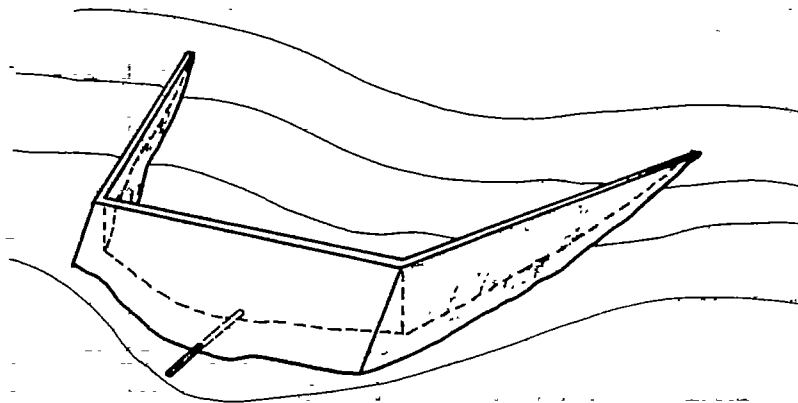


HARVESTING RAINWATER IN SEMI-ARID AFRICA

Manual No. 3

Rock Catchment Dam
with self-closing Watertap.



Erik Nissen-Petersen, Dr. Michael Lee.
Nairobi, 1990

8879

"Harvesting Rainwater in Semi-arid Africa" consists of 6 Manuals:

- Manual No. 1. Water Tanks with Guttering and Hand-pump.
- Manual No. 2. Small Earth Dam built by Animal Traction.
- Manual No. 3. Rock Catchment Dam with self-closing Watertap.
- Manual No. 4. Shallow Wells with Bucketlift.
- Manual No. 5. Sub-surface and Sand-storage Dams.
- Manual No. 6. Spring Protections.

Each Manual deals with siting criteria, standard designs and bills of quantities in a simple text and drawings.

The Manuals are based on practical experience gained by building some 700 water structures for rainwater harvesting in semi-arid Kenya over the last 14 years.

Copyright

Permission is hereby given for reproduction of this material, in whole or part, for educational, scientific, or development related purposes, except those involving commercial sale or services, provided that full citation of the source is given.

Reproduction for commercial purposes may not take place without prior permission from:

ASAL Rainwater Harvesting
P. O. Box 14333
NAIROBI
Kenya

LIBRARY, INTERNATIONAL REFERENCE
CENTRE FOR COMMUNITY WATER SUPPLY
AND SANITATION (IRC)
P.O. Box 93190, 2509 AD The Hague
Tel. (070) 814911 ext. 141/142
ISBN 8879
LO: 217 9080

ACKNOWLEDGMENT

The authors of these manuals are grateful for the grants given by Danida which made possible the compiling and publishing of their experience with rainwater harvesting for self-help groups in semi-arid areas of Africa.

Much gratitude is also due to the Ministry of Agriculture in Kenya, which together with Danida afforded the opportunity of developing low-technology and labour-intensive methods of harvesting rainwater and thereby enabling people and livestock in a semi-arid region of the country to have access to a steady water supply.

Thanks are also due to the local inhabitants with and for whom these techniques were developed and implemented. Their understandable skepticism in starting up these demanding activities gave the process a sound and realistic foundation on which to build.

Personal thanks are very much due to:

Preben Enhard of Mutomo Soil and Water Conservation Project for his considerable support.

Jan Nissen-Petersen for assisting in drawing more than half of the many drawings.

Kim Nissen-Petersen for the many proof-readings and useful comments.

Erik Nissen-Petersen and Michael Lee

C O N T E N T S

	PAGE
SURVEYORS MANUAL ON ROCK CATCHMENT DAMS	1
1. Introduction	1
2. Siting and Selection Considerations	1
3. Deciding on the Size of Dam to Build	4
4. Calculating the Required Catchment Area	5
5. Designing the Dam	7
6. Dam Wall Volume Calculations	8
7. Standard Designs	11
8. Materials, Labour and Transport Requirements	13
9. Bills of Quantities and Costing	16
10. Site Preparations.....	17
11. Setting Up the Templates	18
12. Preparing the Foundations	20
13. Bringing Materials and the Contractor to the Site	20
14. Maintaining and Improving Water Quality	21
CONTRACTORS MANUAL ON ROCK CATCHMENT DAM	23
1. Preparing the Foundations	24
2. Installing the Draw-off Pipe	25
3. Constructing the Dam Wall	26
4. Plastering the Dam Wall	27
5. Laying Out and Building Masonry Gutters	28
6. Constructing the Draw-off Pipe and Tapping Station	30
7. Quality Control and Maintenance	32
CONTRACTORS MANUAL ON SELF-CLOSING WATER TAP	34
1. Self-closing Water Tap.....	35
2. Materials and Cost	36
3. Making the Self-Closing Water Tap	37
4. Installing the Water Tap	39
5. Making a Fixed Spanner for the Caretaker	40

SURVEYORS MANUAL

ON

ROCK CATCHMENT DAMS

1. Introduction

The masonry gravity dam is a vertical wall constructed around the outer edge of a depression or hollow in a rock-surface to capture and retain water running off the rocky surface. Rock surfaces have the same efficient run-off production as iron-sheet rooftops without the cost to the user therefore local people in ASAL regions have taken a great liking to these water harvesting systems. This is particularly true where the materials are provided by an outside agency or the government and the people supply all the manual labour for site preparation and system construction.

Masonry gravity walls can be built in all lengths and sizes depending on the shape of the site where they are built and the size of the reservoir they will hold. There is no standard design for the reservoir as with tanks but there is a standard design for the wall itself and the method by which it is built. A set of techniques are explained that can be used to build a single wall, or a dam with several sections each of a different height or length. Gravity walls have been built that there are 2 metres high and 10 metres long and 6 metres high and 60 metres long. Reservoirs have been created that contain 20,000 litres and ones that contain 4 million litres, all using the same construction design, methods and materials although obviously in different sizes and quantities and with different catchment areas.

The maximum size of the reservoir is ultimately determined by the size of the catchment and the expected rainfall depth in a season or year. This determines the amount of supply, but it can also be limited by the shape of the site where the dam can be built and the amount of labour the self-help group can, or want to supply. This last factor depends on their water demand and their size, organisation and existing time commitments. A brief discussion of these points is given here.

2. Siting and Selection Considerations

Finding a Site

Masonry gravity dams are constructed on rock outcrops either in rocky top slope areas or in the lowlands where inselbergs are found (sometimes called tors or whalebacks).

To site them, features to look for are hollows, depressions or gullies where the rock dips either looking down the slope, across the slope or both. These dips can then be converted into a water-holding reservoir by constructing a single gravity wall dam, or several sections of wall in a V-shaped or U-shaped dam.

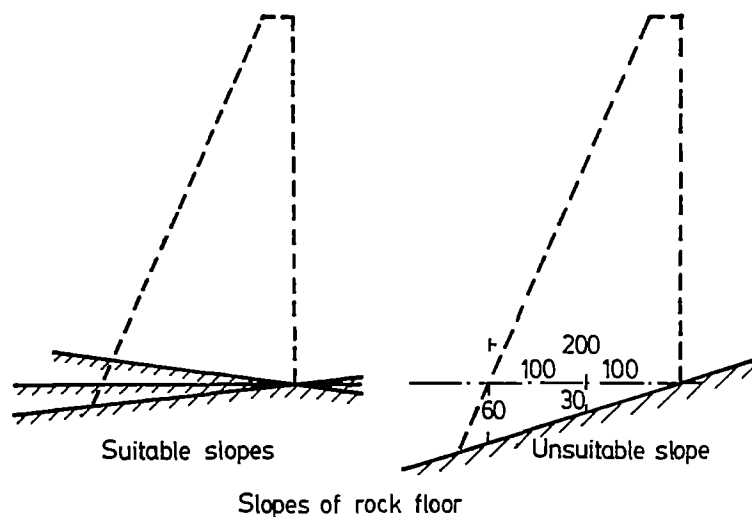
Sometimes the dips are filled with soil. If trees and shrubs grow there this is good because it means there will be a deep dip which can be excavated and store plenty of water.

