them. The pieces of used lumber must fit snugly against the inside wall of the tanks and the top of the lumber must rest flush with the top of the sixth ring. Cut a hole of 45 cm x 50 cm and position it with its center 20 cm from the edge of the roof. The wood platform must be soaked with water. Place the bamboo mat of 2.10 cm diameter so that it is supported 4 cm above the platform and then place the special narrow outer form. Pour the concrete of 1:2:3 mix ratio 7 to 10 cm thick. Adjust the floor mat

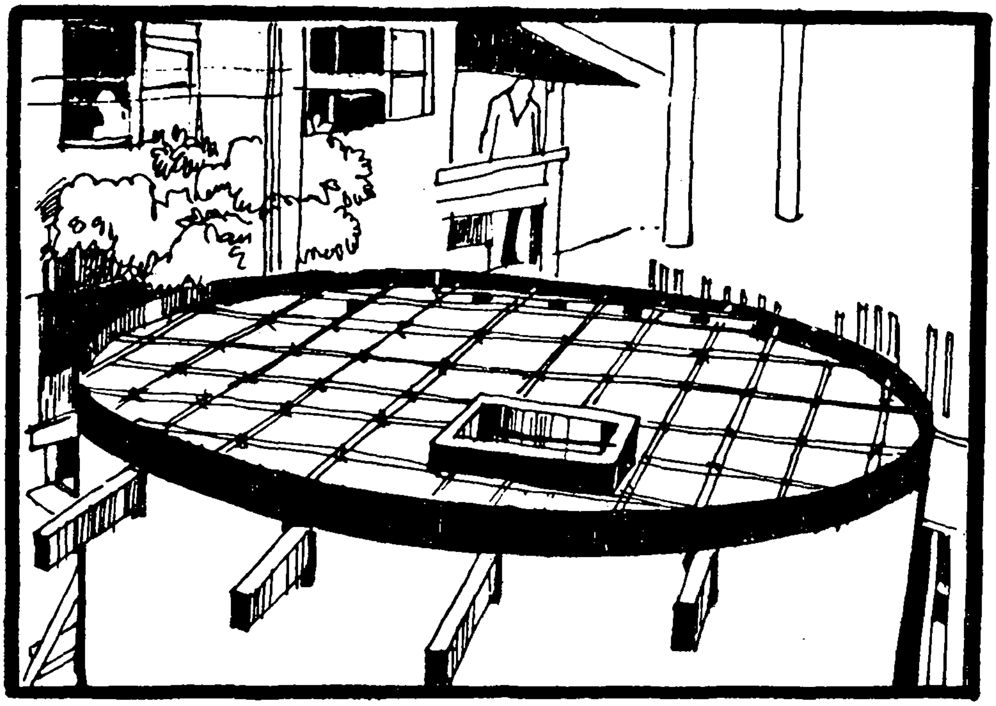


Figure 7

to be inside the concrete. Pour a cement sand mortar to make a lid to cover the hole in the roof.

Removal of the Form

Let the roof harden for at least 3 days before removing the 4 beams and scraps of used lumber, and then strip the outer form. When removing the beams, scraps of used lumber will generally fall inside the tank. They should be carefully taken out through the hole in the roof. Attach the pipe for overflowing water on the side and use brick and cement/water paste to fill the holes where the columns were placed. Finally install and assemble the inlet bypass.

After the construction, all equipment should be cleaned and checked to ensure that it is still in good condition.

To cure the concrete, put water into the tank up to the top of the first ring (60 cm), pour water all over the outside of tank or wrap the whole tank in a wet cloth. If this process is carried out for 7 days, the strength of the tank to support the water weight will be up to 70%,

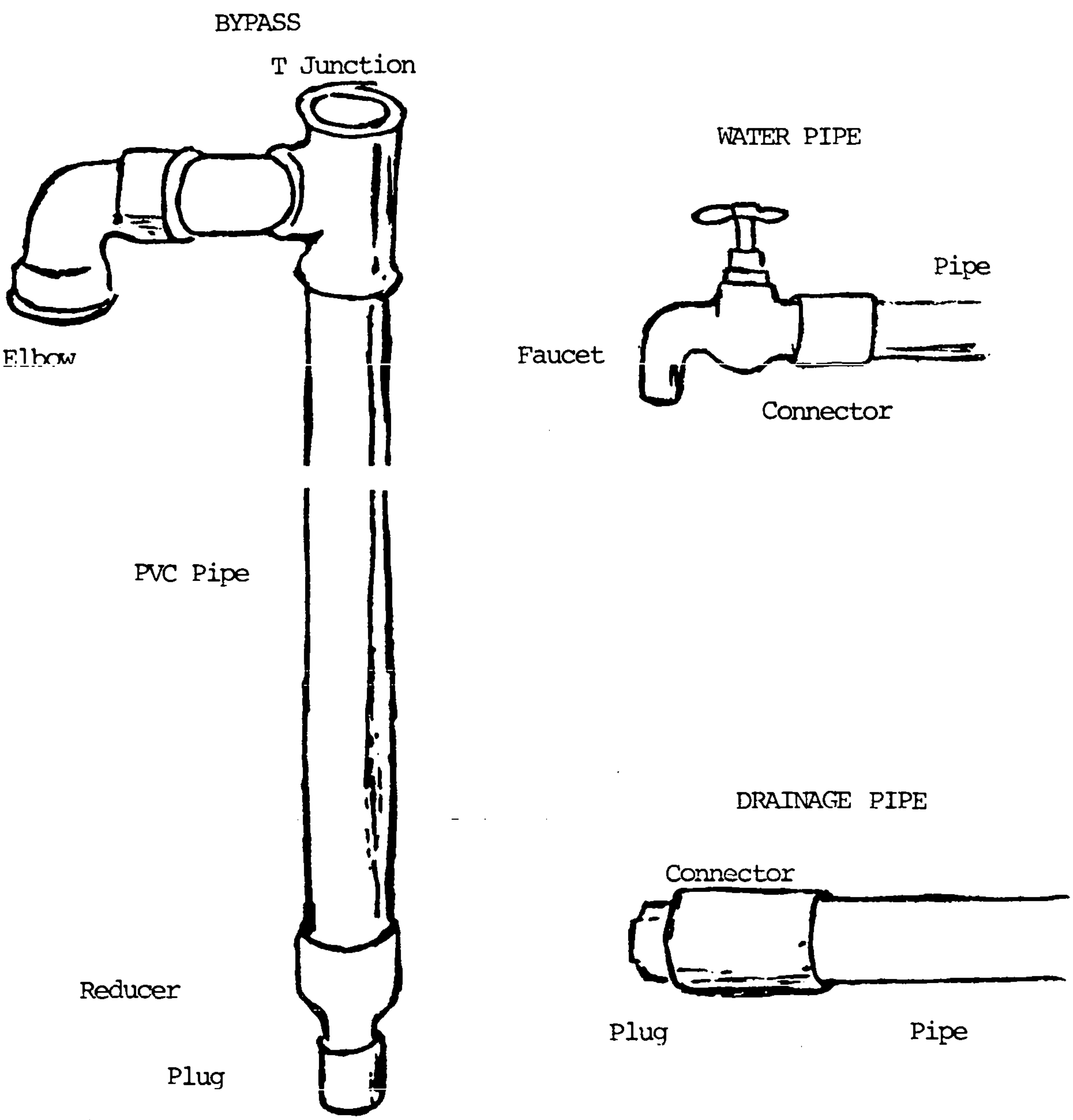


Figure 8. Pipe Components

if it is done for 14 days the strength will be 80-90% and over 21 days, the strength will be 100%.

Open the drainage pipe and let the first rain clean the tank. After the tank is cleaned, fill it up gradually because sudden filling of the tank may cause cracks.

MATERIAL & QUANTITY REQUIRED
FOR A TANK OF 1.5 METRES IN DIAMETER 3 METERS IN HEIGHT

Cement	13	bags
Crushed rock (broken bricks)	2	cu. meters
Stone (gravel) 3/4-1 inch in size	2	cu. meters
Coarse sand	2	cu. meters
Bamboo (At least 3 years old)		
2 cm wide x 5.5 metres long	13	pieces
2 cm wide x 3.4 metres long	20	pieces
2 cm wide x 1.9 metres long	50	pieces
Tie wire for fastening bamboo	1.5	kgs.
Water pipe component: 3/4 inch steel pipe	30	cm
3/4 inch steel connector	1	piece
3/4 inch faucet	1	piece
Drainage pipe component: 1½ inch steel pipe	50	cm
1½ inch steel connector	1	piece
1½ inch steel plug	1	piece
Bypass Component: 3 inch PVC pipe	2	metres
3 inch PVC elbow joint	1	piece
3 inch PVC T-shape junction	1	piece
3-2 inch PVC reducer connector	1	piece
2 inch PVC pipe	30	cm
PVC glue	1	tin
Discarded (used) engine oil	2	litres

MATERIALS & QUANTITY REQUIRED
FOR A TANK OF 2 METRES IN DIAMETER, 3.6 METRES IN HEIGHT

Cement	24	bags
Crushed rock (broken bricks)	2	cu. metres
Stone (gravel) 3/4-1 inch in size	3.5	cu. metres
Coarse sand	3.5	cu. metres
Bamboo (At least 3 years old):		
2 cm wide x 7.5 metres long	13	pieces
2 cm wide x 4 metres long	20	pieces
2 cm wide x 2.4 metres long	50	pieces
Tie wire for fastening bamboo	1.5	kgs.
Water pipe component: 3/4 inch steel pipe	30	cm
3/4 inch steel connector	1	piece
3/4 inch faucet	1	piececm
1½ inch steel connector	1	piece
1½ inch steel plug	1	piece
Bypass Component: 3 inch PVC pipe	2	metres
3 inch PVC elbow joint	1	piece
3 inch PVC T-shape junction	1	piece
3-2 inch PVC reducer connector	1	piece
2 inch PVC pipe	30	cm
2 inch PVC plug	1	piece
PVC glue	1	tin
Discarded (used) engine oil	2	litres

Note: 1 inch = 2.54 cm

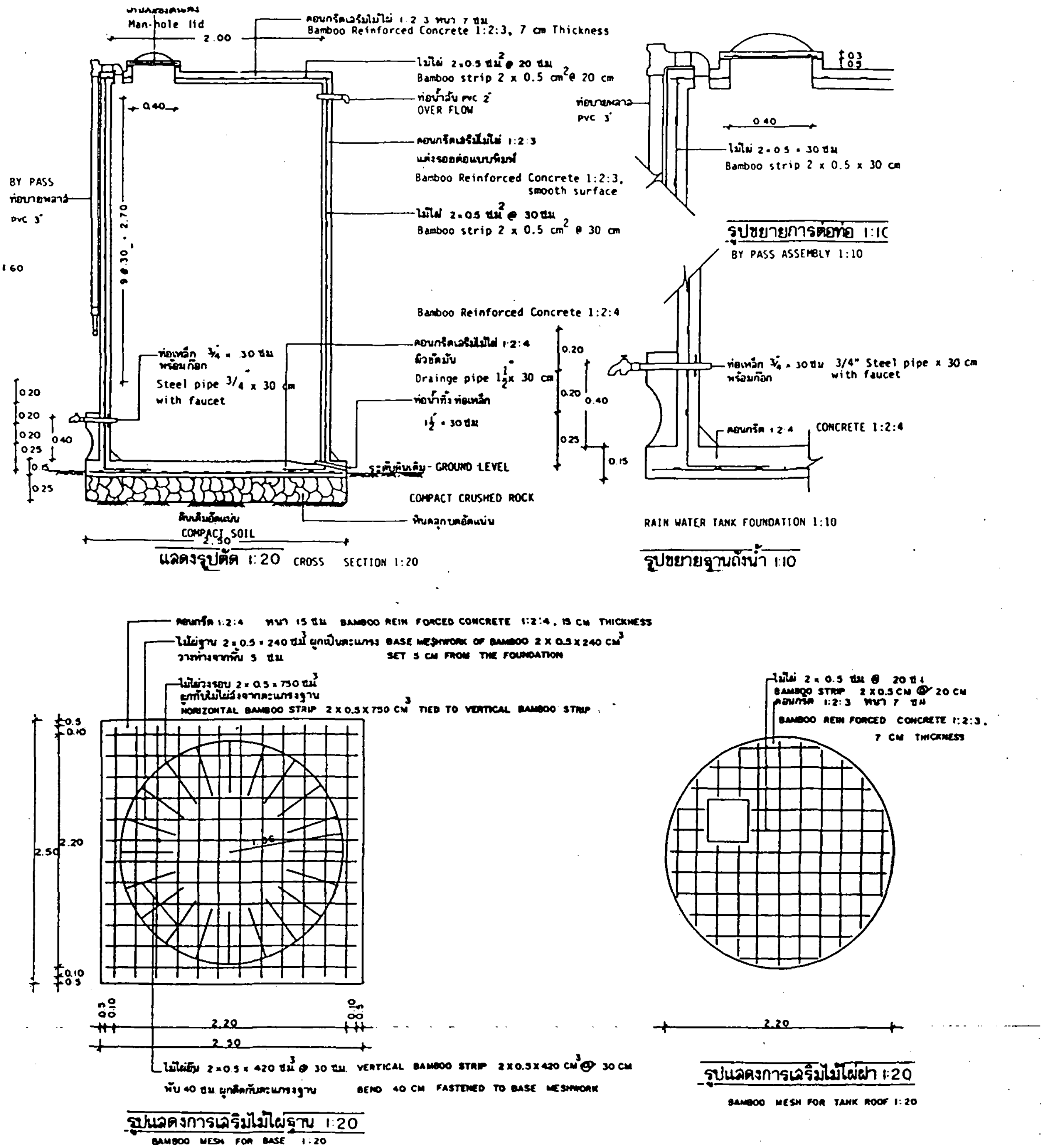


Figure 9. Rainwater Catchment Tank

ROOF CATCHMENT: WATER QUALITY

Vanasri Bunyaratpan
Suparerk Sinsupan
Khon Kaen University
Khon Kaen, Thailand

INTRODUCTION

One of our research tasks is the study of the sanitary quality of rainwater. Except for distilled water which is pure, it is generally accepted that rainwater is the cleanest water. The inevitable dirt which comes with the rain is picked up in the atmosphere: for example, dust and gas from industrial processes. Rainwater collected from roofs picks up dirt from decayed leaves and is contaminated by the faeces of birds.

To protect public health it is important to know and understand the quality of rainwater. The objective of this study was to determine the quality of rainwater collected from three sources: the open air, different types of roofs, and storage containers.

The results and findings are presented and discussed.

METHODOLOGY

Types

The rainwater used for this research was classified into three types:

1. Rainwater from the open air. This was to determine the true quality of the rainwater.
2. Rainwater from roofs. This was to determine the amount of pollution from the roof and catchment area prior to passing into storage.

3. Rainwater from storage containers. This was divided into two sub types: old containers and new containers. The new containers had been coated and were built to determine water quality changes over time.

Locations

Four sampling areas were chosen

1. Khon Kaen University
2. Mu Ban Nong Kung
3. Mu Ban Non Muang
4. Mu Ban Kraduang

All sites are within the Muang District of Khon Kaen.

Periods and Procedures

1. In 1982 during both dry and rainy periods, rainwater from the open air, roofs and old type containers were monitored and tested. Whenever possible, rainwater samples were collected.

2. During the period June-October 1983, monitoring of rainwater in the new storage containers was conducted.

3. Table 1 shows the details of the roofs and type of storage containers at the sampling sites. Table 2 shows details of the sites with new storage containers.

4. In both types of containers, at least once a month, analyses were done to determine important physical, chemical and biological parameters. The parameters, units, analysis methods and instruments are shown in Table 3.

TABLE 1. LOCATIONS AND TYPE OF MATERIALS AT THE SAMPLING SITES.

Area	Code	Roofing or Container Materials
Khon Kaen University	KKU-10	Asbestos cement
	KKU-11	Mortar jar
	KKU-20	Asbestos cement
	KKU-21	Reinforced concrete tank
Khon Kaen	KKU-40	Without roofing material (open air)
Ban Nong Kung, Khon Kaen	NGK-10	Galvanized iron sheet
	NGK-11	Mortar jar
Ban Non Muang, Khon Kaen	NMG-10	Galvanized iron sheet
	NMG-11	Mortar jar

TABLE 2. TYPES OF NEW RAINWATER STORAGE CONTAINERS AND BUILDINGS AT SAMPLING SITES.

Area	Building type	Sampling code	Type of rainwater container		
			size, m diameter & height	capacity m^3	material
Ban Nong Kung	school	NGK-51	2.5x3.0	14.5	brick and mortar
Khon Kaen	dwelling	NGK-52	2.5x2.5	12.0	ferrocement
	dwelling	NGK-53	2.5x2.5	12.0	brick and mortar
Ban Non Muang	school	NMG-51	2.5x3.0	14.5	brick and mortar
	dwelling	NMG-52	2.0x3.0	9.0	ferrocement
Ban Kraduang	school	KDG-51	2.5x3.0	14.5	brick and mortar
	dwelling	KDG-52	2.5x2.5	12.0	ferrocement

TABLE 3. WATER QUALITY PARAMETERS AND PROCEDURES OR EQUIPMENT USED IN THE ANALYSIS.

Parameter	Unit	Method or instrument used for analysis
1. Alkalinity	mg/l as $CaCO_3$	Titration method
2. Calcium hardness	mg/l as $CaCO_3$	EDTA titrimetric method
3. Chloride	mg/l as Cl	Argentometric method
4. Hardness	mg/l as $CaCO_3$	EDTA titrimetric method
5. Iron	mg/l as Fe	Phenanthroline method
6. Nitrate	mg/l as NO_3-N	Brucine method
7. pH	-	pH Meter
8. Coliform Bacteria	MPN/100 ml	Multiple-tube fermentation technic (Presumptive test)
9. Manganese	mg/l as Mn	Persulfate method

RESULTS AND DISCUSSION

The results of the research are listed in Tables 4 and 5 and are also shown in Figures 1 to 3. As mentioned under methodology, samples tested during February-December 1982 were from the open air, roofs, and the old type containers. For the period June-October 1983 only samples from the open air and the new type containers were tested. The results are discussed as follows:

Rainwater From the Open Air

Results of analyses of random samples done in March and April 1982 are shown in Table 5. It was concluded that the pH parameter should receive more attention. Therefore, in June-October 1983, tests were only conducted for the values of pH. Results showed that pH varied from 5.6 to 7.0. The value of pH tended to increase with increased frequency of rainfalls. The results of this test are shown in Fig. 1.

TABLE 4. CHEMICAL AND BACTERIOLOGICAL PROPERTIES OF RAINWATER FROM ASBESTOS CEMENT (AC) AND GALVANIZED IRON (GI) SHEET ROOFS COLLECTED WITHIN 5 MINUTES OF THE START OF A RAINFALL.

station / parameter	KKU-10 (AC)	KKU-20 (AC)	NGK-10 (GI)	NMG-10 (GI)
Hardness	15-220	20-52	13-40	10-14
Fe	0.0-1.4	0.01-1.24	0.0-0.12	0.0-0.02
Cl	3-12.5	2.5-7.0	3.0-5.5	3.5-6.0
pH	4.8-6.3	5.5-6.0	4.8-5.6	5.3-5.7
Coliform Bact.	33-2,400	1,600	13-23	4-27

TABLE 5. COMPARISON OF CHEMICAL PROPERTIES OF RAINWATER COLLECTED WITH AND WITHOUT ROOFS.

station	Fe mg/l	NO_3 mg/l	Mn mg/l	Hardness mg/l	Cl mg/l	pH
KKU-10 (AC)						
26 March 1982	0.88	4.0	0.96	55	6.5	5.8
9 April 1982	0.40	4.0	0.22	29	4.5	5.9
KKU-20 (AC)						
9 April 1982	0.02	4.5	0.60	36	5.5	6.0
KKU-40 (Open air)						
26 March 1982	0.02	0.45	0.00	18	4.0	3.5
9 April 1982	0.00	0.54	0.00	10	4.0	4.5

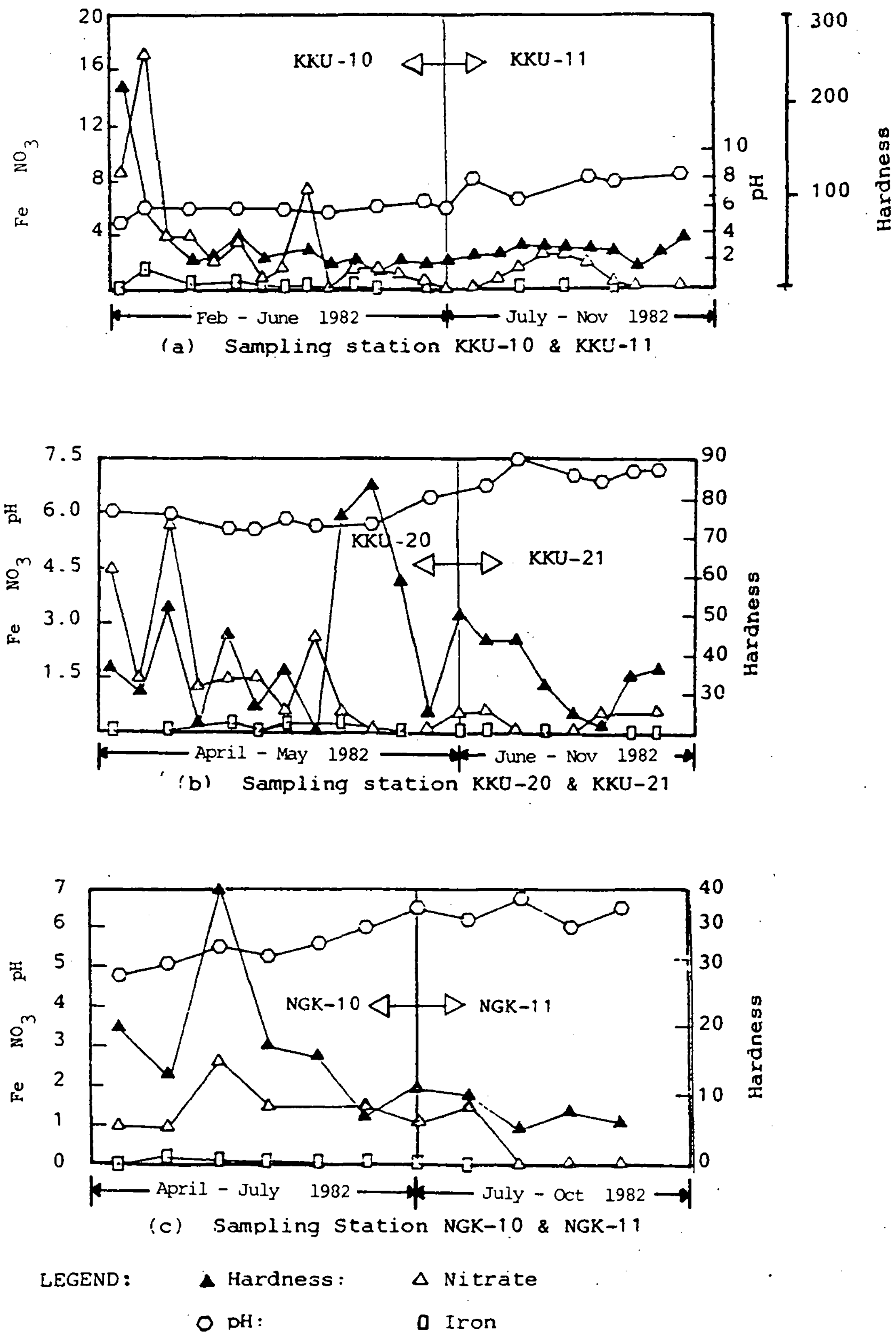


Fig. 1. Chemical properties of rainwater from galvanized iron sheet roof and in a mortar jar at each sampling station

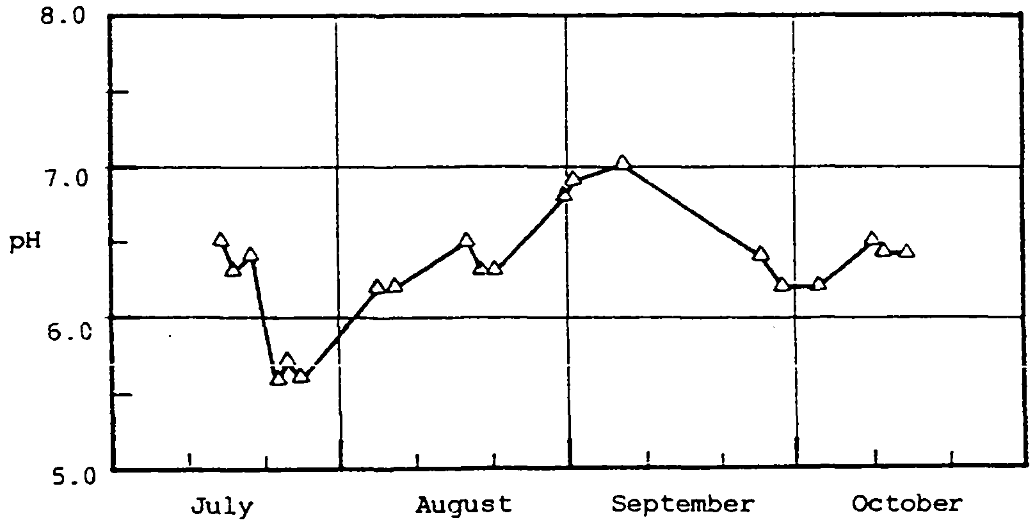


Fig. 2. Variation of pH of rainwater from open air during July-October 1983

Rainwater From Roofs

The rainwater quality analyses from asbestos cement roofs and galvanized iron sheets are shown in Table 4. The open air characteristics were not available due to an instrument defect. The chemical properties of rainwater collected from asbestos cement roofs located in Khon Kaen University seemed to be different than those from galvanized iron sheet roofs located in the villages. For example, the hardness value at KKU-10 was about 15 to 220 mg/l as $CaCO_3$ whereas at NGK-10 it was about 13 to 40 mg/l as $CaCO_3$.

The other parameter worth considering in this case was iron since the rainwater was also collected from galvanized iron roofs. Contrary to what was expected, the iron concentrations in water from asbestos cement roofs were about 0.0-1.4 mg/l as Fe. These readings were much higher than those from galvanized iron roofs which were 0.00 to 0.02 mg/l as Fe. The results suggested that there was no leaching of the galvanized iron sheet.

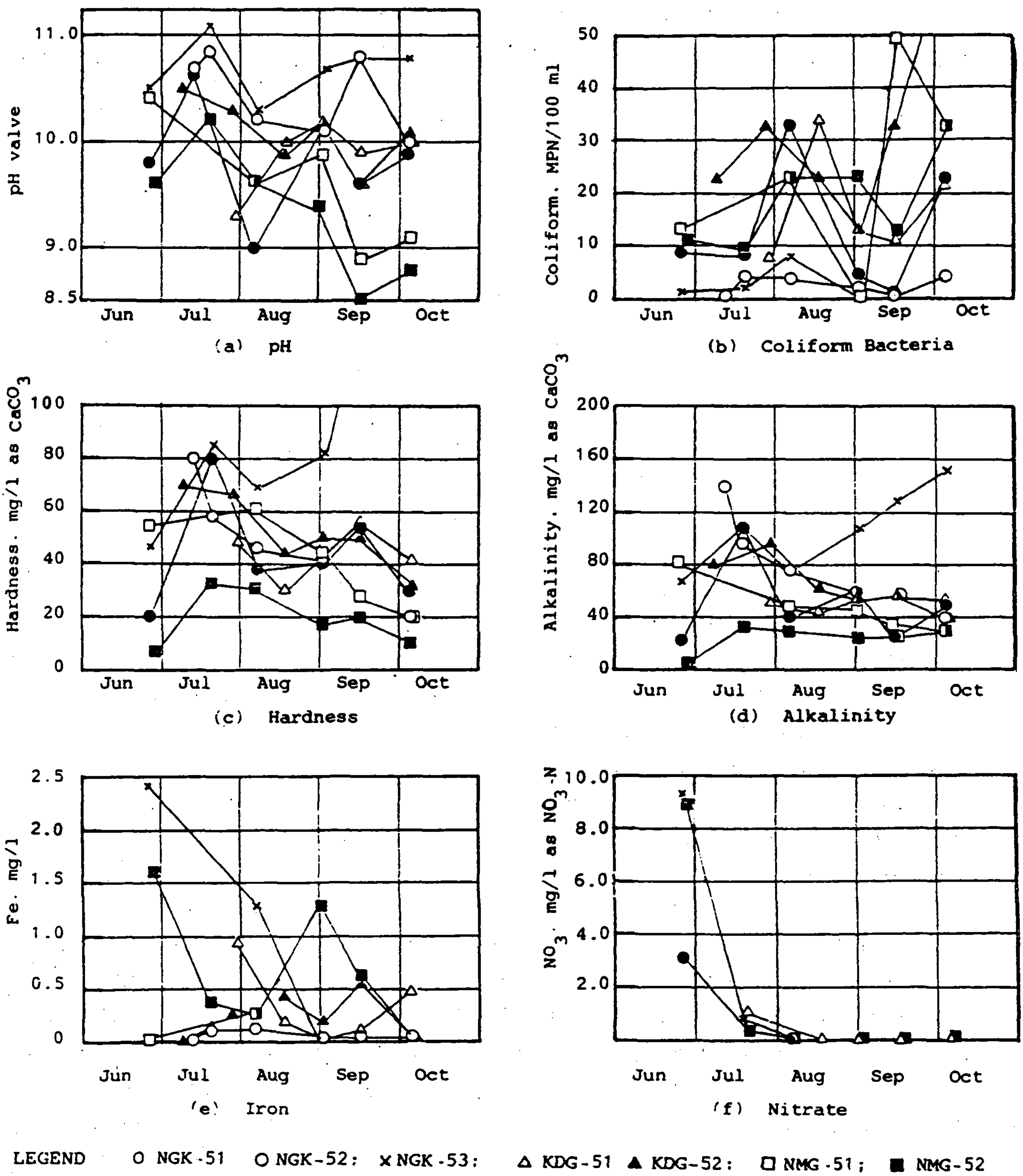


Fig. 3. Variation of rainwater quality in the containers from June to October 1983

The pH values from asbestos cement roofs were higher than those from galvanized iron sheets as shown in Table 4. The results indicate that the type of roofing material does affect the pH value of rainwater.

Table 5 shows the effect of roofing materials on the pH value. The pH values of rainwater collected without any roof catchment on April 9, 1982 were about 4.5 while those from asbestos cement roofs at KKU 10 and KKU 20 were 5.9 and 6.0, respectively for the same date.

The coliform density (Table 4) of the asbestos cement roofs at KKU-10 and KKU-20 was much higher than that obtained at NGK-10 and NMG-10. The reason might be that the galvanized iron roof can absorb more solar heat than the asbestos cement roof. Therefore, there may be some solar disinfection effect on the galvanized iron.

Rainwater in Old Containers

Rainwater from asbestos cement roofs collected in mortar jars located at station KKU-11 was found to have higher pH values than that collected directly from roof catchments. The values found were between 5.7 to 8.2 compared to 5.8 to 5.9 for roof water. Iron content was lower, 0 to 0.16 mg/l compared to 0.40 to 0.88 mg/l. The hardness value changed between 28 to 51 mg/l compared to 29 to 55 mg/l for roof water and nitrate varied between 0 to 2.50 mg/l as NO_3-N compared to 4.0 mg/l. The results of this research can be seen in Fig. 1-a.

From the analysis of rainwater in reinforced concrete tanks at station KKU-21, it was found that the quality was about the same as that stored in mortar jars (KKU-11). That is, the pH had a value between 5.9 to 7.4, iron 0 to 0.20 mg/l, the hardness value changed between 22 to 83 mg/l; and nitrate was between 0 to 5.0 mg/l as NO_3-N. These results are shown in Figure 1-b.

Rainwater collected in mortar jars (station NGK-11) from galvanized iron sheets was found to have differing values as follows: pH value changed between 6.0 to 6.7; iron value was 0 to 0.04 mg/l; the hardness value was 5 to 11 mg/l; and nitrate was about 0.04 to 1.50 mg/l as NO_3-N. These results are shown in Fig. 1-c.

The two existing types of containers in this study, the mortar jar and reinforced concrete tank, had no effects on the rainwater quality. For example the pH value of rainwater in both types of containers increased to be within the range of standard drinking water ranging from 6.5 to 8.5. The other parameters such as iron, nitrate, and hardness decreased when it was stored. Therefore, it is indicative that storage produces improvement in some water quality parameters.

Rainwater in New Containers

The results of the research showed that the pH value in each case was higher (8.5 to 11.0) than in old containers. Results are shown in Fig. 3-a. The coated materials were an important factor in this. However, this higher pH value tends to decrease as new rainfall helps to decrease the initial value. Those containers coated with cement produced the highest values. Although Flintcoated (tarred) containers have high pH values, they were lower than cement coated ones.

Coliform bacteria were found to be of low value. The change in bacterial quantity was inconclusive. Sometimes it appeared to be high and sometimes low as shown in Fig. 3-b. The highest coliform concentration was 79 MPN/100 ml at station KDG-52.

The hardness value was between 6 to 154 mg/l (Fig. 3-c). The highest value measured at station NGK-53 resulting from construction materials was due to the presence of calcium. From the comparison of the hardness and the alkalinity of the water, it can be said that rainwater in new storage containers is initially hard water, as determined by carbonate hardness. As for alkaline values in water shown in Fig. 3-d, they were found to be high. Most alkaline values tended to decrease except at station NGK-53 where they were found to increase.

Iron measurements were found to be of a high value in some storage containers. This may be due to roof materials or clay dust containing iron. The tests showed that it could decrease. A high nitrate value was found in the early stages of storage of rainwater. It could result from the washing of organic matter from the roof. However, these values decreased to zero and it was probably the result of being diluted by new rain. However, there may be other causative factors that have not been identified as yet.

SUMMARY AND CRITICISM

From the results of these experiments of rainwater quality from open air and rainwater in newly built containers, it can be concluded that:

1. rainwater from the open air which does not contact roof materials or is not stored tends to have low pH values. But after it has been stored in a storage container, the pH value increases owing to the influence of coating materials. For Flintcoated storage, the pH value increases to 10.2 but tends to decrease more rapidly than in storage with other types of surfaces. Connecting a pipe to the storage in order to displace old water immediately does not help to decrease the pH value. Decreasing pH economically can be done by cleaning the storage containers more frequently.

