SMALL WATER PROJECT DESIGN AND CONSTRUCTION

General Principles and Techniques For Community Based Projects

Field Co-Ordinator Training Course
ASTC Project, Mahweit

Skills training

Colm Ryder/Michael Cullen

red-t streets

CONTENTS

PAGE NO.

1. INTRODUCTION 1

2. GENERAL INTRODUCTORY TECHNIQUE FOR ALL SMALL WATER 3
PROJECT DESIGN. (Flow Chart)

3. FLOW MEASUREMENT 13
3.0. Introduction 13
3.1. Pipe Flow 13
3.2. Channel Flow Measurement 15

4. PROCEDURES FOR DESIGN AND COSTINGS 19
4.1. Design and Costing of Stone Tank 19
4.1.0. Introduction 19
4.1.1. General Calculations 19
4.1.2. Design of Base 20
4.1.3. Design of Walls 21
4.1.4. Design of Roof 22
4.1.5. Materials Required for Tank Construction 24
4.1.6. Costing of Tank 26

4.2. Design and Costing of Ferro-Cement Tank 28
4.2.0. Introduction 28
4.2.1. General Information/Calculations 29
4.2.2. Design of Base 29
4.2.3. Design of Walls 30
4.2.4. Design of Roof 33
4.2.5. Amount of Wire Mesh required for all of the Tank . 34
4.2.6. Materials required for Tank Construction 35
4.2.7. Costing of Tank 37

5. CONSTRUCTION PROCEDURES 39
5.0. Introduction 39
5.1. Construction Procedure for Stone Tank 39
5.1.1. Introduction 39
5.1.2. Site Preparation 39
5.1.3. Construction of Foundation Slab 40
5.1.4. Wall Construction and Pipe Placement 42
5.1.5. Plastering of Inside Walls 44

.../..

PAGE NO.

5.1.6. Preparation of Wood 44
5.1.7. Construction of the Roof 45
5.1.8. Work on Access Area to taps 46
5.1.9. Inspection 47
5.1.10. Use of Excess Water 47

5.2. Construction Procedure for Ferro-Cement Tank,....... 48
5.2.1. Introduction 48
5.2.2. Site Preparation 48
5.2.3. Placement of the Vertical Reinforcing Bars 48
5.2.4. Construction of the Foundation Slab 49
5.2.5. Placement of Circular Horizontal Bars 49
5.2.6. Placement of Wire Mesh 50
5.2.7. Placement of Tank Fittings 51
5.2.8. Cement Mortar Application 53
5.2.9. The Manhole Cover 54
5.2.10. Access Area to the taps 55
5.2.11. Inspection 55
5.2.12. Use of Excess Water 55

5.3. Design/Costing and Construction of Combination Tank. 55
5.3.0. Introduction 55
5.3.1. Design and Construction of the Base and Walls ... 55
5.3.2. Design and Construction of the Roof 56
5.3.3. Materials and Costings 59

6. PIPELINE PROCEDURES 60
6.1. Pipeline Design and Costing 60
6.1.1. Introduction 60
6.1.2. Basic Calculations 60
6.1.3. Use of Data Book 61
6.1.4. Final Pipe Calculations 61
6.1.5. Example 62
6.1.6. Uses of Valves and Fittings 63
6.1.7. Costing of the Pipeline 64
6.1.8. Pipe and Accessory Prices 65

6.2. Pipeline Construction 66
6.2.1. Pipeline Route 66

.../..

PAGE NO.

6.2.2. Tools needed 66

6.2.3. Program of Work 67

6.2.4. Inspection and Repair of Individual Pipes 67

6.2.5. Connecting of Pipes 68

6.2.6. Pipe Supports 68

6.2.7. Inspection of Pipeline 69

6.2.8. Diagnosis and Correction of Problems 69

LIST OF DIAGRAMS

Section	Page No.	Diagram No.	Title
3.1	14	1	"Pipe Flow" measurement from channel flow situation
4.1.4	22	2	Layout of beams for stone tank roofing.
4.2.1	29	3	View of Standard Ferrocement tank
4.2.3 (d)	31	4	Layout of reinforcement steel for standard ferrocement tank
4.2.3 (e)	31	5	Desired overlap of reinforcing mesh in ferrocement tank.
5.1.3	41	6A	Design Mix for base of tank.
5.1.3	41	6B	Construction Technique for base of tank.
5.1.4 (a)	42	7	Placement of Drain Pipe
5.1.4. (b)	42	8	Design Mix for wall mortar in stone tank.
5.1.4 (c)	43	9	Placement of taps in stone tank.
5.1.4 (d)	43	10	Placement of air vents/overflow pipes in stone tank.
5.1.7 (a)	45	11	Layout of beams for stone tank roofing.
5.1.7 (b)	46	12	Manhole roof opening.
5.1.8	47	13	Layout of stone tank frontage.
5.2.5 (a)	50	14	Layout of Reinforcing Steel in standard ferrocement tank.
5.2.7 (b)	52	15	Placement of tops for ferrocement tank.
5.2.8	53	16	Design mix for mortar in ferrocement tank.
5.2.9	54	17	View of Roof and Roofcover for ferrocement tank.
5.3.2	56	18	Layout of Reinforcing steels for "combination" tank.
5.3.2	57	19	View of"combination" tank.
6.1.6.	63	20	Profile of pipe line and positioning of "drain off" and "air release" valves.
6.2.6	68	21	Typical Pipe Support.

1. INTRODUCTION

This booklet has been developed as a result of experience in the ASTC Mahweit Project in the basic technical training of field co-ordinators for community development work. As will be seen from the General Introductory Technique, the process involves a high level of discussion with the locals and a thorough process of information gathering to ensure each project has a definite chance of success by being fully researched. We have found through experience that there is virtually no water project however small that doesn't involve a variety of local political problems and it is only through rigorous information gathering and a complete survey of villages and springs in the area that problems, during and after construction of the project, can be avoided.

This point cannot be stressed enough and we would advise anybody undertaking this type of project, involving a large community input, not to race ahead and construct what may seem at the outset a very straight-forward project without thorough investigation of the process as outlined in the General Introductory Technique.

The process also involves the use of simple instruments and basic techniques in water flow measurement, and determination of difference in elevations and pipeline lengths. The basic instruments required are:

(i) Stopwatch
(ii) Altimeter
(iii) Measuring Tape.

The stopwatch can be used in conjunction with either a measured bucket (10 litres or 20 litres), or a small float (for channel measurement) to measure the flow from the source. The altimeter is used to determine the difference in elevation between the source and the recipient village, if the water is to be piped from the source to the village. The measuring tape is used to measure the flow of the source if it is a channel measurement, and also of course to measure the length of the pipeline required if any. If a more accurate

.../2.

survey of the land between the source and the village is required (as is the case for projects with a small elevation difference between the source and the village), a level or theodolite should be used.

Hopefully, this manual will provide the necessary technical guidelines in the planning, design, and construction for small water projects here in the Y.A.R. However, these technical guidelines on the implementation of such a project are completely dependent on the gathering of sufficient and accurate base line data and measurements. This will include and involve input from the local community, which, as already stated, is probably the most important input to ensure a successful project.

2.0. GENERAL INTRODUCTORY TECHNIQUE:

The following is a flow-chart of the process involved in the design and execution of a Small Water Project (SWP).

Request received through LDA For SWP

↓

Check Files. Check with other staff on any previous visits, acquire all revelant information through questioning and reading reports

↓

Visit Village and talk with 'Amin and Villagers

↓

Determine Village Population $= P_1$

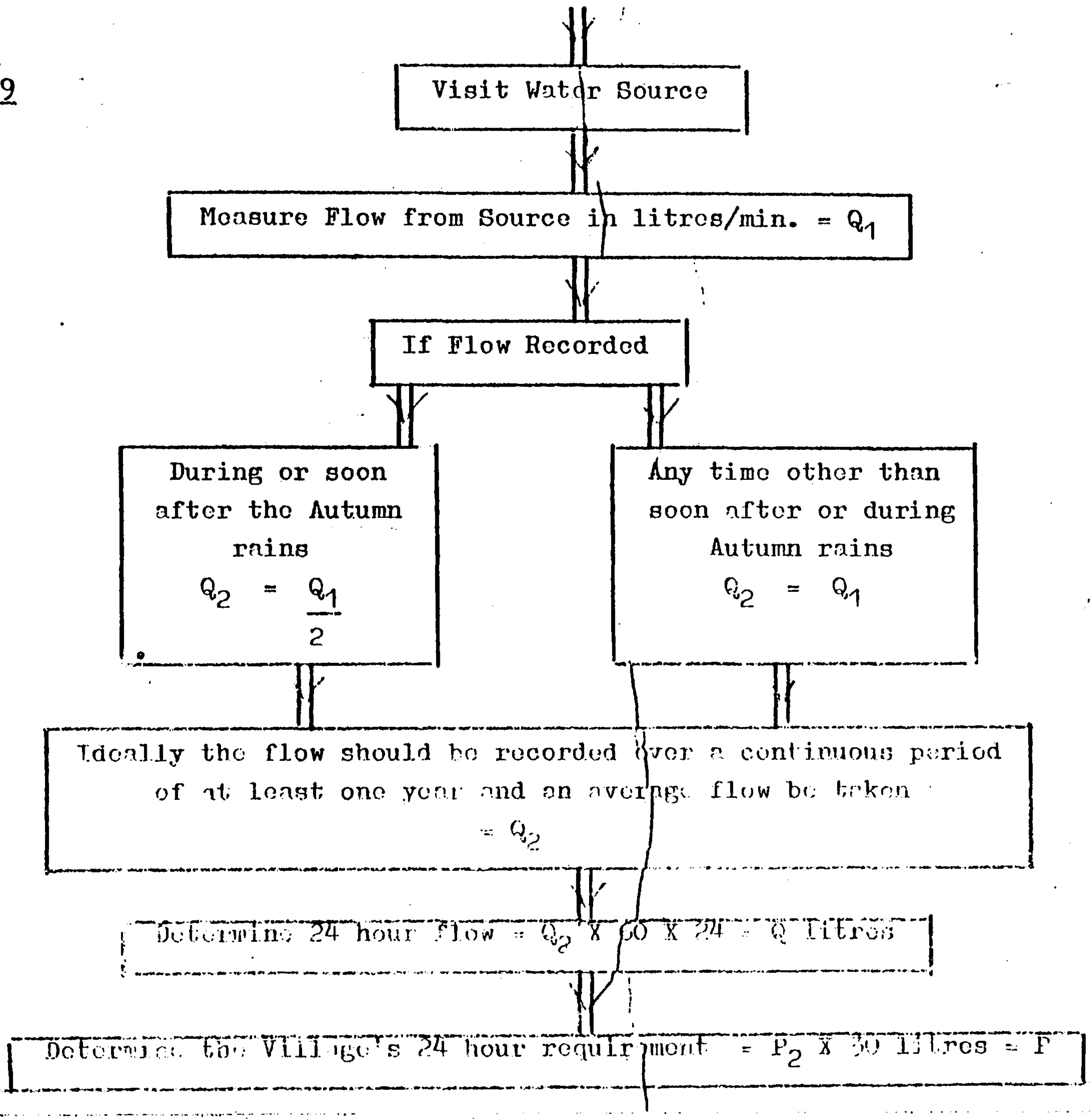
↓

P_2 = Adjusted Village Population $= 1.2 \times P_1$

↓

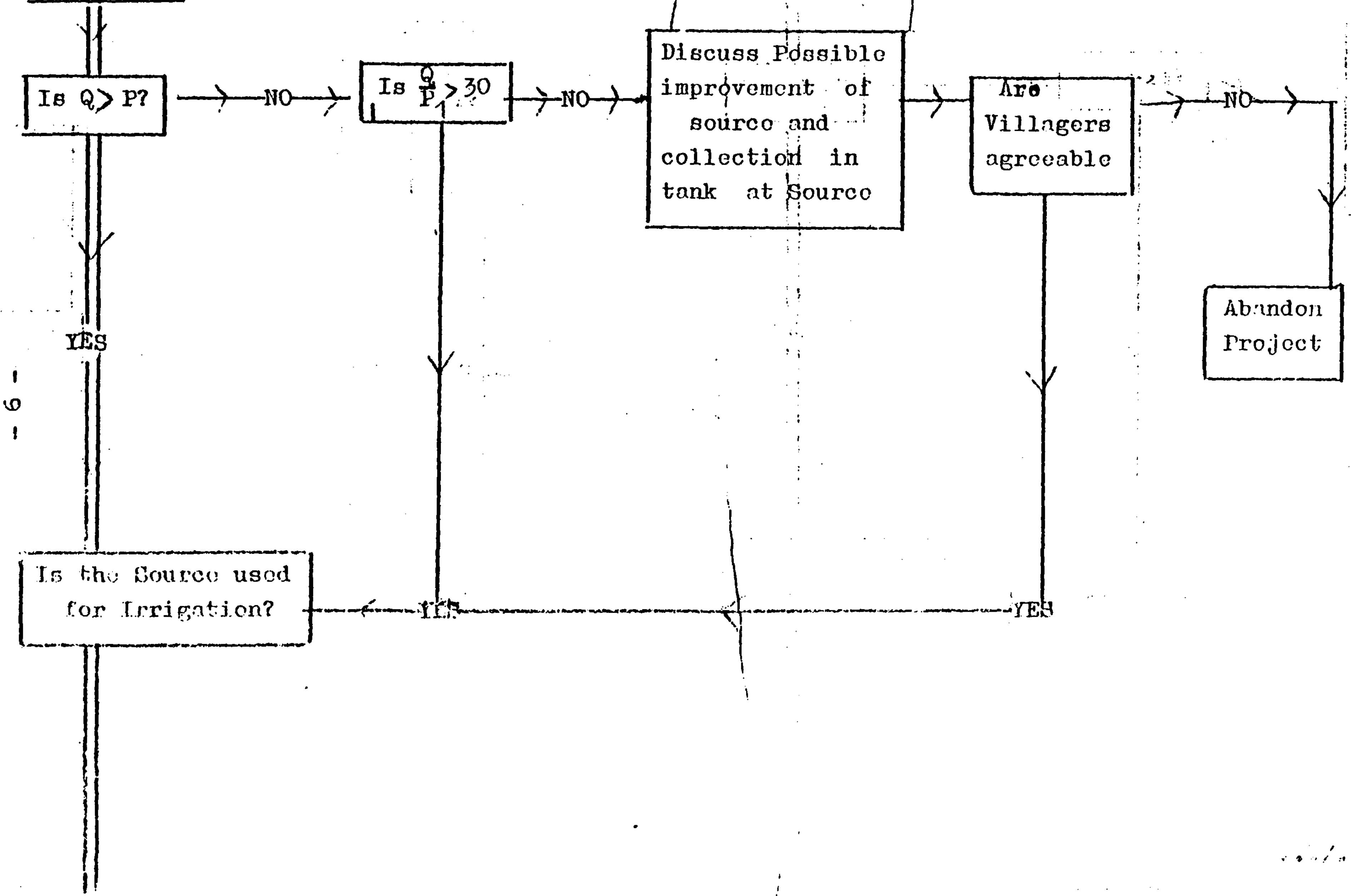
Measure Elevation of Village above sea level $= H_1$

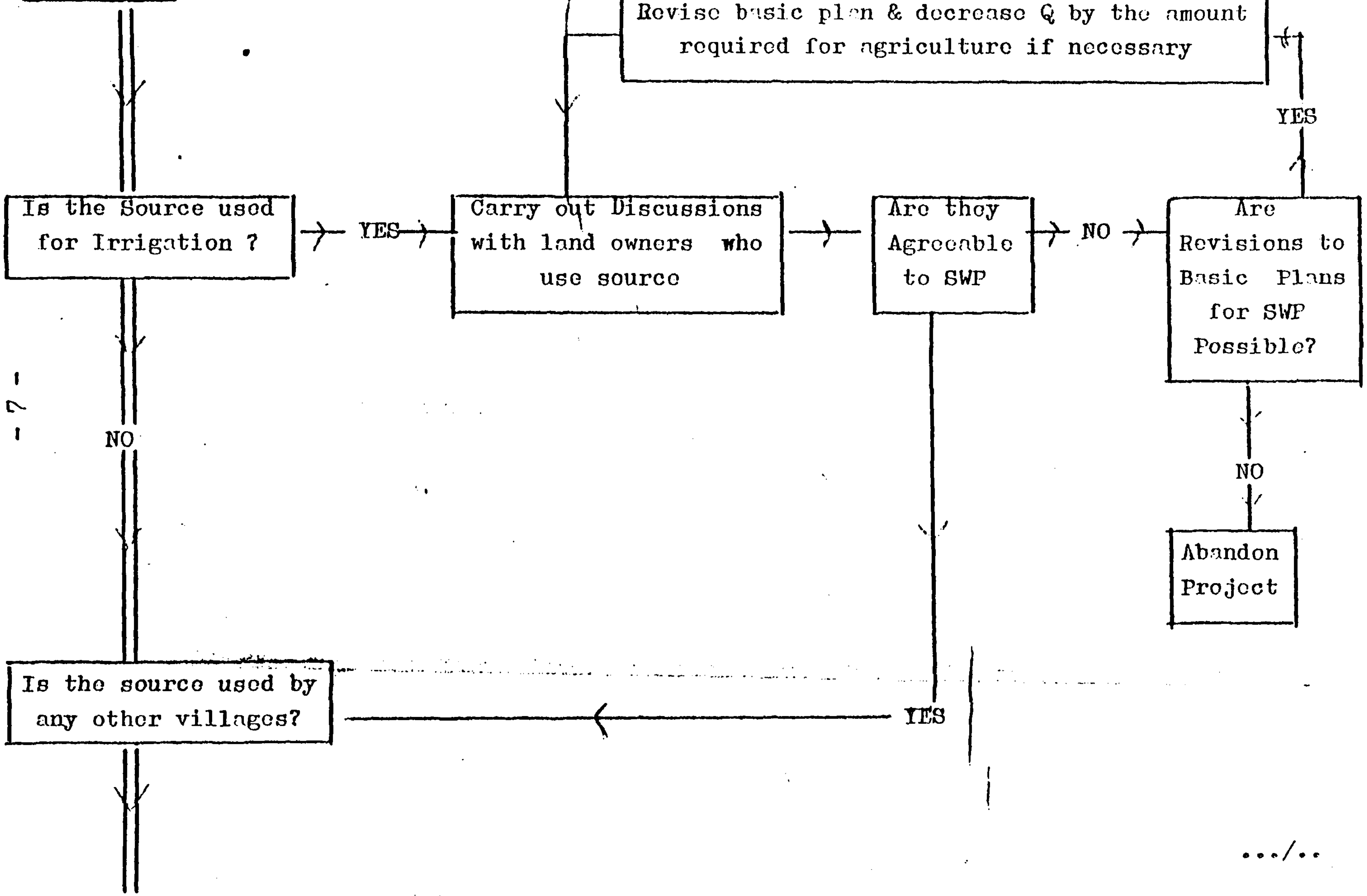
↓


Visit Water Source
Measure Flow from Source in litres/min. = Q_1
If Flow Recorded
During or soon after the Autumn rains $Q_2 = \frac{Q_1}{2}$
Any time other than soon after or during Autumn rains $Q_2 = Q_1$
Ideally the flow should be recorded over a continuous period of at least one year and an average flow be taken = Q_2
Determine 24 hour flow = Q_2 X 60 X 24 = Q litres
Determine the Village's 24 hour requirement = P_2 X 30 litres = F