The rock above the dip should preferably be wide and slope like a funnel towards the dip so that water will drain there. However, straight slopes or rounded hills are suitable catchments because simple stone and mortar raised gutters can be built out from the ends of the gravity dam sloping up and across the rock. They catch run-off water from the rock surface and bring it down to the dam. Where the rock outcrop is a steep-sided, flat-topped hill with the dam built at the base of the cliff these gutters can still be used. In this case they can be built around the top of the rock, bringing water to a point above the dam and letting it flow over the cliff and fall into the reservoir.

Positioning the Dam Wall

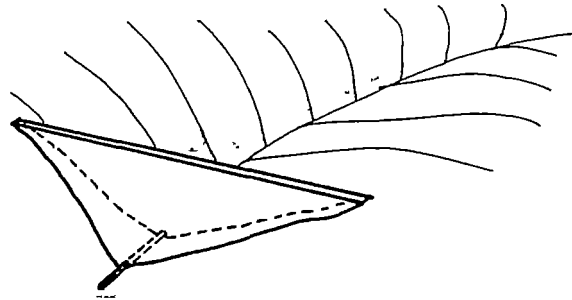
When such a site has been found in the field the best position to build the dam must be decided upon. Looking down the slope of the rock, the best site is the outer edge of a dip, where the angle of the rock face is near the horizontal before it steepens again.

By having a horizontal base, reinforcement of the dam is not required because the weight of the dam can withstand the pressure of the stored water. With no reinforcement the construction and the design becomes simple. The dam wall must be built on a rock sloping down towards the reservoir because the weight of the wall can push it down the rock face and cause its destruction. Make sure the foundations are built on almost flat rock surfaces or ones sloping slightly backwards to the reservoir. The foundation must be a clean, hard rock surface and not soil or loose rock.

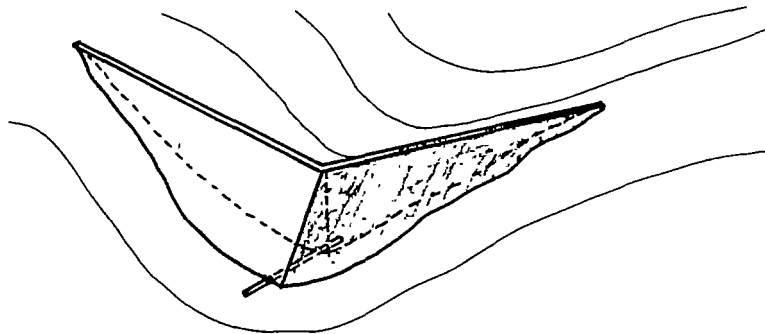


Because these dips in the rocks come in a variety of slopes and sizes, the size and shape of the dam wall varies too. The number of separate sections in the dam will depend on the shape and the curve of the lip or ledge on which the dams foundations are laid.

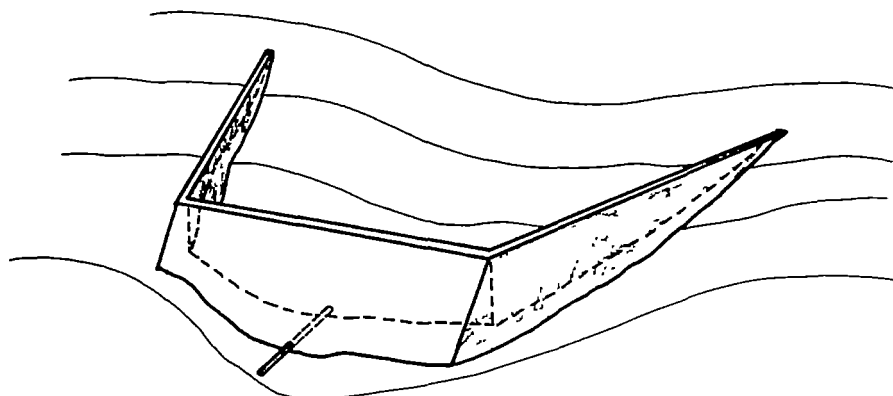
Generally, for a cross-slope depression forming a small valley in the rock surface, a single wall can be built across the dip that is deepest in the middle and tapers to both ends when it joins the valley sides.



For a funnel shaped depression like a small basin, a V-shaped dam will be built with the point at the front of the depression with two tapering arms back to the two sides of the funnel.



For a continuous slope where the dip is downslope stretching across the complete width of the slope a U-shaped dam will be built with a high front-wall and two tapering side walls.



3. Deciding on the Size of Dam to Build

In deciding how big to build a dam several things need to be considered;

- a. the water demand of the self-help builders and users
- b. the amount of labour the self-help group can supply
- c. the size of the catchment area and the rainfall
- d. the volume of the reservoir created by the dam.

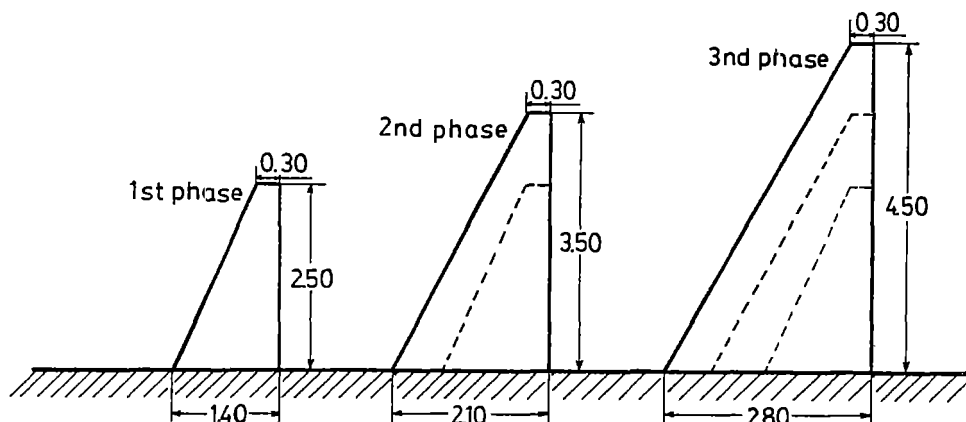
All these have to meet somewhere in the middle for an effective, appropriate water harvesting system.

The best size of self-help group for the construction of a masonry gravity dam is about 60 families so that each family can supply one adult member to the workforce for three or four days per week during the construction.

There is a limit to the number of work days a self-help group can be expected to provide in a given season. This depends on the length of the dry season and the commitments of the self-help group to other activities. Generally, at the most a self-help group can be expected to work for 9 months or 180 work days a year. During the rainy season the construction site will be mostly underwater as the partially finished dam retains water. Some dams have been built too big for the catchment area and never filled completely. For that reason it is necessary to build in stages. The first stage should be a maximum of 2.5 metres. The dam can be raised to 3.5 metres in the next dry season should the catchment area prove big enough. Should the user group need more water and be willing to continue with construction, then the dam wall can be raised another 1.0 metre.

If a dam is built in stages, the designer should not build the foundations of the larger dam in the first season and then add the additional sections using the larger dam design. Instead, a small dam should be built using the templates for a dam of this size. As the dam is built higher both the thickness and the height is built up.

To help fill the dam, gutters can be built to harvest from as large a catchment area as possible, preferably the whole rock.





Water Demand

To calculate the water demand for a group of people is simple.

Formula:

No. of families x litres per family per day in dry season = demand.