2. The levels of concentration of hardness, iron, nitrate, and alkalinity of water depend on the roofing condition and Flintcoated materials. Values for these decrease when roofs and containers are washed by the process of using and collecting water.

3. Bacteria were found but it is thought that they are not harmful to human health.

From this preliminary stage of experiments, it can be concluded that rainwater kept in protected storage containers is clean enough for drinking. It does not have to be treated. However, the storage tank needs to be washed frequently in order to decrease the pH value and to help maintain the necessary chemical and physical quality of drinking water. Rainwater which has been stored for a long time will have a better quality more because of its initial high quality than because of the construction materials used for building the containers. To use cement for building and coating does not seem to help to improve the quality of water.

RAINWATER COLLECTION PROJECT (SIERRA LEONE)

G. T. Tengbeh
Department of Environmental Studies and Geography
Njala University College
(University of Sierra Leone)

INTRODUCTION

This paper presents information on the main activities of the Rainwater Collection Project in Sierra Leone, which started in September 1982. In addition it provides a summary of the preliminary results that have been obtained so far.

OBJECTIVES

The two immediate objectives of this Project are:

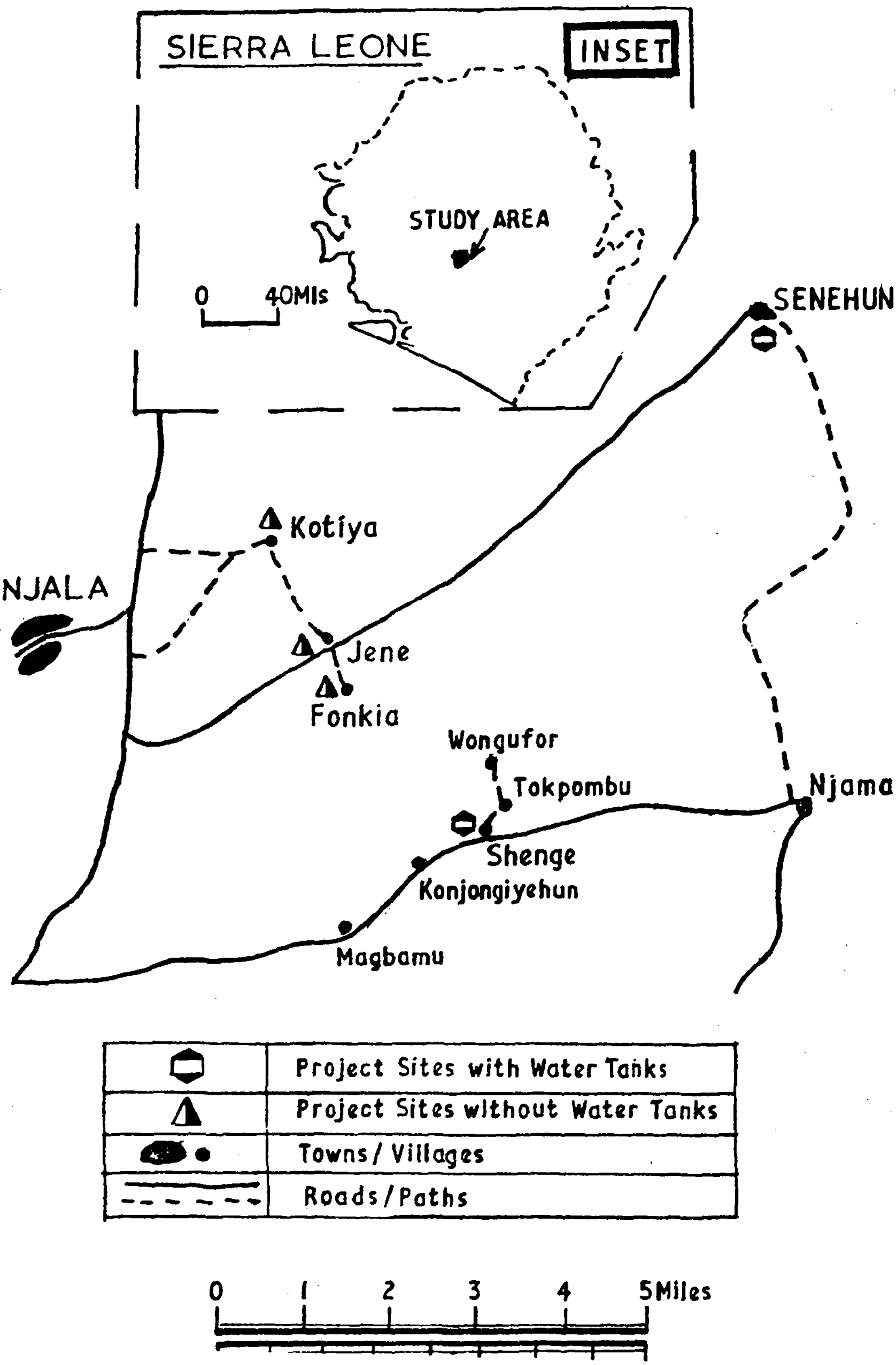
I. To identify the nature and magnitude of the problems of dry season water supplies in some rural areas of Sierra Leone by investigating the seasonal household water needs and by examining the quality of the present water sources used for drinking; and

II. To investigate the volume of rainwater that can be efficiently collected from roof tops for different rainfall events during the rainy season.

RESEARCH, DESIGN AND DATA COLLECTION

Five rural settlements around Njala in the humid tropical Southern Province of Sierra Leone were selected for this study. These are Senehun, Shenge, Jene, Kotiya and Fonkia (Figure 1).

Figure 1. Rainwater Harvesting Project Area



The method of selection was not statistical but purposive - based on a preliminary survey of rural settlements around Njala with very acute dry season water shortage problems.

At each of these settlements, resident Field Assistants collected the following data through participant observation and field measurements for about one year from November 1982 to December 1983.

- The range of roofing materials used

- Population characteristics

- Traditional drinking water sources

- Water levels of existing traditional drinking water sources determined monthly

- Water collection and use habits determined for occupants in a total of 70 dwellings randomly selected from all the five settlements. For this, the occupants of each of these dwellings are being observed in 36- to 40-day cycles. For instance, in Senehun where occupants of 40 dwellings are being observed, there are two Field Assistants. Each is observing the water collection and use habits of the occupants of 20 dwellings, observing each dwelling's occupants for 2 days at a time. Thus, the occupants in all the 40 dwellings are observed in 40-day cycles. In this way, occupants of every dwelling are observed about eight/nine times during different times of the year in order to see how their water collection and use habits change with the seasons. By this participant observation method, the Field Assistants have the opportunity of observing their subjects in the settlements and on their farms and recording the events as they occur during their twelve months stay in the settlements.

- Attitudes towards drinking rainwater determined from a total of 200 subjects randomly selected from all five settlements.

- Rainwater volume per rainfall event, from roofs of known surface areas, orientations and inclinations using three 800-gallon tanks in each of two settlements - Senehun and Shenge.

- Local weather characteristics measured at the two settlements where the tanks are installed, at standard times and during any rainfall event.

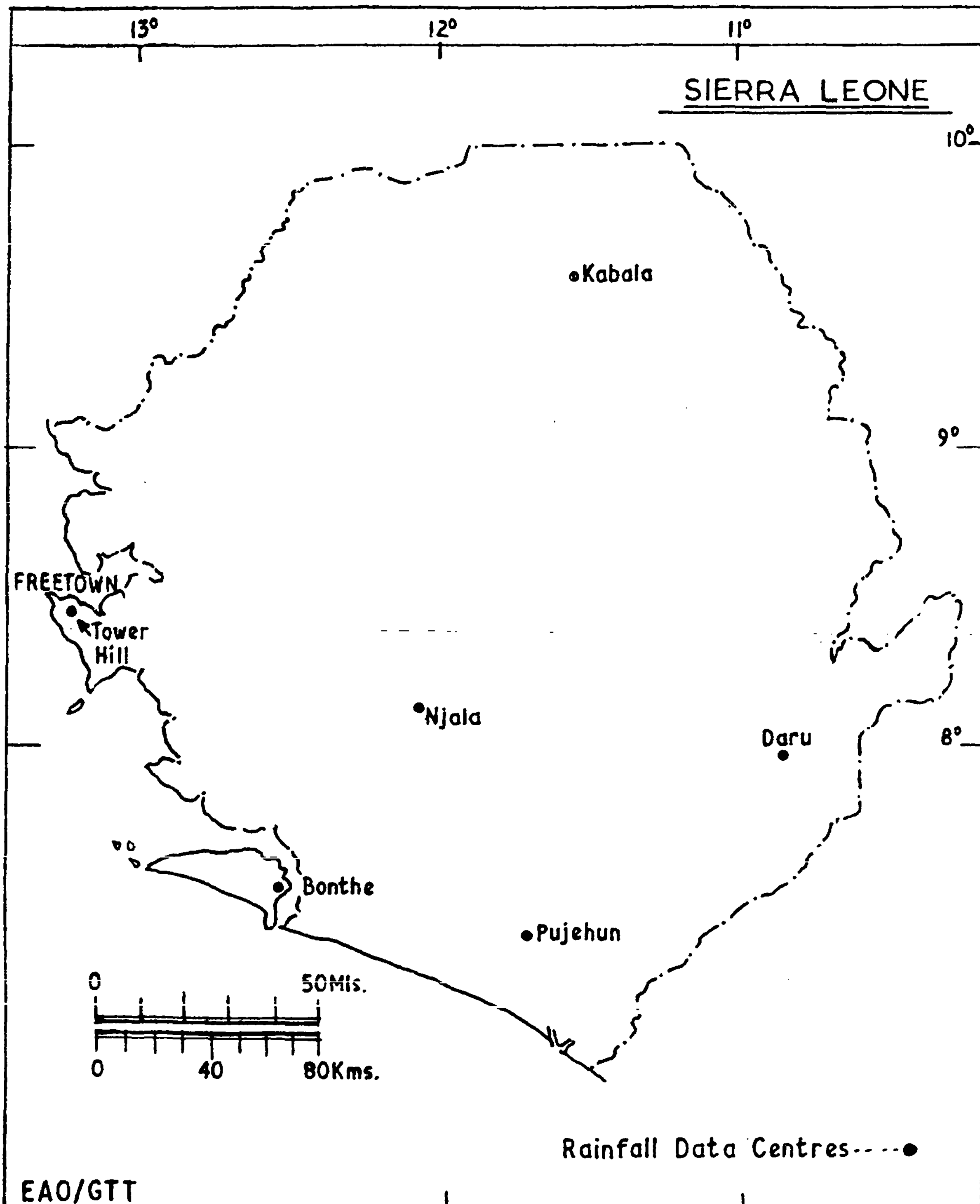
- Water quality-faecal bacterial content and electrolytic conductivity - determined weekly for the traditional water sources and for the stored rainwater from the tanks.

In addition rainfall data has been assembled for the following five centres in Sierra Leone: Tower Hill (Freetown), Kabala, Njala, Bonthe and Daru (Figure 2 and Table 1). Theoretical roofs runoffs computed using these data will subsequently be compared with the rainfall and roof run-off data that are now being collected at Senehun and Shenge.

TABLE 1. CENTRES FOR WHICH RAINFALL DATA HAS BEEN COLLECTED.

CENTRE	LOCATION	NO. OF YEARS OF DATA
Tower Hill (Freetown)	Western area	1875-1982 (108 yrs)
Kabala	Koinadugu District Northern Province	1941-82 (42 yrs)
Njala	Moyamba District Southern Province	1926-82 (57 yrs)
Bonthe	Bonthe District Southern District	1941-82 (42 yrs)
Daru	Kailahun District Eastern Province	1941-82 (42 yrs)

Figure 2. Centres for Which Rainfall Data are Used



PRELIMINARY RESULTS

Roofing Materials

Only two roofing materials are used in all the settlements in the study area - grass and metal (Table 2). The grass used for roofing houses is Iperata cylindrica locally known as Lettie (Mende).

TABLE 2. ROOFING MATERIALS USED.

Settlement	Total Dwellings	Metal Roofs		Grass Roofs	
		Number	% of Dwellings	Number	% of Dwellings
SENEHUN	131	124	95	7	5
SHENGE	26	23	89	3	11
JENE	33	23	70	10	30
KOTIYA	25	17	68	8	32
FONKIA	11	9	82	2	18
ALL	226	196	87	30	13

As Table 2 shows, metal roofing materials are more commonly used (about 87% of the dwellings) than grass (about 13% of the dwellings). This percentage is even higher in the larger settlement of Senehun (95%). Because of this the Project has given attention to metal roofs in collecting rainwater for drinking.

Population Characteristics

The population characteristics of the study area as a whole are summarised in Table 3.

TABLE 3. POPULATION CHARACTERISTICS OF STUDY AREA.

	TOTAL		MALE		FEMALE		
	NUMBER	%	NUMBER	%	NUMBER	%	SEX RATIO: MALE/FEMALE x 100
Children (under 14 yrs)	899	39	493	21.4	406	17.6	120.8
Adults	1405	61	612	27.0	793	34.0	77.2
Total	2304	100	1105	48.4	1199	51.6	92.2

Three characteristics of some importance to this investigation stand out clearly. Firstly, the age structure is that of a youthful population with 39% being less than 14 years old. For the larger settlement of Senehun, this proportion is as high as 42%. Secondly, the age and sex distribution shows an excess of females with a sex ratio of about 92 males to every 100 females. Thirdly, there is an excess of males over females in the age group less than 14 years (the children).

From data being collected on the water collection habits of the population of the settlements being studied, one finds that water is carried mainly by the women and the children. This implies therefore that in the study area as a whole 73% of population are potential carriers of water (Table 2). For the larger settlement of Senehun, this proportion is as high as 75%.

Rainfall Data

Rainfall data has been assembled for Tower Hill (Freetown), Kabala, Njala, Bonthe and Daru (Fig. 2). These data have been grouped into monthly averages (Table 4), annual and seasonal averages and average number of raindays (Table 5) for each centre.

From Table 4 it can be seen that the rainy season sets in in May/June and lasts until October (5/6 months). The amounts vary, with

TABLE 4. AVERAGE MONTHLY RAINFALL (mm)

	Tower Hill	Kabala	Njala	Bonthe	Daru
January	8.5	8.5	11.6	12.9	8.9
February	10.7	7.9	18.8	17.7	30.8
March	21.5	38.6	67.3	36.8	100.0
April	79.2	102.5	123.0	95.8	155.5
May	248.0	192.5	243.3	261.0	260.4
June	447.0	287.2	256.9	556.0	291.0
July	858.0	299.2	403.3	821.4	291.5
August	940.5	361.5	501.8	719.5	347.7
September	772.5	395.5	440.2	577.6	395.7
October	318.0	320.2	329.8	336.5	316.2
November	86.8	102.0	166.8	160.8	179.0
December	30.0	13.8	31.2	57.4	44.9

Freetown and Bonthe being the wettest followed by Njala, Daru and Kabala which is the driest. However in all of these centres rainwater can be collected for about six months of the year.

As Table 5 shows, the wet season can be classified into: the early squalls (May/June) the main wet season (July/August) and the late squalls (September/October). The squalls seasons are linear thunderstorms (line squalls) characterised by high intensity late afternoon rainfall events with very windy conditions caused by high velocity east-west winds which develop from the Eastern highlands of West Africa. The main wet season is characterised by steady rainfall events with rain spells lasting for up to a day or more. During the early and late squalls one would

TABLE 5. ANNUAL AND SEASONAL RAINFALL STATISTICS

Centre	Annual Average	Seasonal Averages (mm)			Aver rain days	No. of Yrs of Data
		Early Squalls May/June	Main wet season July/August	Late Squalls Sept/Oct		
Tower Hill	3608.4	313.0	2768.3	425.7	201	108
Kabala	2129.5	396.2	1276.5	412.2	146	42
Njala	2704.5	375.0	1682.5	531.0	175	57
Bonthe	3682.2	352.5	2655.0	504.0	177	42
Daru	2429.2	502.0	1336.8	494.8	184	42

therefore expect roof runoff to be highest on east-facing roofs. During the main wet season, although roof runoff will be higher than during the early and late squalls, its distribution will be expected to be roughly the same on roofs facing any direction.

Naturally the highest rainfall amounts are recorded during the main wet season and these range from 1276 mm at Kabala to 2768 mm at Tower Hill in Freetown. Tower Hill also has the highest average number of raindays (201) followed this time by Daru (184), Bonthe (177), Njala (175) and Kabala (146). These aspects of rainfall are probably the most important in terms of rainwater collection because they indicate that even at drier Kabala, for instance, wet season rainfall of about 2200 mm on average can be tapped for about five months (146 days) every year.

Domestic Water Need and Roof Runoff

As pointed out earlier, some of these rainfall characteristics will now be used to calculate firstly the domestic water needs (Demand) and then the expected total roof run-off (supply) for each of the settlements under study. These theoretical results (Table 6) will at a later stage in the investigation be compared with the results of data being collected at Senehun and Shenge in order to determine whether these theoretical computations can be done for the five centres (Table 5) with any amount of confidence.

The formula used for the calculation of the dry season domestic water need (tonnes) is that given by Nissen-Peterson (1982) and is expressed as the product of three variables: the total population, the average daily consumption (litres) per person and the longest period without rain. The formula used for calculating total roof run-off (tonnes or cubic metres), also given in the same publication is given as the product of: the size of the roof catchment (sq.m), and the mean annual rainfall (mm). The results of these computations are given in Table 6.

TABLE 6. DRY SEASON WATER DEMAND AND ROOF RUN-OFF FOR PROJECT SETTLEMENT.

Settlements	Total Popn.	Assumed Av. Consumption Per Person Per Day (litres)	Longest No. of Rainless Days *	Dry Season Demand (tonnes)	Calculated Roof Runoff (tonnes)*+	No. of Similar roof Sizes to Satisfy Demand
Senehun	1703	22.7	191	7,384	243	30
Shenge	291	22.7	191	950	243	4
Jene	188	22.7	191	815	243	3.5
Kotiya	141	22.7	191	611	243	2.5
Fonkia	53	22.7	191	23	243	1

* Based on Njala data in Table 5 (2704.5 mm of rain).

+ Minimum roof area from which runoff data is being collected at Shenge (90 sq. m.).

These results show that in the smaller settlements in the study area, very few small roof catchments need to be used to collect enough rainwater during the rains to satisfy the dry season water demand of the inhabitants. In the much larger settlement of Senehun (1703) however, a much larger number of roof catchments are needed to satisfy their dry season water demand. The remaining area in all villages can easily supply the dry season demand.

It is hoped that this investigation will come up with some framework, based on experimental data, for estimating total roof runoff for these settlements under study and for other areas in Sierra Leone.

Water Quality

For the period July-November 1983, a total of 166 samples from traditional drinking sources and from storage tanks have been analyzed for faecal bacterial content and electrolytic conductivity (Ec).

Samples were taken at approximately weekly intervals from five settlements:

i) at Shenge, five samples were taken at each interval, one from a stream traditionally used as a source of water for domestic use, one from a recently-constructed Moyamba Integrated Rural Development Project (MIRDP) well, and three from the three rainwater storage tanks installed here;

ii) at Ngieya, two samples were taken at each interval, one from a traditionally-used stream and one from an MIRDP well;

iii) at Torkpombu, two samples were taken, one from a traditionally used stream and one from an MIRDP well;

iv) at Senehun, where three rainwater storage tanks had been installed, two samples were taken from the traditionally used stream and from the tanks.

Samples were taken aseptically, in sterilised bottles, early in the morning. As soon as possible after sampling, these were tested for faecal bacteria by membrane filtration, using a technique and medium especially suited for use in Sierra Leone (Wright, 1982a, 1982b). The medium allowed a presumptive visual differentiation of faecal bacteria into groups referred to as "presumptive Escherichia coli" and "other faecal coliform (FC)". The presence/numbers of "other FC" and the ratio between the two faecal groups provide further information about the origin(s) of contamination: a high proportion of "other FC" indicates contamination more likely to be non-human or not recent.

Conductivity measurements were made with a conductance bridge. Although no specific chemicals were tested for, a high conductivity reading indicates a high dissolved chemical content. The conductivity of rainwater in Sierra Leone varies between 1-15 S/cm. Figures in excess of this for samples taken from rainwater storage tanks will indicate a "washing" of chemicals from the collecting surface into the tanks. The results of the tests are presented in Table 7.

TABLE 7. COLIFORM AND CONDUCTIVITY TEST RESULTS

Settlement	Source	No. of Samples Tested	Ec*	Presumptive* E. coli	Other FC*
Shenge	Stream	18	15(14)	47(25)	140(140)
Shenge	Well	18	25(16)	8(0)	17(0)
Shenge	Tank 1	18	23(15)	5(0)	5(0)
Shenge	Tank 2	18	19(15)	5(0)	6(0)
Shenge	Tank 3	18	22(14)	5(0)	5(0)
Ngieya	Stream	17	23(13)	32(10)	36(40)
Ngieya	Well	17	23(14)	34(20)	46(90)
Torkpombu	Stream	18	23(16)	39(40)	83(120)
Torkpombu	Well	18	23(22)	88(55)	62(95)
Senehun	River	3	13(13)	25(40)	32(30)
Senehun	Tank	3	35(35)	5(0)	5(0)

* Ec measurements are S/cm. Bacterial counts are dl^{-1}. All figures are geometric means, with medians in parenthesis.

An analysis of the data showed no significant monthly variation between results. However, this will be reviewed after data for a complete one-year period have been collected.

These preliminary results indicate a clear difference between the bacteriological water quality in the rainwater storage tanks, as compared to the natural sources tested. Whereas water from the tanks would usually be regarded as acceptable by International Standards (WHO, 1971), water from the natural sources could not be considered so.

However, it must be stressed that the July-November period corresponds to the wet season in Sierra Leone, when dissolved chemical and faecal bacterial content of sources are expected to be low (Wright, 1982c).

ACKNOWLEDGEMENT

The analysis of the data for this report which was undertaken by Mr. R.C. Wright of the Analytical Laboratory at Njala University College, is hereby acknowledged.

REFERENCES

1. Nissen-Peterson, E. (1982). Rain Catchment and Water Supply in Rural Africa: A Manual. Hodder and Stoughton, London.

2. Wright, R.C. (1982a). "Appropriate field-stations for the bacterial analysis of water supplies in tropical developing countries." Appropriate Technology 8(4), 20-22.

3. Wright, R.C. (1982b). "A medium for the rapid enumeration of Escherichia coli in the presence of other faecal coliforms in tropical waters." Journal of Hygiene 88(2), 265-273.

4. Wright, R.C. (1982c). "A comparison of the levels of faecal indicator bacteria in water and human faeces in a rural area of a tropical developing country (Sierra Leone)". Journal of Hygiene 89(1), 69-78.

5. WHO (1971). International Standards for Drinking Water, 3rd edn. Geneva: World Health Organisation.

SESSION II: REGIONAL REVIEW OF EXISTING SYSTEMS AND DEVELOPMENT PROGRAMMES

CURRENT RESEARCH AND PRACTICES IN RAINWATER CATCHMENT AND STORAGE IN THAILAND

Thamrong Prempridi
Civil Engineering Department
Chulalongkorn University
Bangkok, Thailand

ABSTRACT

Effective rainwater harvesting techniques have been known and practised in Thailand for thousands of years. Today there is a rapid increase in interest in rainwater harvesting and storage as a potential water supply to meet the basic minimum human needs (BMN) in the rural areas. This paper describes harvesting and storing techniques used in ancient times as well as current research and practices.

INTRODUCTION

Rainwater harvesting and storing for domestic uses is an age-old technique used in Thailand. Water jars[1] are evidence of the storing technique used in the past (see Fig. 1). The elaborate system of dykes[2] used to harvest rainwater for use in the City of Sukhothai dates from about 8 centuries ago (see Fig. 2). Dyke no. 1 inscribed on a stone as "Sareed-pongs" was in fact a dam built with stone and natural cementing materials. From the result of a recent survey it was found that the catchment area was about 10 sq. km. and the reservoir could hold up to 200,000 cu.m. of water. Dykes no. 2 to 6 are used to harvest rainwater caught on the slope of mountains west of the city. The four big ponds, known as "Tra Pang", are still in good condition and people are using water from these ponds even today.

Figure 1. Water jar of the past (more than 500 years old)

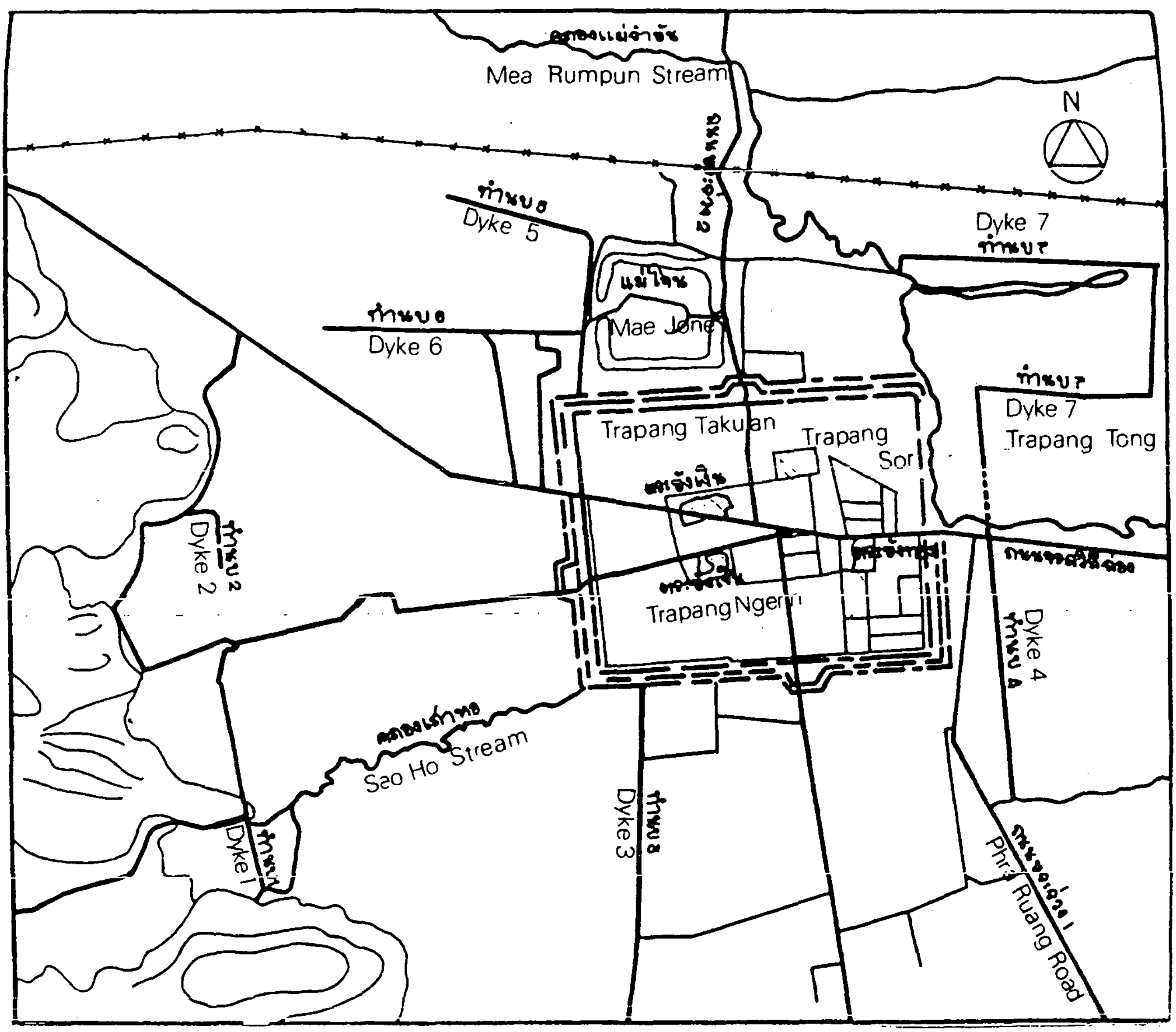


Figure 2. Plan of City of Sukhothai built around 1100 AD

The collection of rainwater is today one of the easiest and cheapest methods of providing a good water supply to rural and urban communities[3]. The first reason for this is that it does not require mobilizing vast quantities of resources and importing materials and expertise involved as in the planning and building of a large complex system of dam and large reservoirs. A small rainwater harvesting and storage system relies and builds upon local skills and experiences in construction, water consumption rate and rainfall patterns. It can also serve as a focal point for community organization effort, e.g., the Village Council. Lack of interest in construction of rainwater harvesting systems during the 1960-1980 period (the 1st to 4th National Five Year Plans) could be due to the fact that members of the national development planning authorities, often western-educated, strove for a large scale impact within a short period and thus went for elaborate systems of a large dam and reservoir. Evaluation of past water resources developments points out the failure of this planning concept especially in providing water for the much needed rural communities. One other reason could be due to the fact that rainwater harvesting and storing systems are relatively simple, requiring no importation of technology or experts. Thailand's Fifth Five Year Plan which began in 1982, shifts the emphasis to developing rural areas. One of the main objectives is to provide clean drinking water for all villages. This is to be done through shallow and deep well development programs as well as rain harvesting and storing programs. For works to be carried out in 1983 ending September 30, see Table 1[4]. Rain harvesting and storage is still far down the list of priorities but it is higher than the rural water works programs. This reflects the thinking of government plannning authorities who do not plan according to the needs of the rural people. In another type of rural development program, the Rural Work Creation Program[5] (Kor Sor Chor), where the priority is based upon the needs of the villagers, the water for crop consumption is ranked first. Rainwater for drinking and domestic uses comes second. Deep well and water works come third. Other works are ranked below water development works (see Table 1).

TABLE 1. NUMBER AND COST OF CLEAN WATER SOURCES PROVIDED FOR VILLAGERS IN 1983.

Type	Numbers					Budget 10^6 B*
	North	N.E.	Central	South	Total	
Deep wells	1053	1994	808	471	4326	324
Shallow wells	282	678	122	273	1355	7
Reservoir and tank	15	16	1	2	34	41.8
Weirs	13	16	10	18	57	69.6
Ponds	46	87	27	22	182	60.3
Concrete tanks (150 m^3)	10	16	6	6	38	7.8
Steel tanks 1.5 m^3	279	247	309	152	988	3.0
Rural water works	4	7	5	4	20	57

Source: Report of the Management Committee Provision of Clean Water for Villagers Project 1983.

* Conversion Rate (1983) $1 US = 23 baht (B)

TABLE 2. AVERAGE RAINFALL DURING MAY-OCTOBER.

Area		M	J	Ju	Au	Sep	Oct	Total
Northern Thailand	mm.	179	162	139	248	243	125	1096
Northeast	mm.	200	231	219	273	286	90	1299
East Thailand	mm.	238	301	315	363	400	250	1867
South Thailand (West side)	mm.	357	405	402	409	457	349	2379
Central Thailand	mm.	162	130	146	170	282	90	980

CURRENT PRACTICES

Rainwater Collection and Storage

Design

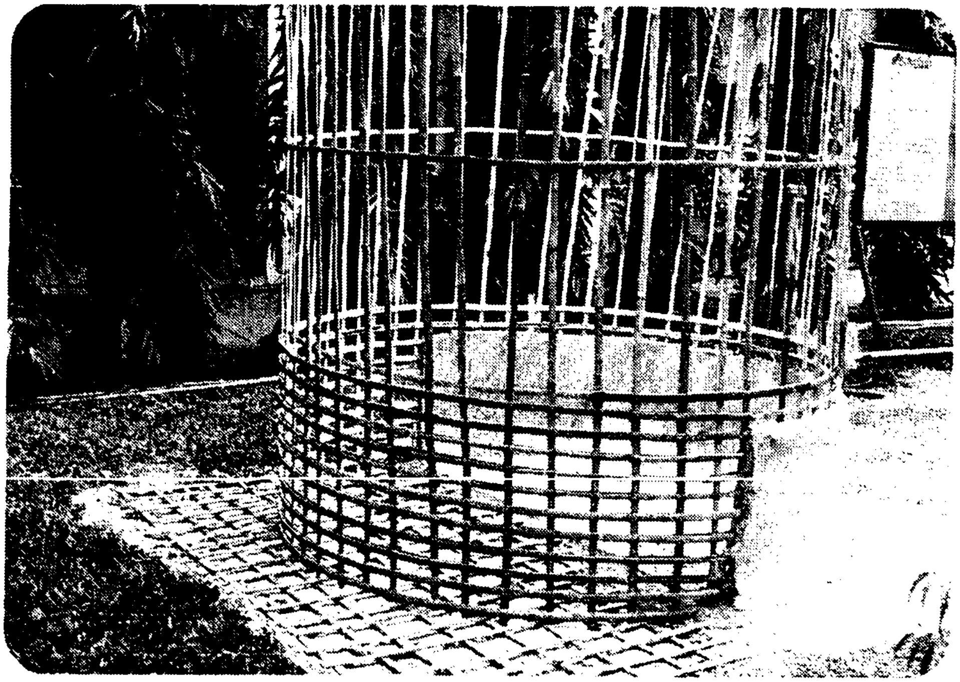
Designs for rainwater catchment are based on rainfall data[6,7,8] catchment area, water consumption[6] and storage. In areas where data on rainfall are not available and the rate of consumption is difficult to obtain, the design is often based on past local experiences. For a domestic system, rainwater from an impervious roof is collected in guttering and channelled into a rainwater storage system. Roofing materials include galvanized corrugated steel sheet, asbestos cement corrugated sheets or grass and leaves (see Fig. 3). The gutter can be galvanized steel or cut open bamboo (see Fig. 3). Containers[8,9,10,11] may be of steel, concrete, ferro or bamboo cement stone or brick, plastic or PVC, fibreglass etc. (see Fig. 4). Pollution entering the container just after a rainfall includes debris and dirt from the roof and can be separated using strainers (see Fig. 5). All openings to the tank must be covered or screened (see Fig. 5).

Rainfall Data[6,7]

Typical rainfall distribution in Thailand is as shown in Fig. 6. Rain in most areas starts in May and lasts till October (Table 2). It can be noticed that in most areas the dry period will extend through 6 to 7 summer or dry months. Water storages for use during the dry period should have enough capacity to supply at least the 200 days of the dry period.