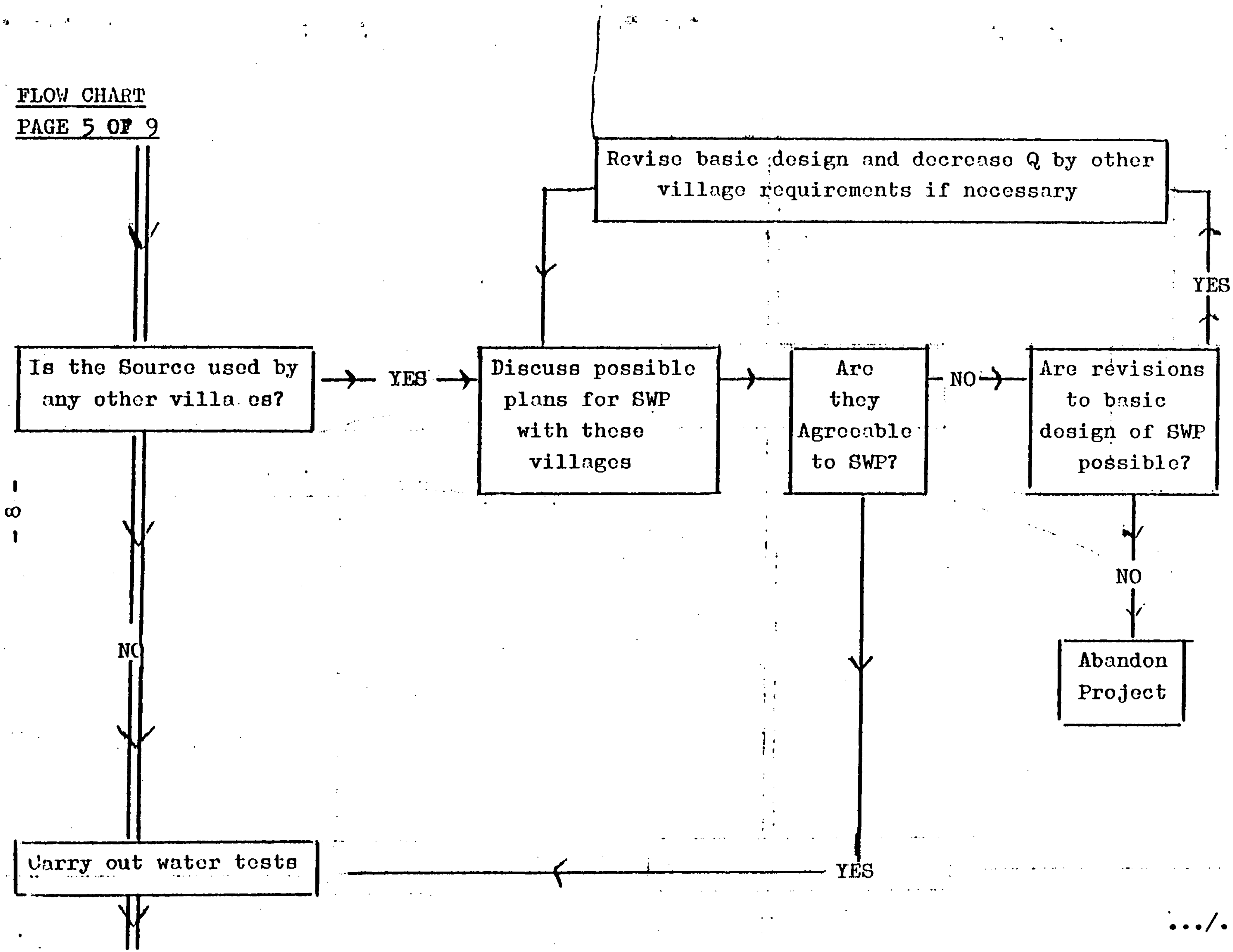
..../..

FLOW CHART
PAGE 3 OF 9

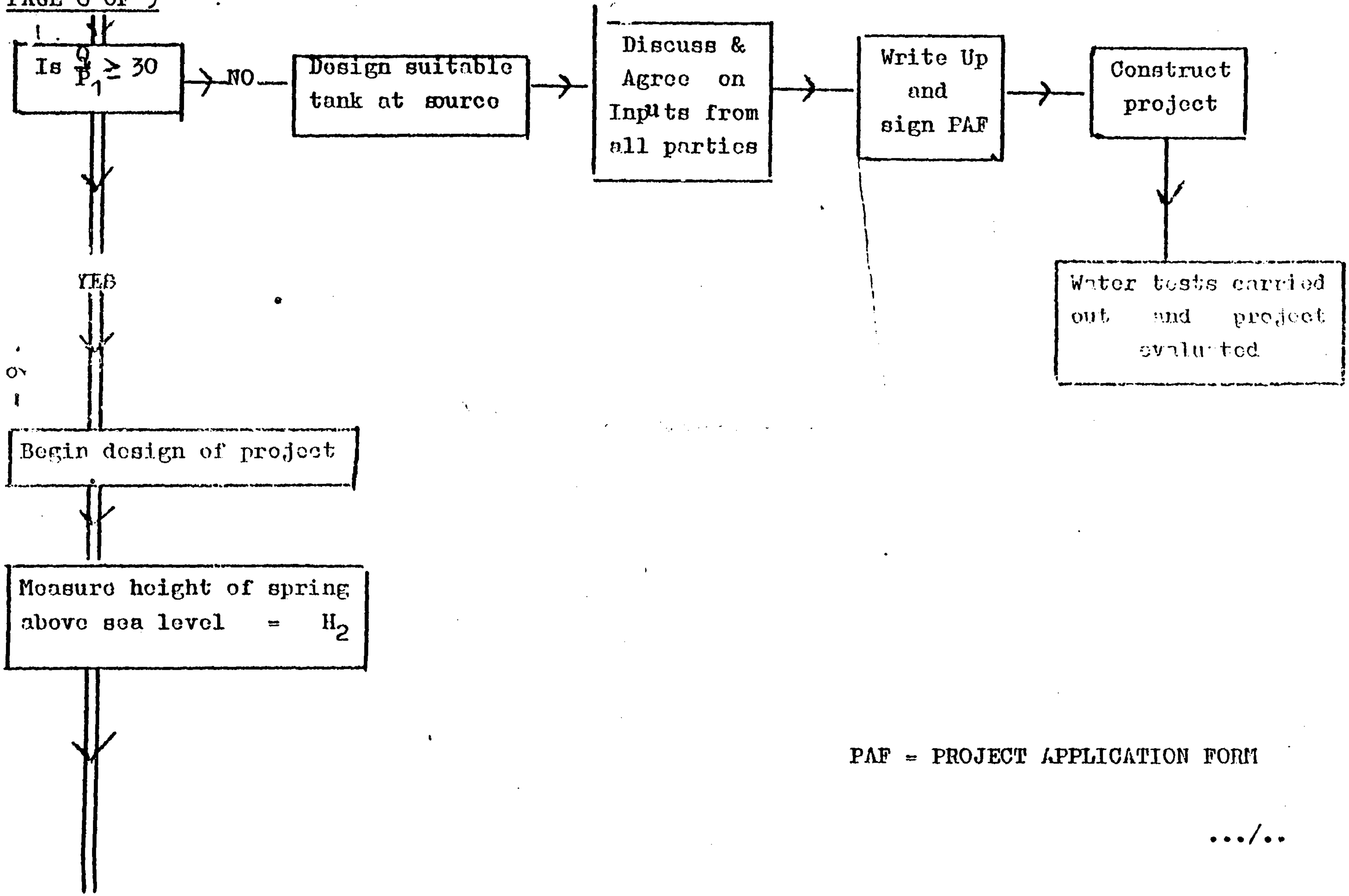



Revise basic plan & decrease Q by the amount required for agriculture if necessary
Is the Source used for Irrigation ?
YES
Carry out Discussions with land owners who use source
Are they Agreeable to SWP
NO
Are Revisions to Basic Plans for SWP Possible?
YES
NO
Abandon Project
NO
YES
Is the source used by any other villages?

..../..

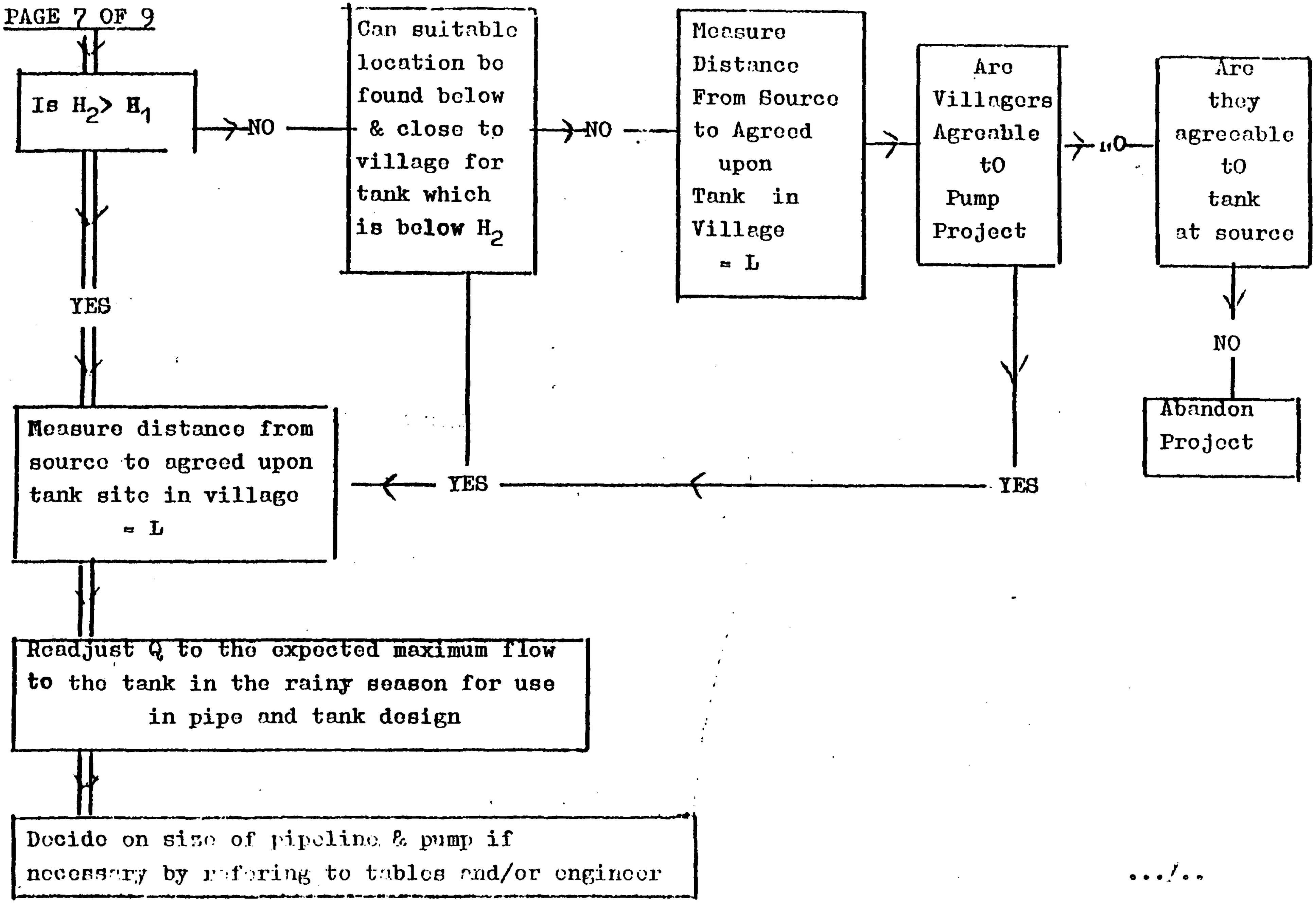

Revise basic design and decrease Q by other village requirements if necessary
YES
Is the Source used by any other villages?
YES
Discuss possible plans for SWP with these villages
Are they Agreeable to SWP?
NO
Are revisions to basic design of SWP possible?
NO
Abandon Project
NO
YES
Carry out water tests

.../..

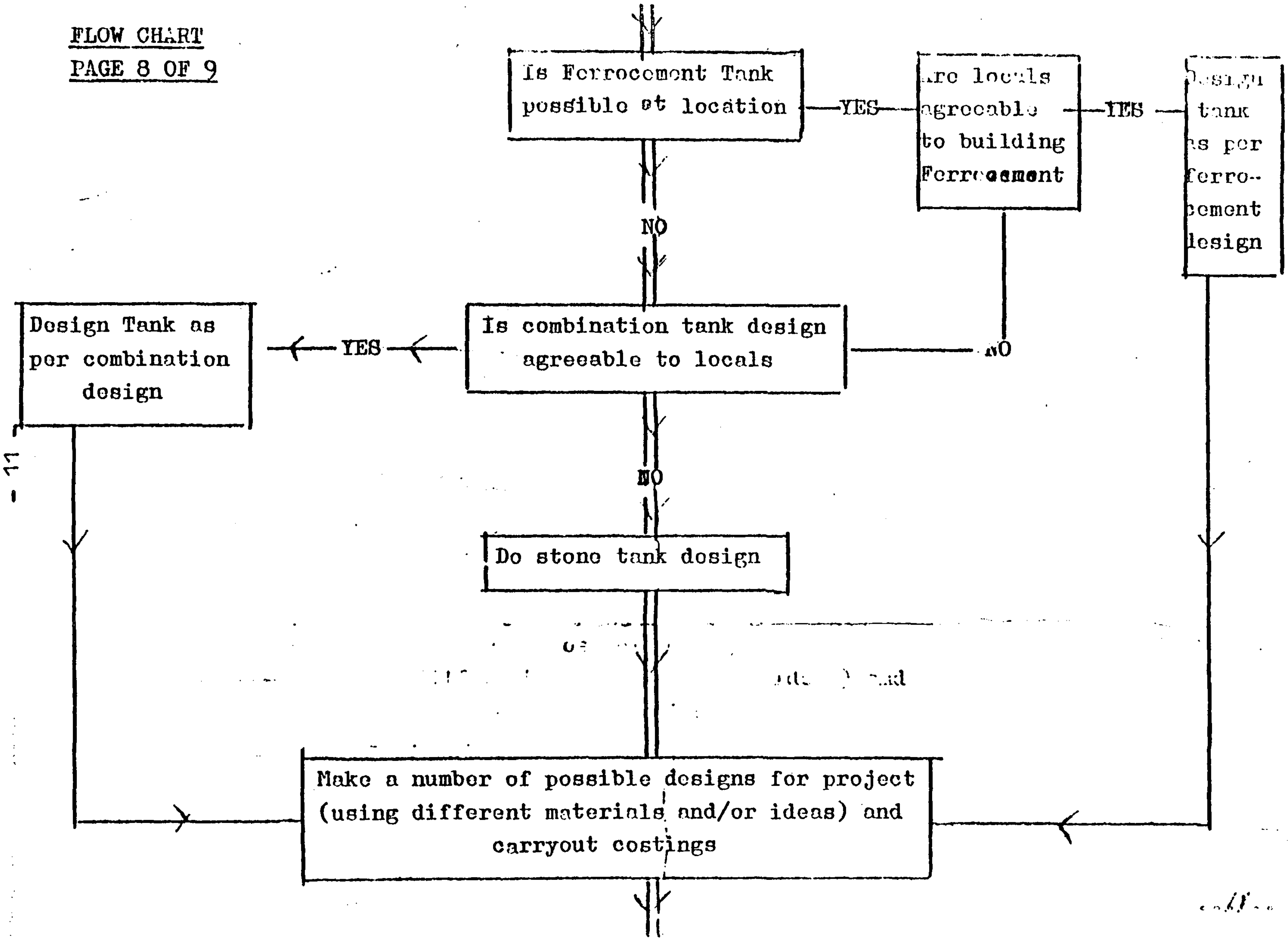


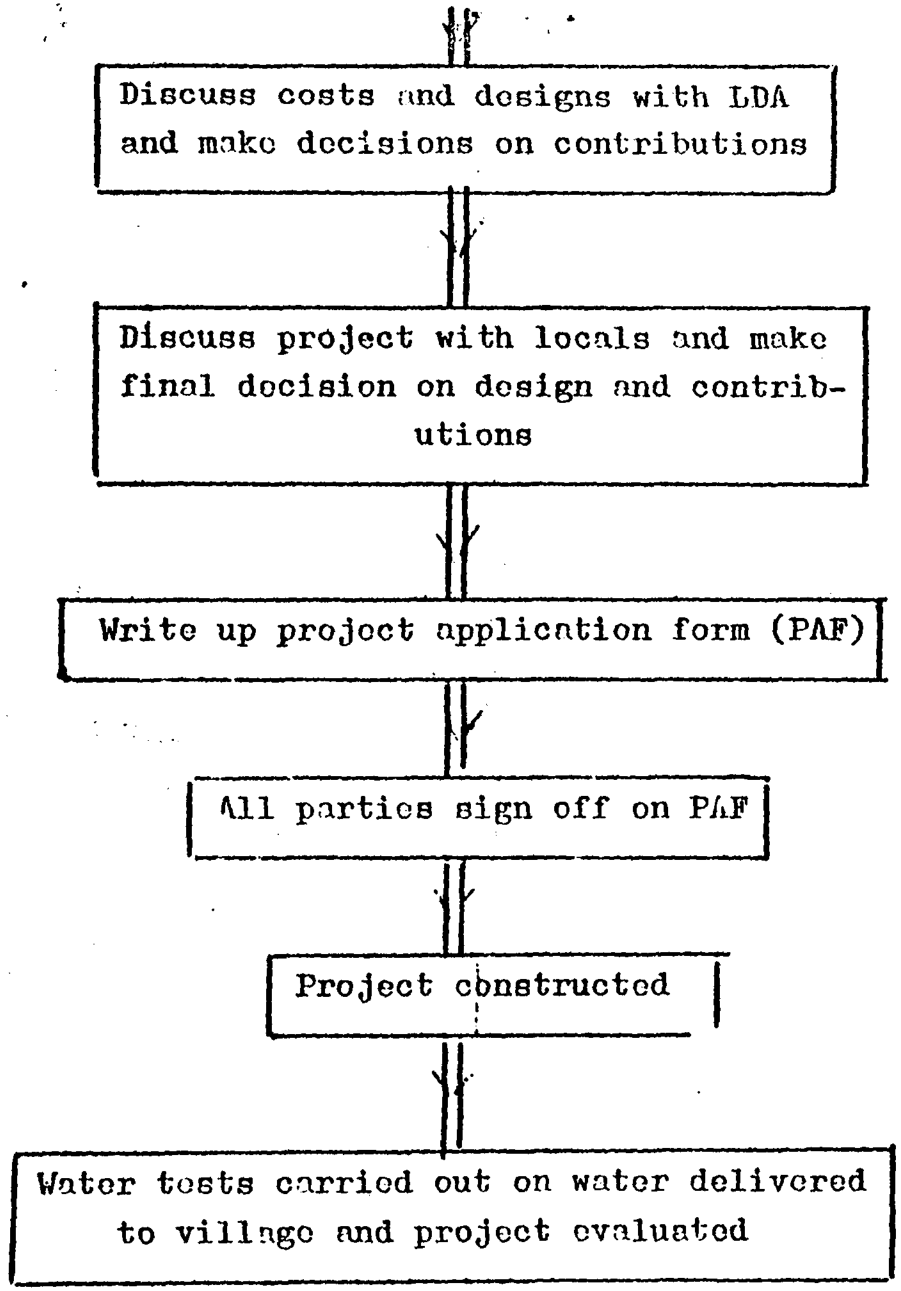
PAF = PROJECT APPLICATION FORM

.../..