Example:

60 families x 60 litres per family per day x 180 days dry season
= 648,00 litres

The amount of water that needs to be stored at the end of the rainy season is therefore 648,000 litres (648 cubic metres) to satisfy demand it is wise to include losses to evaporation of about 33%.

The minimum size of the dam reservoir can then be determined as:

Formula: demand + 33% in evaporation losses

Example:

648,000 litres + $\frac{(648,000 \text{ litres} \times 33)}{100}$ = 861,840 litres (862 cu.m.)
=====

4. Calculating the Required Catchment Area

If the catchment area is all rock outcrop with little soil cover, it is possible to calculate the size of the area that will supply this volume if the seasonal rainfall is known.

Formula for calculating run-off:

Rainfall mm x run-off coefficient x catchment area sq.m. = run-off volume

The run-off coefficient is the proportion of rainfall that will become run-off and for all rock surfaces is 0.9. With small catchment areas it is generally true that the catchment is all rock and the 0.9 run-off coefficient can be used. As dams and catchment areas get bigger, the soil covered area increases and the coefficient 0.7 must be used.

Marking Out the Catchment Area

To calculate the area draining to the proposed dam site estimate where the ends of the dam will be situated. From these points, walk or climb up the slope along the steepest line, marking your route with chalk until you reach a point where the slope is going away from you and you are going downhill again. If that is done for both ends of the dam, the area between the chalk lines drains to the dam-site.

The area used in the calculation is the plan area, that is the area you would see if you looked down from right above. If the slope angles are less than about 15 degrees then the surface area is close to the plan area. As the slope increases, the plan area becomes less than the surface area by increasing amounts.

Since the length of an average step is about 0.60 m (60 cm) following examples on measuring catchment areas by walking can be shown:

- a. easy walk on a square rock sloping only a little, lengths measuring 140 steps x 75 steps = (140 steps x length of step 0.60 m) x (75 steps x length of step 0.60 m) = 129 sq.m.
- b. difficult walk on a square rock sloping much, lengths measuring 140 steps x 75 steps = (140 steps x length 0.60 m x 0.75) x (75 steps x length 0.60 m x 0.75) = 97 sq.m.
- c. climbing on a square rock sloping very much, lengths measuring 140 steps x 75 steps = (140 steps x 0.60 m x 0.5) x (75 steps x 0.60 m x 0.5) = 65 sq.m.

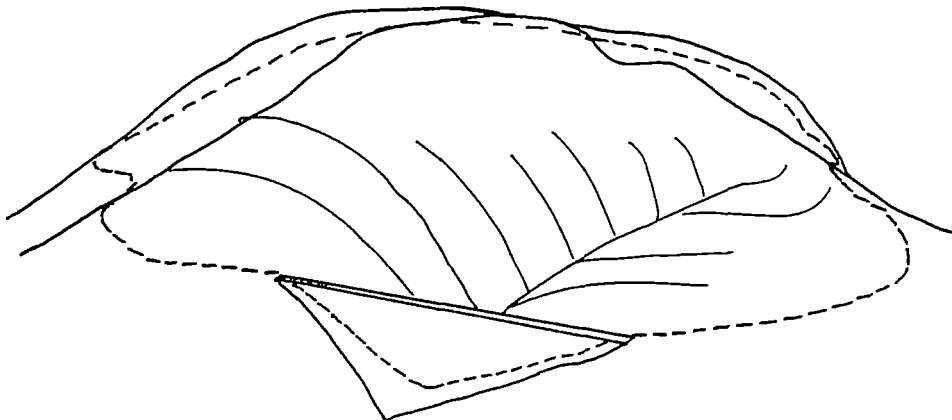
Example of calculating run-off volume:

$$\begin{aligned} \text{Rainfall } 300 \text{ mm} \times \text{run-off coefficient } 0.7 \times \text{catchment area } 97 \text{ sq.m} \\ = 20,370 \text{ litres (20 cu.m.)} \\ \text{=====} \end{aligned}$$

Enlarging a catchment area.

The catchment area of a dam can be enlarged by building stone gutters around the rock. Such gutters will collect run-off which otherwise would have bypassed the dam reservoir. Stone gutters are build of flat stones sat in mortar. Start building the gutters from the ends of the dam wall and let them surround as much rock surface as possible by building them with a gradient sloping 3 cm upwards per 100 cm. this is best measured by using a gutter-level 100 cm long with 2 legs, the one being 3 cm shorter than the other (see contractors manual).

If the rock outcrop is a rounded inselberg and the dam built on one side, the gutters can circle round so that most of the outcrop can be made to drain to the site. Where the dam is situated at the base of a sheer cliff, the measurers can climb to the top, mark a point directly above the dam site and mark out gutters going off either side across the more shallow hill top. This is the catchment area and the water collected can be made to drain straight down the cliff.



Having marked out the area, measured it, and multiplied the surface area by the factor of its steepness the size can be compared against the size of the catchment needed. This will indicate whether the gutters are needed or if the catchment is too small. If it is too small it may still be worth going ahead with the construction if there are no alternative sites nearby. If the area is bigger than that required this is fine because then a bigger reservoir can be built and the demand will stand a greater chance of being exceeded by the supply almost every year.

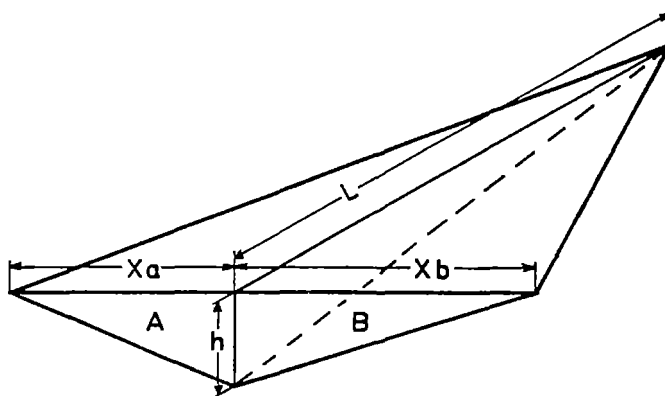
5. Designing the Dam

Having worked out the demand and the supply potential of the catchment it is necessary to work out exactly where to put the dam, how big it must be and how much water the reservoir it creates will hold. With rooftop tanks these things are easy because the shape is standard and the volume can be calculated knowing a few simple measurements. With masonry gravity dams, the shape of the reservoir is not standard and is uneven. To work out volume speedily and without using highly technical methods involves approximating the complicated slopes by convenient standard shapes and taking a few simple field measurements.

The method should be simple enough to take measurements in the field and work out the approximate volumes on paper with a pocket calculator. As an example of the methods to be adopted we use the single-wall gravity dam. To design multiple wall dams requires more experience which will be gained from designing and building some of the less complex dams first.

The Single Gravity Dam

The shape of the reservoir can be approximated as shown below.



To calculate the volume of the reservoir, the following dimensions are required:

- a. the proposed height of the dam at its deepest point (h).
- b. the length of the crest of the dam on either side of the deepest point (Xa and Xb)
- c. the length from the top of the proposed dam wall at the highest point back along the horizontal to the rock surface (L). This marks the surface of the water when the dam is full.