Water Consumption[6,7]

According to a survey made recently in areas in Pranburi, 250 km south of Bangkok, the rate of water consumption varies with locality and



Bamboo Cement Tank

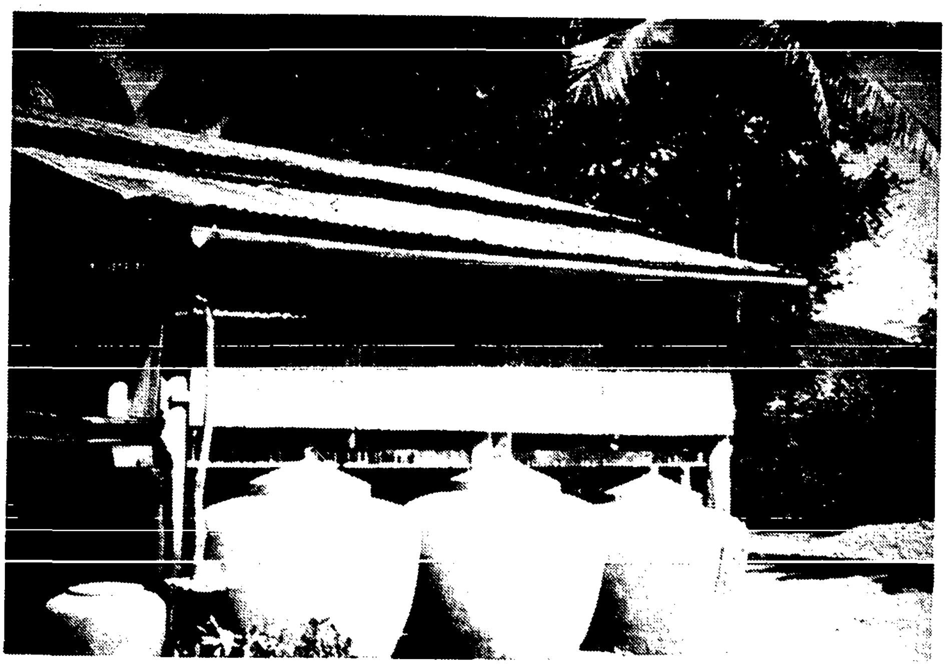
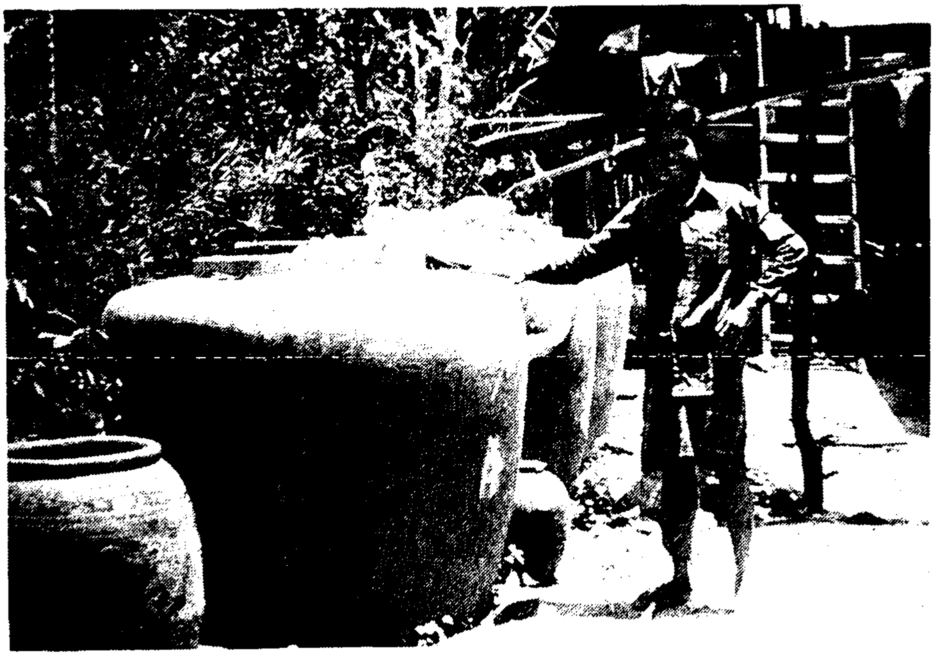
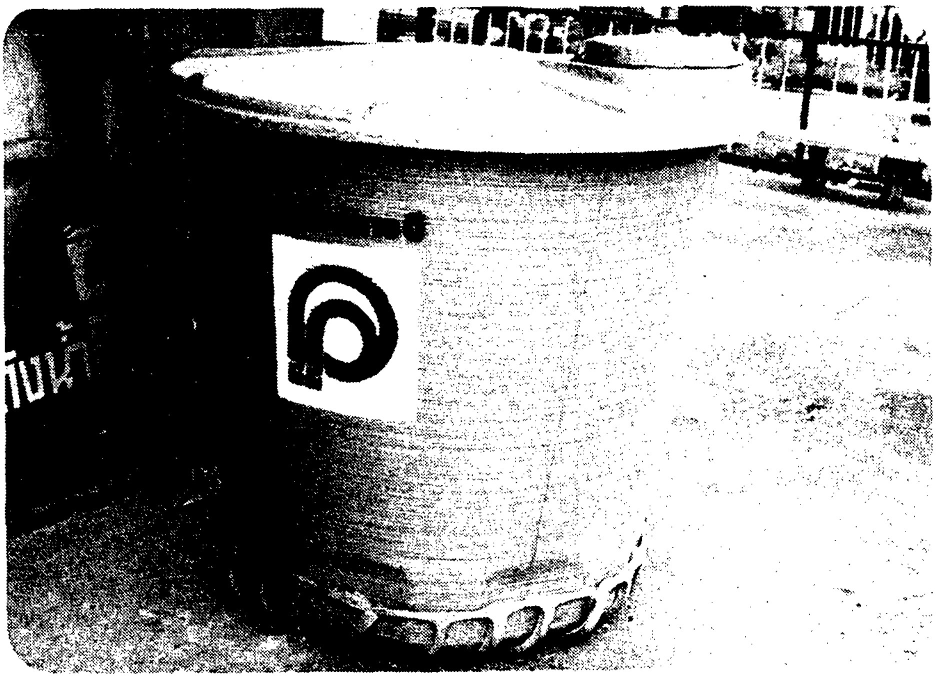


Figure 3. Roofs, Gutters and Storage Jars



Cement jar



Fibreglass Tanks

Figure 4. Rainwater Storage Tanks

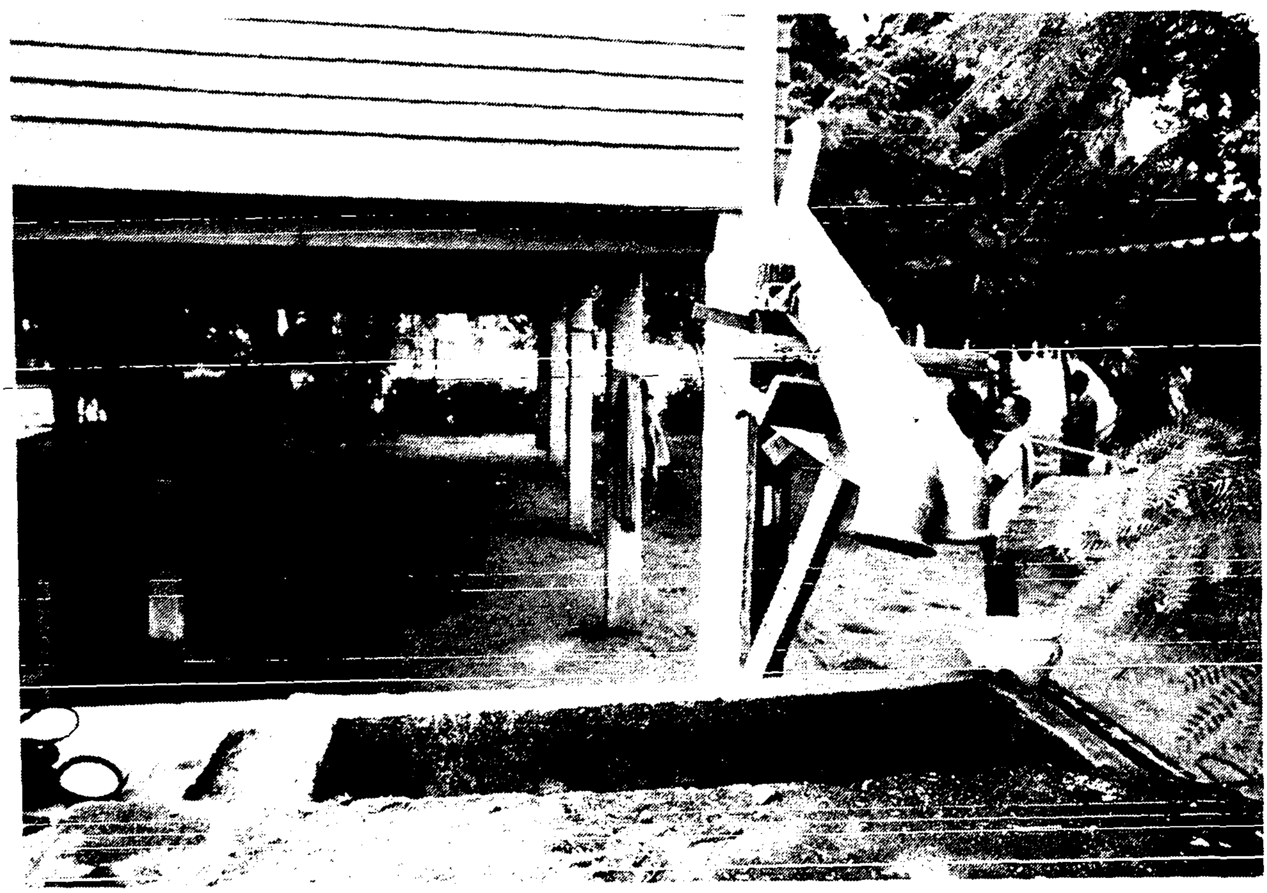


Figure 5. An unscreened opening permits entry of debris and other solid pollutants.

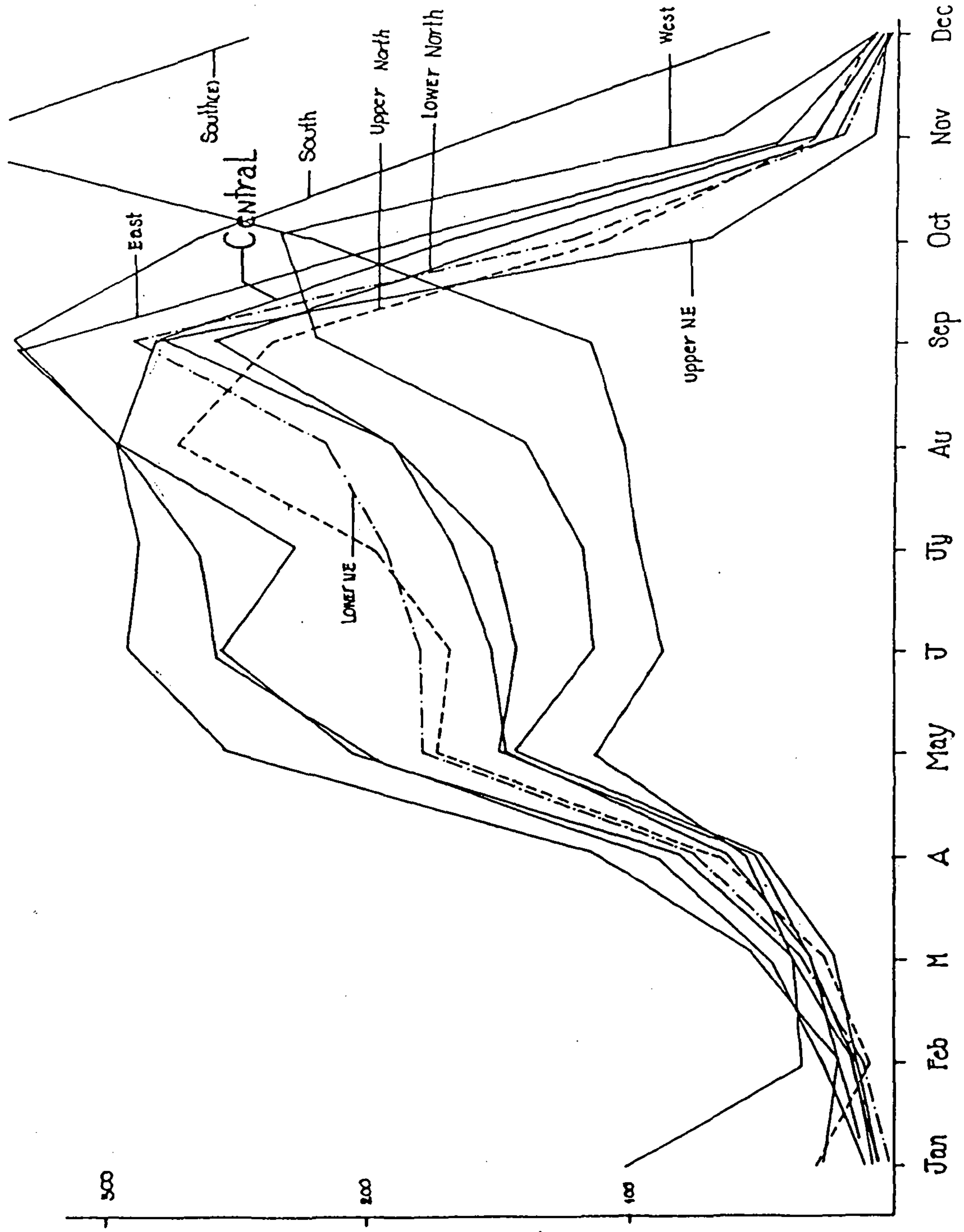


Figure 6. Rainfall distribution in Thailand

the level of technology that exists in that area. The following[6] are typical values used in the designing of a storage system in Thailand.

Household Use

Human consumption	5 litres/man/day
Minimum domestic use	10 litres/man/day
Normal domestic uses	40 litres/man/day

Animal Consumption

Cattle	50 litres/animal/day
Pigs	20 litres/animal/day
Chickens	0.15 litres/animal/day

Number of Members in Each Household

North Thailand	6.72 approx. 7 members
Northeastern	6.15 approx. 6 members
Central	5.34 approx. 6 members
South Thailand	6.40 approx. 7 members

Size of Storage

The minimum size of container to store water sufficient to meet the human consumption requirement during the dry season is recommended to be the product of the number of members in the household; the number of dry days; and the average daily human consumption rate. For example:

$$7 \times 200 \times 15 = 21 \text{ cu.m.}$$

Implementation Aspects

To carry out the planning and construction of a rainwater harvesting and storing system, there are three approaches as follows:

By Individuals

Each household may plan their own rain harvesting and storing system. The usual approach is to use the existing roof area as a catchment area. Gutters may or may not be added to the roof. Storage in most cases will be cement jars which are cheap[11] in comparison to other types of storage (see Table 3). Normal investment costs rarely go beyond 10 000 baht ($450 U.S.) for a 25 cu.m. storage system. Owners will carry out their own maintenance.

TABLE 3. COMPARISON OF COST OF WATER CONTAINERS.

Type	Capacity	Cost (baht)*	(baht)m^3*
Steel (2.0 mm.)	1600 litres	2600	1625
(1.6 mm.)	1600 litres	2400	1500
(1.2 mm.)	1600 litres	2000	1250
Fibreglass	4000 litres	10000	2500
	2600 litres	6700	2577
	1500 litres	4950	3300
	1000 litres	2900	2900
Cement Jars	2000 litres	350 to 500	175 to 250
Glazed Jars	200 litres	180	900
R.C. Concrete Tanks	25 cu.m.	7000 to 10000	280 to 400
PVC Lined Pond	25 cu.m.	2000 to 4000	80 to 160

* Conversion Rate (1983) $1 US = 23 (baht)

By the Village Council

A communal system may be planned by the Village Council. For funding, it usually asks for financial support from the Rural Work Creation Program (Kor Sor Chor). If approved, finance will be provided for up to 70% in labor costs and up to 30% material costs. Each year about 2000 m Baht ($900 m U.S.) are provided for projects throughout the Kingdom. The usual approach is to use the roof area of public buildings such as school houses or monasteries as a catchment area. Galvanized steel gutters are used and the storage tanks are built with steel or bamboo reinforced concrete up to 150 m^3 in capacity. Water rationing is sometimes imposed upon users especially during an unusually dry period. Maintenance is carried out by the villagers.

By Outside Agencies

The communal system may also be planned by outside agencies, the government as well as private organizations. The funding may be obtained from the government or from private sources. Villagers may be asked to help with the construction and provide free labor. The planning often will be done by the agencies concerned. It is usually the case that there is no participation of the villagers in the planning stage as it may not have been needed in the first place. However, problems will arise when maintainance is required. Those who do the planning are thought to be the ones who will perform the maintenance of the project and, in most cases, the project will be left in ruins.

Water Quality

In most cases rainwater will meet the WHO standards or the Thailand standard for drinking water. Strainers are often used to reduce debris and other solid pollutants. Fish are sometimes allowed to live in the large RC tanks to get rid of mosquito larvae. Bacteria are taken care of by boiling of water before use but this is not a common practice. Other problems[12] include acidity and heavy metals in collected rainwater but this has not been found to exceed the allowable value for drinking water. Asbestos particles may be present due to asbestos cement roofing. However, the amount of asbestos present has not yet been examined.

RESEARCH AND DEVELOPMENT ACTIVITIES

Research Activities

Chulalongkorn University

Professor Tiva Suphachanya of the Department of Geology is currently carrying out research on old communities in Thailand with a financial help from the Toyota Foundation. Many findings about the rain harvesting and storage systems in communities more than 2000 years old have been found.

The Appropriate Technology for Rural Development Research Unit of the Faculty of Engineering has carried out research on building materials suitable for making roofs and other catchments as well as for building storage tanks. These include corrugated roof tiles[13] made of cement and sand reinforced by agro-waste fibres, bamboo for bamboo reinforced concrete or bamboo cement water tanks and bins, a rainwater pond lined with PVC, bamboo concrete, soil cement or brick. Rainfall patterns and distributions are also studied.

The Asian Institute of Technology

An excellent collection of publications on ferro-cement can be found in the AIT Library at Rangsit, 33 km north of Bangkok. Other research includes the stochastic study of rainfall.

Khon Kaen University

The Faculty of Engineering has made some studies of building materials and construction methods for building low cost rainwater storage tanks. Rainwater quality has also been studied.

Development Activities

Ministry of Health

The Engineering Division encourages the building of cylindrical RC rainwater storage tanks cast in sections with slip-forms. A cost as low as 7000 baht for a 25 m^3 capacity tank was reported (see Table 3).

Ministry of Interior

The Accelerated Rural Development Administration[14] encourages rural people to build large water jars.

Office of the Prime Minister

The Rural Work Creation Program[14] (Kor Sor Chor) encourages rural people to build cement water jars and cylindrical RC tanks. Instruction manuals on how to build these rainwater storage systems have been developed and sent to every village council and District Office.

Appropriate Technology Association of Thailand[15]

This group develops and disseminates to the rural areas knowledge on how to build bamboo cement tanks. The disseminating agents include Buddhist monks and novices and village volunteers. Instruction manuals have also been developed and distributed to anyone who wants them.

The Regional Network on Appropriate Technology for Rural Development in SE Asia and the Pacific [16,17]

This group encourages the Research and Development of Rainwater Harvesting and storage systems in countries in SE Asia and the Pacific Region. Dissemination problems are discussed in the Regional Seminars.

International Conference on Rainwater Cistern Systems

An international congregation of experts and researchers on Rainwater Cistern Systems encourages the exchange of information on rainwater harvesting and storing systems among members including those from SE Asia and the Pacific Region. The first conference was held in Honolulu, Hawaii in 1982[18] and the next meeting will be in the Virgin Islands in 1984.

CONCLUSIONS

Rainwater is available in large quantities in Thailand but only during a period of about five months in any one year. The water quality is excellent and meets the drinking standards set by the Thai Government. Effective and proper harvesting systems are needed to keep out pollutants. Storage systems with sufficient capacity to supply at least the minimum household needs during the dry season are also needed. Due to the fact that the income of the rural people in Thailand is low, the system cost must be kept as low as possible, utilizing locally available materials and construction skills as much as possible. A number of technologies concerning rainwater harvesting and storage are already available but R & D on adapting these technologies to fit the local conditions is still needed. Dissemination of appropriate technology to the rural communities is a must if the cost of construction of rainwater harvesting and storing systems is to be kept low. Exchange of information concerning the R & D of rainwater harvesting and storage technologies in the future is a must.

REFERENCES

1. Kijngam, A. "Ban Chieng and New Evidences", Matichon Daily Newspaper, August 29, 1983, Bangkok, Thailand (Thai).

2. Department of Fine Arts, Ministry of Education, "Master Plan of Sukhothai Historical Park" Khoa Panish Press, Bangkok, 1978 (Thai)

3. Prempridi, T. et al "Evolution and Development of Technology" A research report funded by Chulalongkorn University Research Fund, Chulalongkorn University, Bangkok, 1982 (Thai).

4. Project Management Committee, Ministry of Interior, "Provision of Clean Water for Rural Communities in the Kingdom of Thailand", Bangkok, Thailand, 1983 (Thai).

5. Office of the Prime Minister "Direction for the Work Creation Program 1984", A letter from the Secretary of the Council of Ministers, October 7, 1983, Bangkok, Thailand (Thai).

6. Prempridi, T. and Chututhasry, C. "Sources of Water in Rural Thailand", a paper presented at Regional Seminar on Rural Water Supply and Sanitation for Developing Countries, Chulalongkorn University, 18-25 July 1983, Bangkok, Thailand.

7. Prempridi, T., Lertanasinchai, V. and Petchpaibool, P. "Rainwater Pond Lined with PVC" UNESCO sponsored student senior project, Faculty of Engineering, Chulalongkorn University, Bangkok, October 1983 (Thai).

8. Read R., "Small Water Sources" a paper presented at the Regional Seminar on Rural Water Supply and Sanitation for Developing Countries 18-25 July 1983, Chulalongkorn University, Bangkok, Thailand.

9. Keller K., "Rainwater Harvesting for Domestic Water Supply in Developing Country", A Literature Review, WASH C-252 presented at an International Conference on Rain Water Cistern System University of Hawaii 1982.

10. Watt. S., "Rain Water Storage Tanks in Thailand" Appropriate Technology, Vol. 5, No. 2, August, London, 1978.

11. Watanarunwongs, B., Harnwiwatwongs, C. and Tantijarukorn, T. "Low-Cost Water Storage Tank " Report submitted to Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, October 1983 (Thai).

12. Bunyaratpan, V. and Sinsupan, S. "Rain Water Quality From Roof Catchment and Storage" a paper presented at the Regional Seminar on Rural Water Supply and Sanitation for Developing Countries 18-25 July 1983, Chulalongkorn University, Bangkok, Thailand.

13. Thammongkol, W. "Corrugated Cement Roofing Tile Reinforced with Jute Fibres" A report submitted to the Department of Civil Engineering, Chulalongkorn University, April 1983 (Thai).

14. Leepatanapan, P. "Sources of Water" A paper presented at the Regional Seminar on Rural Water Supply and Sanitation for Developing Countries, 18-25 July 1983, Chulalongkorn University, Bangkok, Thailand

15. Appropriate Technology Association "Bamboo Cement Tank Instruction Manual", ATA, Sub Road, Off Siphya Rd., Bangkok, Thailand (Thai).

16. Regional Network on Appropriate Technology for Rural Development "Proceedings of Seminar on Water Technology towards Rural Development", Universiti Pertanian, Serdang, Malaysia, 1982.

17. Regional Network on Appropriate Technology for Rural Development "Proceedings of Regional Seminar on Dissemination of Technology to Rural Communities" Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand, 1982.

18. International Conference on Rain Water Cistern Systems, Proceedings on 1st International Conference on Rain water Cistern System" Y.S. Fok, General Chairman, University of Hawaii, Honolulu, Hawaii, 1982.

DIAN DESA'S RAINWATER CATCHMENT PROGRAM - ITS IMPLEMENTATION AND DEVELOPMENT

Christina Aristanti
Yayasan Dian Desa
Indonesia

INTRODUCTION

Indonesia, as one of the developing countries, has made considerable progress in this past decade. Yet, in rural areas, millions of families still suffer from a perennial scarcity of clean drinking water. Moreover, other factors such as deforestation, pollution and extreme population pressures have added to the seriousness of Indonesia's water supply problem.

It should be no surprise that water, the most basic of human needs, has become a primary concern of villagers and of government and non-government groups active in village development work. The Indonesian government alone spends a considerable portion of its development money on this area.

Yayasan Dian Desa, an NGO, describes itself as an Appropriate Technology Group. Since its inception, it has attempted to design water supply systems which utilize simple, low cost technologies which to a large extent depend on local skills and resources, and on the active participation of local community members at all stages of work.

After several years of working on village water supplies with different systems such as gravity feed, hydraulic rams, etc., Dian Desa was struck by the fact that all of those systems were not applicable to certain areas where basic water resources did not exist.

Gunung Kidul, a dry range of mountains southeast of Yogyakarta, is a very critical area. The land is largely deforested, good soil is extremely scarce and groundwater virtually non-existent (porous limestone covers most of the region to a considerable depth).

Various water supply technologies have been tried out in the area, but were not successful. Deep wells were only possible in certain areas and during the dry season these wells did not function as they ran dry. Artesian wells might be possible, but for villagers the technology is too sophisticated and in terms of cost it is far beyond their reach.

Rainwater has traditionally been the main source of water for the people in Gunung Kidul. During the rainy season, they usually catch water from the roof in big jars and which are kept near their kitchen. Richer families built underground storage tanks made of local material (called "keprus", lythographic limestone) and cement.

Local people who do not own jars or tanks take their water from drainage ponds which fill with rainwater during the rainy season. For this purpose, they often have to walk distances ranging from 2 to 7 kilometres. And yet, their efforts seem to be futile as the quality of the water they get is questionable.

During the dry season (which often lasts as long as six months or more) water becomes as scarce as money in most of Gunung Kidul area because most of the ponds and other water sources eventually go dry. The distance covered to get water becomes greater and greater. Very often, villagers have to walk up to 20 kilometres to fetch their usual load of 36 litres.

Compared to other water supply technologies, rainwater catchment seems to be the most appropriate for such areas for the following reasons:

* Local people are familiar with the use of rainwater for their household needs such as drinking, cooking, etc.

* Catching rainwater has been traditionally practised.

The next question is what type of construction would be best. This is the one thing that has become the concern of many organizations, government or individuals working on this matter, and is one of the reasons why this workshop was held.

RAINWATER CATCHMENT IN INDONESIA

Prior to 1975 there had been no water development efforts in Gunung Kidul, that is, until the suffering was so great that the government began to notice the problem.

In 1976, the Government of Indonesia began to help the people in Gunung Kidul to overcome their problems of water scarcity by building some rainwater tanks using bricks, one or two being provided for each village. Due to their bureaucratic constraints, however, they entrusted the construction of the tanks to contractors. And, in order to make the most profit, the contractors built the tanks carelessly. It is not difficult, therefore, to imagine the state of the tanks. This was shown by the fact that within several days after the tanks were completed, they began to leak. Surprisingly, no one bothered to fix them. So, from all the tanks built by the contractors, only about 10% were useable.

Looking at this unfortunate waste of scarce resources, Dian Desa was interested in finding a better way to help the people in Gunung Kidul overcome the problems of water scarcity. There were several lessons that Dian Desa learned from the projects, namely,

* It is not possible to have a development program, especially on the village level, run on a remote control basis.

* If improvements are given as a gift without any effort or participation from the local community, there is a lack of a sense of ownership with regard to the project. This results in poor maintenance.

* As they are communal tanks, no one feels responsible for either their maintenance or the proper use of water (if there is any) in them.

It is in this context that Dian Desa began to enter the Gunung Kidul area with the following basic principles, namely:

* The project must be implemented such that local community members fully participate in all stages of work. In this manner, technical skills as well as confidence and self-esteem will be developed.

* Local lifestyle and traditions must be considered in planning all tank locations.

* Project work schedules must be matched to local time constraints.

* The transfer of technical skills and maintenance know-how must be considered a primary goal of the project.

* Local opinion regarding water consumption and water use patterns must always be taken into consideration.

So, in 1977 Dian Desa began to work in the Gunung Kidul area and together with the local community they developed rainwater tanks using the local material 'keprus' (lythographic limestone) which is abundantly available in the area. Actually this type of construction had previously been practised by the local people. All Dian Desa tried to do was to improve the quality of the tanks and to pay more attention to sanitation aspects, such as by building them above ground (traditionally they were built underground). Dian Desa made three construction designs, namely: type I, a 9 m^3 tank; type II, a 9 m^3 tank with a higher inlet; and type III, a 6.75 m^3 tank.

The materials used in this construction are 'keprus' (which is used instead of sand which is not available in the area), stone, portland cement, and other accessories such as corrugated roofing (for covering the tank), taps, pipes, etc.

During the construction of the tanks, local people participated fully either in collecting and transporting to the site local material such as 'keprus', stone, etc. They also provided labour. So, the only assistance from Dian Desa was the supply of portland cement and skilled labour.

This rainwater tank construction programme seemed to be quite appropriate for helping local people in overcoming their suffering from water scarcity during the dry season. The amount of water in type I and type II tanks (when used by a family of 5 members) could last up to four months with a consumption of 15 litres per day per person. But the water in the smaller type III tank would only last up to 3 months, provided in all cases the water in the tank was properly used.

However, this construction still had some weaknesses, especially concerning the use of 'keprus'. The 'keprus' used had to be a certain quality to make a good quality tank. It was difficult for villagers to do testing and so, sometimes the 'keprus' used was not good enough.

Dian Desa, therefore, was not satisfied by what had been achieved, and continued to look for better ways to lessen the burden of the people.

FERROCEMENT RAINWATER CATCHMENT

At the beginning of 1978, Dian Desa heard about a so-called new technology, ferrocement - a construction technique consisting of a reinforced framework of iron rods (rebar) and chicken wire plastered internally and externally with a thin layer of portland cement. Ferrocement has for years been successfully used for boats, walls and roofs. But, Dian Desa's goal for ferrocement was to design a ferrocement tank which could be used for rainwater catchment in areas where rain represents the only feasible exploitable water resource.

After a number of isolated experiments, Dian Desa finalized a preliminary design for a 9 m^3 tank to be introduced to the Gunung Kidul area. This 9 m^3 ferrocement tank was considered to have great potential for the following reasons:

* The construction process was such that it could be easily mastered by villagers in spite of their limited technical know-how.

* The cost of the tank was considerably below other alternatives (masonry, steel, fibreglass, concrete, etc.) and, because of the reduced thickness, was even cheaper than the 'keprus' construction as less portland cement is needed.

* Its small size is felt to be much more appropriate than the larger communal tank, especially in terms of maintenance because it would be owned by a small number of people.

Accordingly, in 1978 Dian Desa conducted another water catchment project in villages throughout Gunung Kidul using the ferrocement tank design, and soon the number of ferrocement tanks increased.

Yet, considering the economic condition and standard of living of a typical Indonesian village family, it is easy to understand the financial problems posed by the ferrocement tank technology. While ferrocement is certainly less expensive than many other types of tanks, its cost is still beyond the means of most of the villagers except the few wealthy ones. In short, an individual farmer/villager would be hard pressed to purchase on his own, the materials needed for a ferrocement tank. This fact alone greatly limited the extent to which the tanks could ever be financed and built by the villagers themselves without the assistance of Dian Desa or any other outside agency. Thus, the extent to which the tanks would be spread with purely local initiative was limited and several of Dian Desa's own principles were therefore not being met in the project: the technology was not easily reproducible without outside assistance (given its prohibitively expensive cost) and; as virtually all raw materials had to be purchased outside the village, villagers were forced into an undesirable dependency on imported goods.

Considering the above constraints, Dian Desa kept on looking for other alternative materials for tank construction to meet the primary goals. Later Dian Desa came out with a new catchment construction - the bamboo-reinforced cement rainwater tank.

BAMBOO-CEMENT RAINWATER TANK

Adopting a careful approach towards villagers and by actually living with them, Dian Desa has proven that when a proper atmosphere is created, villagers are creative people with innovative ideas.

In 1979, an idea came from the villagers that somehow the ferrocement frame in many ways resembled their "cassava" storage bin, except of course that it was made of woven bamboo. This idea prompted Dian Desa to experiment and look into the possibility of using bamboo as reinforcement instead of iron rod and chicken wire mesh.

Careful experiments and tests progressed swiftly with trial tanks of various shapes and sizes. Finally, Dian Desa came out with a standard round, 4.5 m^3 family size tank. Since its introduction, Dian Desa's field staff have witnessed the spread of the technology beyond their own project area. This is due to several reasons such as,

* Many villagers in Gunung Kidul were already adept weavers of bamboo (as it is one of their traditional skills) and thus they quickly mastered the frame construction technique.

* Bamboo can be found locally and is inexpensive, so the overall cost was quite acceptable to many farmers.

Since then, the ferro and bamboo-cement rainwater tanks have been developing side by side. It should be noted, however, that though bamboo-cement is more acceptable to villagers, ferrocement is stronger and more durable.

IMPLEMENTATION AND DISSEMINATION

In general, Dian Desa has always practised the same approach in implementing a project. Instead of just 'dropping' a foreign piece of technology into a village setting, and then going its own way, Dian Desa takes a more careful and sympathetic approach to the villagers. For this purpose, Dian Desa's field workers live in the village for some time before any construction work takes place. Through surveys and discussions with the local people, they attempt to determine the types of technological changes that are feasible and appropriate for each particular village. In this manner Dian Desa's hope is to achieve a state of 'village development' which definitely will be more meaningful and lasting than a mere piece of equipment or facility. The same approach is also practised with regard to the rainwater catchment program.

During the preparation stage, Dian Desa's strategy is to work through key local individuals. The most important is the 'lurah' (village head), the most influential person within a village setting as well as a government official. At this stage in the rainwater catchment program, Dian Desa carefully chooses recipients of the tanks. The general criterion to be a recipient is that he should be the poorest in the region.