Is $H_2 > H_1$
NO
YES
Can suitable location be found below & close to village for tank which is below H_2
NO
YES
Measure Distance From Source to Agreed upon Tank in Village = L
Are Villagers Agreable to Pump Project
NO
YES
Are they agreeable to tank at source
NO
Abandon Project
Measure distance from source to agreed upon tank site in village = L
Readjust Q to the expected maximum flow to the tank in the rainy season for use in pipe and tank design
Decide on size of pipeline & pump if necessary by refering to tables and/or engineer

..../..


Is Ferrocement Tank possible at location
YES
YES
NO
Design Tank as per combination design
YES
Is combination tank design agreeable to locals
NO
NO
Do stone tank design
Make a number of possible designs for project (using different materials and/or ideas) and carryout costings


Discuss costs and designs with LDA and make decisions on contributions
Discuss project with locals and make final decision on design and contributions
Write up project application form (PAF)
All parties sign off on PAF
Project constructed
Water tests carried out on water delivered to village and project evaluated

3. FLOW MEASUREMENT

3.0. Introduction

The procedure used to measure the flow from a source depends on the type of flow and the constraints and restrictions on it. The two types of flow discussed in this section are pipe flow and channel flow.

3.1. Pipe Flow

a) The measurement of flow from a pipe, or similar type of flow, is the easiest and most accurate to do. The instruments required are a stopwatch, and bucket or container of known quantity.

b) Holding the stopwatch in one hand and the bucket in the other, begin timing as soon as the bucket is placed under the pipe flow. Stop timing as soon as the bucket is full or reaches a level of known quantity. This procedure should be repeated at least three times and the volume of water collected and time recorded each repetition.

c) Now the rate of flow can be calculated by using the following formula:

$$\text{Rate of flow} = \frac{\text{Volume of water}}{\text{Time}}$$

This rate of flow should be calculated for each trial and the average of these used as the determined rate of flow.

d) A flow measurement is always a volume per time ratio, whether the volume is measured in litres, gallons or cubic metres and the time in seconds, minutes or days. That is, if it takes 20 seconds to fill a 10 litre bucket the rate of flow would be,

$$\text{rate of flow} = \frac{\text{Volume}}{\text{time}} = \frac{10 \text{ litres}}{20 \text{ seconds}} \cong 0.5 \text{ Litre/seconds.}$$

To change a litres per second ratio to litres per day ratio we would mutliply the litres per second ratio by the amount of seconds in one day (86,400 sec/day):

.../..

$$0.5\ \frac{\text{litres}}{\text{second}} \times 86{,}400\ \frac{\text{seconds}}{\text{day}} = 43{,}200\ \frac{\text{litres}}{\text{day}}$$

e) It should be remembered that the flow from a spring will vary during the year and is usually dependent on the amount of rain received in its recharge area. Therefore, flow measurements should be taken at various times of the year (every 2-3 months) to determine the amount of water which will be available at any given period of time. If measurement cannot be taken for an entire year, remember that measurements taken in the rainy season will be greater than in the dry season and vice versa. Therefore, for example, rates of flow calculated for the rainy season should be reduced by an appropriate factor (usually at least half) to approximately give the amount of water available on the average.

f) Since pipe flow is the easiest and most accurate to measure, it should be determined if these "pipe flow" conditions can be produced from any given situation. For example, in stream or channel flow, often the water will flow over a rock ledge. By directing the flow out and over this ledge, we can produce a "pipe flow" condition, where the water can be measured with a bucket. Care must be taken to make sure that all the water is made to flow into the bucket, otherwise an accurate measurement will not be possible.

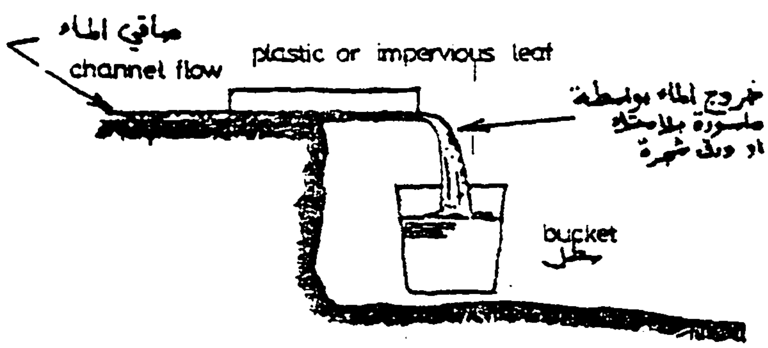


Diagram 1 - "Pipe Flow" measurement from channel flow situation.

3.2. Channel Flow Measurement

a) The measurement of flow in a channel is slightly more complicated than pipe flow measurement, as the flow often cannot be directly measured in a bucket. The instruments required are a stopwatch, a tape measure, and a small float (or piece of wood.)

b) A relatively uniform straight stretch of the channel must be located, preferably greater than 3 metres in length. This length should be measured, and markers (such as stone) placed alongside, at the beginning and end of this stretch so as to clearly define it. Length = L (cm.)

c) The widths and depths must now be measured at three different points on the stretch of channel. We'll make point 1 at the beginning of the stretch (marked by one of the stones), point 2 will be in the middle, and point 3 at the end (marked by the other stone). W_1 is the width in cms. measured at point 1, W_2 (in the middle at point 2), and W_3 at point 3.

d) At the same time as measuring the widths, the average depth must be determined at each of these locations. The average depth D_1 is found by taking a number of depth measurements across the width of the channel at point 1, and finding the average of these. Likewise, at points 2 and 3, D_2 and D_3 are computed. Record these values.

e) Now take the small float, or piece of wood, and soak it with water. Hold the stopwatch in one hand, and with the other hold the float directly over the water at the beginning of the stretch, point 1 (marked by the stone.) Set the float in the water and begin timing at the same moment. When the float flows past the end, of the stretch, point 3, (marked by the other stone), stop timing. This time is t_1. The procedure is repeated thrice to get three time values, t_1, t_2, and t_3. Again 1 cord these values.

..../..

f) Now we can start calculations for the rate of flow. First we calculate the cross sectional areas at points 1, 2 and 3.

$$A_1 = W_1 \times D_1 \text{ cm.}^2$$
$$A_2 = W_2 \times D_2 \text{ cm.}^2$$
$$A_3 = W_3 \times D_3 \text{ cm.}^2$$

(W and D measurements must both be in the same units i.e. cm.)

g) The average cross sectional area (A) is then computed.

$$A = \frac{A_1 + A_2 + A_3}{3} \text{ cm.}^2$$

h) We now compute the volume of water in the stretch of the water channel. Volume (V) = A X L (cm.^3)

For this calculation, A and L must both be in the same basic unit, i.e. if A is in cm.^2, L must be in cm.

j) We will now change the units of volume from cm.^3 to the more familiar units of litres.

$$1000 \text{ cm.}^3 = 1 \text{ litre}$$

Therefore $$\frac{\text{Volume } (\text{cm}^3)}{1000} = \text{Volume (litres)}$$

Or $$V (\text{cm}^3) \div 1000 = V \text{ (litres)}$$

k) The average time of our three trials is then computed = T.

$$T = \frac{t_1 + t_2 + t_3}{3}$$

l) We can now calculate the rate of flow [illegible] source by using the following equation:
Rate of Flow = $0.7 \times \frac{V}{T}$ (litres / seconds) (The multiplying fact of 0.7 is used as the average velocity required is less than the surface velocity measured in this procedure.

m) <u>Example/problem</u> - If the length (L) of the stretch = 5 metres, and the other measurements are as follows:

point 1	W_1 = 12 cm.	D_1 = 1.5 cm.
point 2	W_2 = 8 cm.	D_2 = 2.5 cm.
point 3	W_3 = 10 cm.	D_3 = 2.0 cm.

.../..

time trial 1 $t_1 = 4$ seconds

time trial 2 $t_2 = 5$ seconds

time trial 3 $t_3 = 6$ seconds

<u>Determine the rate of flow:</u>

<u>Step 1</u> (3.2 (f))

$A_1 = W_1 \times D_1 = 12\text{cm.} \times 1.5\text{ cm.} = 18\text{ cm.}^2$

$A_2 = W_2 \times D_2 = 8\text{ cm.} \times 2.5\text{ cm.} = 20\text{ cm.}^2$

$A_3 = W_3 \times D_3 = 10\text{cm.} \times 2.0\text{ cm.} = 20\text{ cm.}^2$

<u>Step 2</u> (3.2 (g))

$$A = \frac{A_1 + A_2 + A_3}{3} = \frac{18 + 20 + 20}{3} = 19.3\text{cm}^2$$

<u>Step 3</u> (3.2 (h))

Volume = A X L

A and L must be in the same basic unit, so let us change L = 5 metres to centimetres.

L = 5m. = 500 cm.

Volume (V) = $19.3\text{ cm.}^2 \times 500\text{ cm.} = 9650\text{ cm.}^3$

<u>Step 4</u> (3.2 (j))

Now, we can change cubic centimetres (cm.^3) to the more familiar unit of litres.

$1000\text{ cm.}^3 = 1$ litre

Therefore, $V = \dfrac{9650\text{ cm.}^3}{1000\ \dfrac{\text{cm.}^3}{\text{litre}}} = 9.65$ litres

<u>Step 5</u> (3.2 (k))

Next, the average time (T) is found:

$$T = \frac{t_1 + t_2 + t_3}{3} = \frac{4 + 5 + 6}{3} = 5 \text{ seconds}$$

<u>Step 6</u> (3.2 (l))

The rate of flow can now be computed:

rate of flow $= 0.7 \times \frac{V}{T} = 0.7 \times \frac{4.65}{5}$ [illegible]

$$= 1.35 \ \frac{\text{litres}}{\text{second}}$$

.../..

Daily Flow Rate - From our rate of flow in litres per second we can change to a daily flow rate in litres per day. 86,400 seconds = 1 day. 1.35 litres/sec. X 86,400 sec./day = 166,640 litres/day. If we want to change litres to $m.^3$ for design purposes, 1000 litres = $1m.^3$

$$\frac{166,640 \text{ litres/day}}{1000 \text{ litres/m}} = 166.64 \text{ m}^3\text{/day.}$$

.../..

4. PROCEDURES FOR DESIGN AND COSTING

4.1. Design and Costing of Stone Tank

4.1.0. Introduction

Stone is the most common form of building material in Yemen, and the high quality work carried out in this medium would point to stone as the natural choice in any kind of construction. If used with a good watertight mortar, stone construction for water tanks provides both a good strong tank and an aesthetically pleasing one as well. Construction and material costs though are much higher than for any comparable ferro-cement tank, although, obviously the technique of building in stone is much more widely accepted throughout the whole of Yemen.

4.1.1. General Calculations

a) Decide on Tank Volume = V metres^3. This is dependent on the amount of water that will be used from the spring flow during the maximum flow period according to the water availibility and population to be served. (See Section 2 - Flow Chart, regarding the revised Q to be used for design purposes.)

It is important to remember that the level of water should always be at least one metre above the level of the taps to maintain adequate pressure. Thus it may become necessary to divide or section the tank into two compartments to ensure this adequate tap pressure in times of low flow, while providing the extra storage required for maximum flow.

b) The inside width of the tank is dependent on the length of the redwood beams (150 mm. X 100 mm.) which will span the final roofing. These are sold in two lengths:

(i) 4.0 m.
(ii) 6.5 m.

.../..

For this reason and because the average width of stone wall construction is 0.5 m. we assume the inside width of the tank to be either:

(i) 3.0 m. or
(ii) 5.5.m.

c) Decide on inside width of tank = (W - 1) metres;
Decide on inside length of tank = (L - 1) metres;
Decide on height of tank = H metres.

d) $V = (W - 1) X (L - 1) X H$ metre^3.

e) Outside measurements of the tank are as follows:

length = L metres
width = W metres
height = H metres

4.1.2. Design of Base

a) The base is a concrete mix in the proportions 1 cement : 2 sand : 4 gravel. Its thickness is 10 cm. = 0.1 M.

b) Volume of base = V_1
$= L X W X 0.1$ metre^3.

c) The gravel is assumed to occupy this entire volume and the interstices between the gravel pieces are occupied by the sand and the cement.

d) Volume of cement = $V_1 \div 4$ metres^3

$1M^3$ = 1000 metres

Therefore, Volume of cement in litres = $1000 X V_1 \div 4$
$= 250 V_1$ litres.

e) Each bag of cement contains 35 litres, therefore. No. of bags of cement required for base construction = C_1

.../..

$= 250 V_1 \div 35$

$= \frac{50V_1}{7}$ bags $= C_1$

f) Volume of sand required $= S_1$

$= \text{Volume of cement} \times 2$

$= \frac{V_1}{4} \times 2 \text{ metre}^3$

$S_1 = \frac{V_1}{2} \text{ metre}^3$

g) Volume of gravel required $= G_1$

$= V_1 \text{ metre}^3$

h) Volume of water required $= W_1$

$= \text{Volume of Cement}$

$W_1 = \frac{V_1}{4} \text{ metre}^3$

4.1.3. <u>Design of Walls</u>

a) The walls are constructed entirely in stone and mortar.

b) The mortar mix used for the walls is 1 cement : 3 sand.

c) Each $1M^2$ of wall area needs approximately 25 stones, therefore, 25 stones per M^2 of wall area.

d) The outside area of the 4 walls $= A_2 = 2 \times H \times (L + W)$ ~~metre~~^{2}
Therefore, number of stones required $= N_1$

$= 25 \times A_2$

$= 25 \times 2 \times H \times (L + W)$

$N_1 = 50 \times H \times (L + W)$

e) Each 1 metre^2 of wall area needs approximately 2 bags of cement for mortar and plaster, i.e. 2 bags of cement per M^2 of wall area.

f) Outside area of 4 walls $= A_2$ (see above)
Therefore, number of bags of cement required for wall construction $= C_2 = 2 \times A_2$

...

g) Volume of 1 bag of cement = 35 litres
Volume of cement required for wall construction = $35 \times 2 \times A_2$ litres
= $70\ A_2$ litres

h) Volume of sand required = 3 X Volume of cement
= $3 \times 70 \times A_2$ litres
= $210 \times A_2$ litres

and $1M^3$ = 1000 litres

So, S_2 = Volume of sand required (M^3)

$$S_2 = \frac{210 \times A_2}{1000}\ M^3$$

j) Volume of water = Volume of Cement
= $70\ A_2$ litres

W_2 = Volume of water (in metre^3) required.

$$W_2 = \frac{70 \times A_2}{1000}\ \text{metre}^3$$

4.1.4. Design of Roof

a) The redwood beams (150mm. X 100mm.) are placed every 0.5M (centre to centre) with one beam on each end wall as in the diagram shown below. Plywood sheeting is placed over this.

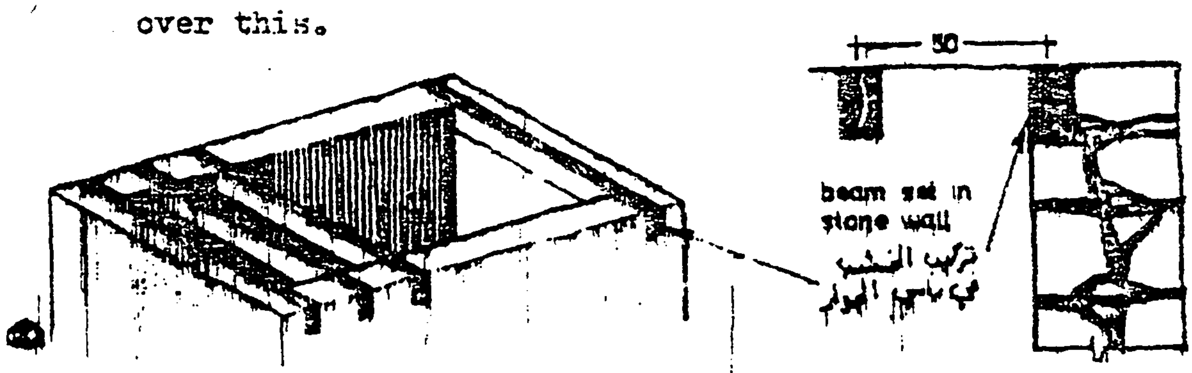


Diagram 2 - Layout of Beams for Stone Tank Roofing.

b) Number of wood lengths required = $N_2 = L \times 2 + 1$

c) Area of roof = $L \times W$ metre^2
Area of 1 sheet of plywood = 1.22×2.44
= $2.98\ M^2$ say $3M^2$

.../..

d) Number of plywood sheets required = $N_3 = \frac{L \times W}{3}$

e) The wood roof is covered in a concrete mix 1 cement : 2 sand : 4 gravel.

f) This has an approximate depth = 5 cm.
= 0.05 M.