With these dimensions the volume of the reservoir can be found by considering the two sides A and B separately;

Formula: $\text{Volume A} = \frac{h \times Xa \times L}{4} + \text{Volume B} = \frac{h \times Xb \times L}{4} = \text{Volume}$

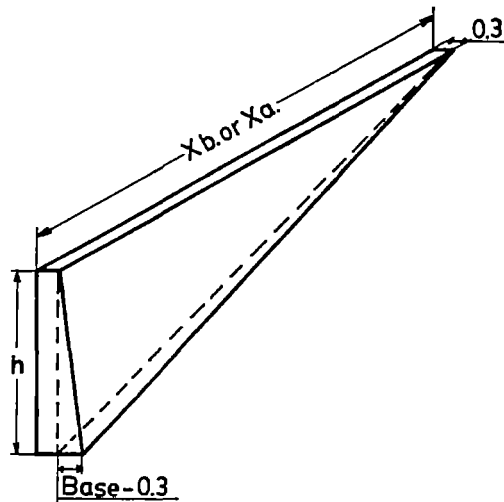
Example:

$$A = \frac{h \ 2.5 \text{ m} \times Xa \ 6.0 \text{ m} \times L \ 34.0\text{m}}{4} + B = \frac{h \ 2.5 \text{ m} \times Xb \ 8.0 \times L \ 34.0 \text{ m}}{4} = 297.5 \text{ cu.m.}$$

=====

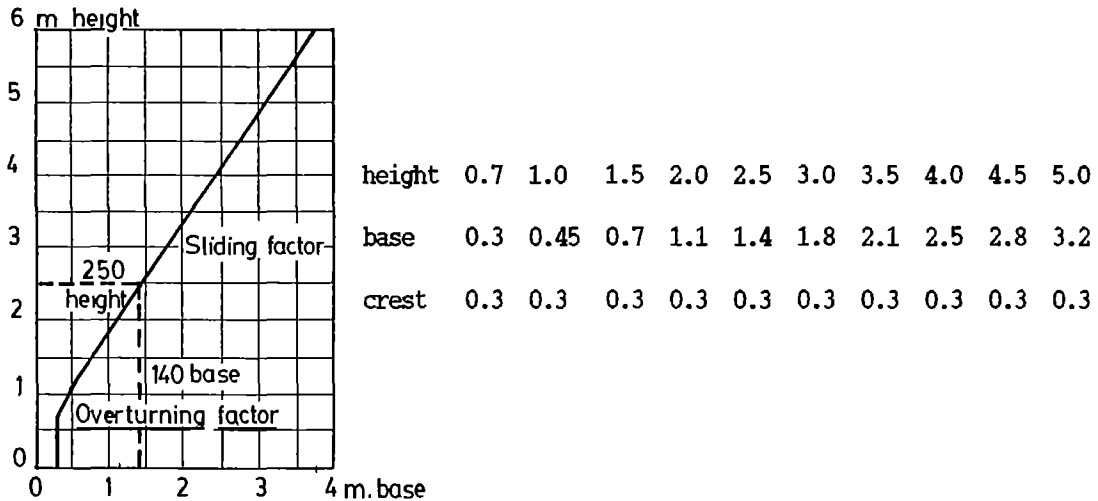
6. Dam Wall Volume Calculations

There are two shapes that the gravity wall sections can have, given the standard design of the wall. They depend on the depth at either end of the section and are illustrated as Section 1 and 2 below.



Section 1 is the shape of each half of a straight, single-wall dam. However, in some situations, a V-shaped, or U-shaped dam needs to be built to take advantage of a particular hollow. In this case, the dam may be made up of separate parts that look like Section 1 and some like section 2. (see page 10)

From measurement we know the heights and lengths of the section. We also know because of the standard design the width of the crest and the base. The crest is always 0.3 m no matter what the dam height. However, the base width varies according to the height as shown in the relationship below.



This graph, which gives us the base for each height allows us to calculate the volumes of the dam walls.

For Section 1, the volume is equal to half a rectangular block plus a quarter of a rectangular block for each of the two halves of the dam wall called A and B.

The volume of a dam wall therefore consists of half block + quarter block for both sides of a dam wall.

Formula for calculating volume of dam wall:

Volume A + volume B = volume of wall.

Volume A and B formulas are similar: $\frac{(h \times X \times 0.3)}{2} \times \frac{(h \times X \times (\text{base} - 0.3))}{4} = \text{volume}$

Example:

$$\text{Volume A} = \frac{(h \ 2.5\text{m} \times X\text{a} \ 6.0\text{m} \times 0.3)}{2} + \frac{(h \ 2.5 \times X\text{a} \ 6.0\text{m} \times (1.4 - 0.3))}{4} = 6.375 \text{ cu.m.}$$

$$\text{Volume B} = \frac{(h \ 2.5 \text{ m} \times X\text{b} \ 8.0 \text{ m} \times 0.3)}{2} + \frac{(h \ 2.5 \text{ m} \times X\text{b} \ 8.0 \text{ m} \times (1.4 - 0.3))}{4} = 8.5 \text{ cu.m.}$$

$$\text{Volume A } 6,375 \text{ cu.m.} + \text{volume B } 8,5 \text{ cu.m.} = \underline{\underline{14,875 \text{ cu.m. volume of dam wall. say 15 cu.m}}}$$

Formula for calculating volume of 4 cm plaster on crest and front wall:

Area to be plastered x 0.04 m thickness of plaster = volume

Example: $\frac{(\text{Area A h } 2.5 \times \text{Xa } 6.0)}{2} + \frac{(\text{Area B h } 2.5 \times \text{Xb } 8.0)}{2} +$

$(\text{Crest } 6.0 + 8.0 \times 0.3) \times 0.04 \text{ m plaster} = \text{volume}$

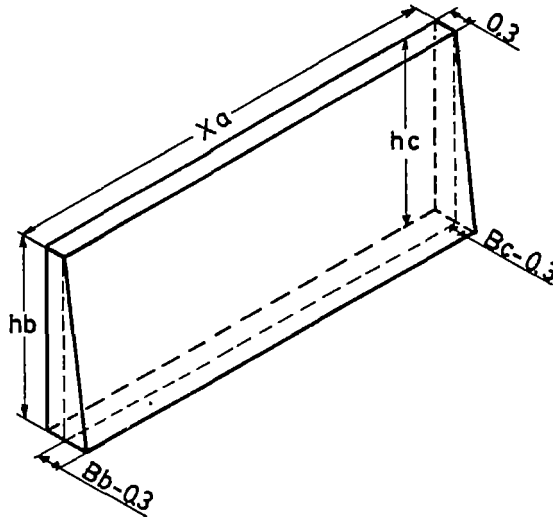
$A \text{ } 7.5 \text{ sq.m.} + B \text{ } 10.0 \text{ sq.m.} + \text{crest } 4.2 \text{ sq.m.} \times 0.04 = \underline{\underline{0.87 \text{ cu.m. plaster} = \text{say } 0.9 \text{ cu.m.}}}$

For section 2, the volume is equal to a block with the average of the two heights ha and hb plus half a block with the average of the two heights ha and hb.

Section 2 therefore consists of block + half block.