The implementation itself went through the following steps:

* At the very beginning, Dian Desa simply asked the recipients to participate in the construction of their tanks. Having the recipients themselves construct their own tanks was a means to encourage a sense of belonging and to restore their self-confidence in being able to help themselves with the least

help of outsiders. Dian Desa's field workers then trained and guided them on how to construct the tanks using the new construction material, i.e. ferrocement.

Working and living with the villagers, Dian Desa's field staff easily identified potential cadres (contact workers) who, after a little more thorough training, were taken on as Dian Desa's local cadres.

* For the construction of subsequent tanks, it was these cadres under supervision of one of Dian Desa's field staff who trained the next recipients in construction of the tanks. From the new recipients, those with good potential were also taken on as cadres. This process went on until there were about 300 cadres in the particular area.

* From the experience gained from this project, Dian Desa noticed a high level of communication among the villagers. As a result, the training and the mastering of the technology was faster than expected. Dian Desa utilized this strategy in a follow-up project by trying to define a new concept of "South-South technology transfer". Villagers were taken to other regions and even other islands to transfer the ferrocement or bamboo-cement rainwater catchment construction technology to the local people and even train the local people to become local cadres. For example, when Dian Desa conducted a ferrocement rainwater catchment project in Madura, the cadres from Gunung Kidul were transported to the construction site accompanied by one of Dian Desa's field staff to advise them whenever needed. The result was even better than expected.

Today, Dian Desa encourages this concept of "South-South technology transfer", not only for rainwater tank construction but other projects as well.

This ability of Dian Desa's trained cadres to, in turn, train other cadres is but another indication of the benefits of following a participatory approach in such development efforts.

FINANCING SCHEME

Considering the economic condition of the villagers who really need assistance, it is unlikely that a credit system for financing rainwater catchment systems can be established. However it does not mean that local people can not financially participate in the tank construction at all, for if their labour is valued then it is indeed a financial contribution.

A unique financing scheme, however, has been developed by Dian Desa to encourage dissemination of this technology without depending on outside funding. Dian Desa lends two she-goats to a family which needs a tank, under a 'gaduh' or equal sharing system between the owner and the borrower. If the two she-goats then bear (usually) four kids, two will be given back to the owners (in this case Dian Desa) and the other two will be kept by the borrower. The latter then takes care of the two kids until they are big enough to be sold. This money is used to build the rainwater tank. The two she-goats will then be loaned to another family and so on. However, if the family still wants to keep the goats, it is allowed to keep them until they bear more kids but it will continue to be under the same system. This means that the family will then own a rainwater tank as well as goats. This system, though it takes time, is progressing very well.

As we all realize, people have different interests and habits especially if they are from different regions with different traditions. Based on this fact, Dian Desa again developed a financing scheme for the encouragement of the dissemination of information on rainwater tanks. Dian Desa realized that there should be a way by which everyone who needs a rainwater tank could get one. But at the same time, Dian Desa also realized that it will not be possible for it to get funds to give everyone a tank. So the following system was tried out and it was quite successful. Assume that in one region or a village there are about 100 families who need rainwater tanks, but Dian Desa can only manage to get funds for 25 tanks. So, it means that each group of four families could get only one rainwater tank. The agreement made with the families is that on every harvest, the four of them have to use a share of their harvest to build a rainwater tank until each of the four families gets a tank.

PROBLEMS

Dian Desa's rainwater catchment program has been widely considered as a great success in overcoming the perennial water scarcity problems in areas where rainwater seems to be the only feasible water resource. How far Dian Desa deserves this praise can be assessed by determining how much the tanks have really served as a means of overcoming the dry-season water scarcity problems.

Ironically, when Dian Desa's social section conducted a study to determine to what extent the new tanks were indeed successful in addressing the problem of dry season water scarcity, their findings showed that 'misuse' or 'improper use' of the tanks was rampant, and that to a large extent the tanks were not yet achieving their intended effect on the local water situation. The tanks were most useful in the rainy season, as at such a time, they were a convenient source of good, clean water. Actually this is just the secondary goal to be achieved. In reality, many tanks were left empty during the dry season. Apparently quite a few tank owners were exhausting their convenient supply of tank water in the transition period between the rainy and dry season. The tanks would then remain empty throughout the critical period of water scarcity.

A problem concerning the management of the use of water in the tank was also identified. This is the extravagance in the use of water when there is still a lot of water in the tank, and also the indiscriminate use of the clean water in the tank for 'non-essential' tasks such as personal bathing and watering livestock.

Some problems with regard to sanitation also occurred in Gunung Kidul concerning the local people's affinity for muddy water which resulted in some tank owners dumping buckets of mud into their tanks of clean rainwater.

Another factor had a totally adverse effect on the existing water resources. The new local practice of filling the rainwater tanks with pond water was increasing the overall consumption of water in Gunung Kidul and was thus causing drainage ponds to dry up even faster than before. This practice has caused additional hardship for those families who do not yet own tanks.

So, on the whole, Dian Desa's programme does not deserve to be called a complete success as yet, though in some other areas where these problems do not exist, the program is very successful.

The time is ripe for Dian Desa to develop a new program in some areas to improve and expand the education of the villagers. The goal would be that tank recipients become more careful and conscientious in the use of their emergency water supply as well as becoming better managers of existing water resources.

IMPACT

In the case of the ferro- and bamboo-cement rainwater catchment programs, the biggest impact is that the tank design and project approach have been followed by supra-village agencies and organizations such as UNICEF, The World Bank, Bangdes (The Government Bureau for Village Development), and the Indonesian Department of Health. Literally, thousands of Dian Desa's style of tanks have been constructed by the above agencies in project sites throughout Indonesia.

This, however, does not mean that no problems occurred, because while the government and aid agencies have been very enthusiastic in the adoption and promotion of ferro and bamboo-cement technologies, they sometimes did not follow the same 'careful and sympathetic approach' which is actually the key to a successful program.

At the village level, Dian Desa's tank project has provided Indonesian villagers with an opportunity to participate in solving one of their own local problems. And, once they are exposed to such a participatory process, they are more likely to remain active in the village decision-making process and thus contribute more fully towards their village's development. Evidence has showed that follow-up activities run smoother in projects where initial work was conducted on a participatory basis.

In spite of the positive impacts of the program, the goals of the program have not been fully met in all areas and especially in the Gunung Kidul area. Dian Desa realizes that this will not be achieved until more attention is paid to the non-technical and educational problems the catchment tank technology has uncovered.

AN OPERATION AND MAINTENANCE SYSTEM FOR RAINWATER COLLECTORS

(As practised by the people of Krangkeng, West Java)

Hari Siswoyo Aji
West Java Rural Water Supply
Project 0-9 (a)
P.O. Box 59
Bandung, Indonesia

INTRODUCTION

Since 1979, in the district of Indramayu in West Java, a total of 300 Rain Water Collectors (RWC) have been built by West Java Rural Water Supply Project 0-9 (a) to provide drinking water for about 6000 people. These were of the family type (with a volume of 2½ m^3 serving a family of 5) and the collective type (for 5 people/family or more with volumes of 5, 10 and 65 m^3).

The system of operation and maintenance (O&M) of the above mentioned RWCs was explained to the users by means of formal and informal leaders of the community. Each user of a RWC was entitled to 0.5 m^3 to be used, to provide water for drinking and cooking purposes during the dry season, estimated on the average to last about 100 days. The collector was to be cleaned yearly at the beginning of the rainy season and be repaired by the people themselves when part(s) of it broke down.

All this, including the information on how to repair a RWC was given to them following three different approaches which complemented each other:

1. by a mass campaign in village meetings

2. by contacting small and special groups i.e. housewives and religious communities and

3. by personally approaching village officials.

The above O&M system is the theory but in the field, implementation of these arrangements needs to be adapted before they are absorbed and become part of the routine of daily life.

By October 1983, the people had been left to manage their O&M system on their own for nearly 4 years. As there was no feedback, it could be presumed that the system was somehow operative and various problems had been solved by their own efforts in conformity with their limited skills and abilities. In other words, their O&M system had reached a stable state.

Whether this was the case, we did not know for certain. The lack of feedback already mentioned made us think of doing a survey in search of the information we felt was needed for future policies. However, as

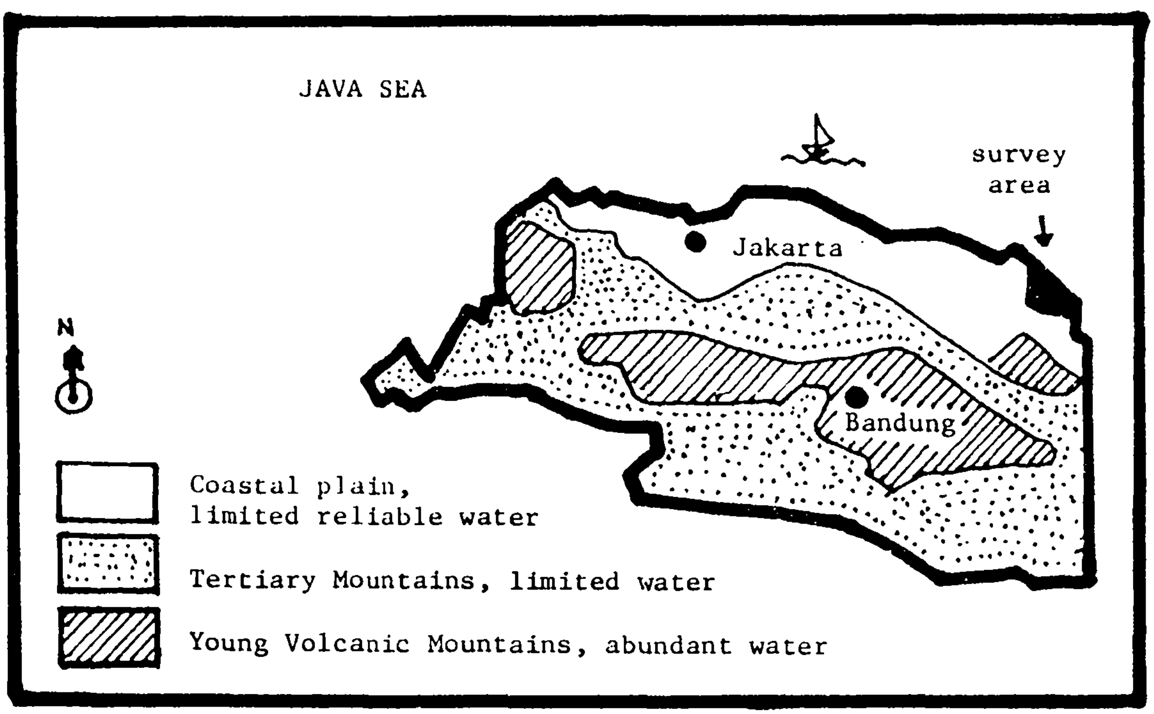


Figure 1. Survey area in sub-district of Krangkeng, district of Indramayu, West Java

surveys are expensive it was decided to do some preliminary work i.e. an exploratory survey.

This exploratory survey was done in the sub-district of Krangkeng where all of the 300 RWCs were built, during the 3rd week of October 1983 which included the end of the dry season (see Figure 1).

The survey and its results are presented in brief in this paper.

EXECUTION OF THE SURVEY

The survey was executed during the 3rd week of October 1983, and involved 100 RWCs and their users consisting of 240 families living in 3 villages in the sub-district, viz. the villages of Tanjakan, Luwunggesik and Singakerta (see Table 1).

The aim of the survey was to explore:

a. The use of rainwater and RWCs during the dry and rainy seasons in the 4 years of their existence

b. The use of other water sources for daily consumption

c. Operation and maintenance of RWCs with respect to cleaning and repairs.

The 100 RWCs surveyed were of various types with respect to the materials used in the building, viz.:

1. reinforced concrete (Figure 5)
2. ferrocement (Figure 2)
3. bamboocement (Figure 6)
4. brick (Figure 3 & 4)
5. clayring (Figure 7)

TABLE 1. NUMBERS OF RESPONDENTS AND RWCs SURVEYED.

	Respondents family user	Rain Water Collectors								
		10 m^3 reinf concr	10 m^3 ferro cemt	10 m^3 brick work	5 m^3 bambo cemt	2½ m^3 ferro cemt	2½ m^3 bambo cemt	2½ m^3 brick work	2½ m^3 clay ring	TOTAL
Tanjakan	83	23	-	-	-	-	-	-	-	23
Luwunggesik	81	24	-	-	-	-	-	-	-	24
Singakerta	76	-	16	3	8	12	7	6	1	53
Total	240	47	16	3	8	12	7	6	1	100

Those in the first group were built in Tanjakan and Luwunggesik in 1979 while the others were built in Singakerta as a Pilot Project during 1979-1980. The report on the Singakerta Pilot Project has been presented at the International Conference of Rainwater Cistern Systems in Hawaii, June 1982.

Figure 2. RWC of ferrocement volume 10 m^3 for 20 people to withdraw rainwater from the tank, a tap is installed in the bottom of the tank

Figure 3. Brickwork RWC volume 10 m^3 for 20 people, with a tap

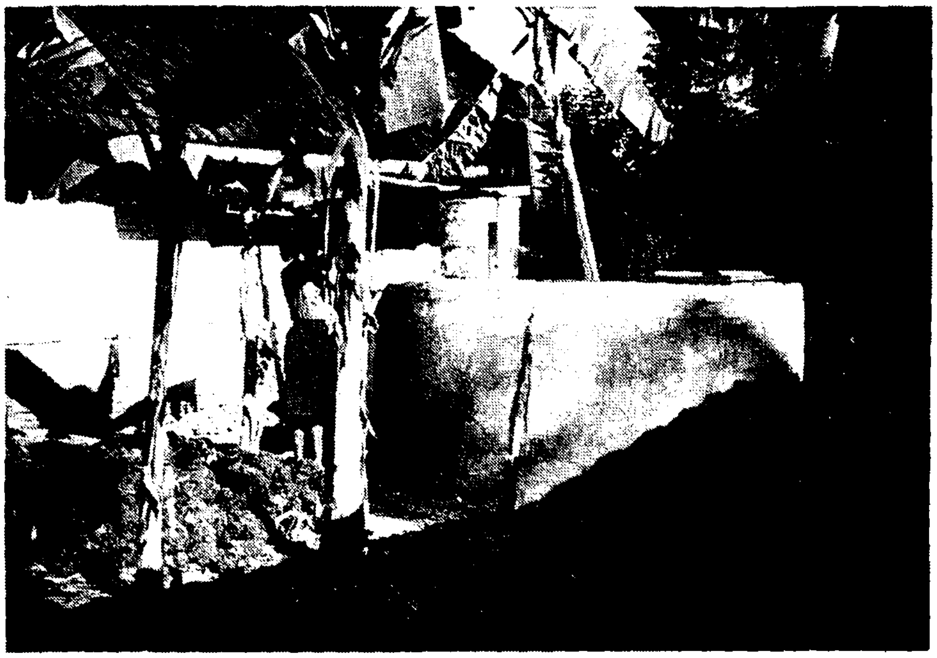


Figure 4. Brickwork RWC volume 10 m^3. With PVC Handpump (handmade) to withdraw rainwater from the tank

Figure 5 Reinforced concrete RWC volume 10 m^3 in desa Tanjakan. With handpump made in Central Java

Figure 6. Bamboocement RWC volume 2½ m^3

Figure 7. Clayring RWC volume 2½ m^3

RESULTS AND DISCUSSION

Utilization of Rainwater and Rainwater Collectors

To analyze this aspect, we compared the planned O&M system with the system as practised, using 3 variables:

1. ratio of users (actual number of consumers to number of consumers designed for)

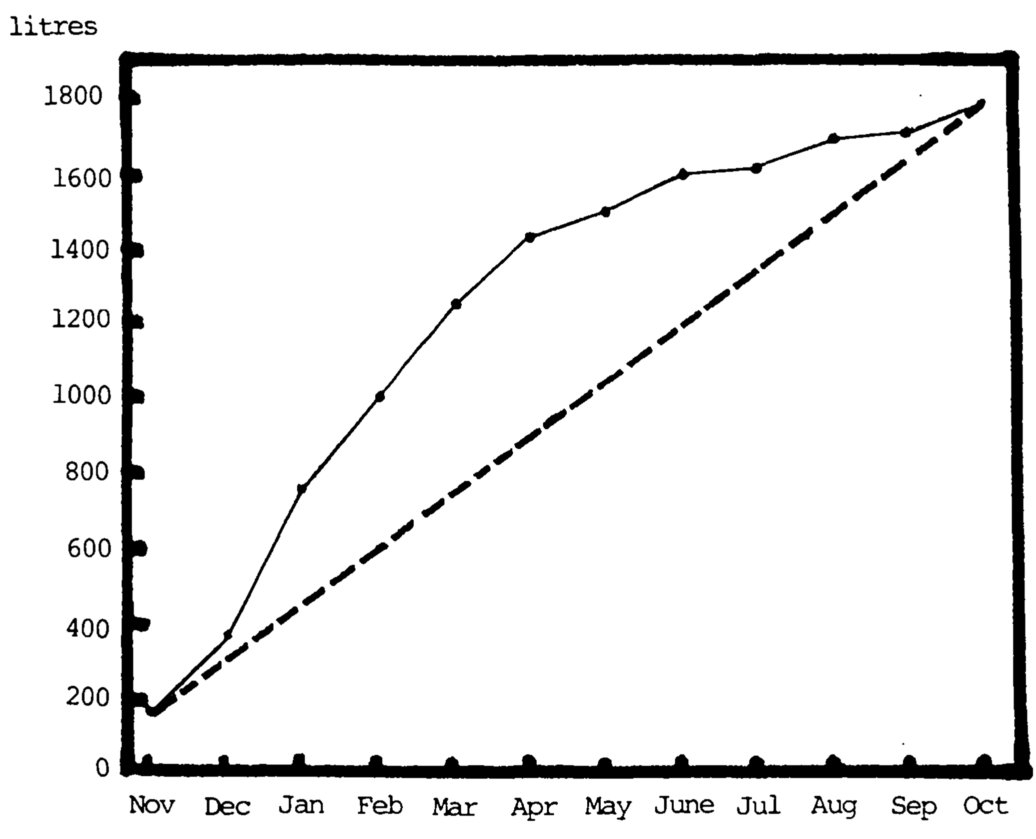


Figure 8. Designed pattern of consumption

—— accumulation of rainwater coming into the collector for 1 person based on rainfall 1200 mm/year, rooftop 3 m^2 per 0.5 m^3 storage and coefficient of run-off 0.54

---- accumulation of rainwater withdrawn from the collector by 1 person with a 5 lcd quota.

2. average volume of rainwater used for drinking and cooking purposes
3. stock of water in the RWC on inspection, which was purposefully done at the end of the dry season.

According to the design of the Department of Health planned O&M system, the tanks provide a daily quota of 5 lcd for 100 days from the beginning of July till the middle of October. Approximately 80 days were left uncovered as the dry season lasts 6 months or 180 days. This period was calculated to be covered by occasional additional rainfall during that period as shown in Figure 8.

Ratio of Users

From the data collected about the 97 functioning RWCs - the 3 others had completely broken down (see later discussion of Repairs) - it was established that the ratio of users during the dry season conformed to the designed number of users (=1), becoming lower in the rainy season (=0.4). See Table 2 below.

TABLE 2. RATIO OF USERS.

	Number of RWCs	Designed Users (People)	Real users		Ratio of users (Real : Designed)	
			dry season (people)	rainy season (people)	dry seson	rainy season
Tanjakan	23	460	510	83	1.1086	0.1804
Luwunggesik	23	460	456	180	0.9913	0.3913
Singakerta	51	560	525	359	0.9375	0.6410
Total	97*	1480	1491	622	1.0074	0.4203

* Excluding 3 collectors completely broken down.

Average Volume of Rainwater Used for Drinking and Cooking Purposes

All respondents stated that they used rainwater from the collector only for drinking and cooking purposes. The amount of rainwater used for those purposes during the dry season, as shown in Table 3 was 4.24 lcd and 3.33 lcd during the rainy season, or in percentages respectively 85% and 67% of the designed standard of 5 lcd.

From the second column in Table 3, it can also be seen that during the rainy season a number of RWCs were not functioning. In Tanjakan only 6 out of 23 RWCs were in use.

Stock of Water in the RWC on Inspection

The survey showed that at the end of the designed period of 100 days, 60% of the RWCs still contained between 1 m^3 and 7 m^3 of water (Figure 9), whereas all of them theoretically should have been empty.

By combining both the findings in the last two sections, and using the findings in the last rainfall period (November 1982 - October 1983: Table 4), it is certain that their O&M system is also capable of facing the worst situation as is shown in Figure 10.

TABLE 3. THE USER OF RAINWATER AND RWCs ACCORDING TO SEASON.

	Total RWCs used by Consumers		Total Consumers (families)		Total Consumers (people)		Average rain-water used by consumers, lcd	
	dry season	rainy season	dry season	rainy season	dry season	rainy season	dry season	rainy season
Tanjakan	23	6	83	12	510	83	4.37	2.05
Luwunggesik	23	12	81	27	456	180	4.48	3.95
Singakerta	51	35	76	51	525	359	3.87	3.99
Total	97	53	240	90	1491	622	4.24	3.33

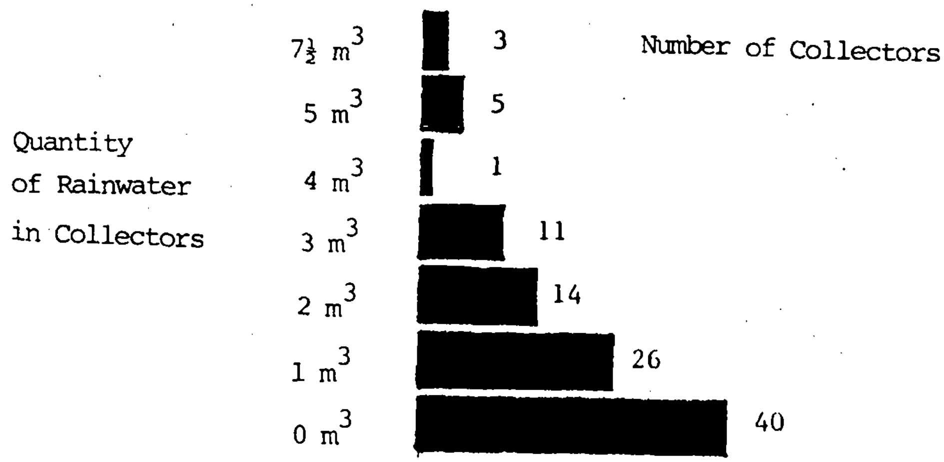


Figure 9. Stock of Rainwater in the collector on inspection (3rd week of October, 1983)

TABLE 4. RAINFALL IN SURVEY AREA (mm).

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
'72-'82	101	133	262	173	164	116	61	55	15	49	20	51	1200
'82-'83	28	126	196	193	116	74	288	25	39	15	-	24	1124

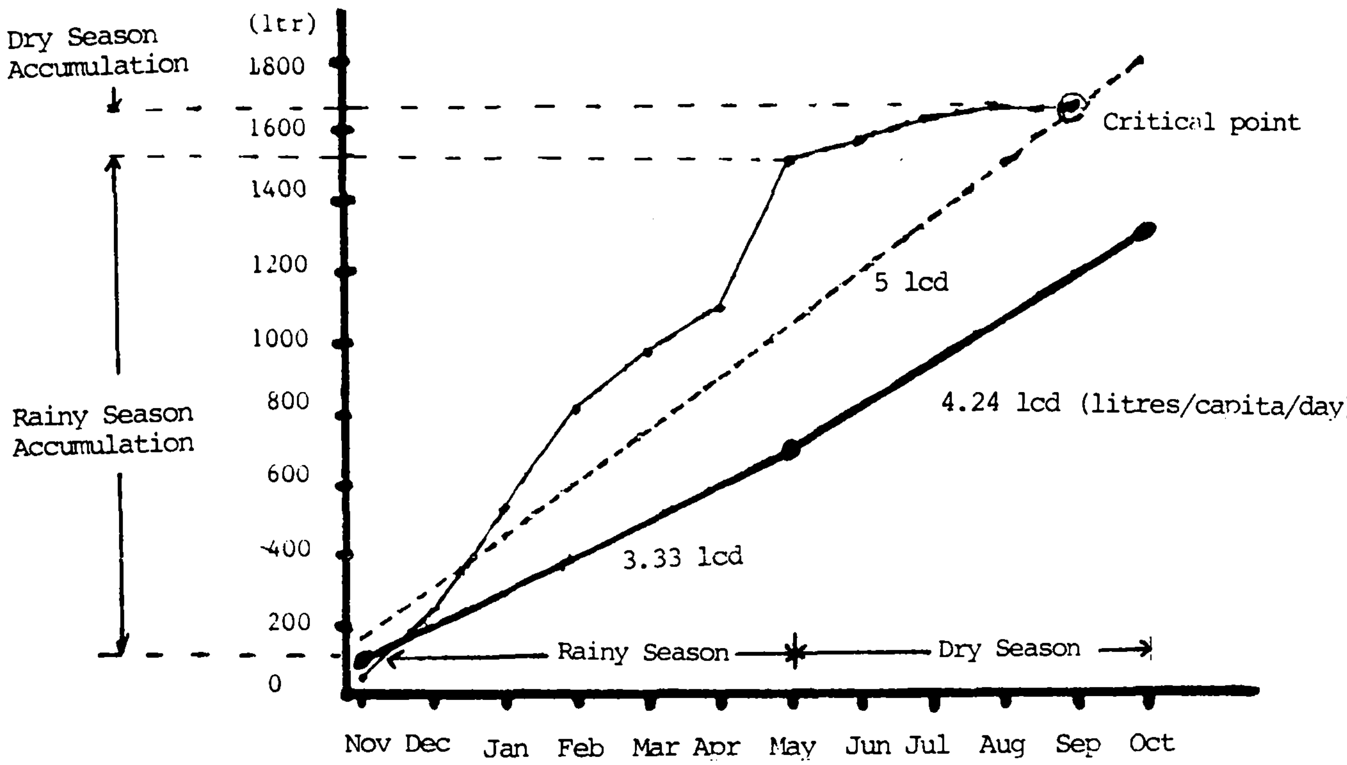
Summary of the Findings

1. The pattern of consumption conforms with the designed operation of the system i.e. utilization of the quota of 0.5 m^3 RWC space per person during the dry season with an average of 4.24 lcd for drinking and cooking only during the service period of 100 days.

2. All 97 functioning RWCs are effectively used during the dry season. As stated by the respondents themselves, this was due to the fact that no other source of water was available on the premises.

3. Consumption of RWC water supplies during the rainy season dropped to 3.33 lcd and with a user ratio of 0.4. A reasonable guess at the reason for this is that during the rainy season

Figure 10. Pattern of consumption practised by the people during the last period (Nov 82 - Oct 83)



-.- accumulation of rainwater coming in the collector for 1 person based on rainfall Nov 82 - Dec 83 with rooftop 3 m^2 per 0.5 m^3 space of RWC and runoff coefficient 0.54

--- accumulation of rainwater if it is withdrawn from collector by 1 person with quota 5 lcd. Note there would be a critical point in September 83

—— accumulation of rainwater withdrawn from the collector by 1 person with quota 3.33 lcd during the rainy season and 4.24 in the dry season. Note the amount of water remaining in the collector at the end of the dry season of 1983.

rainwater is directly collected from the houseroofs. This practice would suit the people well as the collective type of RWC may be quite a distance away from some houses.

Other Water Sources for Daily Consumption

Rainwater is used exclusively for drinking and cooking. For other household purposes i.e. bathing & washing, the average need of 47.5 lcd is served by utilizing other sources in the premises such as dugwells, storage ponds, irrigation canals or rivers, although the water quality from these sources is uniformly poor.

The greatest number of the respondents (about 40% for each source, see Table 5) used water from dugwells and storage ponds while 12% used the irrigation canals.

TABLE 5. THE USE OF OTHER WATER SOURCES BY THE PEOPLE.

	Number of families who take water from					
	storage pond	dug well	irrigatn canal	pond and dug well	canal and dug well	Total
Tanjakan	5	57	12	7	-	83
L.gesik	53	16	12	-	-	81
S.kerta	40	22	5	4	5	76
Total	98	95	29	11	7	240
%	40.8	39.6	12	4.6	2.9	100

Maintenance of Main Water Collectors

Cleaning

Of the 97 RWCs in use, 85 (87%) were well-cleaned once a year at the beginning of the rainy season, the 12 others (13%) having never been cleaned. The reasons given for not cleaning their RWCs were:

1. that the RWCs were not yet dirty (7 RWCs)
2. that cleaning was unnecessary and really did not matter (5 RWCs).

These 12 collectors were all of the collective type. However, the practice of cleaning RWCs properly for the greater part of the consumers has taken root.

Repairs

Of the 100 RWCs surveyed, 55 were in prime condition and 45 had suffered damage. Of these, 38 were slightly damaged (ranging from leaking gutters to broken down pumps), 4 were judged to be heavily damaged but still usable (the damage consisting of leaking walls), 3 were out of order due to the leaks in their base.

TABLE 6. CONDITION OF THE RAIN WATER COLLECTORS.

	Total RWC	RWC never been damaged	RWC already damaged	
			small damage	heavy damage
Tanjakan	23	14	8	1
Luwunggesik	24	9	13	2
Singakerta	53	32	17	4
Total	100	55	38	7

Of the 38 slightly damaged but still functioning RWCs, 26 (68%) had been repaired at an average cost of US$2 per RWC, while the remaining 12 (32%) had their repairs postponed due to the lack of funds, but the owners stated their intention to carry out repairs as soon as possible.

Repairing of the 7 heavily damaged RWCs was never undertaken because of the lack of the necessary skills and the high cost involved, estimated at more than US$100 each, which is out of proportion for a water utility built at a cost ranging from US$200 to US$800.

CONCLUSION

It may be concluded that limited skills and funds are the main causes preventing repairs of heavily damaged RWCs, whereas in the case of minor damages, people are eager to repair the RWC as soon as money is available.

As to the operation of the system, its adaptation by the population has practical advantages as was proven during the long drought of 1983 when a greater reserve of water accumulated than was theoretically calculated.

Campaign promoting the Rain Water Collector, a topic conspicuous in the parade by the people from Indramayu and other district held on occasion of the celebration of National Health Day, November 12th 1983 in Bandung, with the slogans :

- The RWC, a reliable watersource for the people of Indramayu
- Through RWC reaching healthy life

RAINWATER UTILIZATION AS APPROPRIATE TECHNOLOGY IN RESETTLEMENT AREA OF CAVITE, PHILIPPINES

Trinidad Cuyegkeng
Director
Community Education Services Development
Philippine Women's University

INTRODUCTION

This paper will give a limited overview of the practice of rainwater catchment in the Philippines. It will also attempt to establish the possibility of harnessing rainwater as an appropriate technology for resettlement families in Cavite.

BACKGROUND

The United Nations Conferences on various aspects of health and the environment in 1976 to 1978 stressed the need for greatly increased efforts to bring safe water and improved sanitation to all people, especially the poor.[1] The "basic needs" approach to development as well as the "improvement of the quality of life" concept of well-being emphasize the importance of water and its interrelatedness to health and livelihood as predominant factors in the socio-economic package of essential goods and services. Environmental degradation and man's abuse will make water more difficult to use in the near future.

In the Philippines, there are two seasons, the wet and the dry. The wet months are from May to December - seven months of continuous rainfall - whereas, the period from January to April is considered the dry season although, with sporadic rains, it is not totally arid.

The sources of water for human consumption and household purposes and for industrial and agricultural use are classified in general as:

1. rainwater
2. surface water, including rivers, lakes, streams and ponds
3. groundwater including springs, lakes, streams and ponds
4. piped water for homes, factories, farms
5. Metropolitan Waterworks and Sewerage System (MWSS)

RAINWATER CATCHMENT PRACTICES

In the rural areas and provinces, utilization of rainwater is still being practised. The reason for this is the traditional concept that rainwater is safer to use for household and human consumption than rivers. A traditional method still in use is rooftop collection by eaves and gutters and conveyance, via bamboo pipes or galvanized iron downspouts to the desired receptacles. Although all receptacles are covered, the type varies according to the region, the needs of the households and their ability to buy the receptacle. There are brick cisterns, huge cemented adobe tanks, large earthern jars, heavy plastic containers and galvanized iron tanks. The size, shape and capacity of water reservoirs vary in relation to the socio-economic status of the household and the needs of the family members. The water receptacles and/or the tanks are usually located at the rear of the house next to the cooking/washing areas. Receptacles may be permanent or movable, situated inside the house proper in the patio, or outside in the yard. Permanent tanks may be elevated or positioned at ground level. A recent improvement is the use of electricity to pump water to the entire house.

HEALTH SAFETY MEASURES

Simple hygiene is observed in the regular cleaning of containers and surrounding areas. Filtration, the most common water treatment method used, is accomplished by attaching filtering cloth or muslin to the container inlet. Chemical treatment is rarely done, although sulfur is used as a disinfectant and larvicide in central provinces. Boiling, sedimentation and decantation with subsequent filtration or chlorination are used by urbanized residents.

The Ministry of Health is responsible for monitoring water safety and community hygiene to control the spread of communicable diseases and safeguard the health of the people. However, in June 1964, the National Pollution Control Commission, under the Ministry of Human Settlements was created with authority to undertake measures on all types of pollution regarded as health hazards. This authority includes water and the atmosphere, inspection of industries/factories and the enforcement of treatment of waste spillage. The degree of pollution in the atmosphere is recorded and made public.

In its broad perspective, the contributing sources for atmospheric pollution range from household units to large manufacturing firms and power generating plants that are badly needed by our thriving and growing economy.

Urbanization and modernization brought about the mushrooming of squatter colonies with no water facilities in Metro Manila. The government instituted a program for relocating and resettling families in specific rural sites and provinces to provide them with better living conditions. Dasmarinas, in Cavite, is the fourth resettlement area opened in 1975.