Therefore, volume of concrete mix = L X W X 0.05 M^3

Calculations are as in 4.1.2.

$$\text{Volume of cement} = \frac{\text{Volume of mix}}{4} = V_3$$

$$V_3 = \frac{L \times W \times 0.05}{4} \; M^3$$

$$= \frac{L \times W \times 0.05}{4} \times 1000 \text{ Litres}$$

$$= \frac{L \times W \times 50}{4} \text{ litres}$$

g) Number of bags of cement = C_3

$$C_3 = \text{Volume of cement in litres} \div 35$$

$$= \frac{L \times W \times 50}{4 \times 35}$$

$$C_3 = \frac{L \times W \times 10}{28}$$

h) Volume of sand required = S_3 metre^3

$$S_3 = 2 \times \text{volume of cement}$$

$$= 2 \times V_3 \text{ metre}^3$$

j) Volume of gravel required = G_3

$$G_3 = \text{Volume of mix}$$

$$= L \times W \times 0.05 \; M^3$$

k). Volume of water required = W_3

$$W_3 = \text{Volume of cement} = V_3$$

.../..

4.1.5. Materials Required for Tank Construction

a) Cement - The total number of bags of cement required $= C = C_1 + C_2 + C_3$

b) Fine Sand - The total amount of sand required = S metres^3 $= (S_1 + S_2 + S_3)$ metre^3.

c) Gravel - The total amount of gravel required = G metre^3 $= (G_1 + G_3)$ metre^3

d) Water - The amount of water required for construction $= W_1 + W_2 + W_3$

Water is also required for curing of the base and mortared walls at the rate of approximately 2 metre^3 ~~for one week~~. Therefore total amount of water required = W metre = $(W_1 + W_2 + W_3 + 2)$ metre^3.

e) Stones - The total number of stones required for construction $= N_1$

f) Redwood Beams - The total number of redwood beams (150 mm. X 100 mm.) required $= N_2$.

g) Plywood Sheets - The total number of plywood sheets (thickness 18 mm.) required $= N_3$.

h) Taps - Taps are placed on the tank at the rate of 1 tap per 50 people.

P_2 = total population of village X 1.2

Therefore, number of taps on tank $= \frac{P_2}{50}$

$= R_1$

Extra taps required for future repairs $= R_1 \div 2$

Therefore, total no. of taps required $= R = R_1 + \frac{R_1}{2}$

$= 1.5\ R_1$

.../...

P.S. Taps should preferably be of the "push" tap variety rather than screw top as the loss of water from the tank is usually less, since they automatically spring shut.

j) <u>Piping</u> - Each tap requires approximately 1 metre of ½" tubular steel piping. Therefore, length of piping needed for taps = R_1 metres. An air vent/overflow pipe is provided for each wall section of a tank. For example if the tank is a simple rectangular 4 walled tank then the number of air vents = 4; if the tank is divided in 2 sections then the number of air vents is increased by 2 to a total of 6.

Each air vent/overflow pipe is approximately 1 M long.
Number of air vents/overflow pipes = R_2
Therefore, total length of ½" piping for air vents = R_2 metres
Therefore, total length of ½" piping required = $(R_1 + R_2)$ metres but piping is sold in 6 M. lengths.
Therefore, number of 6 M. lengths required = $\frac{R_1 + R_2}{6}$.

This should be a whole number = B
e.g. if $\frac{R_1 + R_2}{6} = 2.5$ Then B = 3

If $\frac{R_2 + R_2}{6} = 3.6$ then B = 4.

i.e. Actual number of ½" X 6 M. pipe lengths required = B

k) <u>Fittings</u> - Each tap requires 2 X ½" couplings. Each air vent/overflow pipe requires one coupling. Therefore, number of ½" couplings required = $(2 \times R_1) + R_2$. This amount should be doubled in case of future repairs required.
Therefore, number of couplings to be purchased = $4 \times R_1 + 2R_2$
= F_1

Each air vent requires 1 X ½" 90° elbow
Therefore, number of ½" X 90° elbows required = R_2
This amount should be doubled in case of future repairs
= $2 R_2$
= F_2 = amount of ½" X 90° elbows to be purchased. .../..

1) Other Construction Materials - The normal tank will require the following tools/materials for construction:

4 Shovels
6 X 10 litre buckets
2 trowels
1 sand sieve (screen with frame)
1 carpenter's level
Hammer and nails
1 Wood saw

4.1.6. Costing of Tank

a) Material Costs - (example given as per Hodaydah April 1980 prices except where otherwise stated.)

C bags of cement @ 36 Y.R. per bag.

N_1 stones @ 10 Y.R. per stone (local Mahweiti price for delivery on site)

N_2redwood beams (150 mm X 100 mm X 6.5 M. long) @ 160 Y.R. per beam.

N_2 redwood beams (150 mm X 100 mm X 4.0. M. long) ¢ 100 Y.R. per beam.

N_3 plywood sheets (18 mm, thick) @ 125 Y.R. per sheet.

B No. ½" push taps @ 12 Y.R. per tap.

B No. 6 M. X ½" tubular steel pipe lengths @ 25 Y.R. per 6 M. length.

F_1 No. ½" pipe couplings @ 2 Y.R. per coupling.

F_2 No. ½" 90° elbows @ 2 Y.R. per elbow.

Other construction materials should be separately priced as per the list above of 4.1.5. (1).

The cost of these above materials will of course vary from time to time and place to place but the above example is merely given to show the rough price levels.

All sand, gravel, and water costs are included under transport (cf (b) below) as they are generally non-purchasing and only require transport to the site. .../..

b) Transport Costs - The transport costs for all of the materials in (a) above should be computed from the place of purchase to the actual site. This may include transport by vehicle, animal, or man and should be fully taken into account. For example it may be one truck load from Hodaydah to the village at a certain rate and then further transport to the site from the village if necessary by animal or man. Computation of sand and water transport to the site (if necessary) should be worked out by contacting local drivers and finding out their rates. An ordinary Toyota pick-up holds approximately $1M^3$ of sand or gravel. Therefore, No. of pick-up loads required = S + G. But, if a large truck is available (usually 8 ton) it will hold approximately $5M^3$. Therefore, number of truck loads = $\frac{S + G}{5}$.

These should then be computed at the local prices to see which system is cheaper. Transport of water (if necessary) should also be computed on a similar basis.

c) Labour Costs - The labour aosts are computed as follows:

(i) 2 mandays per M^2 of construction on the base.

(ii) 1 mason day per 50 stones (i.e. per 2 M^2) on the tank walls.

(iii) 4 mandays (helpers and cutters) per 50 stones (i.e. per 2 M^2) on the tank walls.

(iv) 1 carpenter day per 6 M^2 of tank roofing.

(v) 1 manday (carpenter's helper) per 6 M^2 of tank roofing.

(vi) 1 manday per M^2 of roof area (in construction of final concrete layer on roof).

(vii) 2 mandays for pipe connections.

Therefore, total number of workers days required to complete construction:

= (i) + (ii) + (iii) = (iv) + (v) + (vi) + (vii)

$$= 2 \times A_1 + \frac{A_2}{2} \text{(mason days)} + \left(\frac{A_2}{2} \times 4\right) + \frac{A_3}{6} \text{(carpenters days)} + \frac{A_3}{6} + A_3 + 2$$

.../..

Now if we assume that the cost of unskilled manual labour = 60 Y.R.; per day; and the cost of a daily mason's hire = 300 Y.R. and the cost of a daily carpenter's hire = 300 Y.R.
Then, 1 mason day = 1 carpenter day

= 5 mandays (in terms of costs)

Thus, assuming these rations are roughly correct the total number of mandays required for the construction of the tank = D

$$D = (2 \times A_1) + \left(\frac{A_2}{2} \times 5\right) + \left(\frac{A_2}{2} \times 4\right) + \left(\frac{A_3}{6} \times 5\right) + \left(\frac{A_3}{6} + A_3\right) + 2$$

$$= 2A_1 + \frac{5A_2 + 4A_2}{2} + \frac{5A_3 + A_3}{6} + A_3 + 2$$

$$D = \left(2A_1 + \frac{9A_2}{2} + 2A_3 + 2\right) \text{ mandays.}$$

Therefore, total labour costs = (daily labourer's rate) X D. Cost per manday (daily labourer's rate) will very from region to region but is normally between 60 Y.R. and 100 Y.R. per day.

d) Ancillaries/Extras - It is advisable to include a contingency figure of approximately 15% (of (a) + (b) + (c)) to ensure enough funds are available due to any inflation in costs between time of design of the project and the actual implementation and for any other unforeseen circumstances.

e) Overall Total Costs - The overall cost of the project is thus the sum of the separate sections (a) + (b) + (c) + (d), shown above.

4.2. DESIGN AND COSTING OF FERROCEMENT TANK (between 10-15 M^3 volume)

4.2.0. Introduction

Ferro-cement water tanks are a relatively new idea here in Y.A.R. but could very easily have a large impact on the design and costing of small water projects because of:

.../..

(i) Extremely low cost of materials.

(ii) Very simple construction procedures.

(iii) Long term durability and strength.

(iv) No need for highly skilled labour/can be done at village level.

This design outlined below is similar to that shown in Appropriate Technology Vol. 4 No. 3, but much larger tanks can be constructed. For more information contact, International Ferrocement Information Centre, Asian Institute of Technology, Bangkok, Thailand.

4.2.1. General Information/Calculations

a) The tank is circular in shape with a low inverted saucer-shape roof.

b) The vertical height of the walls is taken as 1.8 metres (this is to conform to size of rolls of wire mesh.)

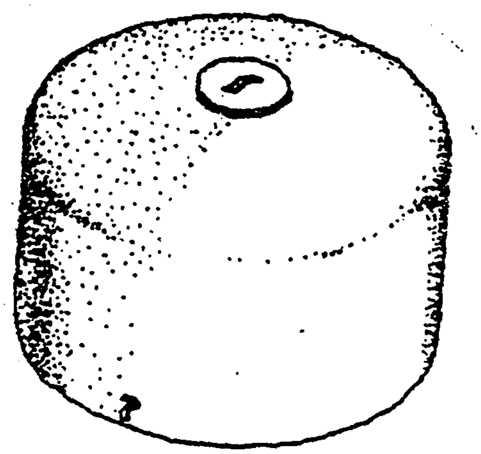


Diagram 3 - View of Standard Ferro-Cement Tank.

c) The maximum volume required to be stored = V $metre^3$.

d) The area of the base = A_1 $metre^2$.

e) $A_1 = \frac{\pi D^2}{4}$ metre ^{2} ; where D= diameter of base (metre).

f) $V = 1.8 \times A_1$ $metre^3$

$V = 1.8 \times \frac{\pi D^2}{4}$ Therefore,

$D = \frac{4V}{1.8 \times \pi}$

4.2.2. Design of Base

a) Depth of base = 10 cm.

b) Area of base = A_1 $metre^2$.

.../..

c) Therefore Volume of base (V_1) = A_1 X 0.1 metre^3

$$V_1 = A_1 \div 10 \text{ metre}^3$$

d) Concrete mix required is 1 : 2 : 4, i.e. 1 cement; 2 sand; 4 gravel.

e) The entire volume of the concrete mix is assumed to be taken up by gravel, with the cement and sand settling into the gravel interspaces, i.e. Volume of gravel = V_1 = G.

f) Volume of cement = $\frac{V_1}{4}$ (metre^3); but 1 metre^3 = 1000 litres

Therefore Volume of cement = $\frac{V_1 \text{ X } 1000}{4}$ litres

$$= 250 \; V_1 \text{ litres}$$

g) Volume of 1 bag of cement = 35 litres

Therefore number of bags of cement required (C_1)

$$C_1 = \frac{250 \text{ X } V_1}{35}$$

h) Volume of Sand (S_1) = 2 X Volume cement

$$S_1 = 2 \text{ X } \frac{V_1}{4} \text{ Metre}^3$$

i) Volume of Water (W_1) = Volume of Cement

$$W_1 = \frac{V_1}{4} \text{ metre}^3$$

4.2.3. Design of Walls

a) The walls are constructed of a combination of wire mesh, reinforcing steel and cement mortar.

b) The average thickness of the walls is approximately 5 cm. or 0.05 M.

c) 8 mm diameter reinforcing rods are placed vertically at intervals of 30 cm. (0.3 M) around the circumference of the base. They should extend 0.5 M into the ground and be held in the concrete base. They extend from the top of the .../..

walls onto the roof, joining close to the top central point where a small circular opening is made.

d) 6 mm. diameter reinforcing rods are placed horizontally at an average interval of 0.5M from the base to the Roof and ring the circumference of the tank.

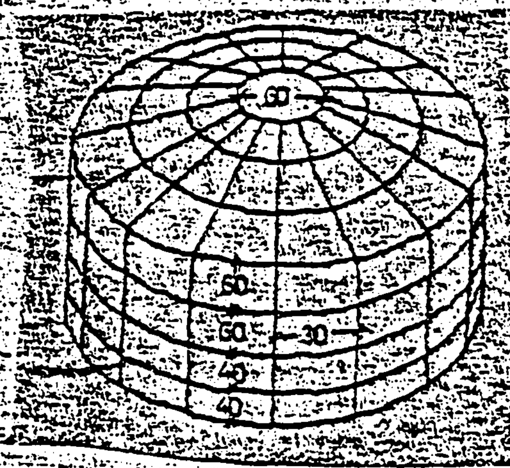


Diagram 4 - Layout of Reinforcement Steel for Standard Ferrocement Tank.

e) The wire mesh is rolled out and connected by wire strands on both sides of the reinforcement. Two layers of the wire mesh are needed, one inside and one outside, and the wire mesh should overlap as in the diagram shown below.

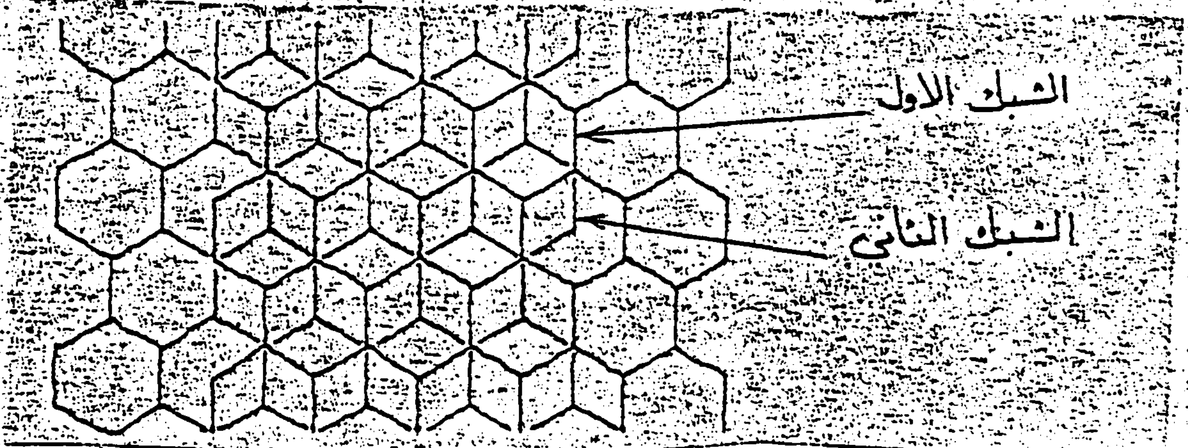


Diagram 5 - Desired Overlap of Reinforcing Mesh in ferrocement tank.

f) Length of walls (L) = length of circumference.

$$L = \pi \times D \text{ metre}$$

g) Height of walls = 1.8 metres.

h) Thickness of walls = 0.05 metres.

j) Therefore Volume of walls (V_2) = L X 1.8 X 0.05 metre^3

V_2 = .09 X (π X D) metre^3

k) Mortar Mix in walls = 1:2 i.e. 1 cement : 2 fine sand.

l) Volume of Cement = $\frac{V_2}{2}$ Metre^3

= $\frac{V_2}{2}$ X 1000 litres

m) Volume of 1 bag of cement = 35 litres; Therefore number of bags of cement required (C_2) = $\frac{1000\ V_2}{2} \div 35$

$C_2 = \frac{1000\ V_2}{70}$

n) Volume of sand (S_2) = 2 X Volume of cement

$S_2 = 2 \times \frac{V_2}{2}$ metre^3

$S_2 = V_2$ metre^3

o) Volume of Water (W_2) = 0.75 X volume of cement

$W_2 = 0.75 \times \frac{V_2}{2}$ metre^3

p) <u>Amount of 18 mm ø steel bars required:</u>

Length of each piece of vertical steel
= 0.5 M (embedded in ground) + 1.8 M (height of walls)
+ 0.5 D (length required for roof)

= (0.5 D + 2.3) metres.
Steel is sold in 12 M <u>lengths</u> on the market
No. of steel pieces in 12 M. = $\frac{12}{(0.5\ D + 2.3)}$

This should be a whole number = E
For example if $\frac{12}{(0.5\ D + 2.3)}$ = 1.6 then E = 1 .../..

If $\frac{12}{(0.5 D + 2.3)}$ = 2.2 then E = 2 etc.

Vertical steel is placed at intervals of 30 cm. = 0.3 M
Length of circumference (L) = π X D
Therefore number of pieces of steel $= \frac{L}{0.3} + 1 = N$

Therefore number of 12 M lengths of steel required $= \frac{N}{E}$

This should also be a whole number = N_1

For example if $\frac{N}{E} = 5.2$ then $N_1 = 6$

if $\frac{N}{E} = 3.7$ then $N_1 = 4$

q) <u>Amount of 6 mm. ø steel bars required in the walls</u>

= length of circumference = L
Number of pieces of 6 mm ø steel required = 5
Therefore total length of 6 mm. ø steel required = 5 X L metres.