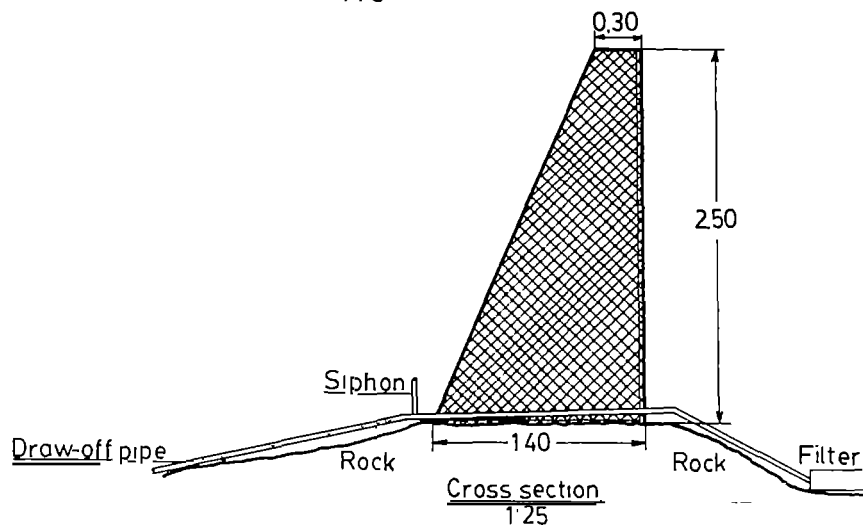
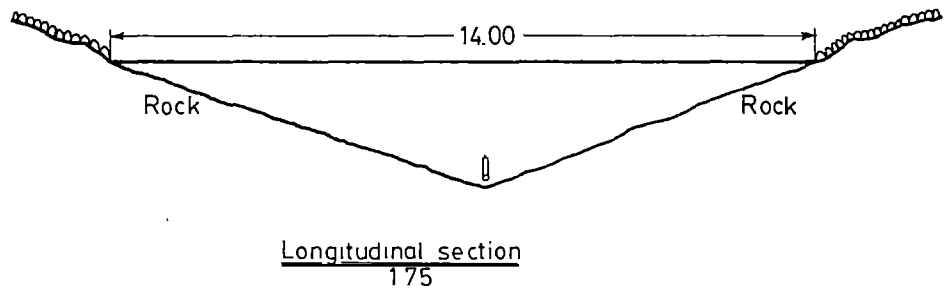
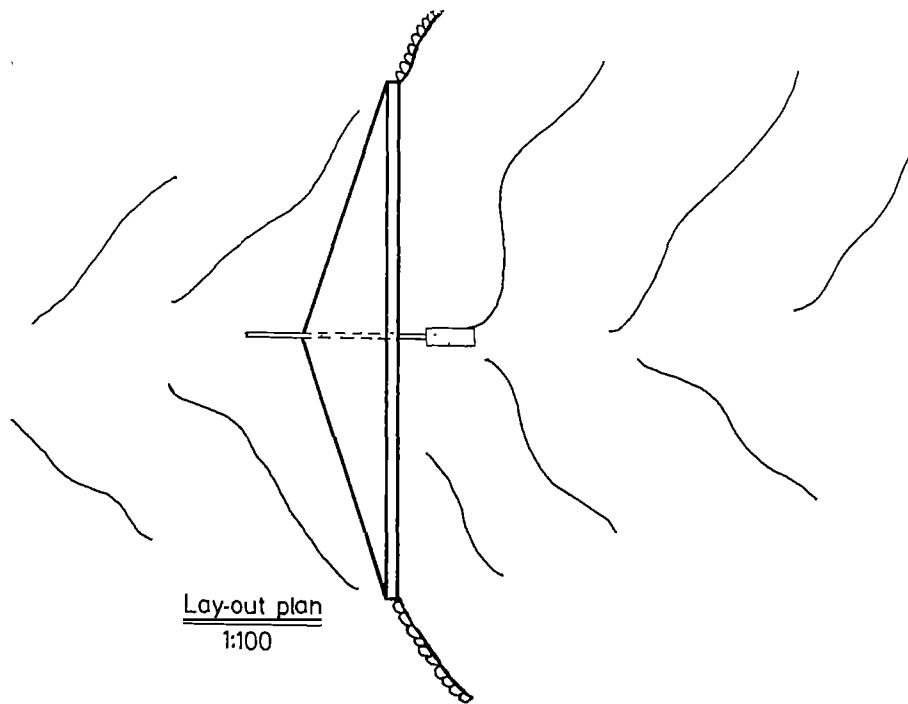
Formula for block: $\frac{(\text{ha} + \text{hb})}{2} \times \text{Xa} \times 0.3 = \text{volume of block}$

Formula for half block: $\frac{(\text{ha} + \text{hb})}{2} \times \text{Xa} \times \frac{(\text{Base b} - \text{Base c} - 0.6)}{2} = \text{volume of half block}$

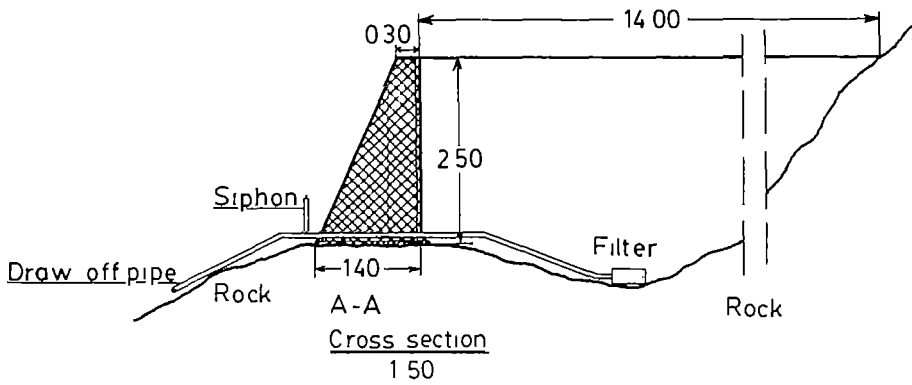
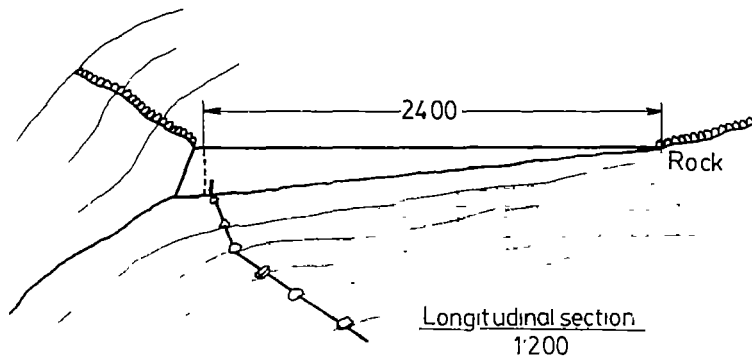
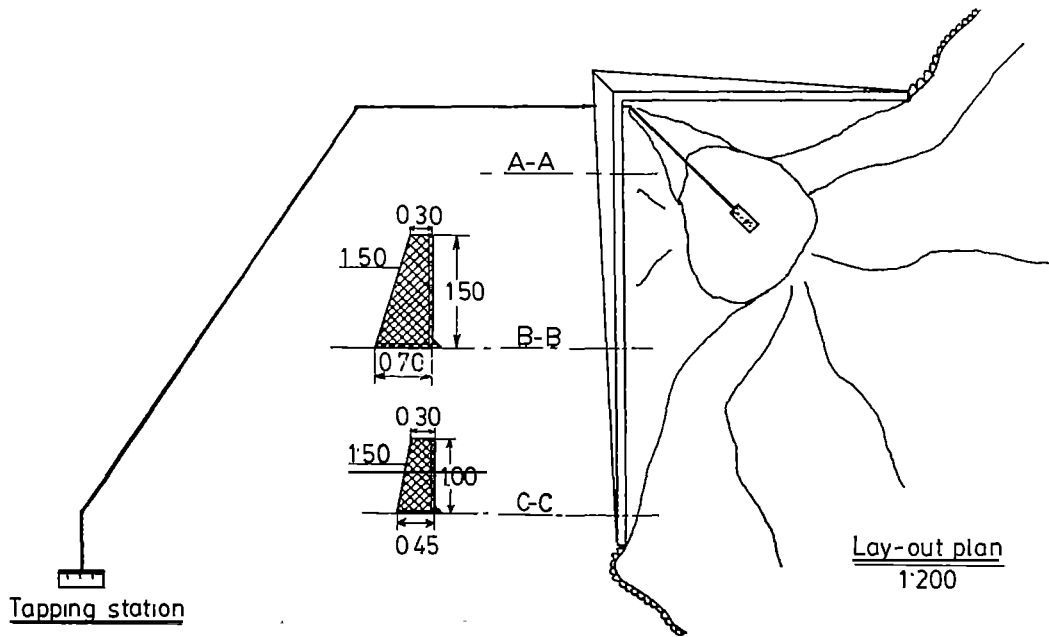


(Section 2 is not included in the examples shown on the following pages)

Standard Designs



Standard Designs



7. Materials, labour and transport requirements

The requirements of materials, labour and transport are calculated as follows:

a. Volume of structure.