DASMARINAS, PILOT AREA

Dasmarinas, Cavite, is located 28 kilometres south of Manila along the Tagaytay Road, on about 234 hectares of land. The present total population is roughly 59,000 people (9,000 families) not including the extended families or non-allocatees who add 10% to this. This is the fourth resettlement community started in 1975, in the government's effort to provide a better system of site preparation and site improvement. This system was based on the experience of the three relocation sites undertaken in the past, i.e. Sapang Palay, Carmona and San Pedro. The important factor is the restructuring of government agency objectives to be supportive of the goals of the new society. This is in line with the change of name of the authority from the Presidential Arm for Housing Resettlement Authority (PAHRA) to National Housing Authority (NHA).[2]

UNICORP[3], an NGO (non-governmental organization) from an educational institution, responded to assist with relocation and resettlement. The first Dasmarinas relocatees, numbering 1,360 families, were assisted by UNICORP in 1975 from the first stage of relocation. Assistance continued as they resettled at Area A2, whose population has increased to the present population of 2,000 families. The joint project with the government National Housing Authority is directed towards community upgrading and development of the families in specific areas in order to form a new town - Dasmarinas Bagong Bayan (DBB). UNICORP aims to improve the "quality of life" of the families and the community within the concept of human settlements. Indicators for human well-being are the basic social concerns of the Filipino in our contemporary society. Action research was completed in 1980. A second phase of the research is awaiting adequate funds. UNICORP takes multidisciplinary approaches in integrating the formal and non-formal aspects into a framework plan of programs and services. People's participation to a marked degree in the organization and management of their own community at Area A1 has been documented. The sample population taken from original relocatees expressed "change" because of UNICORP.

WATER SITUATION

In 1975, accessibility to water supply and sanitary measures was adequate and the maintenance of sanitary services was provided for free through a joint monitoring response between UNICORP and Community Women Extension Workers. However, today the massive influx of a large number of families (4,000 families in 1980-1982) into new areas at the same Bagong Bayan has resulted in a water shortage with its concomitant problems in health, hygiene, nutrition, etc. For example, Area A1 (1,370 families in 1978) has 2,000 families (plus 10% non-allocatees and extended households) which amounts to 13,200 people. There are three water reservoirs of 20,000, 40,000 and 60,000 gallons capacity, totalling to 120,000 gallons, that pipe water to 45 public faucets. The 13,200 people use this water for drinking, cooking and household purposes. However, most of the time, the electric pumps that fill the reservoirs are broken down or are shut off for economic reasons because the people do not pay the fixed rate.

The present Community Development Council (CDC)[4] has instituted a payment scheme based on a minimum cost of 25 to 50 centavos per gallon/can of water fetched from the public faucets to compensate for the maintenance of pumps and cost of electricity and sewage. Moreover, the fee deepens the people's sense of responsibility for the common good of this community by instituting control measures to prevent wasteful use of water.

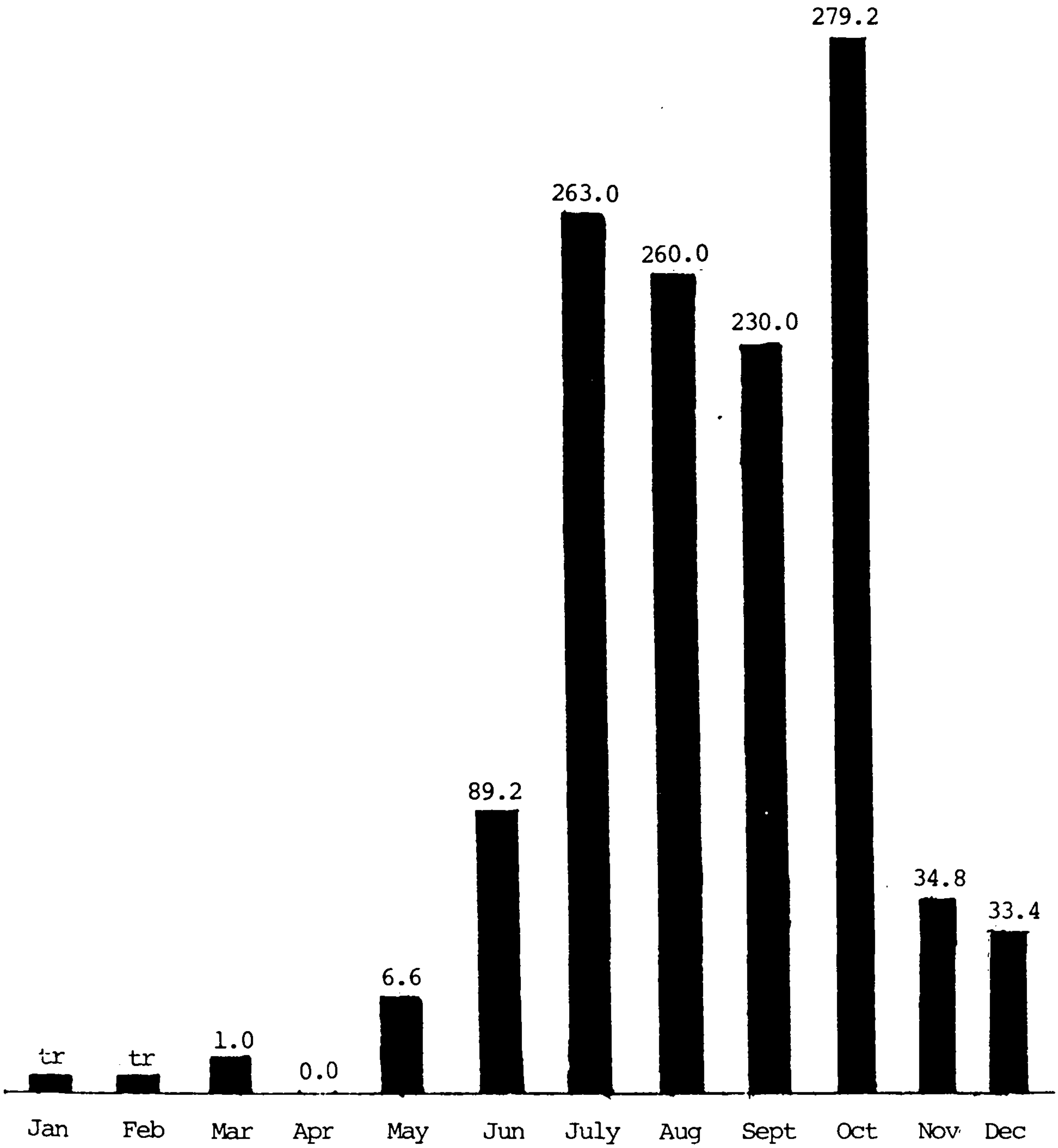
The other source of water is the creek at the boundary of the area. It is about 1 to 2 km distance from Area A1 and Area G. Children and women haul water for household use during dry months, and often times bathe, and do their washing, etc. there. This is done, despite the fact that some areas of the creek are used as a dump for refuse/garbage and are therefore polluted and a source of water-borne communicable diseases. The long walk to fetch water from public faucets or the creek is not only time-consuming but also burdensome for the women. Such time could be utilized in more gainful activities. The worsening water situation is an issue that was brought to the attention of the UNICORP Office by the leaders and extension workers. It seems timely to encourage people to revive rainwater utilization as an appropriate technology source for cleaner water. It is a source of cleaner water that is safer and practically free of charge.

The rainfall pattern for Cavite as observed by PAGASA[5] is recorded as Metro Manila. The rainfalls for 1982 and 1983 are presented in Figures 1 and 2.

HEALTH RELATED PROBLEMS

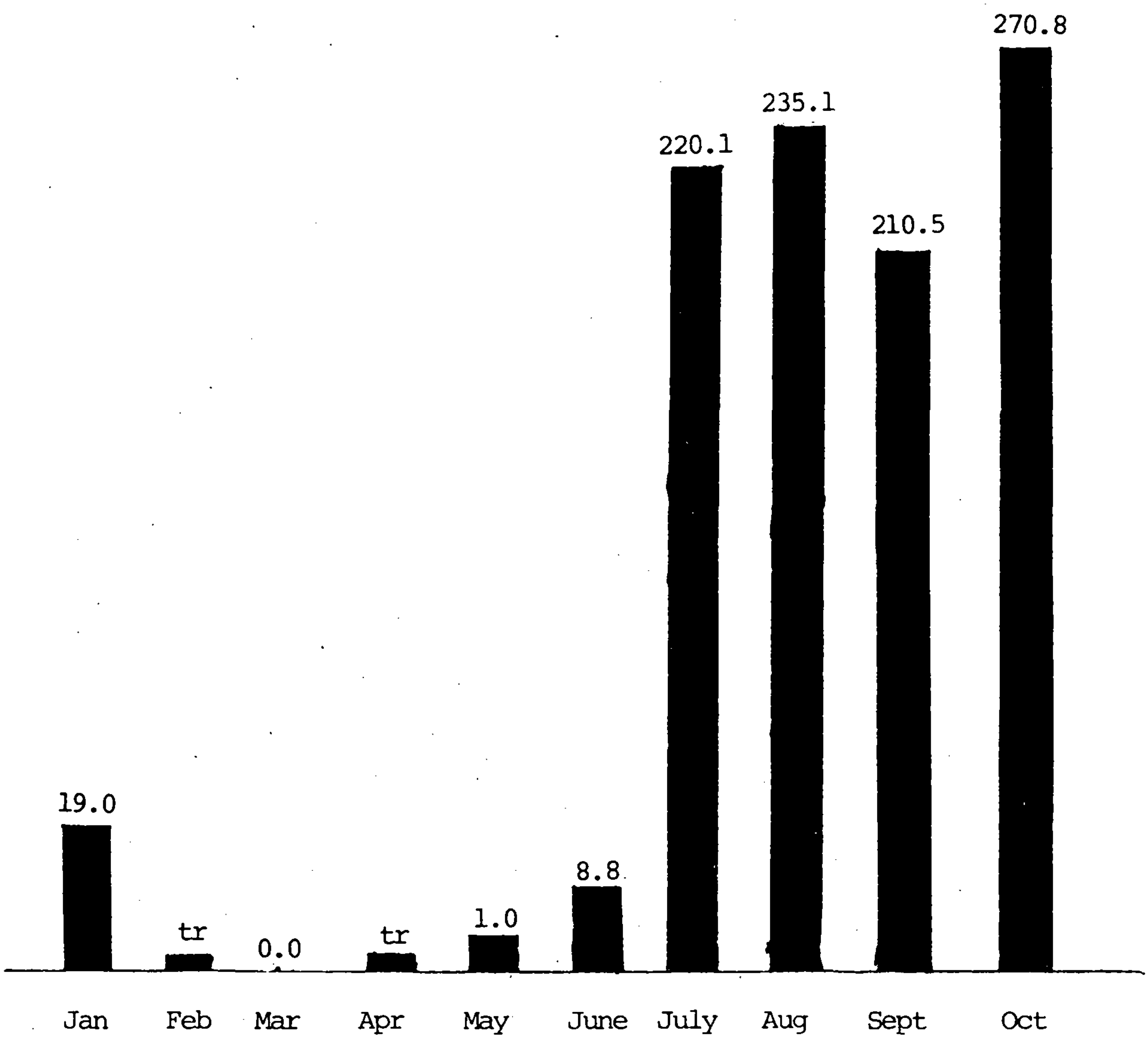
The total population in the whole resettlement town as of 1982 was 9,000 of which 3,800 families of Zoning Areas A and G are designated to be under the UNICORP comprehensive health and nutrition programs. Of the 19,800 persons, 65% are dependent children aged one month to fourteen

Figure 1. Monthly Amount of Rainfall, 1982
(MIA - Pasay City)
(MIA = Manila International Airport)



All amounts in millimetres. tr = trace (less than 1 mm)

Figure 2. Monthly Amount of Rainfall, 1983
(MIA - Pasay City)
(MIA = Manila International Airport)



All amounts in millimetres. tr = trace (less than 1 mm) years. In January 1983, the school health program survey of 2,200 children of ages 3 to 14 years identified the level of health as "below average". From this population, 210 children were given a more comprehensive physical medical examination, and their nutritional level was found to be second degree malnutrition. Sixty percent of the most common sicknesses in the past year were diarrhoea and gastrointestional diseases, while 20% were cough and fever, 15% were parasitism and 5% scabies, skin diseases and others.

During the months of February to March 1983 a team of nutritionists and nurses with Operation Timbang (OPT)[6], undertook a "recall" survey of 150 pre-schoolers who were enrolled in the four child day care feeding centres. The result showed that despite the program of daily food assistance augmented with reconstituted milk (a joint UNICORP - government project), the children were not recovering fast enough and remained with second degree malnutrition. The health protection and medical assistance of nurses took care of the 15 children who were found to have fallen to third degree and were suffering from ill effects such as diarrhoea, debility, etc.

The results of the above two programs were made public to the Community Development Council leaders, the parents, and teachers for them to realize the gravity of children's level of health. The data was used by the school to begin an action plan assisted by UNICORP only. Definitely, it can be said that diseases deplete nutrients and debilitate the children who are "at risk" in the population. Comprehensive health/nutrition education is just as important as safe water. Adequate quantities of water with good sewers and sanitary dispoal measures are vital.

POINTS TO CONSIDER IN RAINWATER UTILIZATION

1. This project for the resettlement town can be within the area of responsibility of UNICORP, specifically related to "new entering families at Area G" under housing assistance, so that some

provision can be made for the rooftop to be used for catchment purposes. The present population is 1,800 families.

2. The entry point for promotion/communication dissemination is a public health/nutrition/ecology program of UNICORP.

3. Communication strategies for development can be undertaken jointly with Community Development Council leaders and community women extension workers. The University Outreach (students/faculties) team's involvement is as *promoters/facilitators* - the software of water technology.

4. National Housing Authority government support has to be forthcoming. In principle, the project manager is willing to know about rainwater utilization and provide knowledge to assist in the hardware of water technology.

5. A community "sensing" baseline socio-economic survey that UNICORP is presently undertaking can include data on what practices the families know from their original province residence, and identify their real need for clean/safe water as one of their priorities.

6. The same model that UNICORP used for Area A1 can be replicated with some improvements.

7. The results of this seminar shall be assessed on their applicability to resettlement acceptability as an appropriate technology.

8. BATEK[7], located 4-5 km or five minutes drive from Area G can set up a laboratory to monitor and evaluate the safety and purity of rainwater and other sources.

SUMMARY AND CONCLUSION

Rainwater utilization has been practised and is still being carried out in the provinces. The same provinces are the origin of the migrant families in depressed urban Metro Manila, who were relocated to Dasmarinas and resettled to organize themselves into a new town. As the need arises, motivation will not be difficult for their acceptance of rainwater. Despite government efforts, the assistance of non-government organizations in problem solving is continually needed to help improve the living conditions of the people and meet the community's basic needs. Inadequate quantity and unsafe quality of water for home consumption threaten 65% of the population and especially the children who are most vulnerable to communicable diseases. Their malnourished condition renders them ready victims of water-borne microorganisms. Even if they are given food assistance and health protection, they still suffer from malnutrition.

Rainwater utilization, when presented as "appropriate technology", will motivate the people to involve themselves in action research in a pilot project in a smaller area of the community to see the appropriateness of this method.

In view of this, UNICORP's programs and services would respond to the very imminent need of the people facing a water crisis, which, in fact, is also a need in other developing countries.

UNICORP's role in providing non-formal education in problem solving strategies in partnership with the leaders and women community extension workers can make this project a reality. The "hardware" and "software" involved, besides the type of water technology utilization, will need the assistance of the experts in this workshop.

In conclusion, therefore, it is a positive hypothesis that rainwater catchment can be utilized for the resettlement towns, Dasmarinas and Bagong Bayan. However, only the analysis by experts and adequate funds can make it possible for action research to be undertaken so as to improve the "quality of life".

FOOTNOTES

1. Metropolitan Waterworks and Sewerage System (MWSS) formerly National Waterworks and Sewerage System (NWSS) is the main water supplier. It utilizes the water from Angat and Ipo rivers and passes it through DICDI Filtration where initial settling takes place. By gravity, water is channelled through various aquaducts. The major portion of it goes to the La Mesa Dam Treatment Plant and the rest to reservoirs like Balara Filters. The pumping station that distributes the piped water is strategically located. Testing treated water for purity is a joint responsibility of the Public Health Officials and the National Commission on Control of Pollution.

2. In the Human Settlements Concept for Housing, the National Housing Authority (NHA) states that housing no longer means only the building of houses and infrastructures and relocation of squatters, but rather the NHA's concern is for the well-being of man in his totality and that of his family, his community of residence and work.

3. "University Community Outreach Program (UNICORP) is one of the most critical SUPPORT departments in the present set-up which was established to provide non-formal education linkage with rural communities, support outreach rural community service programs, retrain rural communities on livelihood generation and social productivity, and extend professional services. Therefore it serves as the venue for exploring and initiating desirable community education linkages with rural communities."

   Vice-President, Dr Amelou B. Reyes, University Programs and Development

4. Community Development Council (CDC) is the smallest unit of the political structure at the resettlement community with 23 to 25 blocks equivalent to Barangay. One block is composed of 20 families.

5. P.A.G.A.S.A. - Philippine Atmospheric Geophysical and Astronomical Services Administration.

6. Operation Timbang (OPT) - the method of evaluating the degree of malnutrition used by the Nutrition Center of the Philippines.

7. BATEK - Barangay Technology.

REFERENCES

1. Journal on Poverty and Basic Needs Published by World Bank, September 1980

2. Journal on Asian Non-Government Organizations' Forum on Water Development, "Clean Drinking Water" A Basic Need, APPROTECH, IDRC and IWATANI NAOJI Foundation, Yogyakarta, Indonesia, September 1983.

3. Cuyegkeng, Trinidad C., Dr. A Model Development Project, The Philippine Educational Forum, Volume 28, Numbers 1,2,3. October 1980 - September 1981, Graduate School of the Philippine Women's University, Manila pp. 29-36.

4. Primer on Pollution, Prepared by Alamin ang Kapaligiran, Special Project 1979, Ministry of Public Information, Manila.

5. Cuyegkeng, Trinidad C., UNICORP: University Community Outreach Program: An agent for Change at A Resettlement Area in Dasmarinas, Cavite. Graduate School of the Philippine Women's University, Manila, Philippines, March 1980.

6. Article on UNICORP: University Community Outreach Program, Compiled by Office of the Vice President, Resources Building & Investment Planning, The Philippine Women's University, January 1982, Metro Manila.

RAINWATER CATCHMENT PROJECT

Francisco Paro, Jr
Office of the Governor
Province of Capiz
Philippines

INTRODUCTION

The venture of Capiz Province in collecting rainwater was initiated in April 1982. The Provincial Leader started the research by borrowing the book entitled "Ferrocement: Applications in Developing Countries". He then called for his Skills Development Technologist and two graduates of the Capiz Mobile Building Construction Course and challenged them to undertake a successful project for experimentation and utilization of it. "If other countries have made and utilized this ferrocement thing, I don't see any reason why we cannot do it here in our province," the Hon. Governor, Cornelio L. Villareal, Jr. remarked.

The Skills Development Technologist studied the book and obtained initial know-how from it. He found out that the project was feasible in terms of availability of raw materials and the felt need of the people.

The experiment was implemented on June 19, 1982. The first targeted project was a 24-square feet fence. Frame making, proper composition and mixing, plastering, and finishing were then undertaken. The first experimental results were satisfying. To make the outside portion of the experimental fence attractive and natural, corrugated G.I. sheet was used as a falsework.

The successful results of the experiment led to the construction of ferrocement grain storages, assorted sizes of rainwater tanks, jars, grotto, and house walling.

RATIONALE

The search for energy generation, preservation, conservation and storage; the salty water supply obtained in the capital of the province especially during summer time; the rising cost of G.I. sheets which are used in making rainwater tanks in the country, the need of the coastal populace for a more durable and economical manner of collecting rainwater; the positive effects of rainwater catchment on the health of the people; the acquisition of indigeneous, innovative and appropriate technology on design, construction, operation and maintenance of rainwater catchment by the rural: all these, among others, constitute the reasons for the commencement of the project.

RELEVANCE IN RELATION TO OTHER FORMS OF WATER CATCHMENT

The advantages of the ferrocement water tanks compared to the other systems cannot be underemphasized. Hereunder is a comparison in table form.

Name of Storage	Availability of Raw Materials	Cost* (50 can capacity)	Durability	Remarks	Technology Requirement
Ferrocement	Readily available	P399.00	Permanent	Water quality good	Expertise not needed
G.I. sheets	Readily available	P300.00	Temporary	Prone to rust; detrimental	Expertise needed
Used tractor tyres	Scarcely available	Not feasible	Temporary	Detrimental	Expertise needed
Clay	Readily available	Not feasible	Highly breakable	Water quality good	Expertise needed

* Conversion rate (1983): $1 US = P10.5

CURRENT AND EMERGING TRENDS

Presently, the provincial government is spearheading the implementation of the project which is situated in Barangay Agkilo, Panitan, Capiz. Water tanks and grain storages with capacities of 19,000, 9,500, 1,900 and 190 liters are now found in the barangays. But due to the financial limitations of the province, the project is incomplete. If funds are available, the Hon. Governor, Cornelio L. Villareal, Jr., has decided to effect technology transfer through the offering of a "Ferrocement Rainwater Catchment Course" in the barangays through the Capiz Mobile School.

PRACTICES

The circular form is the prevalent type. Some are tall, while others are short to suit them to the height of the gutter even though they contain the same volume of water. The materials used are sand, cement, steel bar reinforcement, water, chicken wire, tie wire, bamboo, safety valves and R.C. pipes if needed.

On the implementation aspect, few out-of-school youths, unemployed and underemployed adults have been involved. The clientele are informally organized. They merely come to the center to help when funds are available. This is due to the very limited resources of the province which is the major problem for the projects in operation and maintenance.

It had been conceived and planned that the rural populace would be trained and educated to operate and maintain rainwater tanks through offering a course on this subject matter but efforts were in vain due to a lack or absence of funds.

Water quality poses another major problem especially in the rural areas of the 472 barangays, where only 28 hand artesian wells and some level two water supplies and hand pumps were put in. So, the source of drinking water in general is the open well. People dig wells on the edge of rice fields during rainy days, and during dry season, they dig wells in the rice fields or the dry portion of the river. In the city, the main source of water supply is Roxas City District Waterworks. During heavy rainfall the water that comes out of the pipes is polluted with mud and during the dry season by salt water from the sea. During the peak dry season, this water system is incapable of supplying water. So, the people resort to the use of open wells.

As to water storage in the barangays, the most commonly used method is the kerosene can plastic container. Bamboo tubes, rubber jars, etc. are likewise utilized. These crude and primitive ways of water storage are a health hazard since family members, more particularly the children, simply dip in a cup and more often than not, their dirty hands. Some affluent families use G.I. sheets to make rainwater tanks. This is increased by the high cost of maintenance.

The rainfall pattern of the province is somewhat irregular. The peak month is November with a rainfall of 70 cm, the lowest rainfall is during the month of April and March with 2 cm and 7 cm each respectively. January, February and May have almost the same rainfall of 17 cm. With this distribution of rainfall, there is a necessity for people to store water especially from January to May. Even in the rainy season rainwater, which is the safest source of drinking water, has to be stored so that people's health can be safeguarded.

RESEARCH AND DEVELOPMENT ACTIVITIES

The research project is just 1 year and 4 months old. Research and development work undertaken is herein presented in chronological order as follows:

1. 24 square foot fence
2. Grain storage
3. Assorted sizes of water tanks
4. Assorted sizes of jars

5. Assorted sizes of grotto
6. Bamboo-cement water catchment
7. Bamboo-cement pre-cut house walling

The research activity of the province on rainwater catchment is relatively young. There is a need for continuous research, to eliminate wastage of time, money and effort so that better ferrocement water tanks can be mass produced. If people can be convinced about the innumerable advantages and benefits they will derive from this kind of water supply, they will ultimately be induced to use it. Then their health, and socio-economic status will be greatly enhanced.

Young as the activity under discussion is, there is an urgent need for the furtherance and development of the same. Further studies, observation tours, interaction with people who have sufficient background and experience and expertise, therefore, are of utmost necessity.

Capiz Province has been engaged since 1965 in offering skills courses throughout the province with the barangay as the base. This is implemented through the Capiz Non-Formal Education Program. The Provincial Leadership upholds the effectiveness of the concept of mobility to bring the school to the people. Hence, the Capiz Mobile School, in concept and operation, aims to develop the entire individual aside from the specific course being offered to the out-of-school youth, unemployed and underemployed adults. There are ten courses offered by the school. The eleventh is the "Ferrocement/Bamboo-cement Rainwater Catchment Course". The latter is the most necessary of all the courses offered, especially as the Philippines is beset from time to time by drought. But the course has never been offered due to lack or absence of funds.

RECOMMENDATIONS AND CONCLUSIONS

The offering of Ferrocement/Bamboo-cement Rainwater Catchment Courses is the answer to the problem of rainwater storage. If this can be implemented in the barangays, the health and socio-economic lives of the rural populace will be greatly improved. And if their lives are improved, peace, tranquility and order will reign.

ACKNOWLEDGEMENT

The author would like to take the opportunity, at this point and time, to thank Governor Cornelio L. Villareal, Jr. and Mr Ernesto Garilao of the Philippine Business for Social Progress for the recommendation to attend the workshop. But most of all, I would like to thank the International Development Research Centre for considering me as one of the participants.

RAINWATER CATCHMENT ACTIVITIES AND PROGRAM IN MALAYSIA

Uzir A Malik
Department of Agricultural and Resource Economics
National University of Malaysia

INTRODUCTION

Malaysia is a country with relatively high rainfall, averaging about 2,500 mm per annum. Since a conventional piped system of water supply is largely a twentieth century phenomenon, it can be safely assumed that rainwater has been an important source of supply before that period. In many parts of the country, especially the rural areas, rainwater still assumes an important role. However, it is interesting to note that rainwater has always been only a supplementary source. As such it has never been given much importance and very little has been written about it. One observation made by Hodder (1959) is that rainwater in Peninsular Malaysia was mainly collected in pans, jars and tubs and that as a source of water supply it was rather uncommon.

Although rainwater is regarded as an unconventional source of water supply, its importance is recognised by the relevant authority namely, the Environmental Health and Engineering Unit (EHEU) of the Ministry of Health. However, it is considered only "... when there is no other alternative - i.e. there is no apparent suitable surface or groundwater sources available in the area" (Ministry of Health, 1982). As indicated in Table 1 this is true for many places in the state of Sarawak and certain places in the state of Sabah.

Table 1 also indicates that groundwater is the main source of supply to the rural areas. It accounts for 55.69% of the total number of water supply schemes implemented up to 1980. Next in importance is the rainwater storage system which accounts for 28.21% of the total number of schemes implemented. Surface flow through the gravity feed

TABLE 1. RURAL WATER SUPPLY SCHEMES AS OF 1980.

	Peninsular Malaysia	Sabah	Sarawak	Total
Wells without House connection	7,284* (88.86)	534 (53.08)	319 (5.90)	8,137 (55.69)
Wells with House connection	748 (9.13)	-	-	748 (5.12)
Gravity Feed Water supply	164 (2.00)	321 (31.91)	1,088 (20.12)	1,573 (10.77)
Hydraulic Ram	1 (0.01)	-	30 (0.55)	31 (0.21)
Rainwater Storage	-	151 (15.01)	3,971 (73.43)	4,122 (28.21)
Regional Totals	8197	1006	5408	14611

* Number (Percent of Regional Totals)

system is third in importance and accounts for 10.77% of the total number of schemes implemented.

Most of the wells have been constructed in Peninsular Malaysia. Except for riverine communities this has been the traditional source of water supply for most households in the rural areas of Peninsular Malaysia. The large majority of rainwater schemes, however, are located in the state of Sarawak. This has been the traditional source of supply for the indigenous dayaks who frequently live communally in the famous long houses. The large catchment areas of these houses might have provided the initial inducement to tap this source. The gravity feed system is also popular in Sarawak. The hilly terrain of this state and the dispersed communities favour this system.

Since there has been no empirical study on rainwater usage in the various states in Malaysia, it is not possible to show the real extent of its use and its trend. However, on the basis of government support schemes, it is possible to show in the case of at least one state, Sarawak, the trend is towards an increase. This is indicated by Figure 1.

Rainwater schemes have also been introduced in a number of states in Peninsular Malaysia. Implementation in one of the states, Perlis, will be described in slightly more detail later.

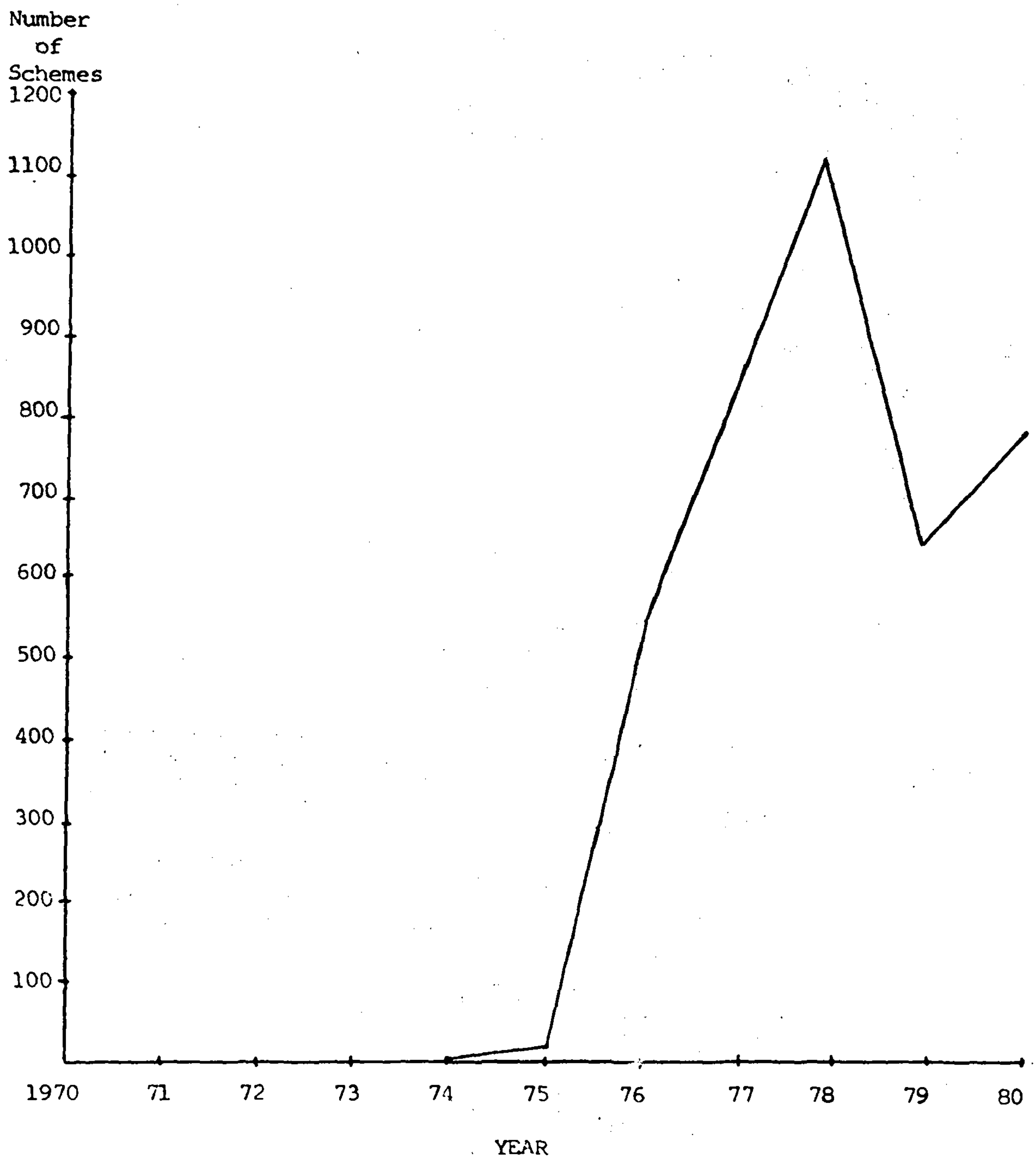
CURRENT PRACTICE

Rainwater catchment systems in Malaysia normally have three basic components namely, a catchment area or roof, gutters and storage areas. In the rural areas, the roofs are normally constructed from corrugated galvanized iron or nipah palm. The gutters are normally made of corrugated galvanized iron while the storage tanks are either constructed using bricks and cement or are simply big vases. An attempt has been made to use cement moulds for the construction of storage tanks in Peninsular Malaysia.

Public involvement in rainwater catchment systems comes under the Rural Environmental Sanitation Programme (RESP). Under this program, four aspects have been emphasized: community participation, health education, appropriate technology and training (Ministry of Health , September 1981). Community participation is regarded as an essential element because it is considered that people must be involved in programmes which affect their lives and living habits. That they would not participate or respond to such programmes unless they are well informed emphasizes the need for health education. The technology introduced should also be appropriate in terms of the community's technical know-how, needs and resources.