Steel is sold in 12 M lengths
Therefore number of lengths of 6 mm. ø required
$= \frac{5 X L}{12}$ lengths
$= N_2$

4.2.4. <u>Design of Roof</u>

a) This design is on the same principle as the walls.

b) Area of roof (A_3) $\approx$ 1.5 X Area of Base (approximately)

$A_3 = 1.5 X A_1$

c) Thickness of roof - 0.05 M
Therefore Volume of roof (V_3) = 0.05 X A_2

d) Volume of Cement required $= \frac{V_3}{2}$ metre^3

$= \frac{V_3}{2}$ x 1000 litres

.../..

e) Volume of 1 bag of cement = 35 litres

Therefore, No. of bags of cement required $(C_3) = \frac{1000V_3}{2} \div 35$

$$C_3 = \frac{1000V_3}{70}$$

f) Volume of Sand (S_3) = 2 X Volume of Cement.

$$S_3 = 2 \times \frac{V_3}{2} = V_3 \text{ metre}^3$$

g) Volume of Water (W_3) = 0.75 X Volume of Cement

$$W_3 = 0.75 \times \frac{V_3}{2} \text{ metre}^3$$

h) Amount of 6 mm. ø steel bars required for the roof:
Three circular horizontal bars will be placed on the roof. They will be of varying length as the circles get smaller as they proceed to the middle of the roof. There need only be 3 of these for this size of tank and they should be spaced evenly. Their average length (L_1) can be taken as

$L_1 = \frac{3L}{4}$ where L = circumference of the walls of the tank.

No. of these bars in 12 M. lengths = $\frac{12}{L_1} = \frac{12 \times 4}{3L} = \frac{16}{L}$

This should be a whole number = E

i.e. if $\frac{16}{L} = 2.7$ then E = 2

if $\frac{16}{L} = 5.3$ then E = 5

There will be three of these bars, so the number of 12M. lengths required = $\frac{3}{E} = N_3$

4.2.5. Amount of Wire Mesh Required for all of the Tank:

a) Length of each roll of wire mesh = 45 M.
Width of each roll of wire mesh = 90 cm. = 0.9 M.
Area of each roll of wire mesh = 0.9 X 45 = 40.5 Metre^2
(say 40 M^2)

.../..

b) <u>Area of walls</u> (A_2) = circumference X height

$$A_2 = D \times 1.8$$

$$A_2 = 5.65\ D\ \text{Metre}^2$$

c) <u>Area of roof</u> = A_3 metre^2 (cf. 4.2.4. (b))

d) Total area to be covered by wire mesh (A) = (A_2+A_3) metre^2

e) Two layers of wire mesh are required to cover this area = A metre^2;
therefore, Area of wire mesh required = 2A metre^2.

f) Number of rolls of wire mesh required =

$$\frac{\text{Area of wire mesh required}}{\text{Area of each roll of wire mesh}} = 2A \div 40 = M$$

4.2.6. <u>Materials Required for Tank Construction:</u>

a) <u>Cement</u> - The total number of bags of cement required

$$= C_1 + C_2 + C_3 = C$$

b) <u>Fine Sand</u> - The total amount of sand required:

$$= S_1 + S_2 + S_3 = S\ \text{metre}^3$$

c) <u>Gravel</u> - The total amount of sand/gravel required = G metre^3

d) <u>Water</u> - The amount of water required for construction is (W_1 + W_2 + W_3) metre ^{3}.
Water is also required for curing of the concrete mix after construction at the rate of approximately 2M^3 for one week.
The total amount of water required = $W_1 + W_2 + W_3 + 2$

$$= W\ \text{metre}^3$$

e) <u>Reinforcing Steel</u> - The amount of 8 mm ø steel bars required = N_1 (12M lengths).
The amount of 6 mm ø steel bars required = N_2 + N_3 (12M lengths

f) <u>Wire Mesh</u> - The no. of rolls of wire mesh required = M

g) <u>Taps</u> - One (1) tap per 50 people to be placed on tank.
P_2 = total population of village X 1.2. Number of taps on tank = $\frac{P_2}{50}$ = R_1

.../..

Extra taps for repairs to system in future = $\frac{R_1}{2}$

i.e. total no. of taps required = 1.5 R_1 = R.

<u>P.S.</u> Taps should preferably be of the "push" variety rather than screw top as the loss of water from the tank is likely to be less.

h) <u>Piping</u> - Each tap on the tank requires approximately 0.5M of ½" piping therefore, length of piping needed for taps = R_1 X 0.5 M. = B_1.

Air vents/overflow pipes should be provided at the rate of one for each 4 taps i.e. number of air vents = $\frac{R_1}{4}$.

Each air vent requires approximately 0.25 M of ½" piping Therefore length of ½" piping required = $\frac{R_1}{4}$ X 0.25 = $\frac{R_1}{16}$ metres = B_2.

Total length of ½" piping required = $B_1 + B_2$.

Piping is sold in 6M. lengths therefore, number of lengths of ½" pipe required = $\frac{B_1 + B_2}{6}$.

This should be a whole number = B. For example if $\frac{B_1 + B_2}{6}$ = 2.3 then B = 3 if $\frac{B_1 + B_2}{6}$ = 4.8 then B = 5

i.e. actual number of ½" X 6M. pipelengths required = B
Drain pipe: approximately 1M. of 1½" or 2" pipe is needed for draining the tank.

j) <u>Fittings</u> - Each tap requires two (2) ½" couplings and each air vent/overflow pipe requires one (1) ½" coupling. Therefore, number of ½" couplings = 2 X R_1 + $\frac{R_1}{4}$ = $\frac{9R_1}{4}$

This amount should be doubled in case of future repairs, therefore, number of ½" couplings to be purchased = $\frac{9R_1}{2}$ = F_1

Each air vent requires 1 X ½" 90° elbow.
Number of 90° elbows required = $\frac{R_1}{4}$

.../..

This amount should be doubled in case of future repairs

$\therefore \frac{R_1}{2} = F_2$.

The drain pipe will need one union and one gate valve of similar size.

k) <u>Other Construction Materials</u> - The normal tank will require the following tools/material for construction purposes

4 Shovels
6 X 10 litre buckets
2 trowels
6 pairs of rubber gloves (for hand laying of mortar)
1 sand sieve (wire screen and frame)
1 plywood sheet for concrete-mixing surface.
1 carpenter's level
Metal wire for tying
3 pliers.

4.2.7. <u>Costing of Tank</u>

a) <u>Material Costs</u> - (As per Hodaydah prices, April 1980)

C...bags of cement at 36 Y.R. per bag

N_1...lengths of 10 mm. ø reinforcing steel at 20 Y.R./length

N_2+N_3...lengths of 6 mm. ø reinforcing steel at 15 Y.R./length

M...rolls of wire mesh at 250 Y.R. per roll.

T...number ½" push taps at 12 Y.R. per tap

B...lengths of ½" tubular steel piping at 25 Y.R. per 6M length.

F_1...number ½" pipe couplings at 2 Y.R. per coupling.

F_2...number ½" 90° elbows at 2 Y.R. per elbow.

<u>Other Construction Materials</u> (As per list of 4.2.6.(h) above)
The cost of these above materials will, naturally, vary from time to time and place to place but the above example is merely given to show the rough price levels.

.../..

All sand, and gravel and water costs are included under transport costs (cf (b) below) as they are generally non-purchasing and only require transport to the site.

b) Transport Costs

This section is the same as Section 4.1.6. (b).

c) Labour Costs

The labour costs are computed as follows:

2 mandays per M^2 of construction on base, walls and roof + 2 mandays for pipe connections, i.e. total number of mandays = D.

$$(2A_1 + 2A_2 + 2A_3 + 2) \text{ days} = D$$

Total labour costs = daily labourer's rate X D.
Cost per manday will vary from area to area but is normally in the region of 60 Y.R. to 100 Y.R. per day.

d) Ancillaries/Extras

This section is the same as Section 4.1.6. (d).

e) Overall Total Costs

This section is the same as Section 4.1.6. (e).

5. CONSTRUCTION PROCEDURES

5.0. Introduction

5.1. Construction Procedure for Stone Tank

5.1.1. Introduction

The selection of the site for the water tank can be one of the most crucial steps, as the limitations of the site can determine the size and shape of the tank itself, as well as the ease or difficulty of its construction. Some points to remember in choosing a site are as follows:

a) The site should be accessible, preferably by a road if materials such as stone, sand, cement etc. need to be transported to the site. Otherwise the site should be close in proximity to most of these materials.

b) The site should require a minimum of rock excavation as this type of work is costly and time consuming.

c) The site should be located so as to provide good accessibility to potential users.

d) The soil or ground should be strong enough to support the tank.

e) And of course, with gravity flow systems, water rarely flows up, therefore position the tank accordingly with respect to the water source.

Often it is impossible to meet all these criteria and it becomes necessary to compromise on some of these points. Choose the site which makes the best fit to this list.

5.1.2. Site Preparation

a) Site Clearance - Clear reservoir site of all rock etc. which will interfere with the construction of the water ../

tank, and level the ground surface.

b) Delivery of Materials - All work materials, such as cement, stones, sand, gravel, pipe, wood and water should be delivered to the site prior to the start of construction or be delivered to the work site at appropriate intervals so as not to impede the progress of work. Materials such as cement and wood should be placed in storage facilities or adequately protected from the weather.

c) Layout and excavation of foundation - The dimensions of the length (L) and width (W) for the outside area, should be taken from the reservoir design and these dimensions should then be measured and marked out on the reservoir site surface making sure all sides are at right angles and straight. The lines can be marked out with stones, paint, or string tied on wood or metal stakes placed so that the string follows the straight course of the dimension lines. Adequate drainage around the site should be provided so that no water from rain or a spring source can flow over the site.

The foundation area should then be excavated to a depth of approximately 20 cm. below the ground surface.

5.1.3. Construction of Foundation Slab

A 10 cm. deep bed of gravel (3/4" - 1½" diameter stones) should then be placed in the excavated area. The gravel should be watered. Then either of the two procedures A or B, shown below, can be used to make the foundation slab.

A

Make a series of 1:2:4 concrete mixes i.e. 1 bucket of cement with 2 buckets of sand and 4 buckets of gravel. Mix these thoroughly with 1 bucket of water.

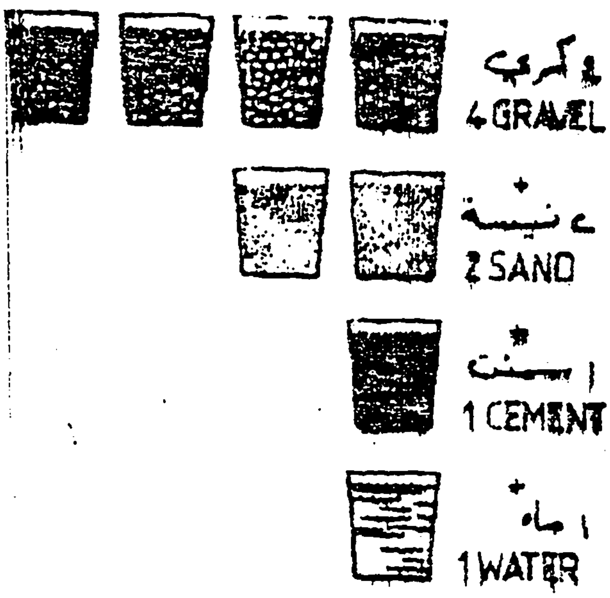


Diagram 6A - Design Mix for Base of Tank

Shovel this concrete mix over the watered gravel, making enough to bring the slab to ground level. (approx. 10cm. high).

B

Lay a level of stones, no higher than 12 cm. on the watered gravel, allowing a space of at least 3 cm. between the stones. Water the stones then shovel a 1:2:4 concrete mix over and between the stones to bring the slab to ground level.

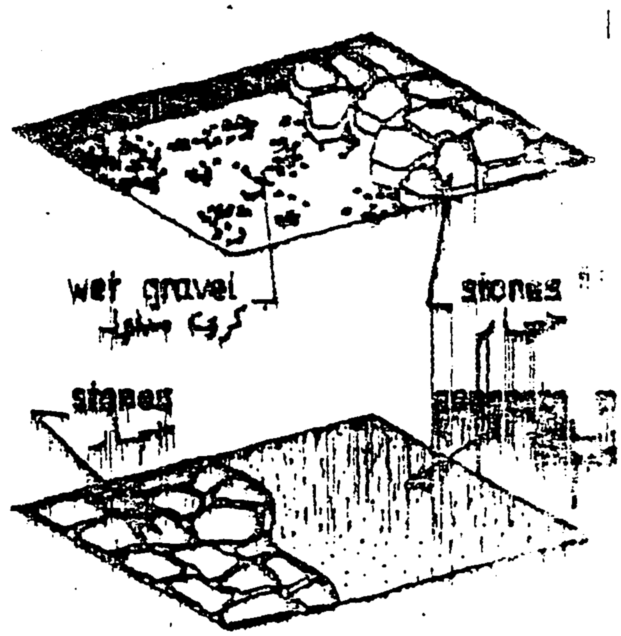


Diagram 6B - Construction Technique for Base of Tank

This procedure will reduce the amount of concrete required

The sand used in all work should be as clean as possible, being free of dirt and small stones. It should be sifted through a wire mesh which can be used to selectively remove the larger particles. The gravel used should be similar to that used previously.

In both procedures, the foundation slab should be sloped to the point where the drain will be placed. It should then be allowed to set for a day, keeping the slab constantly watered to ensure the concrete attains maximum strength and to resist cracking.

5.1.4. Wall Construction and Pipe Placement

a) Placement of drain pipe -. After the foundation slab has been allowed to set for one day, construction of the walls may be started. First, however, a 2" steel drain pipe with attached 2" gate valve should be placed in position at the low point of the slab.

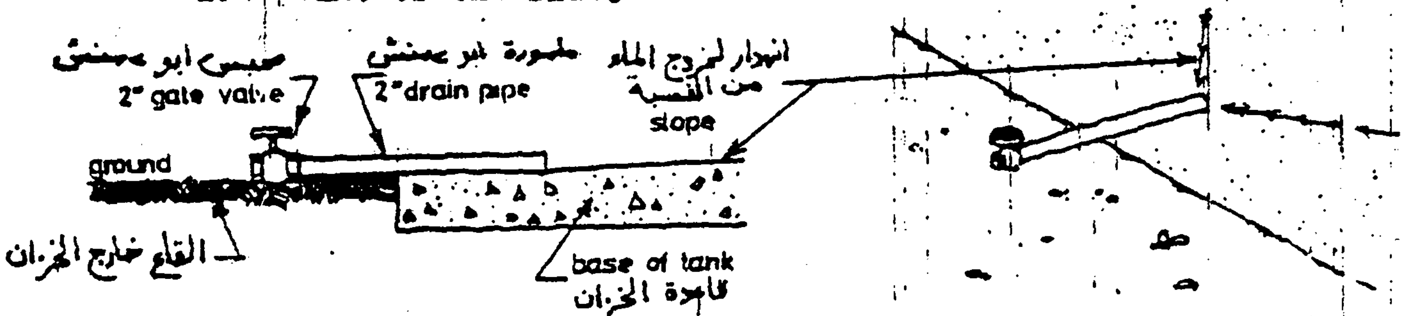


Diagram 7 Placement of Drain Pipe.

b) Wall Construction - At this time wall construction may now proceed. The dimensions of the inside area of the reservoir should be marked out on the foundation slab with paint or chalk, making sure the lines are straight and at right angles. Roughly chiseled stones of adequate strength and a mortar of a 1:3 mix should then be used for construction.

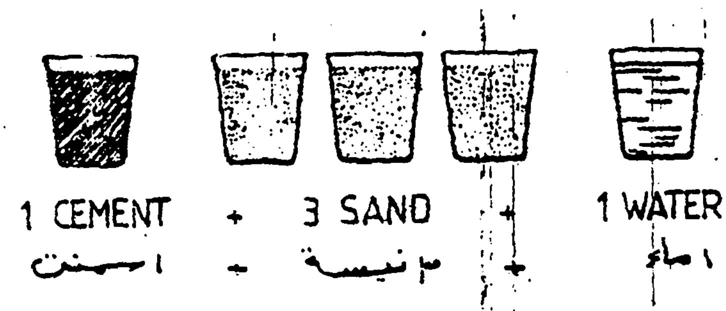


Diagram 8 Design Mix for Wall Mortar in Stone Tank.

The sifted sand and cement should be thoroughly mixed to a uniform greyish color and then mixed with the water. The mortar is placed above, below, and between all stones and the 2" steel drain pipe should be cemented between two stones. Initially one level of stones is built up on all sides.

c) Tap Placement - At this time the ½" taps with connected pipe are put in position at the desired locations. At least a 60 cm. spacing should be allowed for between taps, and the connecting pipes from the taps should extend into the reservoir about 10cm., with the nozzle of the tap extending 15 cm. from the outside wall.

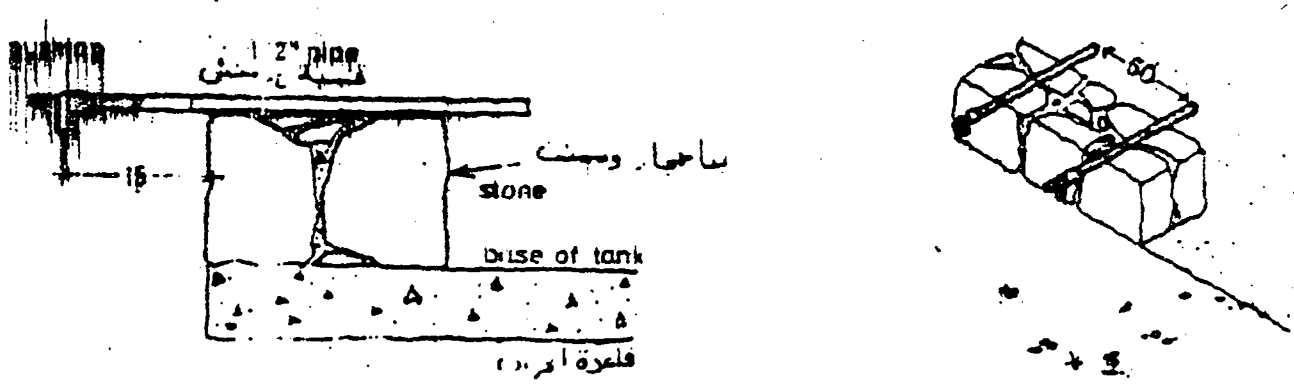


Diagram 9 - Placement of taps in stone tank.

d) Air vent/Overflow Pipes and Connection Pipe from the Spring

From there the walls are built up to the desired height, according to the design. The walls should be constantly watered. On top of the last level of stones are placed the overflow and air vent pipes. These should be made of ½" steel pipe with a ½" - 90° elbow connected on one end and be of adequate length so as to extend approximately 5 cm. into the inside of the tank and 5cm. to the outside.