First calculate the total volume of the structure to be build by finding the volumes of the various parts of the structure and thereafter adding it all together. The result will be the total volume measured in cubic metres (cu.m.).

b. Type and weight of materials.

When the total volume of the structure has been found, the type and weight of the various components of that volume can be estimated by using the following formula:

Weight per 1 cubic metre (cu.m.) material.	Converted measurements.
Water 1 cu.m. weighs 1000 kg = 1.00 tonne	1 tonne = approx. 5 drums of water.
Cement 1 cu.m. weighs 1350 kg = 1.35 tonne	1 tonne = 20 bags of cement.
Sand 1 cu.m. weighs 1600 kg = 1.60 tonne	1 tonne = approx. 8 wheelbarrows of sand.
Stones 1 cu.m. weighs 2200 kg = 2.20 tonne	1 tonne = approx. 8 wheelbarrows of stones.

1 cu.m. Stone-masonry weighs 2850 kg = 2.85 tonne and consists of:

stones 75%	1650 kg = 1.65 tonne = 14 wheelbarrow of stones
mortar 1:4 25%	
cement	200 kg = 0.2 tonne = 4 bags of cement
sand	800 kg = 0.8 tonne = 7 wheelbarrows of sand
water	200 kg = 0.2 tonne = 1 drum of water

1 cu.m. Mortar, 1:3 with nil weighs 2400 kg = 2.4 tonne and consists of:

cement	500 kg = 0.5 tonne = 10 bags of cement
sand	1600 kg = 1.6 tonne = 13 wheelbarrows of sand
water	300 kg = 0.3 tonne = 1 1/2 drum of water

1 cu.m. Mortar, 1:4 weighs 2200 kg = 2.2 tonne and consists of:

cement	400 kg = 0.4 tonne = 8 bags of cement
sand	1600 kg = 1.6 tonne = 13 wheelbarrows of sand
water	200 kg = 0.2 tonne = 1 drum of water

Example:

For walls: Multiply volume with requirements for 1 cu.m. of stone masonry.

Volume of wall x 1 cu.m. requirements = tonnes = converted measurements.

15.0 cu.m. x cement 0.20 tonne = 3.0 tonnes x 20 = 60 bags of cement

15.0 cu.m. x stones 1.65 tonne = 24.8 tonnes x 8 = 198 wheelbarrows of stone

15.0 cu.m. x sand 0.80 tonne = 12.0 tonnes x 8 = 96 wheelbarrows of sand

15.0 cu.m. x water 0.20 tonne = 3.0 tonnes x 5 = 15 drums of water

For plastering: Multiply volume with requirements for 1 cu.m. mortar 1:3 with nil.

Volume of plaster x 1 cu.m. requirements = tonnes = converted measurements

0.9 cu.m. x cement 0.50 tonnes = 0.5 tonnes x 20 = 10 bags of cement

0.9 cu.m. x sand 1.60 tonnes = 1.5 tonnes x 8 = 12 wheelbarrows of sand

0.9 cu.m. x water 0.30 tonnes = 0.3 tonnes x 5 = 2 drums of water

For stone gutters: 1 cu.m. mortar, 1:4, gives 100 metres of stone gutters.

Required length x Requirements per 1 m = kg = tonnes = converted measurements

Example:

200 m gutters x cement 4.0 kg per 1 m = 800 kg = 0.8 tonnes = 16 bags of cement

200 m gutters x sand 16.0 kg per 1 m = 3200 kg = 3.2 tonnes = 26 wheelbarrows/sand

200 m gutters x stones 90.0 kg per 1 m = 18000 kg = 18.0 tonnes = 144 wheelbarrows/stones

200 m gutters x water 2.0 kg per 1 m = 400 kg = 0.4 tonnes = 2 drums of water

Total requirements of materials

Cement 4.3 tonnes = 86 bags of cement

Stones 42.6 tonnes = 343 wheelbarrows of stones

Sand 16.7 tonnes = 134 wheelbarrows of sand

Water 3.7 tonnes = 19 drums of water

67.3 tonnes

Enter the requirements on the bills of quantities



Labour requirements:

On experience it is known that one skilled artisan with the help of 15 self-help labourers can prepare the site, carry material, mix mortar and build 0.8 cubic metre of stone masonry per day. The estimate for labour requirements is therefore as follows:

Formula for wall: $\frac{\text{Volume cu.m.}}{0.8 \text{ cu.m. per day}} = \text{skilled days required. Unskilled days} = \times 15$

Example: $\frac{\text{Volume 15 cu.m.}}{0.8 \text{ cu.m. per day}} = 19 \text{ days of skilled labour. Unskilled days } 285$

Formula for stone gutters: $\frac{\text{m of gutters}}{15\text{m}} = \text{skilled days. Unskilled days} = \times 15$

Example: $\frac{200 \text{ m of gutters}}{15} = 14 \text{ skilled days and } 210 \text{ unskilled days}$

Enter the requirements on the Bills of Quantities

Transport requirements of material

Transportation of materials is divided into two categories:

- a. Transport of local materials, such as sand, stones and water, will be transported to the site by the self-help groups using oxen-donkey and hand carts given to them by the project. The number of loads to be transported and the distances involved depends on local conditions and cannot be estimated here.
- b. Transport of purchased materials, e.g. cement, reinforcement wire and templates is estimated according to tonnage, distance and cost per km.

Formula: Tonnes x return distance (km) x Shs. per km.

Example: 5 tonnes x return distance 86 km x Shs. 6/50 per km = Shs 2,795/00

Enter the requirements on the bills of quantities

8. Bills of Quantities and Costing.

Two bills of quantities are needed, because about half the items will be delivered by the donor/ministry and the other half will be delivered free of charge by the community concerned. Since the community is supposed to contribute about half the cost of the project, a value of their input has to be calculated.

Example.

Bills of Quantities for items to be delivered by the donor/ministry.

Skilled labour: 1 contractor for 33 days	x Shs.....	= Shs.....
Cement 4.3 tonnes = 86 bags	x Shs.....	= Shs.....
G.I. piping, 1" : 90 metres / 6 = 15 lengths	x Shs.....	= Shs.....
Polythene sheeting for curing: 20 metres	x Shs.....	= Shs.....
Transport of contractor and materials 8 tonnes x... km	x Shs.....	= Shs.....
	Total cost	Shs.....

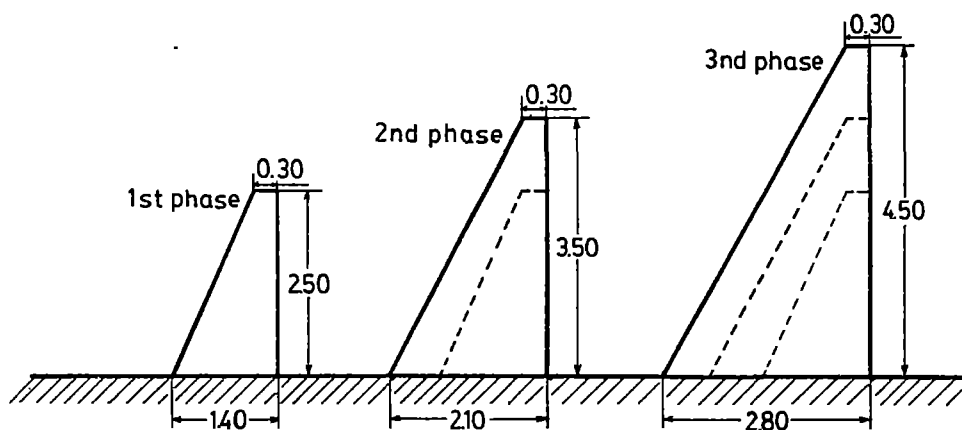
Bill of Quantity for items to be delivered free of charge by the self-help group

Unskilled labour: 495 labour days	x Shs.....	= Shs.....
Sand: 16.7 tonnes (= 134 wheelbarrows)	x Shs.....	= Shs.....
Stones: 42.6 tonnes (= 343 wheelbarrows)	x Shs.....	= Shs.....
Water: 3.7 tonnes (= 19 drums)	x Shs.....	= Shs.....
Transport: 63 tonnes (= 126 cart loads)	x Shs.....	= Shs.....
	Total value of self-help	Shs.....