As indicated earlier, rainwater catchment systems are not given much emphasis under the RESP. Generally, under the RESP, participating communities are required to contribute a nominal sum, normally M$20.00

Figure 1. Number of Rainwater Schemes in Sarawak (1970-1980)

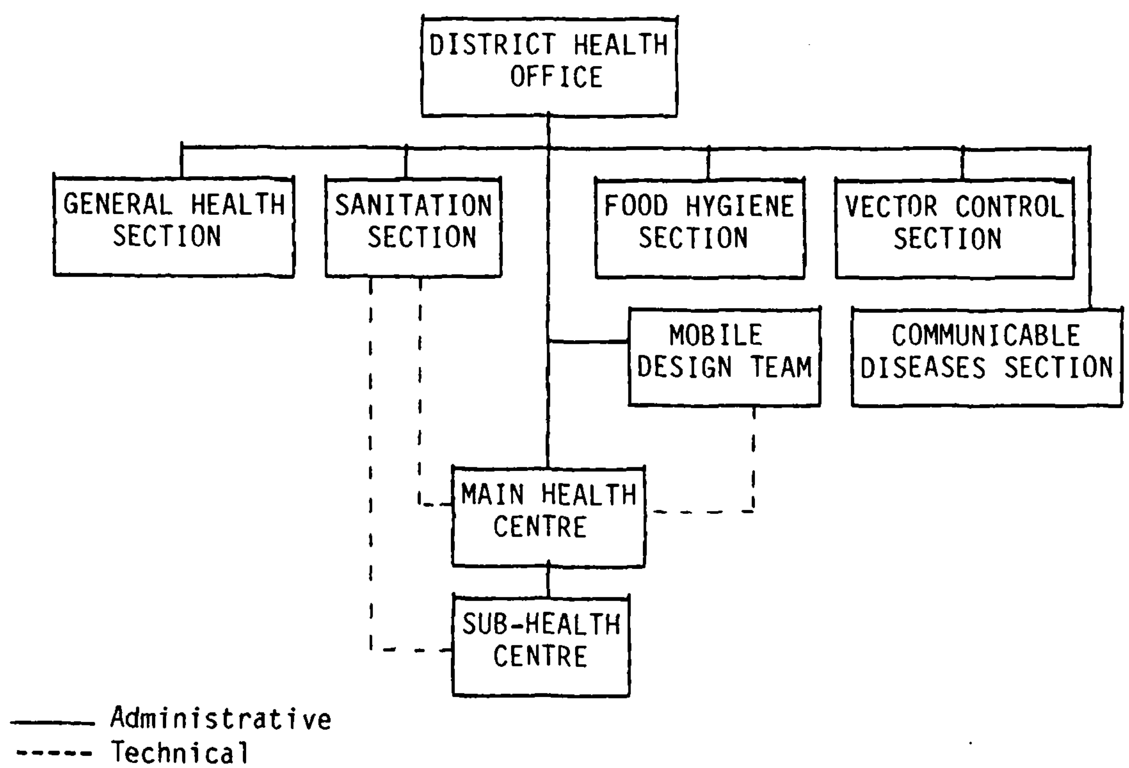


per household for water supply systems. Funding for this programme comes from the Federal Government allocations as well as state funds. In order to emphasize the community participation element, all operating and maintenance works are relegated to the communities concerned.

The RESP incorporates both water supply and excreta disposal activities. It is supposed to complement the other health programmes which include communicable disease control, food hygiene, vector control and general health. For water supply, the problems of waste water are also given attention.

The implementation of the RESP comes under the sanitation section of the District Health Office. Together with the Mobile Design Team, the RESP provides technical services to the Main Health Centre and Sub-Health Centre. Diagramatically, the flow of administrative and technical services is as illustrated in Figure 2.

Figure 2. Administrative/Technical Functions of the District Health Office



RAINWATER CATCHMENT SCHEME IN PERLIS

The rainwater catchment scheme was introduced in Perlis in 1979. The reasons given for its introduction are:

i) The serious outbreak of typhoid and cholera during the period 1978-1979 in the southern part of the state.

ii) The endemic nature of many water-borne diseases and those transmitted through human waste and food such as cholera, typhoid, dysentery and others.

iii) The acidic condition of soils and the prevalence of brackish water.

iv) The desire to provide safe water to the poor and to complement the piped water schemes of the Public Works Department.

This scheme was considered feasible because the rainfall pattern in the state was fairly stable and of fairly high intensity. Rain falls throughout the year but there is a distinct dry period between December and February. The rainfalls for the year 1980 and 1981 were 1897.1 mm and 1431.0 mm respectively. Table 2 below shows the monthly rainfall distribution for the two years.

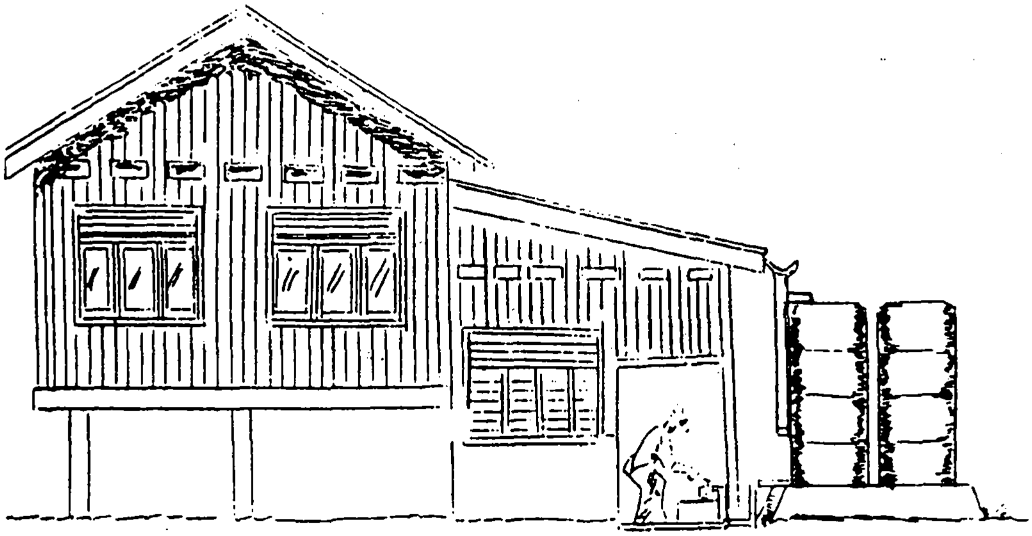
On the basis of the rainfall information, an average family size of 6 and water consumption of 9 gallons (41 l) per family per day, it has been recommended that 8 cement storage tanks be constructed per house. Each storage tank is 4 feet in diameter and 2 feet high. This will give a total capacity of (711 x 8) = 5688 litres and it is estimated that this could last the family for about 4½ months. A sketch of the cement mould and a cistern system in Perlis is shown in Figure 3 and the costs of the scheme per household are shown in Table 3.

TABLE 2. MONTHLY RAINFALL IN 1980 AND 1981 IN PERLIS.

Month	1980 (mm)	1981 (mm)
January	-	2.50
February	32.8	63.0
March	63.7	70.0
April	162.3	281.2
May	233.3	177.2
June	192.0	133.0
July	156.3	132.3
August	291.8	176.7
September	210.7	98.2
October	170.0	149.6
November	233.1	143.5
December	151.1	23.7
Total	1897.1	1431.0

The rainwater catchment scheme in Perlis also emphasized community participation. A participant of the scheme is required to contribute M$100.00 to purchase the items necessary for connection to the house and the system is supposed to be constructed on a self-help and cooperative basis. The cost per household is M$508.21 and this is very high compared to the other rural water supply schemes.

Figure 3. Rainwater Catchment System in Perlis
(Catchment Area and Cement Mould)
Source: Reference 4



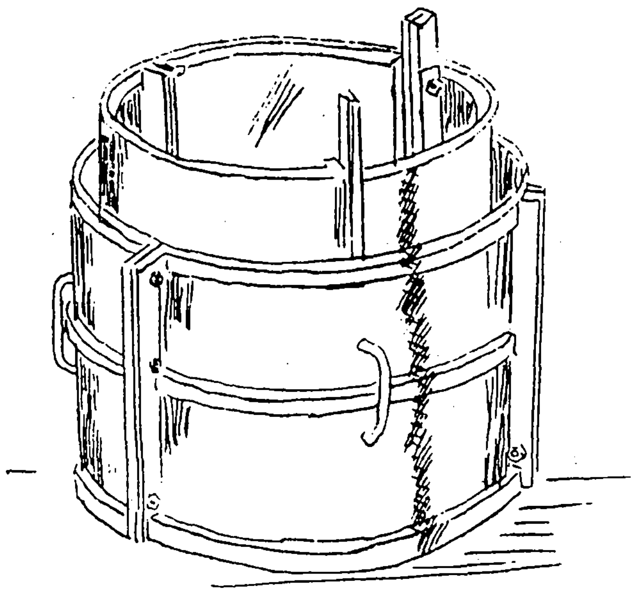


TABLE 3. ESTIMATED COST OF RAINWATER CATCHMENT SCHEME PER HOUSEHOLD IN PERLIS. (Source: Reference 4)

Item	Quantity	Price per unit M$*	Total cost M$*
A. Storage Tank and Foundation			
1. River sand	5 cu feet	$18.00	$90.00
2. Bricks (3/4")	2½ cu feet	22.00	55.00
3. Bricks (1½")	1 cu feet	20.00	20.00
4. Cement	10½ bags	9.20	96.60
5. Steel B.R.C. No. 10	48 x 6½'	0.91	43.68
6. PVC pipe	2 feet	2.11	4.22
		Total	$309.50
B. Gutters			
7. Zinc sheet (6½" wide)	30 feet		$123.00
8. Down pipe outlet	15 feet	$ 4.10	61.50
		Total	$184.50
C. House Connection			
9. PVC pipe ½"	25 feet	$ 0.16	$ 7.17
10. PVC Elbow ½"	4 pieces	0.42	1.68
11. PVC ½" Faucet Socket	1 piece	0.46	0.45
12. ½" Brass Socket	1 piece	4.90	4.90
		Total	$ 14.21
	GRAND TOTAL		$508.21

* Conversion rate (1983): $1 US = M$ 2.30

REFERENCES

1. Hodder, B.W., Man in Malaya, University of London Press, London 1979

2. Ministry of Health, Rural Environmental and Sanitation Programme (1973-1980), September 1981

3. Ministry of Health, Rural Environmental Sanitation and Community Water Supply Programme Peninsular Malaysia: Guidelines For Implementation (1975-1980), Undated

4. Pejabat Pengarah Perkhidmatan Perubatan dan Kesihatan Negeri Perlis, Laporan Kebersihan Alam Sekeliling, 1981

5. The Secretariat, Malaysian National Committee of the International Hydrological Programme, Drainage and Irrigation Division, Ministry of Agriculture, United Nations Water Conference Country Report (ESCAP Regional Preparatory Meeting, Bangkok 27th July - 2nd August 1976), 1976

6. Uzir Abdul Malik, Rainwater Cistern Systems and Policy in Malaysia, Rainwater Cistern Systems Conference, Honolulu, June 15-18, 1982

THE RAIN WATER CATCHMENT PROGRAMME IN SRI LANKA

D. Pathirana
Lanka Jathika Sarvodaya Shramadana Sangamaya
77, de Soysa Road, Moratuwa
Sri Lanka

INTRODUCTION

The precise links between improved water supply and health benefits are difficult to document. However, all people appreciate the significance of a clean, adequate water supply. Nevertheless, changes that affect personal hygiene and sanitation practices must be made before enteric diseases can be significantly reduced. These changes are complex and are not likely to occur spontaneously. The target population must be supplied with readily understood information about the benefits of change and persuaded to adopt new behavioural patterns and accept new technologies. Furthermore, consumer acceptance of water and sanitation technology depends on having devices that can be purchased and maintained by the villagers themselves, hold up to abuse, and function for long periods. (Village Handpump Technology: Research and Evaluation in Asia. IDRC, 1982.)

The technology has been tried, tested, and proven. But the question remains: how can the desire to utilize it, and maintain it be best transferred to those who need it most? It is our sincere hope that this rain water catchment workshop will stimulate efforts to implement this technology and foster new research initiatives in all the developing countries to provide a reliable answer to this so-called question. It would be a giant step forward in the struggle to provide adequate clean water supplies to the rural population.

HISTORICAL REVIEW OF RAIN WATER CATCHMENT IN SRI LANKA

Sri Lanka is a tropical country which has a hot and wet climate (Table 1). The two main climatic zones are known as the dry and wet zones (Figure 1). The major towns of the dry zone, Anuradhapura and Polonnaruwa, were the capitals of our ancient Kingdoms. The inhabitants of those areas are accustomed to using those tanks built by our ancient kings to cultivate their farm-lands in addition to using the water for household and drinking purposes.

"We can grow more food but please give us enough water to fill the barns of this country". That was the only requisition by the people of the king by whom they were governed. So, it was the duty of the king to supply more water to match the demands of the people. They built many tanks, large enough to store masses of water for their day-to-day usage. By means of these tanks they irrigated their farm-lands. When there was less rainfall, the tanks dried up and then they had to suffer terrible privations.

The Tissa Vewa (in the dry zone)

During the reign of the King Devanampiyatissa, the Tissa Vewa reservoir was built in a shallow valley about a mile and a half east of the Kirindi Oya, a river which flowed past the capital of Anuradhapura. The town occupied the ground between the tank and the river, extended for some distance lower down the valley, and was also on the eastern side of the tank. The chief purpose of the work was the storage of water (mainly rain water) for the use of the city. It is also not improbable that it served the irrigation of rice fields as well.

The area covered by the tank was 652 acres (264 hectares) and its capacity was 160 million cubic feet (4.5 million cubic metres) at that time. Although the catchment of the tank is very small, it is considerably larger than that of the King Pandukabaya's tank which had been built for the same purpose. This was also at Anuradhapura, our

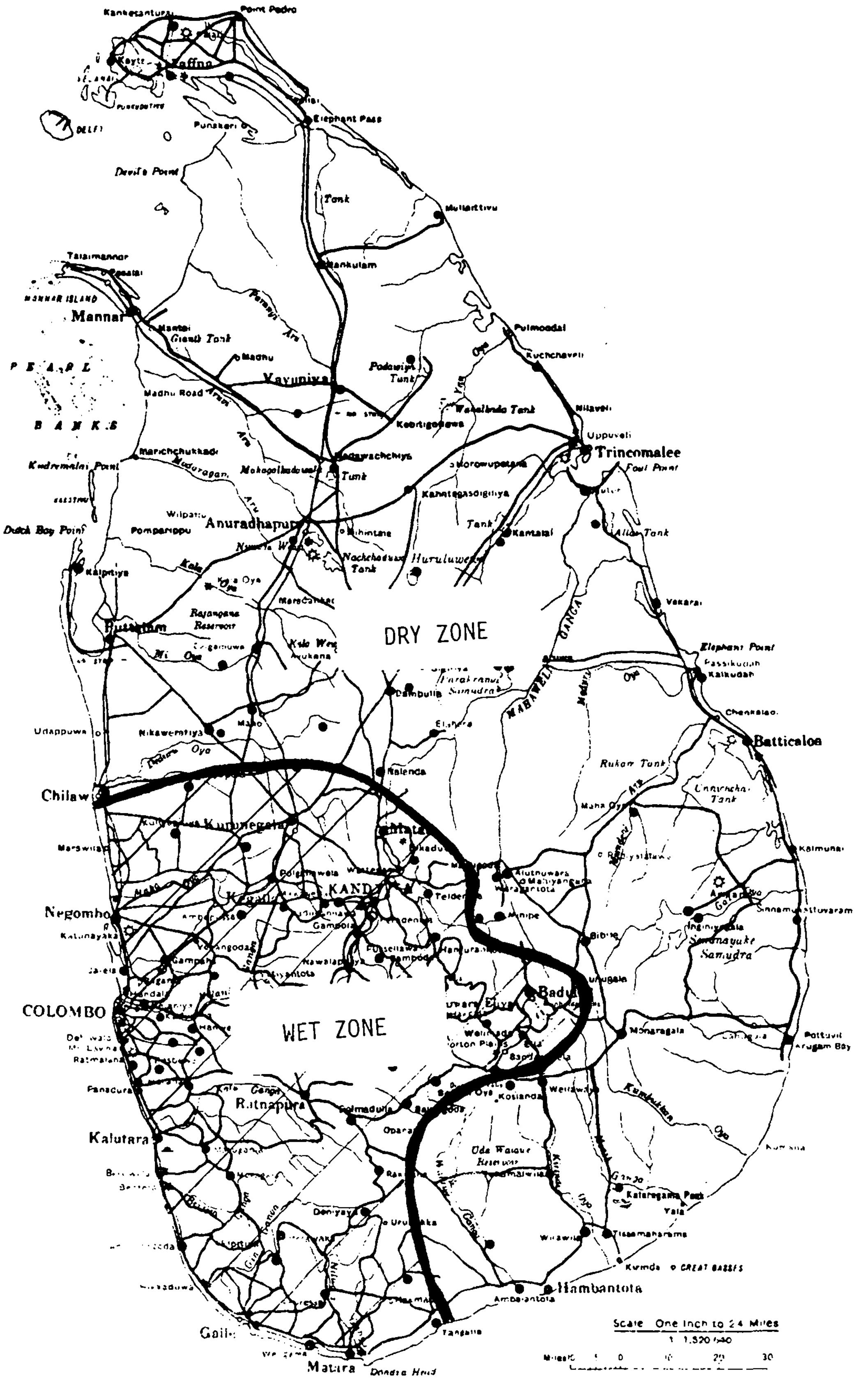


Figure 1: Climate Zones

TABLE 1. ANNUAL RAINFALL, TEMPERATURE AND RELATIVE HUMIDITY AT NINE PRINCIPAL STATIONS DURING 1978 AND 1979

Station	Annual Rainfall Millimetres		Mean Annual Temperature (Degrees Celcius)		Mean Annual Relative Humidity (percent)			
	1978	1979	1978	1979	1978		1979	
					Day	Night	Day	Night
Colombo	1,954.4	2,450.6	27.5	27.1	74	89	76	89
Jaffna	1,162.0	1,391.3	28.0	26.3	75	86	69	82
Trincomalee	1,464.6	1,473.0	28.6	26.6	70	81	71	65
Hambantota	976.5	796.6	27.2	26.5	76	87	75	87
Ratnapura	3,742.5	3,490.4	27.4	27.1	76	94	76	87
Anuradhapura	1,194.7	1,371.3	27.8	26.3	68	89	73	92
Kandy	1,924.5	1,995.4	24.7	24.5	74	92	80	90
Diyatalawa	1,275.1	1,658.3	20.4	19.3	67	85	75	87
Nuwara Eliya	2,604.6	2,195.8	15.4	15.5	82	91	70	81

ancient kingdom and was known as "Abhaya-Vewa". The rainfall there amounts to about 47 inches (120 mm) per annum.

The bank of the Tissa Vewa was a well made and substantial work, so much so that modern engineers declare that, with a little attention, "it may last practically forever". Amidst the remarkable creations of our ancient kings are the distinctive reservoirs that prevail and still serve our irrigation network. Even today, we Sri Lankans cannot forget the golden saying of our great king Parakramabahu the great, "It is my ambition not to discharge a single drop of rain water to the sea, without maximum usage of it". He was so interested in cultivation that he didn't want to waste a single drop of water by which the earth is moistened.

After the foreign invasions, the whole economic, social, and cultural aspects, and principles of the people were completely changed. Some of the major tanks were abandoned. But, fortunately, they were restored and are being used again.

At the restoration of Tissa-Vewa in 1871, a great part of the tip was found to be worn away. So, the higher parts of the banks were cut down by three feet (1 metre). The depth of the water retained was ten feet (3 metres). After more than a quarter of a century, however, it was found necessary to raise the water level once more to what seems to have been the height originally fixed by the old Sri Lankan engineers. This is a high mark of appreciation of the excellence of the ancient Sri Lankan designs and their suitability under the conditions which control such work.

The tank was of vital necessity to the city and experience proved that it often remained unfilled after the dry season. Important measures were adopted in order to ensure that it received a better supply of water. For this purpose a permanent stone dam (it was possibly the first one of that kind built in Sri Lanka) was erected across the Kirindi Oya at a distance of two and a half miles (4 km) from the upper part of the tank. A short channel was then opened from a point immediately above it in the river, to a site where the water conveyed by it could flow into the tank by gravity. The dam had a height of 15 feet (4.5 m) and was built of large roughly-hewn blocks of stone, few of which are less than a ton in weight, while many are far more.

The special point of interest in this dam is the astonishing fact that instead of being taken across the river by the shortest possible line as one would expect, it was built at an oblique angle, which was apparently about 45 degrees from the direct line. This would appear to prove the principle of the oblique dam and of its greater discharging power than the one built at right-angles to a river. This knowledge was acquired in Europe only in comparatively recent time but was understood in Sri Lanka over two thousand years ago. That is the remarkable history of irrigation in our country.

Unfortunately such ancient water facilities are not available in the central parts of the country especially in the Colombo area. Hence, in 1939, a new major water supply scheme, the Kalatuwawa reservoir, was started, which has a surface area of 7000 acres (2800 hectares). With an annual rainfall of 162 inches (411 mm), it has a storage capacity of 3100 million gallons (14 million cubic metres) of water, which provides about half the water demand of the Colombo area. Kalatuwawa and Lagugama are the main reservoirs using rain water catchment in Sri Lanka that prevail at present.

COMMUNITY INVOLVEMENT AND ORGANIZATION: THE SARVODAYA SHRAMADANA MOVEMENT

The literal meaning of "Sarvodaya Shramadana" is the awakening of all in society by the mutual sharing of one's time, thoughts, and energy. Philosophy development takes place first through an awakening of the human being. Then of his or her direct family environment - the village or the urban community - and then the nation and world.

The Sarvodaya Shramadana Movement of Sri Lanka was founded in 1958 and was legally recognized by an act of parliament as a non-governmental people's movement in the country engaged in national development with emphasis on the following aspects:

* Traditional cultural values.
* Small rural and urban community organization and self-reliance, community participation and self-development.

The Movement's activities are geared to integrated rural development based on traditional and cultural values. People's participation is the foundation on which the Movement originated in the past.

The first stage in its programme is to develop a psychosocial infrastructure through the creation of awareness among the village population about:

(1) The factors that led to the socio-economic impoverishment of villages and the country.

(2) The factors that led to the disintegration of social cohesion and the breakdown of cultural and traditional values.

(3) The fact that the economic regeneration of villages must be preceded by restoration of social values and relationships.

Initially the process of creation of awareness takes place in "Shramadana Camps" where the village population is brought together in work of common interest for the whole village.

With twenty-six years experience behind it, its programmes are operating in over 4,000 villages in Sri Lanka. It has earned both national and international recognition.

Technical Activities of Sarvodaya

The organization has a full time staff of over 6,000 serving in villages and over two hundred Sarvodaya training and support centres in all districts in the country. Over the past years of its work, the Sarvodaya Movement has developed an organizational structure with a wide range of service sections to carry out the ever-increasing range of development work.

One of the rather specialized sections is the Rural Technical Services Section. Through this section, rural infrastructural work is initiated, planned and implemented in many areas of Sri Lanka where Sarvodaya is active and was asked for help. The District Co-ordinators are directly responsible for the implementation of any assisted project.

Regional Technical Offices of Sarvodaya are located in Moratuwa (for West and South Coast), Anuradhapura (North) and Palletalawinna (Hill Country and East Coast). Their activities are as follows:

* Agricultural training and extension work with emphasis on home gardening and improved methods for rainfed farming in the Dry Zone.

* Construction of simple village water supplies in the Hill Country.

* Construction of drinking water wells and development of a locally manufactured handpump (P.V.C.).

* Sanitation programmes.

* Mason training.

* Technical training.

* Afforestation and soil conservation programmes.

* Rural settlements, low cost housing.

* Design and construction of appropriate tools and implements, such as windmills, handpumps, agricultural equipment, tools and materials for building construction, etc.

The Need for Clean Water

The present situation with regard to drinking water in Sri Lanka is as follows: In 1980 only about 12% of the total population had access to safe drinking water. In the rural sector, 99% obtain their daily requirements of water from shallow wells or surface sources. These wells and sources are not sanitarily protected and hence the quality of available water is highly questionable. There is an additional problem of these sources drying up during the dry season especially in the Dry Zone of the country.

As a consequence of this bad situation, it is not surprising that 40% of the hospital beds are occupied by patients suffering from water-related bowel diseases. Outbreaks of diarrhea and cholera are common, and a great number of people are weakened by intestinal parasites (amoebiasia, worms, etc.) without being aware of it.

A Method to Promote Rainwater Collection

Sarvodaya Sangamaya can play a vital role in promoting rainwater catchment projects by means of educational workshops which can reach the rural and urban population through the mass media, such as local newspapers, radio, T.V. and seminars. These rainwater catchment workshops can be conducted especially in the Dry Zone and should concentrate on imparting knowledge about maintaining small-scale systems to women in their capacity as housewives. At present some housewives who live in both rural areas and towns use rainwater by collecting it in big open pots, pans or tanks. They do this and make use of that water only for domestic purposes with the intention of saving time and labour.

However, there is a longstanding belief that collected rainwater has impurities and therefore, most people do not like to use it for drinking purposes. To get the maximum value from rainwater, means should be found either to collect rainwater without impurities or to purify it. If this is done, people will gradually become more accustomed to using rainwater without wasting it. Hence one sees the great importance of rainwater catchment workshops in developing this technology on a massive scale throughout our country.

This approach is in keeping with tradition as it would help our people to fulfill the ancient desire of King Paradramabahu the Great, "not to discharge a single drop of water into the sea without gaining the maximum usage of it".

SRI LANKA'S CONTRIBUTION TOWARDS RAINWATER CATCHMENT TECHNOLOGY

R.K.C. Rajapakse
Chief Engineer
National Water Supply and Drainage Board
Sri Lanka

HISTORICAL BACKGROUND

Rainwater catchment technology is perhaps as old as human civilization, but population expansion and limited resources, dictated by climate and/or topography influenced the development of the technology. In Sri Lanka we are able to trace the evidence of such well-defined technology back to the fifth century.

The ancient monastries in the dry zone, usually associated with natural rock caves, collected rainwater for drinking and domestic purposes by adopting this technology. Here, the precipitation falling on large rock surfaces was diverted into holes dug into the rock inside caves (Gal Kataran). Water thus preserved was used during dry spells. Evaporation from such storage inside caves was small.

The archaeological evidence on one of our rock fortresses known as Sigiriya contains a wealth of information on a device built to harvest the rain for many uses. In this fortress we find elaborate control methods and ornamental micro-hydraulics. They form a network of storage reservoirs that serve swimming pools, reflecting ponds, moated islands, water pavilions, underground conduits, artificial streams and bubbling fountains. According to one of our eminent archaeologists, Dr. Senaka Bandaranayake, Sigiriya displayed one of the world's most sophisticated hydraulic technologies.

Sri Lanka is also full of surface water tanks which provided water for irrigation purposes as well as for drinking. Ground wells were dug near the tanks to extract water for drinking. Our ancient kings are remembered more by the number of tanks built to catch rainwater, than the wars they fought and won.

While these tanks have operated through several centuries and are still in use, from the point of view of assessing the present practice of rainwater catchment, some of the impounding reservoirs can serve as examples. They are quite recent and two of them are still serving parts of the city of Colombo. The one in Kandy, the hill capital of Sri Lanka, serves as a standby supply. The Hiyare Reservoir is in Galle - one of the major sea towns where Lorenze de Almeida from Portugal landed. Although it was the Portugese who came to Galle first, it was the British, the last to leave, who built this reservoir. This is now abandoned. Incidentally, it is ironic that the present water supply system which resulted in the abandonment of this reservoir was constructed with British assistance.

Other than these instances, Sri Lanka cannot claim a well-defined rainwater harvesting system like the ones you find in Thailand or Indonesia.

RAINFALL PATTERN

Sri Lanka is divided into two major zones - wet and dry. The dry zone occupies the majority of the land area (65% of the total land area) while the wet zone covers the rest of the land area. The dry zone gets the rainfall from the North-East monsoon from November through April and the wet zone gets the rain from May through October mainly (see Figure 1).

The terms 'dry' and 'wet' are used here only in a local relative context in order to emphasize the markedly contrasting conditions evident in the spatial and seasonal distribution patterns of rainfall which, in turn, have produced corresponding differences in the totality of the natural environment and the cultural landscape.

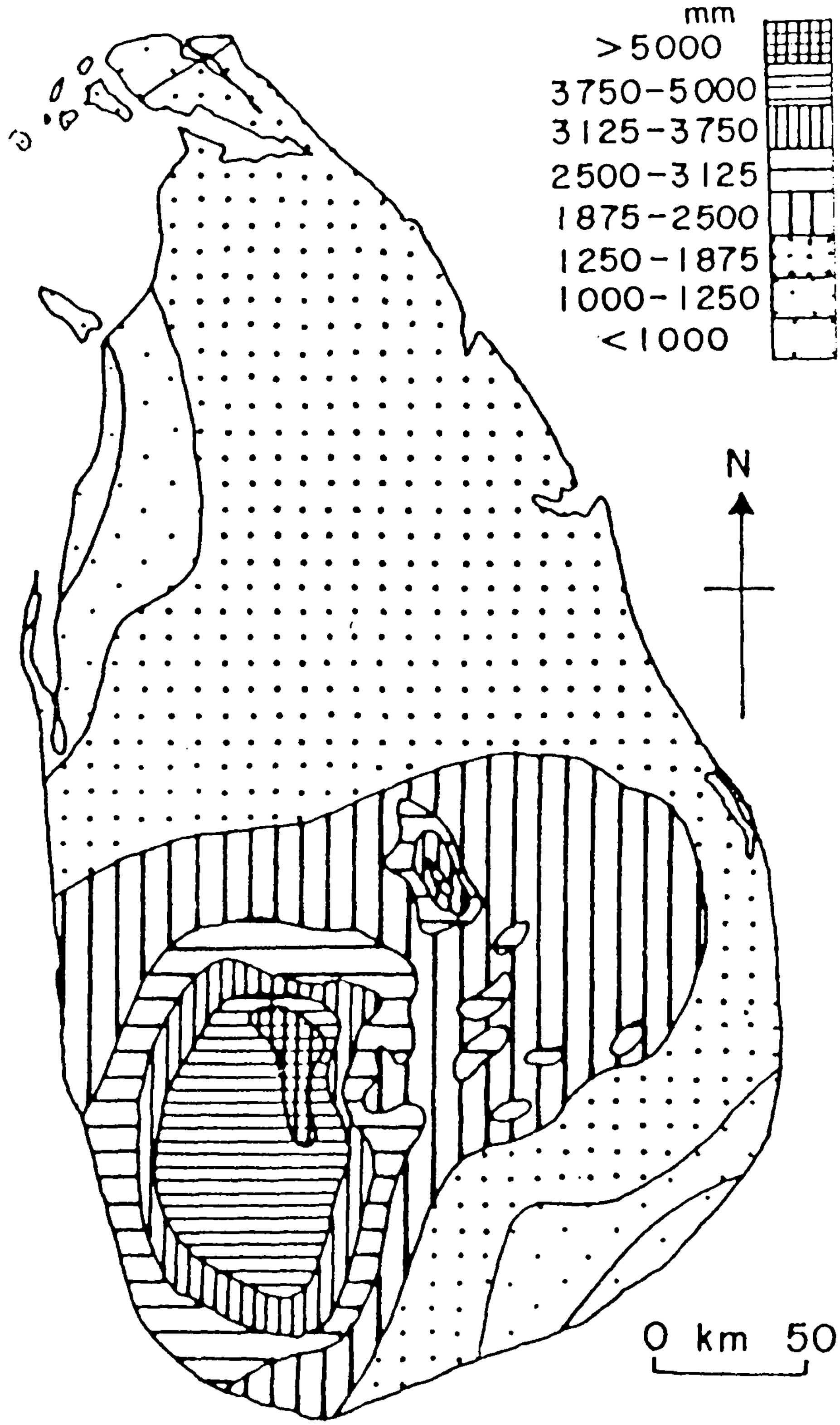


Figure 1. Mean Annual Rainfall (mm)

CURRENT PRACTICE OF RAINWATER COLLECTION

A few hotels close to beaches collect rainwater from roofs in reinforced concrete (RC) and masonry tanks because the available ground water is brackish. Overflows from these storage tanks are piped to wells to create a fresh water lens floating on brackish water around the well (see Figure 2).

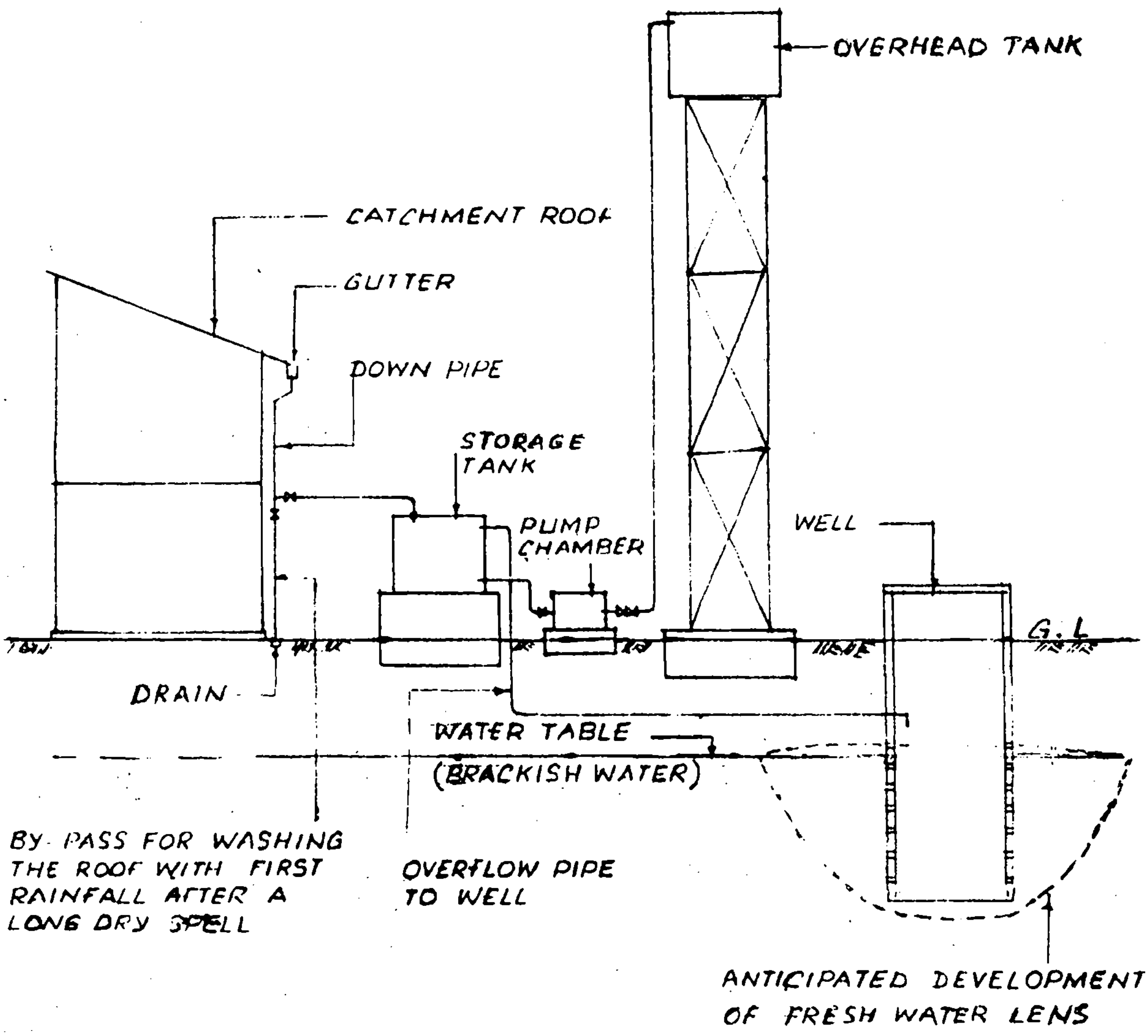


Figure 2. Schematic Drawing of Fresh Water Lens Storage System

A better method would be to lay perforated pipes around the well to inject rainwater into the ground (see Figure 3). This would avoid high velocities of injection at the well steining and the possible mixing of rainwater with brackish water.