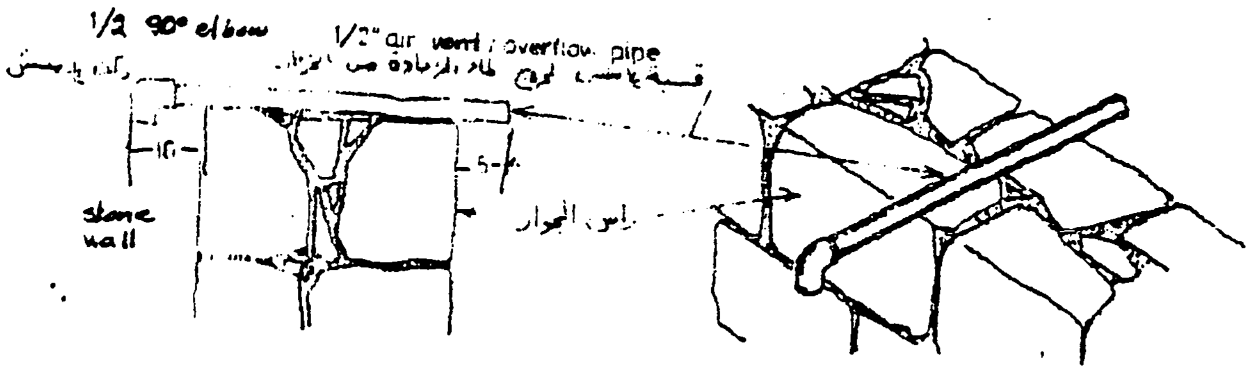


Diagram 10. Placement of air Vents/Overflow Pipes in Stone Tank.

There should be one (1) overflow/air vent pipe for every side wall of tank i.e. they should be located on each wall. Alternatively, the air vent pipes can be placed extending out of the roof with one overflow pipe placed on the wall as described above. At this time, the pipe from the spring source should be connected to the reservoir and cemented through the wall like the overflow pipe. There should be a globe valve attached to this pipe to allow the water to be shut off to the tank if repairs or cleaning of the inside of the tank needs to be done. An overflow pipe from the enclosed water source may thus be required.

5.1.5. Plastering of Inside Walls

At this point the inside walls of the tank should be plastered with a rich mortar mix of 1 cement : 2 sand : 0.75 water. That is each bucket of cement should be first dry mixed completely with 2 buckets of sand and approximately 3/4 buckets of water should be added in. (Slightly more water may be required depending on the most workable consistency.)

This mortar mix should be applied to a thickness of approximately 2 cm. overall and the plastering should be constantly watered. Water can be allowed to flow to the tank the next day.

5.1.6. Preparation of Wood

Before construction of the roof begins all the wood to be used should be primed and coated with at least 2 coats of paint/sealant.

.../..

5.1.7. Construction of the Roof

a) Beams - Next, the 150 mm. X 100 mm. wood beams can be put in position. These will be placed on the top level of stone and should be spaced at 50 cm. intervals (center to center), with their 150 mm. side placed from top to bottom. The beams should span the width of the tank with a beam being placed at both ends, on the inside of the end walls

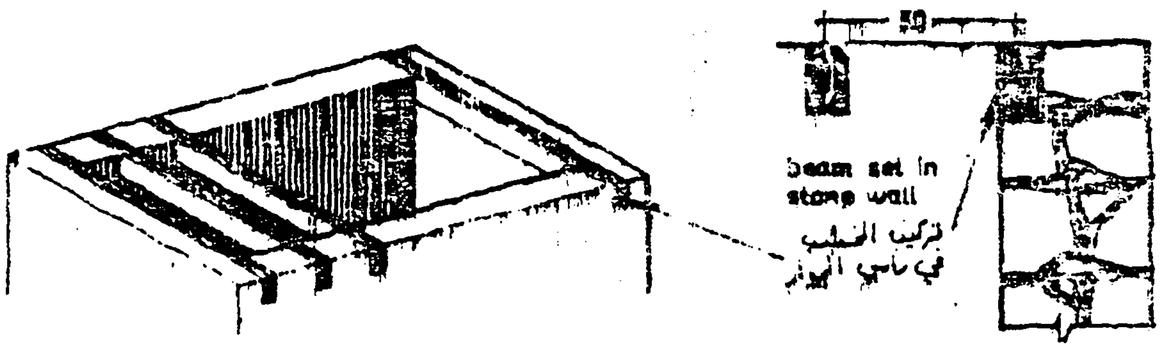


Diagram 17 - Layout of beams for Stone Tank Roofing.

Stone should then be cemented on top of the walls between the wood beams and on the ends so as to make the walls flush with the beams, but they must not be higher than the beam themselves so that the roofing can be placed level on the beams.

b) Roofing and Manhole - The plywood sheeting (cut to size if necessary), is then placed on top of the beams and nailed to them. Again, remember, this wood should be primed and painted before use. A manhole opening 50 cm. X 65 cm. should be cut from the plywood sheet along one of the walls, but should not be located directly over a wall. 1" X 4" board is then nailed around the manhole opening, with the 4" dimension from top to bottom.

.../..

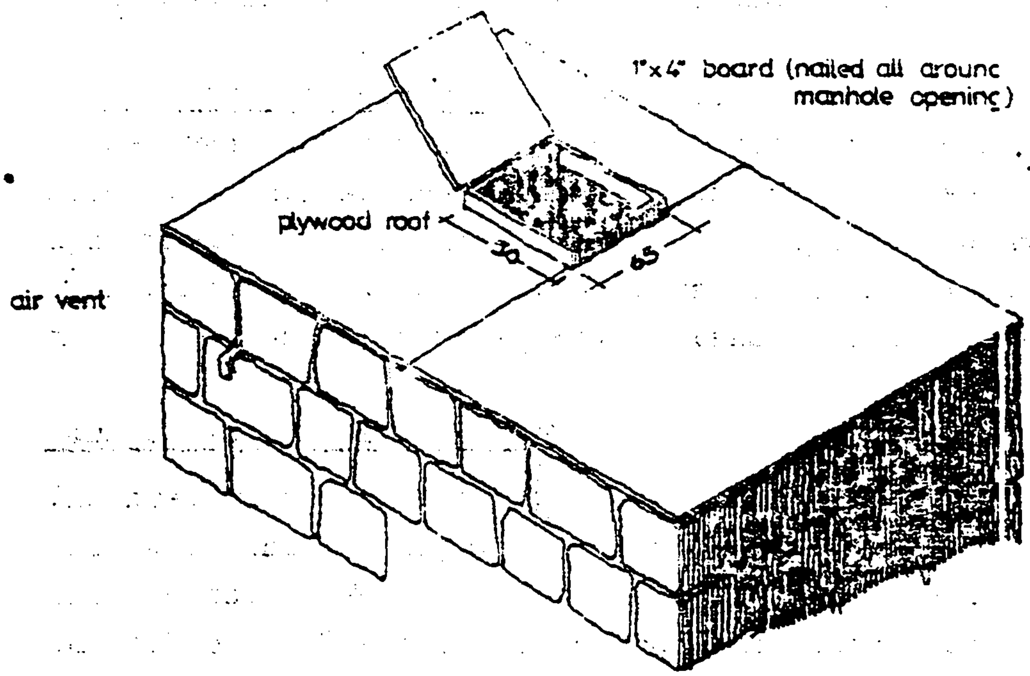


Diagram 12 - Manhole Roof Opening.

On top of this will be placed a hinged wooden cover. (This should also be painted or covered with metal sheeting.)

c) Top Layer of Concrete - Now a concrete layer should be placed over the plywood. The concrete will be made of the same 1:2:4 mix as mentioned earlier and the layer should be approximately 5 cm. thick, although sloped so rainwater will run off. This concrete layer is then allowed to set and is constantly watered for at least 5 consecutive days.

5.1.8. Work on Access Area to Taps

The area in front of the reservoir can now be worked on. This will include digging out the ground in front of the taps so that a 20 litre jerry can can be set under the taps and filled. The area dug out as such should be about 1M. wide to allow easy access to the taps, and then this area should be laid with a 5cm. deep, 1:2:4 concrete mix on top of a bed of gravel, and any excavated sides built up with stones.

This access area should be sloped to a drainage point, so that any water which collects on the surface will be drained off. This may require the building of a water channel from this area to a point where the water can be drained. Water drained from the tank flows out onto this surface and out the drainage channel.

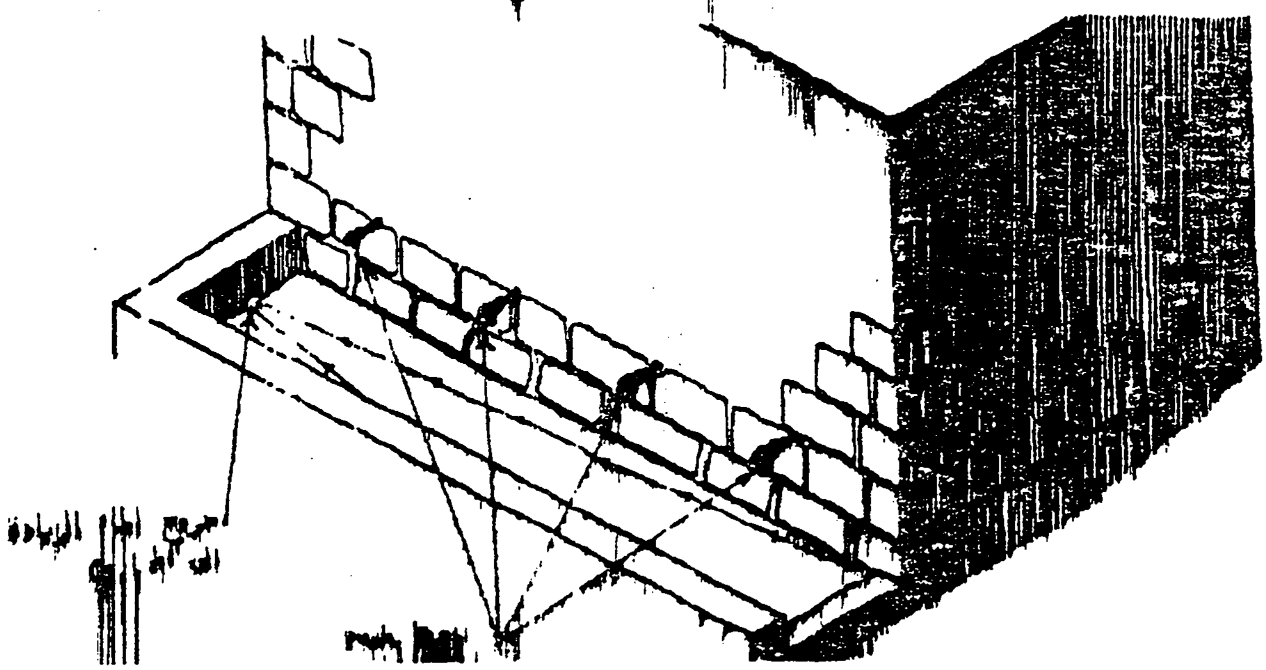


Diagram 13 - Layout of Stone Tank Frontage.

5.1.9. Inspection

The tank should be inspected for a few days after it is filled and in use to determine if it is properly sealed and the taps in good working condition. Also the drainage should be inspected to determine if water which collects on the access area, roof, and around the tank is adequately drained away.

5.1.10. Use of Excess Water

In areas where water is scarce or water conservation is to be practised remember that all drain water, overflow water, and runoff rain water can be put to good use. The water draining off the access area can be used for washing or drinking by animals if allowed to collect in a pool. (It may have to settle out for awhile for washing purposes) and rain water flowing off the roof can easily be channeled or piped to a collecting point for the same use or for human consumption if the roof is clean at all times.

.../..

5.2. Construction Procedure For Ferro-Cement Tank

5.2.1. Introduction

The same criteria used in site selection for stone tanks applies to this section. Refer to Section 5.1.1. for these.

5.2.2. Site Preparation

a) Site clearance - remove all rock etc., which will interfere with the construction of the water tank, and level the ground surface.

b) Delivery of materials - all work materials required, such as cement, sand, stones, steel reinforcing, wire mesh, gravel, water, and tools should be transported to the site before beginning actual construction or delivered at appropriate intervals. Protect the cement from the weather.

c) Layout and excavation of foundation - the dimension for the diameter of the base (D) is taken from the design and a string or piece of rope cut to a length 15 cm. longer than the dimension D/2, i.e. length of string = (D/2 + 0.15) M. A short metal stake then should be driven into the ground at the location of the centre of the proposed water tank. The string or rope is tied to the stake in a loop which will allow the string to move around it, and tied so that the distance from the stake to the end of the string is (D/2+0.1) M. The string is moved around the stake in a circular manner so as to outline the circumference of the base of the tank with a diameter of (D + 0.2)M. This outline should be marked with paint or "goss" so as to clearly define the limit of the base.

This circular area is then excavated to a depth of approximately 20 cm. below the ground surface.

5.2.3. Placement of the Vertical Reinforcing Bars (8 mm ø)

The metal stake is now driven into the excavated ground at the center of the base and the string tied to it. This time the marked length of string = D/2. Describe a circle with the string and mark the outline with "goss" or paint.

Then, decide on a point on the circumference where the first 8 mm. ø bar will be sunk, and mark out each successive position for the vertical bars at intervals of 30 cm.(0.3M) around the marked line (the circumference). Excavate at each of these points to a depth of 30 cm. (0.3 M).

Now, cut the 8 mm ø steel bars to a length = (0.5D +2.3) M. and place them in the excavated holes securing them with dirt and rock and if necessary some cement mortar. Make sure that these bars are all at a distance of D/2 from the center stake.

5.2.4. Construction of the Foundation Slab

A 10 cm. deep bed of gravel (3/4" - 1½" diameter) is now placed at the bottom of the excavated area and around the vertical steel, and it is watered. Then, either of the two procedures described in section 5.1.3. for stone tanks is used to make the foundation slab for this tank. Remember that the slab should be sloped to the point where the drain pipe will be placed, and also that it should be constantly watered. Allow it to set for at least 3 days. (More time is allowed for setting than was outlined in Section 5.1.3. as the vertical steel bars must be secured firmly in the slab.)

5.2.5. Placement of the Circular Horizontal Bars (6 mm. ø)

a) Walls - these bars are cut to a length = π X D metres long and bent around the outside of the vertical bars (8 mm ø) and tied to them by metal wire. There will be a total of five of them placed in the positions shown in the following diagram.

.../..

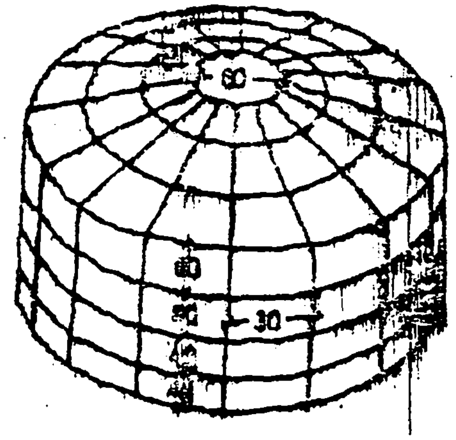


Diagram 14 - Layout of Reinforcing Steel in Standard Ferrocement Tank.

b) Roof - There will be three (3) 6mm. horizontal bars placed on the roof. Cut the first bar to a length = 1.9 metres, bend it into a circular shape and place it at the top of the roof where a 60 cm. diameter opening should be left for access to the tank. (If necessary, cut the extended and bent over 8mm. vertical bars so as to allow for this opening; cf above diagram.) The 8mm. bar ends should then be tied firmly to this circular steel ring. The second bar should be cut to a length = (D/6 + 0.2) metres. Cut the third bar = (D/3 + 0.2) metres.

Bend these bars into a circular shape and place them on the roof where they will lay flat on the extended 8 mm. bars. Connect them both firmly to the 8mm. bars with metal wire to attain the final steel framework as shown in the above diagram.

5.2.6. Placement of Wire Mesh

At this time the wire mesh can be put into place. Unroll the wire and attach the free end to one of the vertical 8 mm. bars so that the bottom of the wire rests on the surface of the slab and extends upwards the width of the roll (90 cm.) All connections are made with metal wire and twisted tight with a pliers.

.../..

The wire mesh is unrolled around the entire circumference of the tank making sure the wire is fairly tight and connected firmly to the vertical and horizontal bars. Overlap the free end of the mesh (which was connected first), by about 30 cm. Cut themesh at this length but do not connect the final 60 cm. in order to leave an opening for access during construction work.

Next, connect the mesh to the top part of the wall above this lower width. This should be done in the same manner as the first but making sure the top level of mesh overlaps with the bottom by about 2 cm. and connecting the wire mesh firmly to the reinforcing bars all the way through. (Do not leave an access opening on top.)

Now, wire mesh has to be connected to the inside of the tank to form a double layer. This should ideally be done by running the mesh from top to bottom of the walls rather than around the circumference. This will achieve the greatest strength for the ferro-cement. The access opening is not covered.

Wire mesh is then placed on the inside and outside of the roof area except for the 60 cm. circular opening at the roof apex. Since the area to be covered is not a flat surface, the wire mesh may have to be slit in order for it to lay flush with the surface.