Grand total cost and value of project Shs.....

9. Site Preparations

Having decided on the layout of the dam wall sections and shape of the dam and having calculated the size of dam that can be built in one work season the construction site can be prepared. As indicated in the previous section, if a large dam is to be built, but in stages then the site should be prepared for the smaller dam (2.5 m first stage) first (with the templates for the height of the smaller stage). In future work seasons the dam can be built upwards and outward. If the base of the dam is built according to larger templates a lot of effort is needed to create even a low structure and this effort will be wasted if the future work plans are abandoned.



Preparing the site involves the following steps:

- a. clearing a track to the site from the nearest road and sources of building materials
- b. clearing a flat area near the site for the construction camp and for stockpiling materials
- c. setting up the templates and builders lines marking out the sections of the gravity wall
- d. preparing the foundation of the rock ready for building
- e. training a storekeeper who will be responsible for looking after materials delivered to the site
- f. local sources of sand, ballast and water can be located and transported to the site by the self-help group by donkey cart, wheelbarrow or basket, or by jerrycan. If this is not possible, materials can be brought by tractor and trailer.

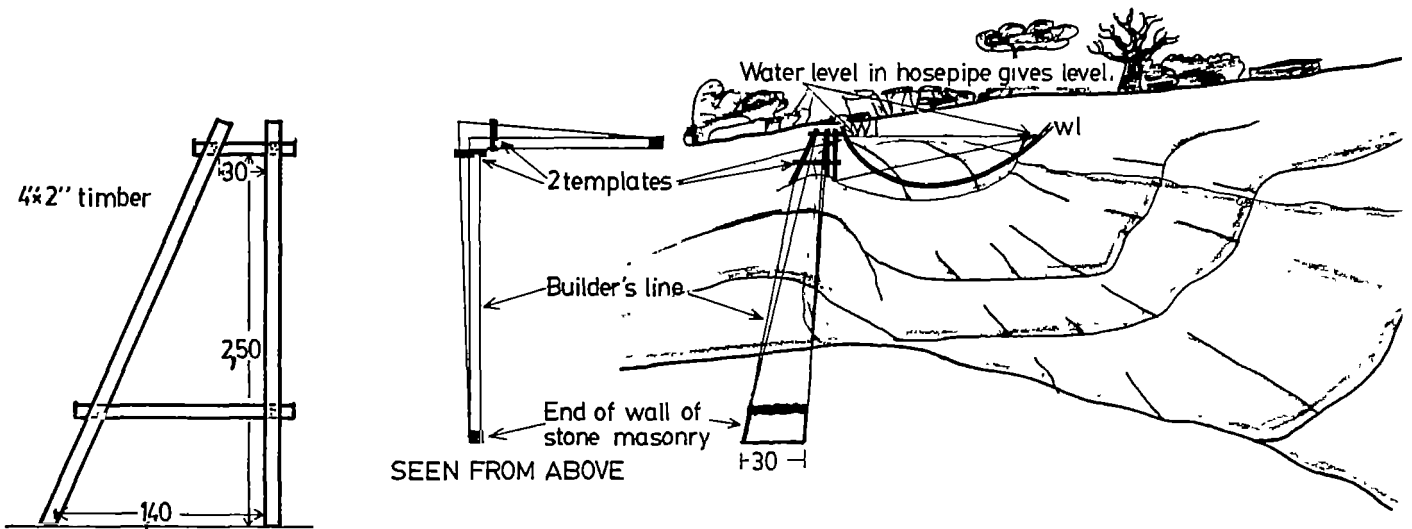
The templates are made in the workshop using the measurements discussed earlier. As explained there are two templates for each corner of the dam wall and there can be intermediate templates.

Clearing a Track and the Construction Camp:

- a. The self-help group should be issued with tools on loan such as machetes, hoes and axes with which they can clear a track wide enough for a tractor with trailer. They should avoid felling large trees to prevent the need for stump removal, and should not cross deep gullies or steep slopes.
- b. At the end of the track, as close to the construction site as possible, the self-help group should clear a large enough area for vehicles to park and turn, for materials to be piled and for the self-help group to sit and rest and for meetings.
- c. At the dam site, the self-help group should excavate any soil contained where the reservoir will be and sweep and clear soil from the catchment area where relevant. If there is a lot of soil it should be carried to the foot of the rock outcrop and built into a semi-circular earth dam to catch water and provide a livestock watering point.

10. Setting Up the Templates

- a. The templates should be placed upright at the corners of the dam, at the deepest point of the single wall and can be supported by small stones and mortar. In the sketch this is shown for a double-walled dam.
- b. The sites for the templates should have already been marked in the site assessment but can be double-checked. Having confirmed this then the templates should be positioned at right angles to the line of the wall section they mark the position of. A mason's square can be used to sight along to the other template at the end of the dam.



Setting-up templates

- c. The end of the dam should be fixed with a small cement ledge 30 cm wide to which the builders lines can be attached and which mark the point the dam will be built to.

Use a hose pipe filled with water to measure that the top of the templates are in a horizontal level, and to locate the ends of the dam wall on the rock.

- d. Four builders lines should be fixed from the ledge to the template (and between templates) to show the form of the masonry wall along its length.
- e. The two top lines should pass inside the template frame and be tied around the top corners of the frame. The bottom or side lines must also pass inside the template and can be tied around the sides of the frame.
- f. Once the templates and dam ends are definitely level and the lines fixed the templates can be anchored in the upright by applying mortar and stones to their base.
- g. As a double check, the lengths of the section crests should be measured again and compared to the earlier measurements. If there is any difference, the materials calculations should be made again to ensure the correct amount of materials are delivered.

11. Preparing the Foundations

Once the builders lines have been strung, the foundation of the dam walls can be traced exactly. The self-help group need to follow these steps to ready the rock surface as a foundation for the dam wall;

- a. Remove all dirt and loose rock fragments inside these lines which will form the foundation of the dam wall.
- b. Thereafter, chisel this area so that it has a rough enough surface to ensure proper bonding with the dam wall to be build upon it. Any hollow sound from the rock indicates a fracture or hollow space underneath. The rock must be chiseled away until the sound of solid rock is heard on striking with the hammer.

12. Bringing Materials and the Contractor to the Site

- a. On clearing the reservoir area of soil, many stones will be unearthed. These should be piled separately at the edge of the site near the foundations for use in the dam fill. If the rock outcrop is granite and has been folded and fractured, then it will be possible to lever off large flat slabs of stones 3-10 cm thick like large roofing slates. these can be prized off for use in facing the outside of the dam and for the gutters.
- b. Cement should be brought by tractor and trailer and the bags carefully counted and guarded by a trained storekeeper from the local community. A careful account of each bag used in construction should be kept to make sure none goes missing.
- c. The contractor and staff bring their tools and the first load of cement with them to the site and the Inspector will hand over the detailed instructions for construction to them.