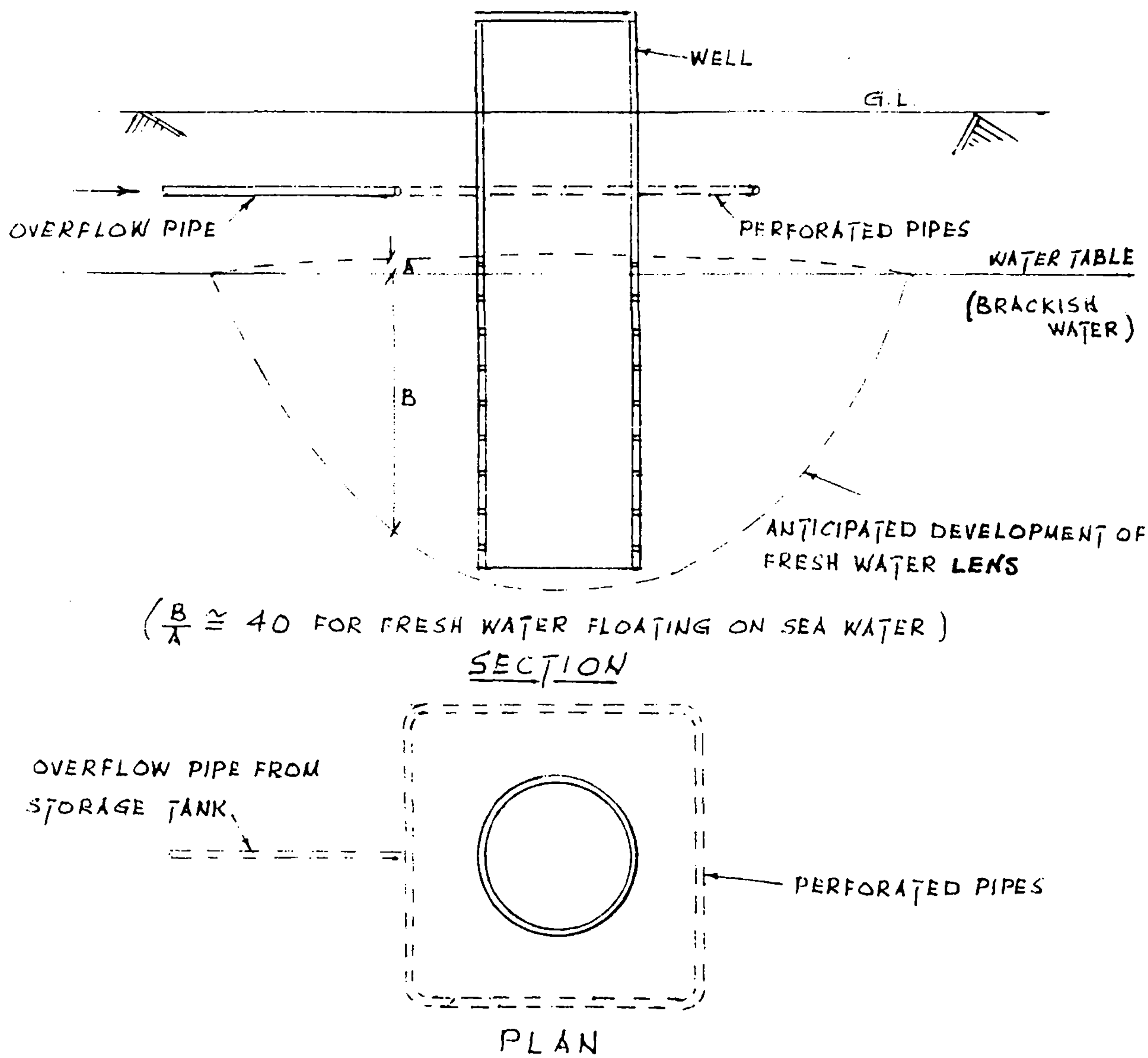


Figure 3. Perforated Pipe Injection System

POTENTIAL FOR USE OF RAINWATER

The time has come when serious consideration should be given to rainwater catchment projects.

In the dry zone many areas potentially suitable for rainwater harvesting remain undeveloped due to limited resources available from state and other aid agencies. Most of these are peasant settlements found around irrigation tanks because water from the tank is used for daily needs. This includes water for domestic use, agriculture and animal husbandry. The tank water is highly polluted as bathing and washing are done in the tank itself. Incidence of disease is very high among these settlers due to consumption of polluted water. Rainwater harvesting can be an important means of providing drinking water to alleviate the suffering of these people.

Rainwater also has potential in the coastal areas and isolated islands where salinity intrusion is a very serious problem.

THE EXAMPLE OF RAINWATER COLLECTION STUDIES IN MALE, MALDIVES

Binnie & Partners, Consulting Engineers of U.K. in association with Engineering Consultants Ltd. of Sri Lanka have completed feasibility studies for a rainwater scheme in Male, the capital of the Republic of Maldives. Detailed designs are nearing completion and it is anticipated that the construction work would commence around April 1984. Accurate analyses of rainfall records have been carried out to determine a specific yield figure for Male roof catchments. These show that 350 litres of storage per m^2 of roof area would maintain 4 litres/day per m^2 of roof area.

The Male rainwater project consists of two schemes:

(1) a private rainwater scheme providing individual tanks to private households.

(2) a public rainwater scheme to collect rainwater from large roofs.

Private House Rainwater Tanks

The population estimate for 1983 is 39,600 (excluding visitors). The average house occupancy is 11.3 persons/house. However, to give 4 l/d per person on the above basis, it would require the construction of unacceptably large tanks in many houses, 20% of which have 16-35 people. A 7.0 m^3 tank would be required for a 20 person house. Hence, it became necessary to think in terms of smaller tanks to provide only drinking water. The minimum average consumption of drinking water is considered to be at 2.5 lcd (litres per capita per day) and a survey showed that the maximum size of tank which can generally be accommodated in most houses with high occupancy rates, is 4.0-5.0 m^3.

Considering a dry season of 88 days, the storage per person = 88 x 2.5 = 220 litres and the roof area required is .625 m^2. Since more roof area is available, 1.25 m^2 roof area was provided increasing the yield to 3.5 lcd average.

The "effective contribution" of such house rainwater tanks over a long period would be 3.73 lcd (3.5 lcd for 3 months + 3.8 lcd for 9 months). If this is possible for 96% of the houses, then using a total of 3367 houses (survey report) and an average occupancy of 11.3, the total daily average volume of water supplied would theoretically be:

$$0.96 \times 3367 \times 11.3 \times 3.73 \div 1000 = 136 \text{ m}^3/\text{d}$$

Public Rainwater Collection Scheme

Roof Available and Potential Development

Two principal difficulties arise in the design of public large-scale rainwater collection schemes:

(1) The need for large storage reservoirs which are costly.

(2) Lack of land-space for such storage reservoirs close to the major concentrations of undeveloped roof areas.

For full development of a roof, 350 m^3 of storage is required for each 1000 m^2 of roof area. The yield from this unit of development is 4 m^3/day sustainable throughout wet and dry seasons. The theoretical maximum contribution all the available roofs could make is 200 m^3/day, but less than this amount will be available in practice because many roofs are too isolated or too small for incorporation into an economic rainwater collection system.

It is easier and cheaper to operate a single water distribution system than to operate 3 or 4 separate systems. Its estimated maintainable yield during wet and dry periods is about 105 m^3/d (see Table 1).

TABLE 1

Roof Group	Yield m^3/d
Northern	31
Central	29
Southern	15
Eastern	20
Storage tank roof	10
Total	105

Distribution System

In addition to the 105 m^3/d, it is intended to supply 200 m^3/d of desalinated water. This brings the total to be distributed to 305 m^3/d.

The network of distribution mains has been made extensive, to meet the additional supply.

In either case the supply will need to be intermittent and it is envisaged to turn on supply twice daily, morning and evening.

An elevated tank will be constructed so that economic pumping against a variable demand is possible. The elevated storage proposed will give just under 1 day's supply at 105 m^3/d or about one-third of a days supply at 305 m^3/d. The rainwater supply will come from the storage reservoir. The supply of desalinated water will come from storage associated with the desalination plant, the two waters being blended together.

A small amount of chlorine will be added to the rainwater to ensure disinfection of any contamination from the roof. The dosage may be intermittent and will in any case be low.

DESIGN CONSIDERATIONS FOR SRI LANKA

Catchment Roof

The roof should be made of suitable materials such as galvanized iron (GI) sheets. Thatched roofs are not suitable as decaying vegetative materials would add taste and colour to the water. There should be no trees overshadowing the roof as falling leaves also would act similarly. If GI roofs are painted the paint used should be non-toxic, e.g. red lead based paint should not be used. Generally, there is a fear of using asbestos roofs as rainwater catchments. Some authorities maintain that this fear is not justified as the asbestos fibre is causing cancer only when inhaled during the process of manufacture. Tiled roofs have the drawback that they are difficult to clean, gather dust and are susceptible to algal growth. The best option would be GI sheets painted with non-toxic paint.

Gutters and Down Pipes

GI or UPVC can be used for gutters and down pipes. Sizing will depend on the roof area, the time of concentration and the rainfall intensity. The design rainfall intensity varies from region to region. Most reliable data could be obtained by analysing rainfall records available for the region. For this analysis, records from automatic rain gauges are necessary. If such records are not available, "rainfall intensity - duration curves" prepared for similar climatic regions could be used for arriving at the design intensity (see Figure 4).

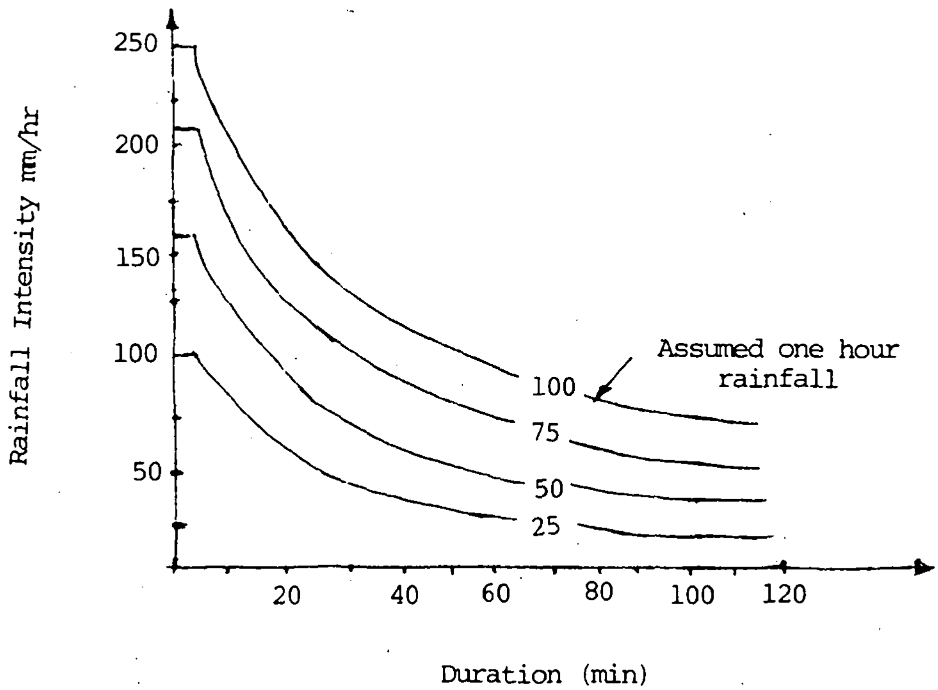


Figure 4. Intensity-Duration Curves for 1-Hour Rainfall Accumulations

The use of such curves could be best illustrated by an example.

Data: (1) Design gutters for storms having a return period of one year.
(2) One hour rainfall for the regions, to be expected once in every year is 25 mm.
(3) Time of concentration for the roof is 5 minutes.

Solution:

Using the curves, design intensity for a duration of 5 minutes for 25 mm rain per hour = 100 mm/hr. It is uneconomical to design gutters and down pipes for the very high rainfall intensities which may occur, in average, say, once in ten years or even longer return periods. Therefore, a certain amount of rainfall would be lost due to spillage. The allowable limit of spillage would depend on:

(1) Location of gutter (e.g. valley gutters should have zero spillage);
(2) The extent of dependence on rainwater;

and should not normally exceed 5% of the annual precipitation in a wet year.

When the design flow is known, the gutter size could be determined by applying the formula for 'spatially varied flow with increasing discharge' in open channel flow theory:

$$\frac{dy}{dx} = \frac{S_o - S_f - 2Qq/gA^2}{1 - Q^2/gA^2D}$$

(Ref: chapter 12 Open Channel Hydraulics by Ven Te Chow)

where

S_o = Slope of gutter

S_f = Friction slope = $\frac{Q^2n^2}{1.005\ A^2R^{4/3}}$

Q = Flow m^3/sec

q = Lateral inflow per unit length in m^3/sec per metre length of gutter

x = Distance from beginning of gutter in metres

A = Cross sectional area, m^2

T = Top width m

P = Wetted perimeter in metres

D = Hydraulic depth = A/T in metres

R = Hydraulic radius = A/P in metres

n = Manning's coefficient for the gutter material

This is a very tedious equation to solve, which has to be done by trial and error. Tables giving the gutter size for given roof area and rainfall intensity could be developed using the above formula for use by practising engineers. In the development of such tables, consideration should be given to the common practice of the country with regard to gutter materials and shapes, the available range of roof areas and the range of rainfall intensities experienced.

The down pipe size should be such that at the design flow an "orifice control condition" should not occur and possibly lead to gutter overflow. In other words, the circumference of the down pipe should be sufficient to admit the design flow as a weirflow and at any point of the down pipe full flow, creating the orifice condition, should not occur. The formula applicable is:

$$Q = C_d \, (2 - R) \, H^{3/2}$$

where

H = Head over the crest

R = Ratio of the crest

C_d = Coefficient of discharge (depends on the entrance condition, shape of transition and vortex formation)

Tables could be prepared giving down pipe sizes for given roof areas and rainfall intensities taking into consideration the specific conditions affecting C_d. Roof areas for a rainfall intensity of 75 mm/h. are presented in Table 2 as an example.

Bypass for Flushing the Roof

It is essential to have a bypass branch to the down pipe before the storage tank for the purpose of flushing the roof when required. For small systems this can be done by simply fixing a small length of flexible hose at the end of the down pipe. When the roof is being

TABLE 2. MAXIMUM ROOF AREA (m^2) FOR UPVC GUTTER AND DOWN PIPES FOR 75 mm/h RAINFALL INTENSITY

Gutter/Down Pipe System	Level-Gutter		Gutter with 1:600 Fall	
	Outlet at Centre	Outlet at One End	Outlet at Centre	Outlet at One End
75 mm. half round Gutter with 55 mm. Down Pipe	28.7	14.4	40.2	20.1
112 mm. half round Gutter with 68 mm. Down Pipe	83.2	41.6	116.5	58.3
125 mm. half round Gutter with 81 mm. Down Pipe	139.5	69.7	195.3	97.7
150 mm. half round Gutter with 110 mm. Down Pipe	221.6	110.8	310.2	155.1
100 mm. square Gutter with 61 mm. Down Pipe	95.8	47.9	134.1	67.0

Source: Waving Plastics Ltd., publication TT46.

flushed this flexible hose would be taken out of the storage tank inlet and directed to a drain or a similar outlet. When the roof is clean this would be inserted back into the storage tank inlet.

Just before the rainy season the roof is usually cleaned by sweeping off the impurities collected on it such as dust, leaves, bird droppings, etc. The first rainfall is then used to flush the roof by keeping the bypass open.

Storage Tank

Materials

Fibreglass tanks of the size required would have to be made of panels bolted and sealed together, supported externally by galvanized steel box girders. We are not convinced they would have a long life.

Galvanized steel tanks are in several cases being erected but their life depends entirely upon the internal and external protective paint coatings applied and their continual maintenance. Unless adequate annual maintenance can be guaranteed, corrosion will set in and the life of the tank is then limited, because it is difficult to arrest corrosion once it has set in.

Asbestos cement tanks have the advantage of a good resistance to corrosion by water. Although doubts have been expressed as to the suitability of asbestos materials for the storage of potable water, these are not supported by evidence of danger to health in this application.

Ferrocement tanks are made by building up layers of cement mortar plastered on either side of steel wire mesh sheets supported by a cage of reinforcing bars of 6 mm or 13 mm diameter. Such tanks have been successfully constructed in a number of countries, such as Indonesia, Malaysia and India, and they can prove cheap.

Reinforced concrete tanks are capable of proving satisfactory if care is exercised in choice of the correct aggregate, use of tested cement, and use of fresh water (i.e. rainwater or groundwater) for mixing. Appropriate tests can ensure these conditions are met, and designs appropriate to the conditions applying, coupled with careful workmanship, should ensure long-lasting tanks. An advantage of such tanks is that even if defects should arise, they are normally curable if action is taken in time.

In Sri Lanka we propose to use reinforced concrete tanks for large rainwater systems and ferrocement tanks for individual domestic schemes. The choice of material varies from country to country depending on the available raw materials and resources.

Size

The size of storage tank depends on three factors:

(i) Level of service.
(ii) Available roof area.
(iii) Rainfall characteristics of the region.

Level of Service: The minimum average consumption of drinking water is 2.5 lcd. A supply of 4 lcd is considered sufficient to provide minimum drinking and cooking water requirements. The water requirement for drinking, cooking and food preparation is 10 to 12 lcd. The level of service that can be provided would depend on the economics of providing the required storage. For a region having an average dry period of 90 days, a storage of 900 litres/person would be required to provide a supply of 10 lcd. This would mean a tank of 4.5 m^3 for a family of 5 persons. A low income family would not be able to afford such a tank. Therefore, for rainwater systems involving long term storage, the level of service has to be restricted to the bare minimum.

The storage tank should be completely leakproof as even a minute seepage over a long period will amount to a considerable loss of water. It should have a good cover to minimize evaporation losses and possible pollution. The tank should be provided with an insect proof ventilator.

Available Roof Area and Rainfall Characteristics: By analysing past rainfall records maintained over a long period of time, preferably for a continuous period of 30 years and at least for a minimum period of 10 years, it is possible to arrive at the optimum storage required for a unit roof area. The optimum storage is the minimum storage that would provide a uniform yield throughout the year using the entire collectable rainfall falling on the catchment roof area.

Collectable Rainfall = Total rainfall - Evaporation losses
- Gutter spillage.

An accurate analysis to arrive at the optimum storage would involve several runs of operational studies using records for periods over 10 years and the fundamental water balance equation:

Inflow - Outflow = Increase in Storage

which in this case is:

Collectable Rainfall - Yield = Increase in Storage.

Curves such as that in Figure 2 could be produced but this method usually requires computer facilities.

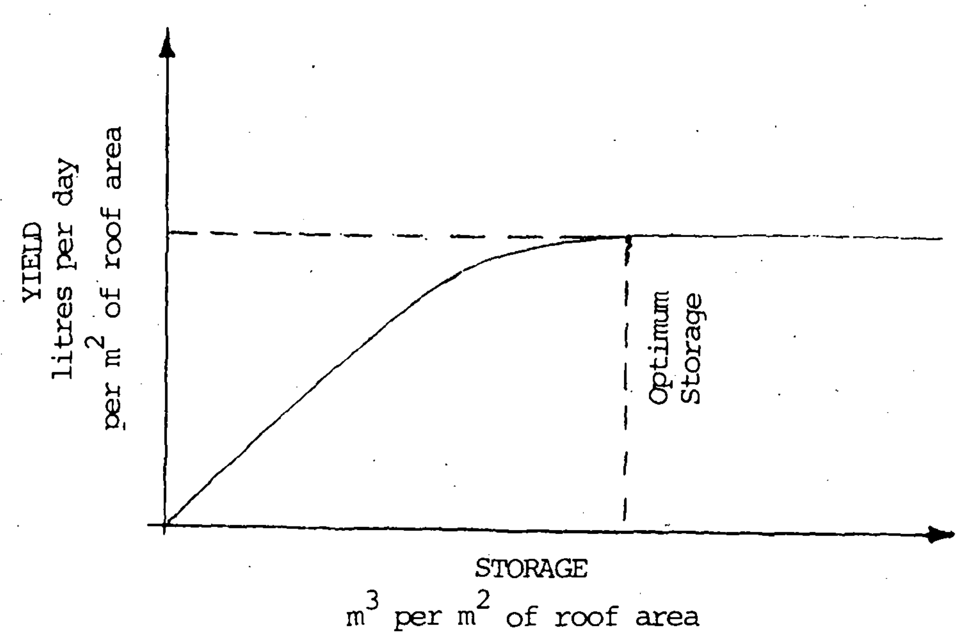


Figure 2. Yield Versus Storage Curve for Rainfall Analysis

For particular cases, a similar hand calculation can be done. A reasonably accurate value for the optimum storage could be obtained by the following method:

(1) From past rainfall records, identify the climatic year. For Sri Lanka generally this is taken from the first of October to the end of September in the following year.

(2) Examine records for each climatic year and note the longest dry period for each climatic year. (Disregard insignificant rainfalls within dry spells.)

(3) Select the year having a dry period, where the probability, over the entire period of records, of having a dry period of the same length or less is 75%.

(4) For the selected year compute the collectable rainfall, as follows:

Month	Total Rain-fall mm.	Number of Rainy Days	Evaporation Loss (1mm/ Rainy Day)	Gutter Spillage (5%)	Collectable Rainfall mm.
October	153	17	17	7	129
November	441	22	22	21	398
December	221	15	15	10	196
January	57	9	9	2	46
February	142	10	10	7	125
March	5	5	5	0	0
April	109	14	14	5	90
May	70	10	10	3	57
June	3	3	3	0	0
July	0	0	0	0	0
August	120	6	6	6	108
September	151	6	6	7	138
TOTAL	1472	117			1287

(5) Estimate the minimum storage requirement:

Collectable Rainfall	= 1.287 m
Volume over 1 m^2 of Roof Area	= 1.287 m^3
Optimum Yield	= $\frac{1.287}{365}$ x 1000
	= 3.5 litres/m^2 of roof area per day (lpd)
Longest Continuous Dry Period (say)	= 75 days
Minimum Storage Required	= 75 x 3.5
	= 263 litres/m^2 of roof area

(6) Check the adequacy of the minimum storage to regulate the inflow, in monthly units. The calculation can be carried out in table form as in Table 3.

Definitions:

D	= Storage at end of previous month
Inflow	= Collectable rainfall on one square metre in litres
Desired Yield	= Optimum yield (3.5 lpd) x no. of days per month = A
Available Yield	= Inflow + storage at end of previous month = B
Outflow	= Lesser value of A and B
C	= Inflow - Outflow
E	= D + C = total available for storage
F	= Capacity of rainwater tank/m^2 of roof area
Storage at end	= Lesser value of E and F of current month
Deficit	= A - B, if A greater than B
Spill	= E - F, if E greater than F

TABLE 3. VERIFICATION OF MINIMUM STORAGE VALUE

Month	Storage at end of previous month D	Inflow [litres] I	OUTFLOW Desired yield [litres] A	Available yield [litres] B	Outflow [litres] O	I - O C	STORAGE C + D E	Capacity [litres] F	Storage end of current month [litres]	Deficit [litres] A-B	Spill [litres] E-F
OCT	0	129	108.5	129	108.5	20.5	20.5	263	20.5	0	0
NOV	20.5	398	105	418.5	105	293	313.5	263	263	0	50.5
DEC	263	196	108.5	459	108.5	87.5	350.5	263	263	0	87.5
JAN	263	46	108.5	309	108.5	-62.5	200.5	263	200.5	0	0
FEB	200.5	125	98	325.5	98	27	227.5	263	227.5	0	0
MAR	227.5	0	108.5	227.5	108.5	-108.5	119	263	119	0	0
APR	119	90	105	209	105	-15	104	263	104	0	0
MAY	104	57	108.5	161	108.5	-51.5	52.5	263	52.5	0	0
JUN	52.5	0	105	52.5	52.5	-52.5	0	263	0	52.5	0
JUL	0	0	108.5	0	0	0	0	263	0	108.5	0
AUG	0	108	108.5	108	108	0	0	263	0	0.5	0
SEP	0	138	105	138	105	33	33	263	33	0	0
TOTAL	-	1287	1277.5	-	1116	-	-	-	-	161.5	138.0

Check: (1) Total Inflow = Total outflow + total spill + (Final storage - initial storage)

= 1116 + 138 + (33 - 0) = 1287

(2) Total Deficit = Total desired yield - total outflow

= 1277.5 - 1116 = 161.5

The tank size is inadequate. The deficit is around 13%.

(7) Select a higher capacity and check for adequacy, and so on until a suitable size is determined.

For the above example a size of 350 litres per square metre of roof area would be adequate to yield 3.5 lpd per square metre of roof area throughout the year. For years wetter than the selected year, the yield would be higher, and vice versa. If a smaller size is selected due to say economic reasons, the tank could be operated in such a manner to yield higher drawoffs in the wet season and a minimum requirement during the dry season.

Using the values determined above, it is possible to fix the size of the storage tank required for a village. The following example illustrates the steps involved:

Number of persons to be supplied with rainwater = 100
Level of service = 4 lcd
Rainwater requirement = 400 lpd
Yield = 3.5 lpd/m^2 of roof area when a storage of 350 l/m^2 of roof area is available

Therefore, area of roof required $= \frac{400}{3.5} = 114.3\ m^2$

Say 115 m^2

$$\text{Storage required} = \frac{115 \times 350}{1000} = 40.25\ m^3$$

Infiltration (Perforated) Pipes for Fresh Water Lens Storage
(see Figure 3)

The design of an infiltration system depends on field investigations carried out to determine the infiltration rate from a perforated pipe system. The trial trench should be about 2.0 m long and 0.6 m wide. The depth should be approximately the depth proposed for the prototype. Water should be infiltrated into the ground from a horizontal 100 mm PVC perforated pipe laid in the trench. The pipe should be covered with suitable size sand and the trench back filled. During test pumping, the water level in the pipe should not be more than 0.5 m below ground level. The result of the test should be adjusted to allow for the 'end' losses from the trench.

SESSION III: RESEARCH PRIORITIES OF RAINWATER CATCHMENT SYSTEMS IN SOUTH EAST ASIA

DESIGN AND DEVELOPMENT ASPECTS OF RAIN WATER CISTERN SYSTEMS IN SOUTH EAST ASIA

Adhityan Appan
Associate Professor
Nanyang Technological Institute
Singapore

INTRODUCTION

There is evidence that Rain Water Cistern Systems (RWCS) have been in existence in many countries since the second millenium B.C. (OZIS, 1982, RAINE, 1967, DIXEY, 1950, PRASAD, 1979). Yet it is a sad realty that even in the twentieth century (1980 to be exact), hardly 30% of the world's population has access to safe drinking water (WORLD WATER, 1981). One wonders why RWCS have not been universally put to use, as all the experience, development and research accrued over the years should have resulted in standardised systems based on well-defined methodologies. This lack of development could be due to the advent of the concept of larger water supply and associated central quality control systems that were established in the western world (CLARK et al, 1977). Thus a traditional and simple system has been backstaged. With financial constraints being imposed on developing countries and the world at large worrying at the rising demands for potable water, RWCS could help to alleviate, to a great extent, this demand for water.

THE SPECIAL ATTRACTION OF RWCS

Though traditional collection, treatment and distribution systems using large catchment runoffs are proven systems, the financial backing for such systems may not be forthcoming or is beyond the reach of many developing countries. Very often the support services necessary to maintain the necessary infrastructure may also be lacking. Under such conditions, RWCS have a potential to at least tide over an interim period. Besides, in areas where there is a lack of potential for potable water or the sources are contaminated, RWCS can prove to be a substitute with potential for replacing or supplementing conventional large-scale systems.

An additional benefit of RWCS particularly in developing countries is the fact that by using rainwater for drinking and culinary purposes the incidence of some endemic water-borne diseases can be reduced (MALIK, 1982).

The quality of rainwater is of a high order (FEACHEM, 1975) when compared with runoff from large catchment areas that are tending to become more and more polluted due to man's activities (APPAN, 1977). So rainwater is a far cleaner input and in this respect it is definitely a preferred source requiring a minimum amount of treatment (W.H.O., 1971).

In developed countries, the industrial growth and overall influence is creating a rapidly rising demand for water. With global limitations imposed on a closed hydrological system that only accounts for 3.8% of the volume of water available in the world (CHOW, 1964), there is a need and urgency to look for alternative or complementary sources.

RWCS could fill this void and this calls for a systematic and well-organised program that will make it a system capable of supplying water that is safe, palatable and cheap.

DESIGN AND PLANNING

To design an appropriate system for the abstraction of water, investigations have to be carried out to ascertain the availability of raw water from various sources. When there are no existing schemes, alternate sources like rivers, streams, wells etc., are used. Field conditions such as a low groundwater table or availability of only brackish water are factors that have deprived many areas of reliable water supplies.

Some important aspects of investigation necessary for planning and designing RWCS are as follows:

Rainfall Data

Rain is the primary input for RWCS and past records have to be dug up to study the quantity and pattern. Stochastic variations play an important part in the design of the system. Rainfall data should be continuous and discretised preferably on a daily basis though analyses have been done on weekly rainfall data (FOK, 1980). Rainfall will vary from place to place and so the rainfall stations nearest to the location of interest have to be considered for analysis of data. If this is not possible, suitable adjustments have to be made based on the isohyetal patterns.

System Parameters

The relationship amongst the parameters like catchment (or roof) area, storage volume of the cistern and rainfall will decide the reliable rate of supply that can be obtained from the system. These relationships have been assessed in many different ways varying from simple deterministic models (HOEY and WEST, 1982) to probabilistic (FOK et al, 1982), simulation (PERENS, 1982) and stochastic models (LEUNG and FOK, 1982). A simple system taking into consideration all weekly rainfall values over a 3 year period is represented (APPAN, 1982) as follows:

$$Q_i = Ar_i - [(E_i + b_i) + D]$$

where

Q_i is the quantity of water at end of day i,

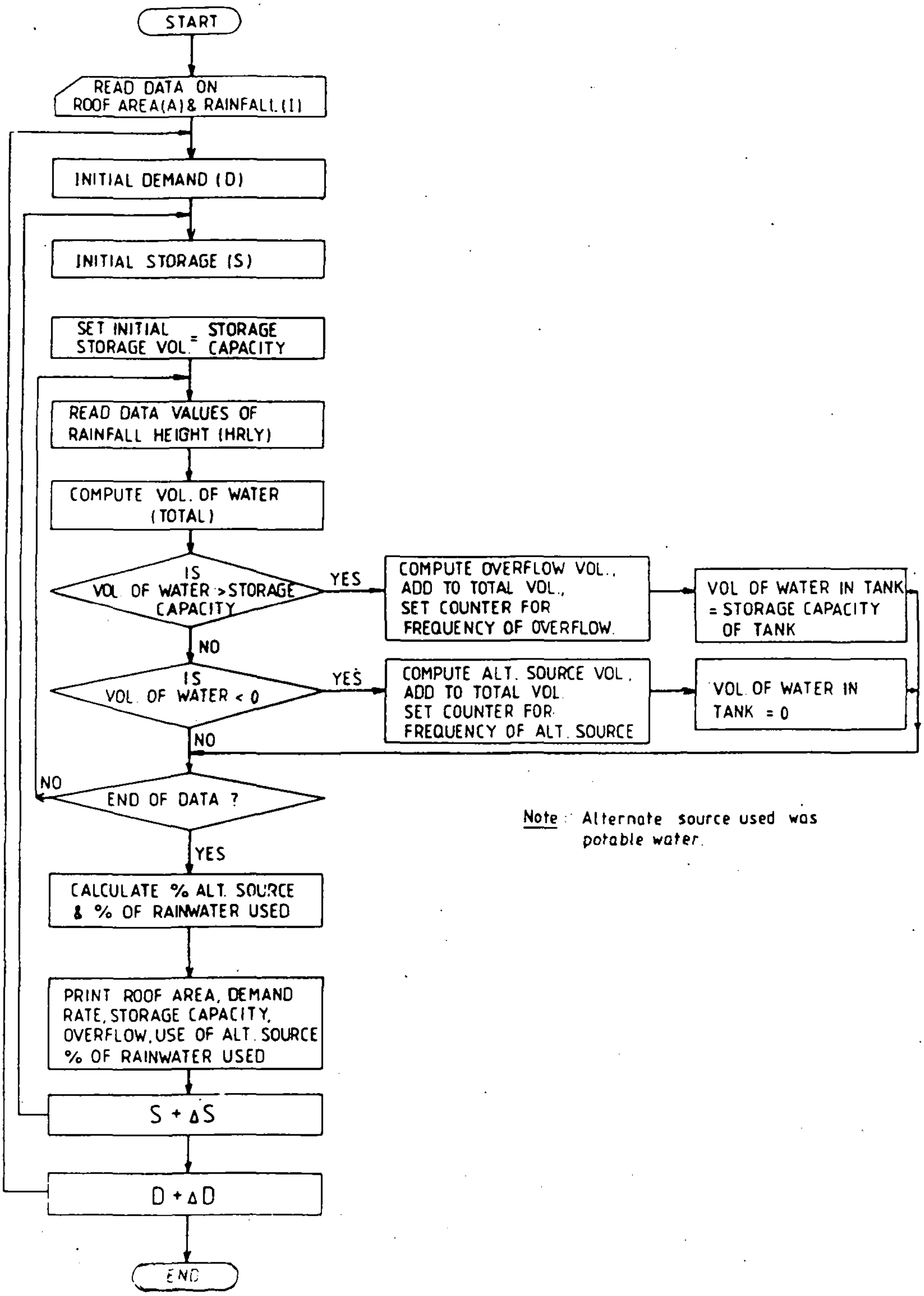
A is the roof (catchment) area,
r_i is the rainfall during day i,
b_i is the roof absorption rate in day i
E_i is the evaporation at end of day i, and
D is the daily demand (supply).