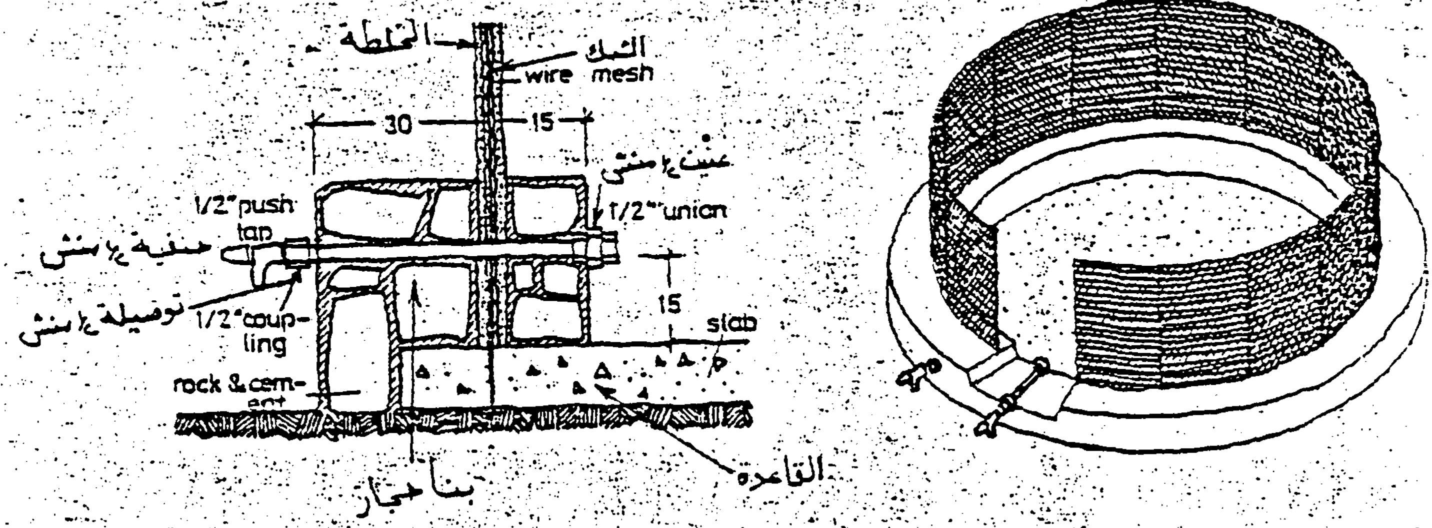
5.2.7. Placement of Tank Fittings

a) Drain Pipe - The drain pipe used is a 50 cm. long X 1½" ø steel pipe, connected at one end with a 1½" gate valve and at the other end with a 1½" union. The union is connected so as to provide greater resistance to slip along the surface of the base and through the wall. It is placed at the low (drainage) point of the tank and should extend approximately 15 cm. inside the tank and 30 cm. outside.

.../..

Rock should be cemented over this pipe so as to secure it to the slab surface.

b) <u>Taps</u> - The ½" push taps may be put in position before the mortar is placed on the walls. A ½"ø steel pipe is cut to a length of 50 cm. and threaded with a union at one end and a coupling and tap at the other. It should then be placed in its desired position, pushing it through the wire mesh and supporting it with rock cemented above and below the pipe which should be at least 15 cm. above the slab surface. The pipe should extend approximately 30 cm. outside the tank and 15 cm. inside (cf diagram below). The union provides resistance to slip. All taps are connected similarly but they should be placed at least 60 cm. apart.



<u>Diagram 15</u> - Placement of Taps for Ferrocement Tank.

c) <u>Overflow/Air Vent Pipes</u> - The ½" ø steel pipe is cut in 10 cm. long lengths and threaded at one end on which a 90° elbow is connected. They are placed at the top of the walls and are secured in position by tying them firmly to the wire mesh and reinforcing bars with metal wire.

d) <u>Pipe from the Source</u> - The connecting pipe from the source should be connected to the top of the tank in the same manner as the overflow/air vent pipes.

5.2.8. Cement Mortar Application

The cement mortar for the work can now be made. A very fine sand is desired, so the sand should be run through a fine wire screen which will select out the larger particles. This sand should be thoroughly mixed with the cement in a ratio of:

1 bucket cement : 2 buckets of sand.

This will then be mixed with 3/4 buckets of water.

Diagram 16 - Design Mix for Mortar in Ferrocement Tank.

The final mortar should be slightly drier than normal and the temptation to add more water should be resisted.

It is preferable if the mixing is done on a smooth clean surface, such as plywood sheet. The mortar is applied with teams of two people, (preferably wearing gloves to protect their hands) one stationed inside the tank and the other outside. While one person holds his/her hands against the wire mesh, the person from the other side forces the mortar into the mesh and up against his/her companion's hands. This is done until the entire surface of the wall and roof are covered. (except the bottom half of the "access" panel and the panels on either side of it.) Don't worry about getting it perfect as it must be gone over again a second time. Let the completed work set for a day or two, being constantly watered.

When the roof has acquired enough strength to allow people to walk on it and gain access through the roof, the "access" panel and the two adjoining panels should be finally wired up with the wire mesh, tied firmly and impregnated with mortar as was done with the rest of the tank.

.../..

After this apply a second application of this aame 1:2 mortar to all surfaces of the tank making sure it is entirely sealed. As for all mortar work, keep it watered constantly until curing is completed (for at least 3 days).

A third light application may be necessary after testing of the tank to plug any leak points, although this should not be necessary if the work has been carried out as desired.

5.2.9. The Manhole Cover

A cover is now made to fit the 60 cm. diameter opening left on the top of the roof section. This will also be made of ferrocement and should be curved to fit on the roof as shown in the following diagram. A 6mm. reinforcing bar is cut to a length of 2.2. metres and bent into a circular shape (this will give a cover diameter of 70 cm.) Next, 6mm. reinforcing bars are cut and placed on the inside of this circle, as shown in the diagram. They should be tied to the circular bar.

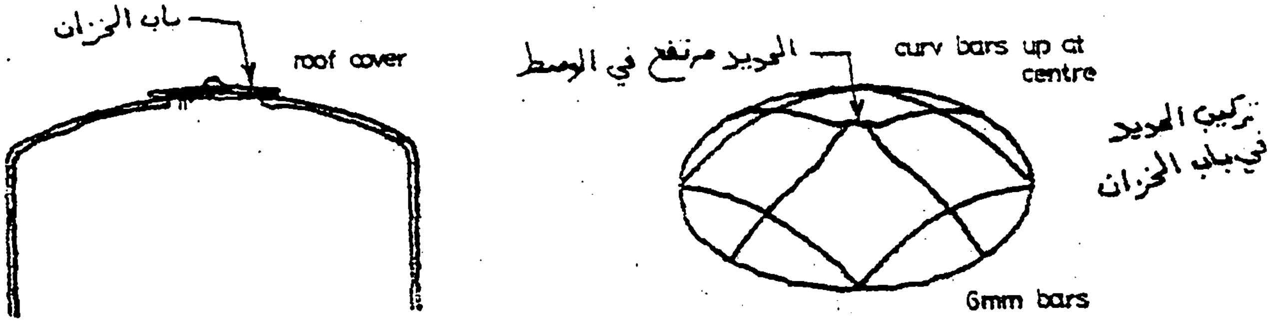


Diagram 17 - View of Roof and Roof Cover For Ferrocement Tank.

Wire mesh is now placed on both sides of this cover frame and tied to it with metal wire. A small handle is made from the 6 mm. steel and firmly secured to the cover (cf diagram above). Cement mortar is then applied to the wire mesh as was done to the walls and roof of the tank. Apply more cement mortar as needed after allowing the cover to set a day between applications. Keep the mortar constantly watered as was done with the tank.

5.2.10. Access Area to the Taps

The area in front of the taps must now be worked on to allow a container to be set under the taps for filling and to allow easy access to the taps themselves. This should be done in the same way as was described in Section 5.1.6 for construction of the access area for stone tanks. The important thing to remember is that proper drainage must be provided for from this access area.

5.2.11. Inspection

Inspection should be carried out as described in Section 5.1.9. for stone tanks.

5.2.12. Use of Excess Water

Use the drainage water and rain runoff water as recommended previously in Section 5.1.10.

5.3. Design/Costing And Construction of Combination Tank

5.3.0. Introduction

The concept behind this tank is to use the more generally accepted construction of building with stone in combination with a ferro-cement roof. The design and construction process is similar to what has already been covered in the previous sections, with only the roof being different from what has already been described. The ferro-cement roof will be less expensive than the wood and cement roof described in Section 4.1. due to the high cost of wood in the Yemen.

5.3.1. Design and Construction of the base and walls

The design will be the same as with the stone tank explained in Section 4.1.1., 4.1.2. and 4.1.3. Construction will be carried out as per Section 5.1.1., 5.1.5. through 5.1.8.

.../..

inclusive.

5.3.2. Design and Construction of the Roof

A reinforcing bar frame must be constructed for the arched roof of the tank, on which the wire mesh for the ferrocement work will be tied. Reinforcing bars (6 mm. ø) span the width in an arch shape and must be imbedded into the walls to a depth of 60 cm. to support them, which means that this should be done before the top three levels of stone are placed on the walls since each stone level is 20 cm. high. These bars should be bent in their arch shape, leaving 60 cm. on each end to be keyed in the walls. See diagram below.

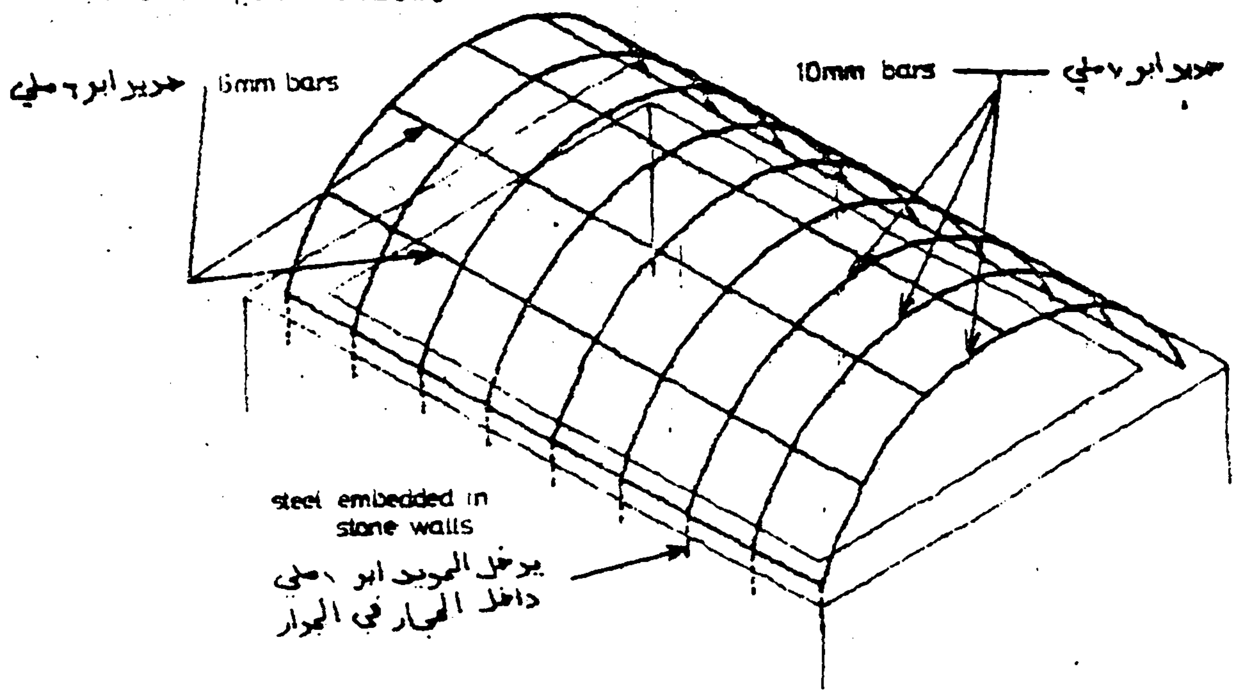
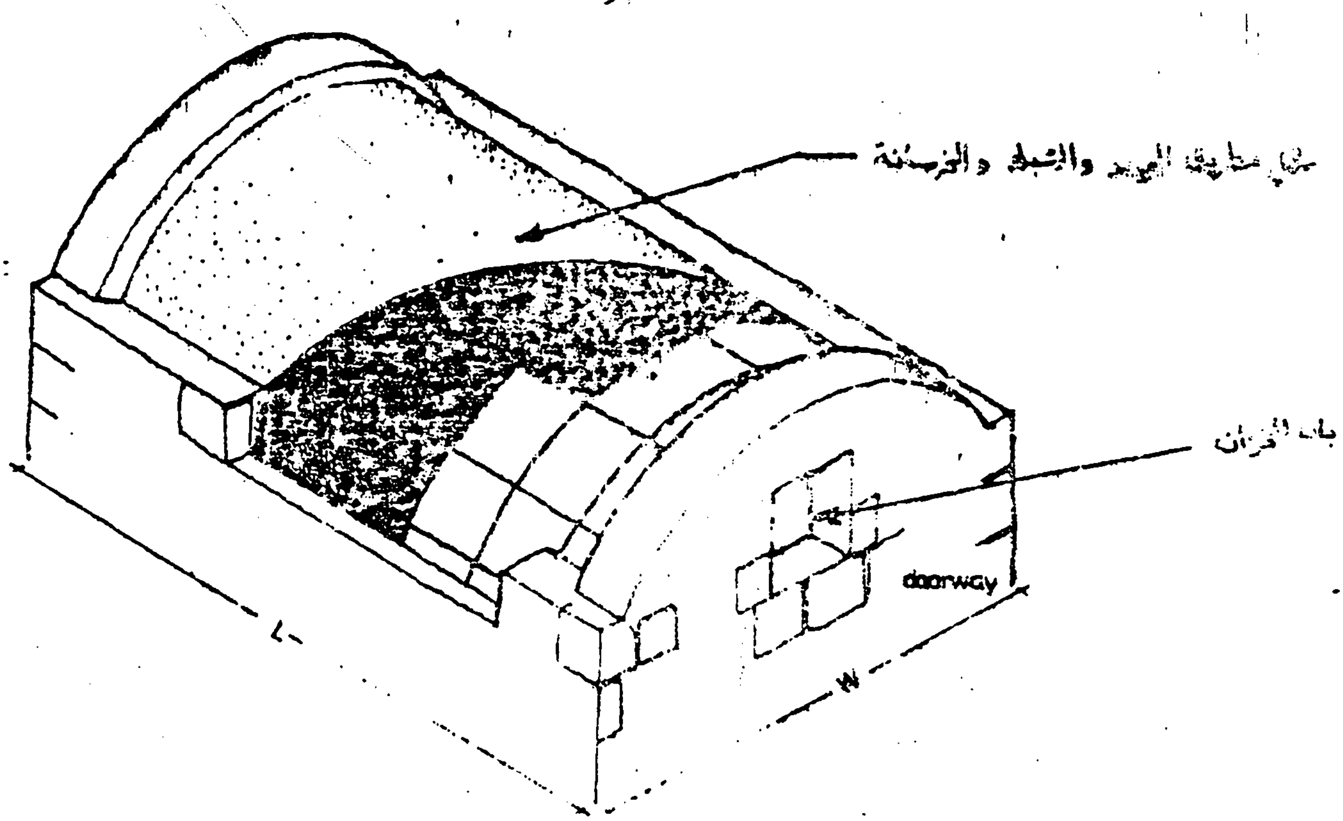


Diagram 13 - Layout of Reinforcing Steels for "Combination" Tank.

Next, 6mm. reinforcing bars will be cut to a dimension equal to the length of the tank, and placed on top of the arched bars running at right angles to the arched bars. These should be placed every 30 cm., and be tied to the arched bars.

The walls at the ends of the tank should then be built up so as to completely fill in the arched openings with stone and mortar (see diagram). A 60 cm. X 60 cm. "doorway" entrance can be left in one end of these built up walls to allow for access to the tank. A wood door and frame should be fitted and cemented to the opening.



<u>Diagram 19</u> - View of "combination" tank.

a) <u>6mm. Bars required for arches</u> - The length of the arched bars (L_1) will be = 1.5 X W + 1.2 where W = outside width of the tank.

$$L_1 = 3/2\,W - 1.2$$

Reinforcing bars are sold in 12M. lengths, therefore the number of these arched pieces per 12 M. = $12 \div L_1 = \frac{12}{L_1}$

This should be a whole number = E (round down)

i.e. if $\frac{12}{L_1} = 2.6$ then E = 2.

if $\frac{12}{L_1} = 3.2$ then E = 3

The number of these arched bars needed will be = $\frac{L}{0.3} + 1$

where L = outside length of tank.

Now we can calculate the number of 12M. lengths required:

$$= \frac{\frac{L}{0.3} + 1}{E}$$

This should also be a whole number = N_1 (round up this time.)

i.e. if $\frac{(\frac{L}{0.3} + 1)}{E}$ = [illegible] then N_1 = 8

if $\frac{(\frac{L}{0.3} + 1)}{E}$ = [illegible] then N_1 = 6

b) <u>6 mm. bars required for length pieces</u> - The dimension of the length pieces will be = L (L = length of tank in metres). The number of length pieces will be

$$= \frac{3W}{2} \times \frac{10}{3} = 5\,W \text{ (W = width of tank in metres)}$$

Therefore total length of reinforcing steel (6mm. ø) for the length pieces required = L X 5W metres.

Now we can calculate the number of 12 M. lengths required $= \frac{L \times 5W}{12}$, this should also be a whole number = N_2 (round up this time):

if $\frac{5W}{E} = 15.3$ then, $N_2 = 16$

if $\frac{5W}{E} = 6.9$, then $N_2 = 7$

c) <u>Total number of 6 mm. ø bars required</u> - Total no of 6 mm. ø X 12 M. lengths needed $(N_3) = N_1 + N_2$. Use this figure for costing.

d) <u>Wire mesh required (M)</u> - Wire mesh is to be placed on both sides of the reinforcing steel.

(A_3) Area of roof = 1.5 X area of base

= 1.5 WL

Therefore, the number of rolls required = $2A_3$
Area of 1 roll of wire mesh = 40 M^2
Therefore, the number of rolls required $= \frac{2A_3}{40} = \frac{A_3}{20} = M$

e) The cement mortar is applied to the wire mesh as outlined in Section 5.2.8. Using an average mortar thickness of 0.05 M., amount of mortar required = area of roof X 0.05

$= 0.05\ A_3\ m^3$

Using a 1:2 mix for the mortar and assuming the sand takes up the entire volume of the mix the amount of cement required is:

.../..

$C_3 = \frac{0.05\ A_3}{2}$ metres ^{3} 1000 litres = 1 M^3

$C_3 = \frac{50\ A_3}{2}$ litres 35 litres = 1 bag.