In the above equation, the cistern will or will not be subjected to spillage in day i according to whether Ar_i is greater or less than $(E_i + b_i) + D$. This simple model has further been developed and the flowchart is shown in Figure 1. In this process of computation, except for the roof area all the other parameters are variables. A matrix of solutions can be printed and also the efficiency of the RWCS can be assessed by determining the percentage of rainwater being used, the volume that overflows and the quantity from the alternate source being used to tide over the low rainfall periods. The methodology is very straightforward and can be easily programmed in a microcomputer.

Quality of Rainwater

Physico-chemical and bacteriological analyses should be done for the samples collected. Under normal circumstances, atmospheric gases such as carbon dioxide dissolve in rainwater as carbonic acid, a weak acid. The dissociation constant for the weak acid is such that when rain is saturated with carbonic acid, the pH is 5.65. However, there are instances where the presence of sulphuric acid in the air has resulted in acid rain with pH of 2.5 to 3.0 (PENKETT et al, 1979, LIKENS, 1979). Such low pH values will create much higher treatment costs but one way to avoid its initial impact, which is greatest, is to divert the first flush by operation of a suitable bypass (KING, 1982). Acid rain has also recently been observed in Canada and was reported to have affected groundwater sources resulting in higher than normal concentrations of Copper, Zinc and Lead in domestic supplies (Journal of Groundwater, 1983). Rainwater tends to be soft in most cases.

Figure 1. Flowchart for Rainwater Cistern Systems



Note: Alternate source used was potable water.

Treatment

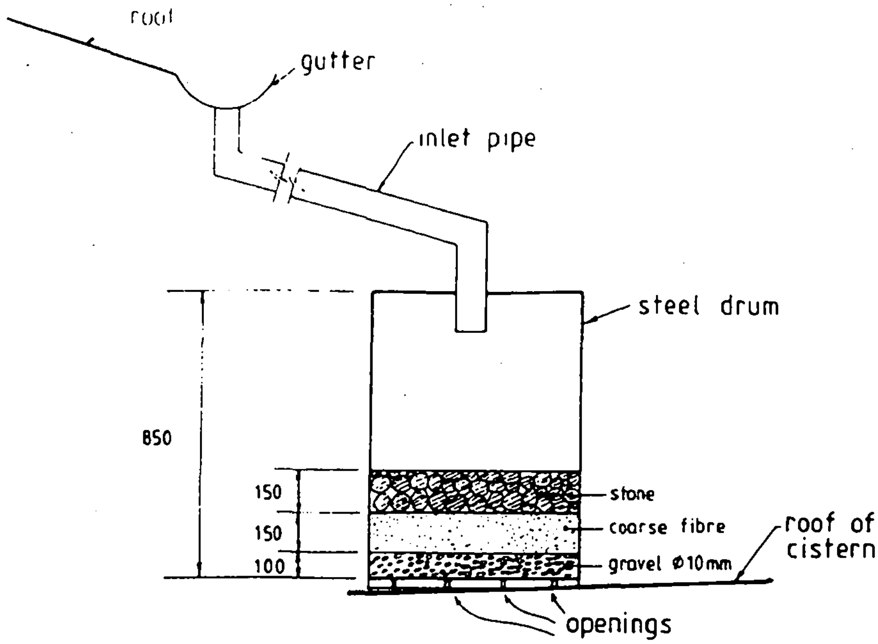
In most locations the quality of rainwater may be acceptable but the process of collection on roofs and transfer through open gutters and the ultimate storage in cisterns exposes the system to a horde of different system channels that are all potential sources of contamination. It is not unusual to have simple filters at the end of the inlet pipe from roofs before entering the cistern as practised in Indonesia (WINARTO, 1982, KERKVOORDEN, 1982) California (CAPTURED RAINFALL, 1981) etc., (See Figure 2.).

Due to some contamination either in the atmosphere or that accrued in transmission resulting in the buildup of sludge in the cistern, rainwater may have to be disinfected. Boiling of water is an effective method of disinfection and for rural schemes, a solution of chlorine made from powder or chlorine tablets is convenient (PICKFORD, 1977). It is also recommended that sufficiently strong solutions of chlorine in the form of Chlorox or bleach should be added to the cistern each night so that residual chlorine the next morning is in the order of 0.5 mg Cl^-/l or greater (LEE and JONES, 1982).

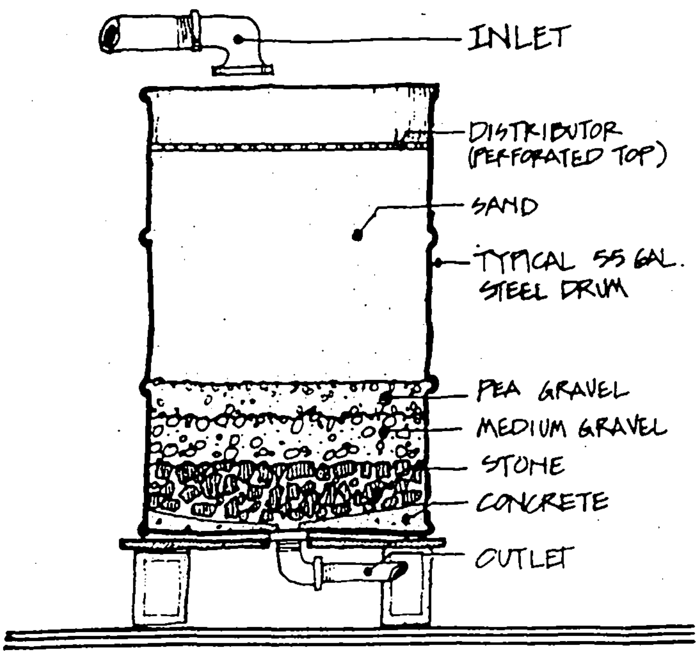
Material Costs

The cost factor is very critical in acceptance of RWCS as a mode of supply in a developing country. Materials used and the location from which the cistern is obtained have a distinct bearing on the costs.

From the material costs which appear to be generally irregular, it would still appear that larger tanks can be built at lower unit costs. Varying standards and specifications of construction would affect the price structure (KELLER, 1982). The general materials that go into a cistern vary from cement mortar, concrete, ferro-cement and reinforced concrete to steel, redwood, brick, corrugated metal sheets, fibre glass, bamboo, etc. The choice of material is a very subjective matter and will



Filter Used in West Java
(after Kerkvoorden, 1982)



Filter Used in California
(after Captured Rainfall, 1981)

Figure 2

be dependent largely on the economic status of the potential user, the source of funding, the availability of raw materials in the locality, etc.

Total Costs and Financing

Financing of these RWCS is an important aspect as at least the capital costs for the cistern have to be borne by the owner of the dwelling. This type of problem can be quite acute and calls for a form of subsidy in some of the developing countries. Though a high percentage of the cost of RWCS can be attributed to cisterns, there will be other associated expenditures for maintaining roof surfaces, guttering systems, downpipes, treatment processes like filtration and, perhaps, some disinfection. In other words, there will be maintenance of the whole system, a function that should be carried out diligently to ensure that the quality of water being obtained is not reduced. As far as possible, maintenance costs should be minimised so as to fall within the pocket book of the user.

PROBLEMS FOR FURTHER DEVELOPMENT AND RESEARCH

Different types of problems can be encountered in Rain Water Cistern Systems especially when water of pre-determined quality level has to be delivered. Each of these problems has to be addressed according to the region in which it arises. Development work in RWCS will depend on the use to which the rainwater is put, the quality of the rainwater, the socio-economic level of the users, institutional constraints, structural limitations etc. Some development and related problems are listed:

Construction Materials

With a wide variety of materials available in the market, the most effective need not necessarily be the cheapest or most appropriate type for use in a specific region. In this respect, the appropriate technology should be geared towards a choice between affordable and locally acceptable alternative materials. The main criterion should be the cost factor and the efficiency of the system.

Vector Control

The retention of water collected in tropical and subtropial regions in a stagnant state makes it an ideal ground for breeding mosquitoes that can lead to malaria, dengue haemorrhaegic fever and also a general nuisance. In fact, in some developing countries, particularly Malaysia and Singapore, this is one of the arguments against the use of such RWCS. So care has to be taken to ensure that under no circumstances will the RWCS be instrumental in propagating such potentially lethal diseases.

A simple wire-mesh inlet cover has been found to be reasonably effective but in Singapore, it was found that this could not prevent the ingress of both larvae and eggs (APPAN, 1982). When the cisterns were opened there was a swarm of mosquitoes that had bred within. The application of kerosene can be useful in this respect but it imparts an unpleasant taste and has a strong odour. In Australia it is recommended that to control mosquito larvae, medicinal quality paraffin oil can be spread sparingly on the surface of the water (RAINWATER TANKS, 1981). Also in tropical countries, the addition of non-toxic insecticides in water containers has been recommended (BRADLEY, 1978).

A definitive and effective means of controlling larvae of any variety has to be researched and developed for use particularly in the tropical and subtropical areas as the consequences are more telling in these regions.

Health Education

Based on the quality of rainwater available and the state of the collecting system, there is a need to work out systems for imparting proper health education regarding all or some of these aspects so that there will be no contamination of the water supply system.

One important aspect of RWCS is the fact that the onus of looking after the quality of water ingested or used for other purposes lies with each and every householder. This is very much unlike larger systems where the responsibility of maintaining water quality lies with the central water supply authority. So this awareness has to be brought to the potential user.

Long Term Effects

From its historical background, rainwater appears to have been accepted socially though mention has been made that certain ailments like rheumatism have been ascribed to the use of rainwater (MALIK, 1982). With isolated areas having problems of acid rain and the movement of developing countries towards technological development, the quality of rainwater has to be monitored regularly to appraise its quality. The effect of imbibing such water on a long term basis is an area that needs to be looked into as no work has been done in this direction.

Rainwater as a Dual Source of Supply

The abundance of rainwater makes it an attractive proposition in many countries to use it in conjunction with the water being supplied. However in most countries like Australia and Singapore (PUBLIC UTILITIES BOARD, 1977), it is forbidden to have cross connexions between potable water and water from other non-potable sources. So there is the need for developing systems that entail the use of the collected rainwater either in its own state or in mixed form only for non-potable purposes. In Singapore where there is a water-borne sewerage system, as much as 24% of the potable water is used for WC flushing purposes (LIM, 1983). The systems being developed are based on potable supplies that are available with a pressure head (Figure 3) and potable and rainwater tanks that are at the same level (Figure 4). In both cases, priority is given to the utilization of rainwater as it is planned to be used for non-potable purposes. These systems can be sufficiently developed and adapted for use in suburban and rural areas.

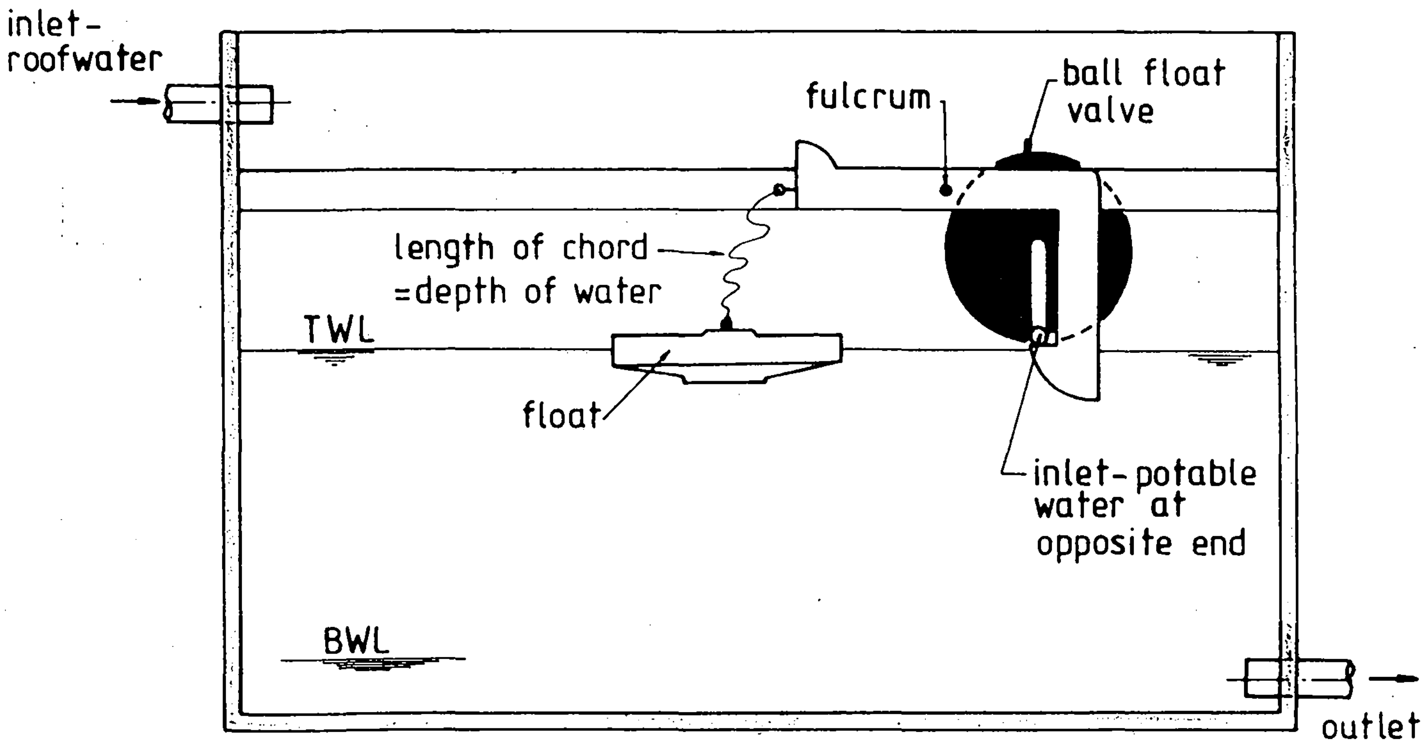


Figure 3. Roofwater Priority System
(Potable Water under Pressure)

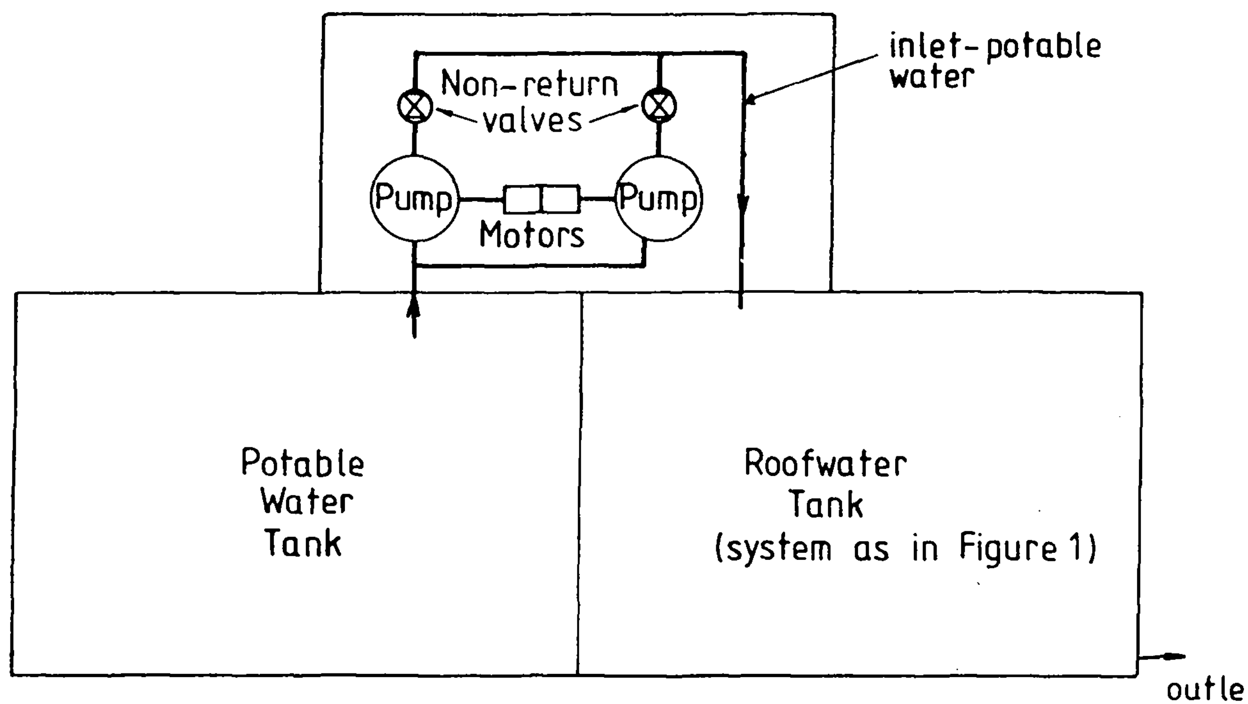


Figure 4. Roofwater Priority System
(Potable and Roofwater Tanks at the Same Level)

Structural Considerations

When cisterns have to be placed on the roofs of structures, obviously the additional superimposed loads have not been catered for in the original design. This poses size limitations on the cistern that can placed on an existing roof. If rainwater tanks become mandatory, then the live load requirements need to be specified to cater for this additional load.

In this case the trade-off lies between the additional structural costs incurred and the direct benefit of use of large volumes of rainwater. Intangible benefits would include attenuation of floods, lower discharges in sewers etc. In the interim period, the safe load allowed on roofs will have to be ascertained by examining existing structural features.

THE NEED FOR A NETWORK ON RWCS IN SOUTH EAST ASIA

From a cursory glance of the scanty overall network of RWCS activity in South East Asia, it would appear that only Indonesia (WINARTO, 1982, KERKVOORDEN, 1982) and Thailand (GROVER and KUKIELKA, 1980, PREMPRIDI, 1982) have ventured into RWCS in some organised manner. In the rest of the countries, there is very limited or no concerted work being done in spite of the fact that there are vast tracts of rural areas that do not have proper water supply systems.

Reviewing the techniques for designing RWCS, it is apparent that sufficient development and research has been done to get a reasonable system going. What exactly is necessary is analysis of regional data and expertise to tune the RWCS properly. As the initial work required is to establish operational norms, it would be most appropriate if a network of pilot RWCS is installed in the Southeast Asian region.

Objectives

The main aims of a network would be:

(i) to identify those areas in the region which are ideally located and sufficiently representative,

(ii) to establish a network of RWCS pilot stations and gather actual field data in terms of rainfall, pattern of demand in relation to roof area, roof-water quality etc.,

(iii) to use the data obtained for arriving at an ideal relationship between volume of cistern, roof area, demand etc.,

(iv) to use different types of materials including indigenous types for construction of storage tanks and assess the efficacy in terms of cost, quality of water etc.,

(v) to study the effect of environmental factors on the RWCS being used and to emphasize that a system must, as far as possible, ensure a totally safe and palatable water supply system and

(vi) to use the accrued information to arrive at the most appropriate system(s) suitable for each of the locations after having done a proper economic appraisal.

Typical RWCS Pilot Stations

The setup should be such that the necessary data can be gathered making sure that the officer in charge is sufficiently trained to be able to make changes or alterations to the existing system. This can be done by utilising the monitored information from the inception of the project.

For the pilot RWCS, it is recommended that there be:

(a) Different tank sizes, variable roof areas and cisterns made with different materials

(b) Quantitative measuring equipment like a flow recorder, a water level recorder etc.

(c) Quality measuring devices (in situ) like a pH meter, a turbidity meter, a conductivity meter

(d) Continuous rainfall recorder to be located in the immediate vicinity

(e) Sufficient number of water sampling bottles to collect samples for determining physical, chemical and bacteriological quality.

In remote areas, it will be necessary to appoint full-time personnel to man the pilot station and take readings regularly. This information can then be conveyed to the officer in charge of the region or country.

Distribution of Network Stations

It is proposed that a network of at least 16 stations be set up in not less than 6 countries as follows:

Malaysia	- 4 stations
Thailand	- 2 stations
Indonesia	- 2 stations
Philippines	- 3 stations
Papua New Guinea	- 2 stations
Others	- 3 stations
TOTAL	16 stations

The above proposal is only tentative and the final distribution will be largely influenced by the state of knowledge or practice of RWCS in the particular country or location.

Dissemination of Information

In the establishment of a regional network of RWCS, there are two distinct phases of passing on information:

1. Initially the information available in a country level has to be obtained by the officer responsible for all the stations in a national level. This officer who is to actually spearhead the country's stations should have earlier contacted the relevant authorities to set up the stations.

2. Using all the available data, a Seminar should be organised so as to pass on all the accrued experiences. Problems encountered should be highlighted and the final outcome should be such that the goals set have been met.

In short, there should be sufficient documented information to make the RWCS a viable proposition in the respective country.

CONCLUSIONS

RWCS are an attractive proposition either as an independent or supplementary source. Methodologies for the design of RWCS are sufficiently developed for field implementation. Some problem areas, specifically region-oriented or institutional in nature, need to be researched.

The time is now ripe for countries in South East Asia to get actively involved in the establishment of a network of pilot RWCS with a view to calibrating their models to suit specific requirements. Following this, if a transfer of appropriate technology is effected, the stage should be set for more comprehensive RWCS to be established in these countries.

REFERENCES

APPAN, A., 1977. A Total Approach to Water Quality Management in Urbanised Catchments. Ph. D. Thesis, University of Singapore, pp. 86.

APPAN, A., 1982. "Some Aspects of Roof Water Collection in a Subtropical Region", Proceedings of the Rain Water Cistern Systems Conference, June 1982, Honolulu, pp 220-226.

BRADLEY, D.J., 1978. "Health Aspects of Water Supplies in Tropical Countries" in Water, Wastes and Health in Hot Climates ed. by R. Feacham, M. McGarry and D. Mara, John Wiley & Sons, pp 3-17.

CAPTURED RAINFALL. Small-Scale Water Supply Systems, The Resources Agency, Department of Water Resources, State of California, May 1981.

CHOW, V.T., 1964. Handbook of Applied Hydrology. McGraw-Hill.

CLARK, J.W.; W. VIESMAN, Jr; M.J. HAMMER, 1977. Water Supply and Pollution Control. Harper & Row, New York. pp. 10.

DIXEY, F., 1950. A Practical Handbook of Water Supply, Second Edition. Murby, London.

FEACHEM, R.G., 1975, "Water Supply for Low Income Communities in Developing Countries", ASCE Env. Eng. Dn. 101:EE5:pp 687-702.

FOK, Y.S.; R.H.L. FONG; J. HUNG; E.T. MURABAYASHI; A. LO, 1980. "Bayes-Markov Analysis for Rain Catchment Systems", Technical Report 133, Water Resources Research Center, University of Hawaii, Honolulu.

FOK, Y.S.; R.H.L. FONG, E.T. MURABAYASHI and A. LO., "Deterministic and Probabilistic Processes of Weekly Rainfall", Proceedings of the Rain Water Cistern Systems Conference, Honolulu, June 1982, pp 83-91.

GROVER, B.; B.J. KUKIELKA, 1980. Thailand Village Water Supply and Sanitation Sector Reconnaisance Mission. Report for Asian Development Bank.

HOEY, P.J.; S.F. WEST, 1982. "Recent Initiatives in Raintank Supply Systems for South Australia", Proceedings of the Rain Water Cistern Systems Conference, June 1982, Honolulu, pp. 284-293.

JOURNAL OF GROUNDWATER, Technology Division 1983. National Water Well Association, September - October 1983, Vol. 21, No 5, pp. 657.

KELLER, K., 1982. Rainwater Harvesting for Domestic Water Supply in Developing Countries: A Literature Survey. Water for Sanitation and Health (WASH), USAID Draft Report C-252, June 1, 1982, pp. 103.

van KERKVOORDEN, R., 1982. "Rainwater Collectors for Villages in West Java", Proceedings of the Rain Water Cistern Systems Conference, Honolulu, June 1982, pp. 299-303.

KING, T.L.; P.B. BEDIENT, 1982. "Effect of Acid Rain Upon Cistern Water Quality". Proceedings of the Rain Water Cistern Systems Conference, Honolulu, June 1982, pp. 244-248.

LEE, G.F.; R.A. JONES, 1982. "Quality of St Thomas U.S. Virgin Islands Household Cistern Water Supplies", Proceedings of the Rain Water Cistern Systems Conference, June 1982, Honolulu, pp. 233-243.

LEUNG, P.; Y.S. FOK, 1982. "Determining the Desirable Storage Volume of a Rain-Catchment System: A Stochastic Assessment", Proceedings of the Rain Water Cistern Systems Conference, Honolulu, June 1983, pp. 128-134.

LIKENS, G.E., 1979. "Acid Rain". Scientific American, 241, pp. 43-51.

LIM, R.Y.H., 1983. "Singapore Industrial Water Supply". Seminar on Water Conservation for Manufacturers held on 29 Sept 1983 at Singapore, Seminar Proceedings pp. B-1.

MALIK, U.A., 1982. "Rainwater Cistern Systems and Policy in Malaysia". Proceedings of the Rain Water Cistern Systems Conference, June 1982, Honolulu, Addenda pp. 7.

OZIS, U., 1982. "Outlook on Ancient Cisterns in Anatolia, Turkey". Proceedings of the Rain Water Cistern Systems Conference, June 1982, Honolulu, pp. 9.

PENKETT, S.A.; B.M.R. JONES; A.E.J. EGGLETON, 1979. A Study of SO_2 Oxidation in Stored Rainwater Samples, Atmospheric Environ, No. 13, pp. 139-147.

PERRENS, S.J., 1982. "Design Strategy for Domestic Rainwater Systems in Australia", Proceedings of the Rain Water Cistern Systems Conference, June 1982, Honolulu, pp. 108-117.

PICKFORD, J., 1977. "Water Treatment in Developing Countries", in Water, Wastes and Health in Hot Climates Ed. by R. Feachem, M. McGarry, D. Mara. John Wiley & Sons, pp. 186-188.

PRASAD, R., 1979. Rainwater Harvesting in India and the Middle East Report to UNEP Rain and Stormwater Harvesting Project, 80 p.

PREMPRIDI, T., 1982. "Collection and Storage of Rainwater in Rural Thailand", Proceedings of the Rain Water Cistern Systems Conference, June 1982, Honolulu, Addenda, 8 p.

PUBLIC UTILITIES BOARD, 1977. Public Utilities Board (Water Supply) Regulations, Chap. 211, Gazette No 25, No 5126, Clause 10(3) pp. 257.

RAINE, D.F., 1967. Architecture - Bermuda Style. Hamilton: Longtail.

RAINWATER TANKS, 1981. Their Selection, Use and Maintenance, Prepared by Engineering & Water Supply Dept., The Government of South Australia.

WORLD WATER, 1981. "D-day for the Water Decade", World Water, Liverpool, U.K.

W.H.O., 1971. International Standards for Drinking Water. W.H.O. Geneva.

WINARTO, 1982. "Rural Rainwater Cistern Design in Indonesia", Proceedings of the Rain Water Cistern Systems Conference, Honolulu, June 1982, pp. 294-298.

SESSION IV: WORKSHOP: RESEARCH PRIORITIES IN SOUTHEAST ASIA

Three workshop groups were formed to discuss research priorities according to the following topics:

GROUP A: SOCIO-CULTURAL, ECONOMIC AND FINANCIAL ASPECTS

(Leader: Mrs Cecilia Verzosa)

Socio-Cultural

There is a dire need to increase community acceptance, improve understanding in the correct installation, maintenance and repair of rainwater tanks. Users have to be educated on the health and economic benefits of using this type of water system. The following research priorities were identified:

1. Development of appropriate instructional materials on the construction, installation and maintenance of rainwater tanks.

2. Cross-country comparisons on the use of rainwater as an acceptable form of drinking water.

3. Socio-behavioural and health impacts of using rainwater catchment systems as a source of water.

4. Investigation on villagers' attitudes on, perceptions of, and ability to purchase rainwater systems for drinking purposes.

Economic and Financial

Bearing in mind that the target beneficiaries are from the poor sector of the population and that this form of water supply should cover as large a population as possible, there is a need to develop and test strategies for the villagers to pay or partially pay for the cost of the tanks. The following research priorities were identified:

1. Economic studies to compare the viability of rainwater catchment to other forms of water supply.

2. Studies to compare rainwater projects fully subsidized by the government with those operated by non-government organizations.

3. Development and testing of alternative financing and repayment schemes appropriate for specific target beneficiaries.

GROUP B: TECHNOLOGICAL ASPECTS

(Leader: Dr. Adhityan Appan)

The design of rainwater collection systems is highly localized and is affected by the meteorological conditions and the cost and availability of construction materials in the target areas. There is a need to develop analytic procedures that can be used locally and to test the effectiveness of new materials and components that come out of local experience. The following research priorities were identified:

1. Development of design criteria for individual country requirements in terms of differing roof areas, stochastic rainfall patterns, varying water demands, and corresponding cistern sizes.

2. Evaluation of different types of local construction materials (bamboo reinforcement, clay jars, ferrocement, bricks, mortar bricks) and construction techniques in the region. Investigation of bamboo reinforcement should include long term effects in terms of structural behaviour and the effect of microbes on decomposition of the bamboo.

3. Development and testing of automatic or manual devices to divert the initial volume of rain.

4. Development of alternative construction techniques for underground tanks to reduce cost of construction

5. Development and testing of simple strainers and filters which are easy to install, operate and maintain.

6. Testing and standardization of procedures for disinfecting stored rainwater, such as use of chlorine tablets and bleach.

7. Testing of means of preventing the growth of insect larvae in the stored water, such as the use of paraffin.

8. Development of a simple manual of procedures for maintenance and repair of communal and individual rainwater tanks.

9. Development of dual source water systems that use both rain and treated potable water on a lowest-cost basis, particularly in areas where treated water is expensive or not readily available.

GROUP C: WATER QUALITY ASPECTS

(Leader: Dr. Donald S. Sharp)

The major advantage of the use of rainwater is its high quality. However, to be effective, this quality must be both available during collection and maintained until the water is consumed. In the past, this aspect has not been adequately addressed. As a result, the following research priorities were identified:

1. Investigation of the effects on the physico-chemical quality of stored rainwater of roofing materials and construction materials of containers.

2. Investigation of the effect on health of the use of roofing materials made of asbestos, asphalt and various metals.

3. Use of alternative roofing materials to improve the quality, taste and colour of stored rainwater.

4. Effect of duration and intensity of rainstorms on the quality of stored water.

5. Study of the bactericidal effect of solar radiation on stored water.

6. Investigation of the effect of first flush diversion devices on the quality of stored rainwater.

7. Investigation of the effect of screening devices in preventing mosquito breeding in the stored water.

8. Investigation of the change in bacterial contamination levels of stored rainwater.

LIST OF PARTICIPANTS

A. THAILAND

Dr. Pairojana Sornjitti
Population and Community
Development Association (PDA)
8 Sukumvit Soi 12
Bangkok 11
Thailand

Mr. Chai Penparkul
Population and Community
Development Association (PDA)
Khon Kaen
Thailand

Prof. Thamrong Prempridi
Head
Appropriate Technology Research
Unit
Faculty of Engineering
Chulalongkorn University
Phyathai Road
Bangkok 10500
Thailand

The following were from
Khon Kaen University:

Mr. Chayatit Vadhanavikkit
Dr. Pradit Nopmongkol
Dr. Nipon Thiensiripipat
Dr. Suthiphol Viwatthanathepa
Miss Vanasri Bunyaratpan
Mr. Suparerk Sinsupan
Dr. Chariya Sethaputra

Faculty of Engineering
Khon Kaen University
Friendship Highway
Khon Kaen
Thailand

B. MALAYSIA

Dr. Uzir A. Malik
Department of Agricultural
Economics and Water
Resources
National University of
Malaysia
Bangi, Selangor
Malaysia

Dr. Ahmad Fauzi Mustapha
Faculty of Engineering
University of Malaya
Pantai Valley
Kuala Lumpur
Malaysia

C. INDONESIA

Dr. Hari Siswoyo Aji
IWACO B V
Jalan Sederhana 7
Bandung, Java
Indonesia

Miss Christina Aristanti
Yayasan Dian Desa
7 km Jalan Kaliurang
(P O Box 19)
Bulaksumur
Yogyakarta, Java
Indonesia

D. PHILIPPINES

Trinidad Francesco
c/o Dr Ignacio S. Pablo
Vice President, Science
and Technology
The Philipping Women's
University
Taft Avenue
Metro Manila
Philippines

Mr. Francisco Paro, Jr.
Office of The Governor
Roxas City
Capiz, Panay Island
Philippines

Mrs. Cecilia Verzosa
Program for the Introduction
and Adaptation of
Contraceptive Technology
(PIACT)
MCC P O Box 189
Makati 3117
Metro Manila
Philippines

E. **SINGAPORE**

Dr. Adhityan Appan
School of Civil and Structural
Engineering
Nanyang Technological Institute
Upper Jurong Road
Singapore 2263

F. **SRI LANKA**

Mr. Dharmadasa Pathirana
Lanka Jatika Sarvodaya
Shramadana Sangamaya Inc.
"Meth Medura"
77 De Soysa Road
Moratuwa
Sri Lanka

Mr. R.K.C. Rajapakse
Chief Engineer, Construction
National Water Supply and
Drainage Board
P O Box 14
Mount Lavinia
Galle Road
Ratmalana
Sri Lanka

G. **SIERRA LEONE**

Mr. G.T. Tengbeh
Department of Environmental
Studies and Geography
Njala University College
Freetown
Sierra Leone

H. **INTERNATIONAL DEVELOPMENT RESEARCH CENTRE**

Dr. Donald Sharp
Associate Director
Health Sciences Division
International Development
Research Centre
Box 8500
Ottawa
Canada K1G 3H9

Mr. Alexander Redekopp
Senior Program Officer
Health Sciences Division
International Development
Research Centre
Box 8500
Ottawa
Canada K1G 3H9

Mr. Lee Kam Wing
Program Officer
Health Sciences Division
Tanglin PO Box 101
Singapore 9124
Republic of Singapore