$C_3 = \frac{50\ A_3}{2 \times 35}$ bags = $\frac{5\ A_3}{7}$ bags cement.

f) Sand (S_3) - Volume sand = .05 A_3 metres^3 = S_3

g) Door and Frame - One 4 M. length of 100 mm x 50 mm white wood.
- 0.36M^2 of 18 mm. guage plywood i.e. 1 sheet of 18 mm. guage plywood.
- hinges and latch.

5.3.3. Materials and Costings

The same procedure is followed as shown in Section 4.1.5., 4.1.6., 4.2.6. and 4.2.7. using the figures computed in the above sections for 4.2.6. and 4.2.7.

.../..

6. PIPELINE PROCEDURES

6.1. Pipeline Design and Costing

6.1.1. Introduction

The design of a pipeline involves determining the size of pipe required for a specific flow rate (or range of flow rates), and for a set elevation difference between the inlet and outlet of the flow through the pipe. What is required for this design is as follows:

(i) hydrological data book with tables of pipe flow head losses versus flow rate for specific types and sizes of pipes.

(ii) Basic information for the pipeline to be designed including pipeline profile (length of pipe line and elevation measurements), the maximum flow rate to be delivered, the type of pipe to be used, and the sizes of pipe available.

If the above data book is not available or the following design procedure proves to be too complicated, take the basic information in (ii) above to a qualified person for the design of the pipe.

The pipeline for a gravity flow system (no pump) will be considered here, although the same pricniples are involved for a pump line design, with the only differences being the positive head (driving force) is provided by the pump and not gravity, and the elevation difference is part of the head loss if the water is being pumped up.

6.1.2. Basic Calculations

a) Determine the elevation between the inlet and outlet of the pipeline. If h_1 is the elevation measured at the inlet (source) and h_2 is the elevation measured at the outlet (tank) the elevation difference is:

$h_1 - h_2$ = elevation difference (H)

.../..

(h_1 and h_2 should both be in metres).

b) Determine length of pipeline = L (metres)

c) Determine the maximum flow rate to be given (See section 3 for flow rate measurement). Maximum flow rate = Q (litres/min.). (This will be the maximum flow to be expected in the rainy season.)

d) Since many of the tables in hydrological data books are in gpm (gallons per minute) flow rates, we might have to change Q in litres/min. to gpm.

Q litres/min. ÷ 3.785 litres/gallon = Q gpm

6.1.3. Use of data book

a) Now open the data book to the tables which list the type of pipe which will be used (use 10 year old steel pipe listing) and which lists the flow rate which we want to use versus the various head loss ratios.

b) Choose a pipe size (usually between ¼" and 2") which is commercially available.

c) Open to the table which lists this chosen pipe size and type and the flow rate desired. Look down the column under the chosen pipe type and size until the row with the desired flow rate is intersected. This number is the head loss ratio (f) to be used for calculations. This number will be in ft./100 ft. or M./100 M. It may be necessary to interpolate between numbers if the exact flow rate desired is not listed.

6.1.4. Final Pipe Calculations

Now we can determine if the pipe size chosen is adequate.

$$L \div 100 = L^1$$

$$\text{Head loss } (h_L) = L^1 \times f$$

.../..

If h_L is greater than elevation difference (H) the chosen pipe size is inadequate, and we must repeat the procedure described in 6.1.3. and 6.1.4. with a larger pipe size. If h_L is less than elevation difference (H) the pipe is adequate. However, it might be oversized and we must repeat the above procedure 6.1.3. and 6.1.4. with the next smaller pipe size and continue this repetition until the smallest adequate pipe size is found.

H should be greater than h_L by anything from 5 M. to 40 M. to allow for flow to the top of the reservoir and as a safety factor.

6.1.5. Example

If the elevation of the water source is 1500 M (above sea level) and the location of the proposed water tank is 1485 m., and is 850 m. away from the water source, and the ~~maximum~~ flow rate to be delivered is 57 litres per min., what pipe size of steel pipe should be used? 3/4", 1", ½" and 2" pipe is available.

Step 1 - $H = h_1 - h_2$ = 1500 m - 1485 m = 15 m.

Step 2 - L = 850 m.

Step 3 - Q = 57 litres per minute

Step 4 - 57 litres/min. ÷ 3.785 lit./gal. = 15 gpm.

Step 5 - Look in the data book under 10 year old steel pipe and find the table which lists 2" pipe (standard gage). Look down this column until the row with the flow rate of 15 gpm is intersected. This number is our f = 1.11 ft./100 ft.

Step 6 - $L^1 = L \div 100 = 850 \div 100 = 8.5$ m.

$h_L = f \times L^1 = 1.11 \times 8.5$ m. = 9.44 m.

Step 7 - H = 15 m.; h_L = 9.44 m.
Therefore, h_L is less than H so the pipe is adequate. (Also H is at least 5 m. greater than h_L)

.../..

Step 8 - Repeat steps 5-7 with 1½" pipe. If we do this we'll find h_L is greater than H therefore, we must use 2" pipe.

6.1.6. Use of Valves and Fittings

a) Gate (shut off) valves should be placed at the beginning of the line (near the water source), upon entrance to the water tank, and on any branch lines.

b) Air release valves should be placed at the high points of the pipeline if the pipeline rises and falls in elevation as it traverses its course.

c) Drain off valves (gate valves connected to tee connection) should be placed at the low points.

d) If the pipe line has sharp curves or bends an appropriate number of 45° and 90° bends should be ordered.

e) Unions should be placed every five pipe lengths.

f) Extra couplings should be ordered as replacements.

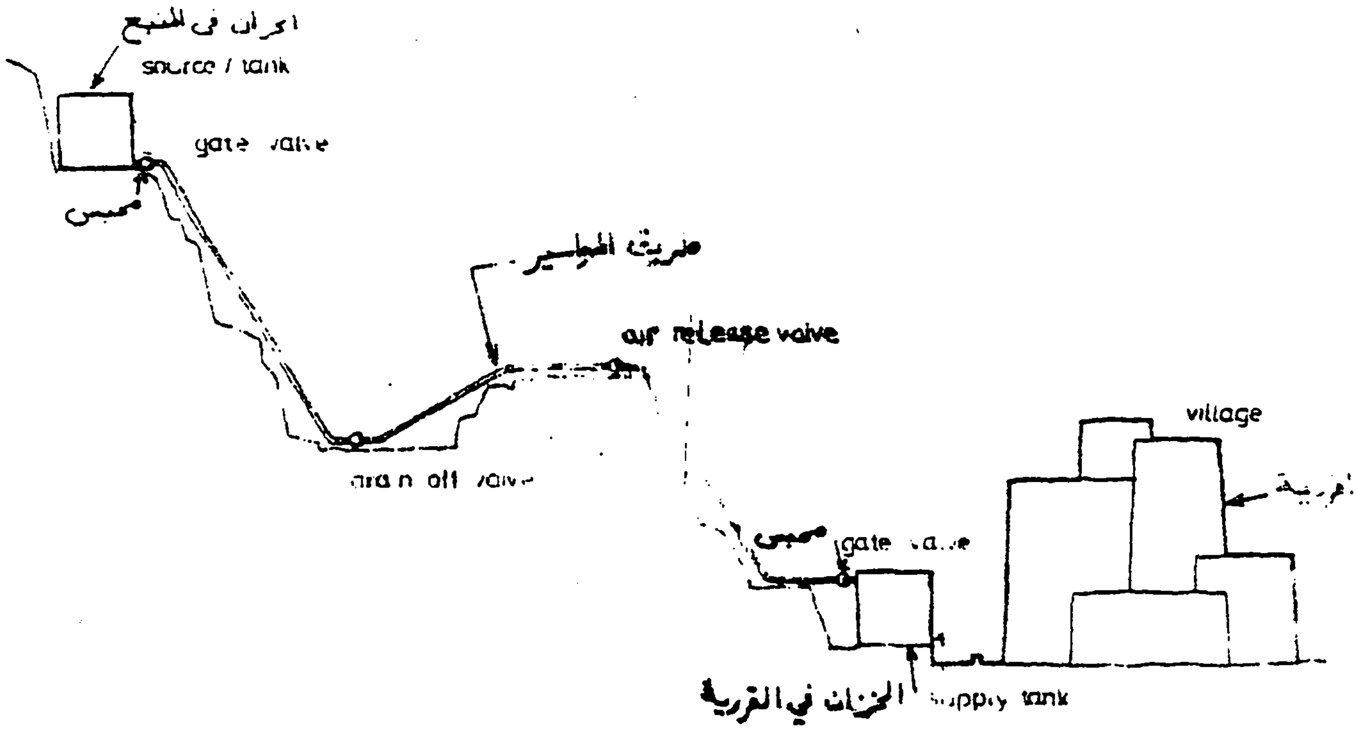


Diagram 20 - Profile of pipe line and positioning of "drain off" and "air release" valves.

6.1.7. Costing of the Pipeline

a) Labor - The cost of labor depends on the size of the pipe being layed. For pipe between the sizes of 3/4" - 2" an average of 18m. per manday can be laid (slightly higher for 3/4", lower for 2"). This includes work on construction of supports, inspection and repair etc. Length of pipeline (L) ÷ 18m. = No. of mandays required = (M).

$$M \times 100 \text{ Y.R./manday} = \text{Cost of labor} = Y_1$$

N.B. This will of course vary from area to area.

b) Pipes - From the length of pipe needed, determine the amount of 6m. sections of pipe required, since pipe is sold in 6m. lengths.

Length of pipe (L) ÷ 6m. = Number of 6m. lengths = (N_p).

Multiply this number by 10% to allow for replacement pipes.

$$N_p + (N_p \times 0.10) = N_{p'}$$

$$N_{p'} \times \text{price of pipe} = \text{Cost of Pipe} = Y_2$$

c) Valves, Fittings, Extra Couplings, etc. (Accessories)

The individual number of these items can be determined and costed or what is often done is to use the figure of 10% of the cost of the pipe used.

$$0.10 \times Y_2 = \text{Cost of Accessories} = Y_3.$$

d) Tools - The tools required for the connecting of the pipeline are as follows:

(i) Pipe threader (1)
(ii) Pipe clamp or vice grip with stand (1)
(iii) Pipe wrenches (3)
(iv) Metal file (1)
(v) 3m. tape measure (1)
(vi) Pipe cutter with extra blades (1)
(vii) Pipe tape or compound (1 roll/can per 50m. of pipe).
(viii) Oil can and oil.

.../..

Multiply the number of these items by their individual costs to get the cost of tools = Y_4.

e) <u>Cement</u> - Cement will be required if supports need to be built for the pipe, if the pipeline is placed over irregular terrain. The exact amount will depend on the amount and size of supports required, but an average that may be used is 1 bag of cement per every 100m. of pipe line.

$L \div 100$ = No. of bags of cement required

No. of bags X price per bag = Y_5 cost of cement.

f) <u>Sand</u> - Sand will be required for the cement mix. Twice as much sand will be required as cement.

1 bag = 35 litres = 0.035 M^3

Amount of sand required = No. bags of cement x 2 X 0.035 (m^3)

Amount of sand X price of sand/m^3 = Y_6 cost of sand.

g) <u>Transportation</u> - The cost of transportation of the pipes and other materials from the place of purchase to the work site must be determined = Y_7.

h) The total cost of the pipeline (Y) equals the sum of these different costs.

$$Y - Y_1 + Y_2 + Y_3 + Y_4 + Y_5 + Y_6 + Y_7$$

6.1.8. <u>Pipe and Accessory Prices (as of Jan. 1980 Hodeidah)</u>

SIZE	PIPES	GATE VALVES	UNIONS	PUSH TAPS	90° ELBOW
½"	22 YR/6m.	8 YR	5 YR	12 YR	2 YR
¾"	48 YR/7.5m.	11 YR	8 YR		3 YR
1"	48 YR/6m.	15 YR	10 YR	35 YR	4 YR
1¼"	55 YR/6m.	25 YR	12 YR		6 YR
1½"	74 YR/6m.	30 YR	15 YR		9 YR
2"	94 YR/6m.	40 YR	20 YR		12 YR
2½"	155 YR/6m.	74 YR	35 YR		25 YR
3"	180 YR/6m.	100 YR	55 YR		40 YR
4"	280 YR/6m.	170 YR	90 YR		60 YR

.../..

Jointing pipe tape	5 YR/roll
Jointing pipe compound	8 YR/can
# 18 pipe wrench	35 YR
½-2" pipe threader (Chinese)	500 YR
½"-4" pipe clamp (chain)	250 YR
2" pipe cutter	200 YR
45° elbows only available in 1" size	5 YR.

6.2. Pipeline Construction

6.2.1. Pipeline Route - The initial phase of pipeline construction should involve the marking of the proposed pipeline course on the terrain which must be traversed. For gravity flow lines, if the elevation difference between the water source and proposed tank is fairly great the pipeline course may be readily apparent without any exact marking of location. If not, it may be necessary to mark out the course with the use of survey equipment to ensure that the pipeline has the proper elevation drop on each part of the line. This can be checked by using the elevation drop to any point on the line and calculating the head loss (h_L) to that point as described in section 6.1. Make sure the elevation drop is greater than h_L.

Take the straightest and most direct route, avoiding excessive bends, rises and drops, although this is often impossible due to geographical constraints.

6.2.2. Tools Needed - The equipment and tools required for the construction of the pipeline are as described in the previous section on design 6.1. but will be listed here again. The size of these tools are dependent on size of pipe to be used:

(i) Pipethreader (1)
(ii) Pipe clamp and stand (1)
(iii) Pipe wrenches (3)
(iv) Pipe cutter with extra blades (1)
(v) Metal file (1)
(vi) Oil can and oil

.../..

(vii) Pipe tape
(viii) 3m. measuring tape.

6.2.3. Program of Work - Typically, the pipes will be delivered to the village which is the recipient of the water project and sometimes they will be damaged from shipping. As such, it has been found that to set up the pipe inspection and repair operation in the village and to then carry and distribute the pipes along theppipeline route is the most efficient means of getting this work done. Work can begin on the pipeline as the pipes are distributed. The program of work will thus be as follows:

a) Delivery of pipe to village
b) Inspection and repair of individual pipes, and cutting and threading if necessary.
c) Distributing pipe along pipeline course.
d) Connecting the pipe.
e) Buying the pipe where necessary.
f) Building of pipe supports where required.
g) Inspection and testing of pipeline.

6.2.4. Inspection and Repair of Individual Pipes - The pipes are first inspected to determine if the threading on both ends is adequate. This can be accomplished simply by trying a coupling on each end. If the threads are not good, use the pipe threader to rethread the damaged end. If it is severly damaged, this part may have to be cut off and then rethreaded. Adjust the threader to the proper size setting and apply sufficient oil to the surface to be threaded to minimize wear on the threading teeth and to ease the effort required for this work. The total length of the thread should be about 1" (slightly less for ½" and 3/4" pipes, larger for pipes bigger than 2"). One coupling or union should be connected to one of the ends after this. It is often easier to connect it now than in the field. The pipe is left in the clamp or vice grip, pipe tape or joint compound is put on the threads so as to cover all of them, and the coupling or union is tightened onto the

.../..

pipe with one of the pipe wrenches. (Remember a union should be placed on every fifth pipe). Pipes can also be cut and threaded for the tap, airvent, and overflow pipes for the water tank. The pipe can now be distributed where needed, being careful not to damage the threaded ends.

6.2.5. Connecting the Pipe - The pipe is connected, first by placing tape or compound on the threaded end, and then connecting it into the coupling or union of the previously connected pipe. One pipe wrench should be used to hold the coupling and pipe of the previous pipe in place, and another wrench used to tighten the connecting pipe. Make sure the inside pipe is free of dirt and obstructions. The steel pipe can generally be laid on top of the ground surface. Any pipe which crosses a road or frequently travelled pathway should be buried. Crossing a road, bury the pipe 80 cm. from the top of the pipe to the road surface. Always place the pipe where it is protected from vehicle, animal, or human traffic, falling rocks, flowing water etc.

All valves or special fittings which are connected on the pipeline, should be proceeded or followed by a union which will allow for easy disconnection of the line if the valves need replacement or repair.

6.2.6. Pipe Supports - Pipe supports should be built under, or in special cases tied from above, any pipe connections which are suspended in air. The threaded part of the pipe is the weakest part of the pipe and therefore must be supported on the ground surface or with specially built supports. The support can be as simple as a rock placed under a pipe connection which is only a few centimeters above the ground surface or bigger structures as shown below.

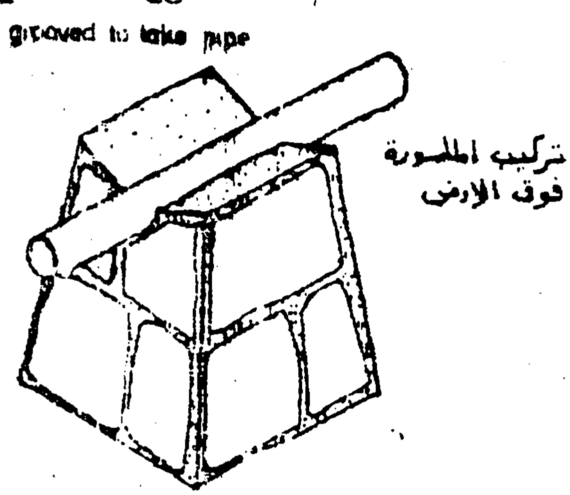


Diagram - "Typical Pipe Support"

6.2.7. Inspection of Pipeline - Water should be allowed to flow through the pipeline to determine if leaks exist, and if the line is properly placed with regards to elevation drop. This can be done as work proceeds, inspecting a completed section of pipe before continuing on to the next.

Remember, that when working on a connected pipeline, tightening one end of a pipe has the effect of loosening the other end or an end of a following connected pipe. Therefore, if a lot of tightening is required, it may be necessary to disconnect the pipe at the union, tighten the pipe or pipes and then connect the union again. The advantage of the union is that it can be disconnected and reconnected without affecting the rest of the line.

6.2.8. Diagnosis and Correction of Problems - If water does not flow through the pipeline it is usually the result of a blockage of the line, leakage, or insufficient elevation drop on a gravity flow line. For blockages of the pipeline, the line must be opened up to determine the exact location of the block and the line cleared. For insufficient elevation drops, the section of line which is too high must be located and placed at a lower elevation. This section can be found where the water is not flowing.