13. Maintaining and Improving Water Quality

Water Quality

To be able to obtain unpolluted water from a rock catchment, it is important to keep the catchment area and the reservoir clean and tidy. This is best done by the following methods;

- a. Fence off the entire rock formation on which the rock catchment is situated by planting a live fence of thorny bushes along its sides and/or around its entire foothill. Recommended plants include; Fig Cactus (Prickly Pear) which also provide fruit, Sisal which provide poles for roofing, and any local thorny plants which deter livestock, wild animals and people from entering the area.
- b. Keep the catchment area clean by removing all soil, vegetation or other loose debris from it. If necessary, sweep the catchment area once or twice a year.
- c. Just before the onset of the rainy season, it is recommended that the dam be emptied and cleaned thoroughly of silt and algae.
- d. Dig a ditch at the tapping station to lead waste water away from the tapping point. The ditch can end up in a pit where bananas, sugar cane or fruit trees can benefit from the waste water.
- e. To avoid mosquito breeding which promotes the spread of malaria, Tilapia fish can be brought to the site and introduced to the reservoir. Besides eating mosquito larvae and algae, the fish make good sport and a protein rich food in the dry seasons when eggs and vegetables are scarce. Fish excrement pollutes a reservoir less than if the reservoir had no fish and organisms were allowed to breed unchecked.

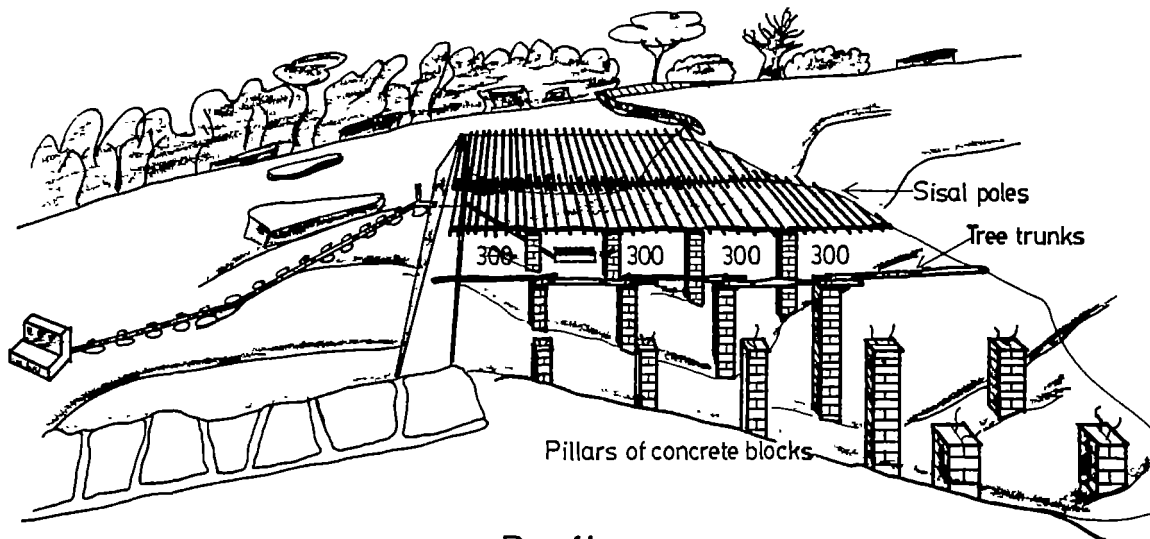


Water Quantity

Evaporation in ASAL regions can result in two metres of water being lost from a reservoir in a year. For a single dry season in the tropics, this will be more than one metre which amounts to between 25% and 50% of the volume of most masonry gravity dam reservoirs.

Where a rock catchment dam cannot supply sufficient water, either because it is too small, has too many consumers, or each consumer draws too much then the reservoir can be roofed to reduce evaporation by up to half.

In our experience, the most effective low-cost roof is made by building pillars of concrete blocks within the reservoir spaced 3 to 4 metres apart. Trunks cut from nearby trees are then tied onto the top of the pillars with galvanized wire. Sisal poles are then tied across these trunks with rope. Although roofs are expensive to build, it is often cheaper to roof a reservoir to conserve water than it is to extend the dam wall another metre to compensate for the evaporation lost.



Roofing.

CONTRACTORS MANUAL ON ROCK CATCHMENT DAM

C O N T E N T S

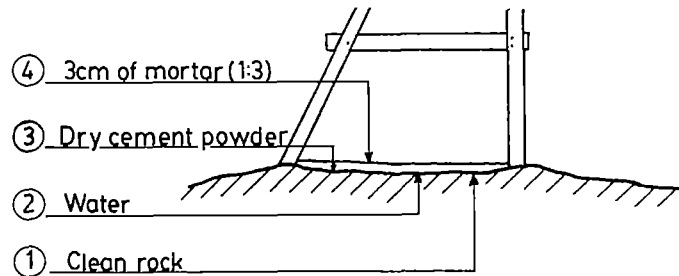
	PAGE
CONTRACTORS MANUAL ON ROCK CATCHMENT DAM	23
1. Preparing the Foundation	24
2. Installing the Draw-off Pipe	25
3. Constructing the Dam Wall	26
4. Plastering the Dam Wall	27
5. Laying Out and Building Masonry Gutters	27
6. Constructing the Draw-off Pipe and Tapping Station	30
7. Quality Control and Maintenance	32
CONTRACTORS MANUAL ON SELF-CLOSING WATER TAP	34
1. Self-closing Water Tap	35
2. Materials and Cost	36
3. Making the self-closing Water tap	37
4. Installing the Water Tap	39
5. Making a Fixed Spanner for the Caretaker	40

The design of the rock catchment dam will be made by the Inspector. The Inspector will also set up the templates and ensure the necessary site preparation has been carried out by the community group. The Inspector will decide how much material is needed for the construction and supply the sufficient cement, rock ballast, sand and water for the job.

1. Preparing the Foundations

Once the builders lines have been strung, the foundation of the dam walls can be traced exactly. The artisans need to follow these steps to ready the rock surface as a foundation for the dam wall.

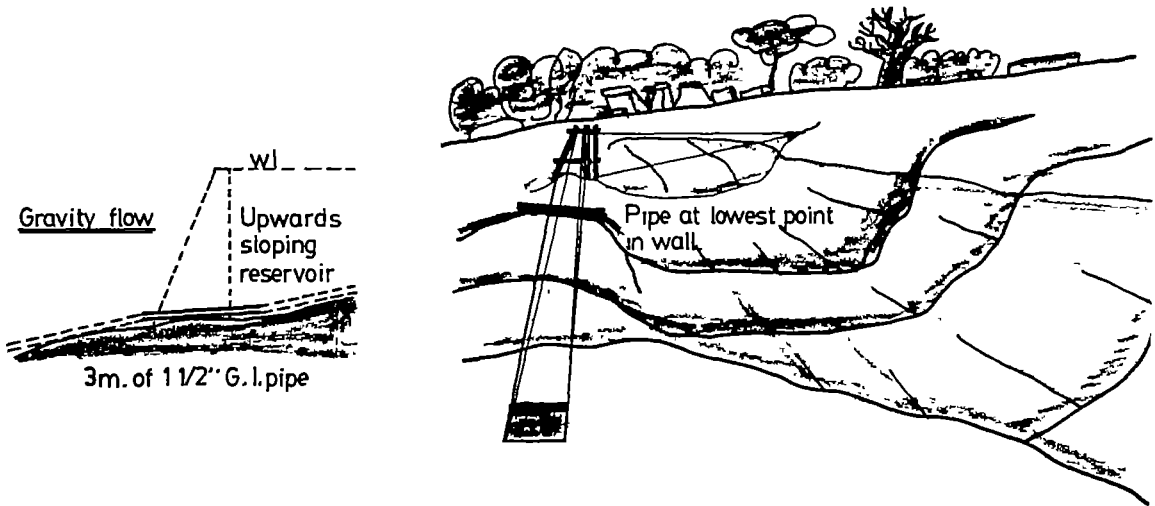
- a. Remove all dirt and loose rock fragments inside these lines which will form the foundation of the dam wall.
- b. Thereafter, chisel this area so that it has a rough enough surface to ensure proper bonding with the dam wall to be built upon it. Any hollow sound from the rock indicates a fracture or hollow space underneath. The rock must be chiseled away until the sound of solid rock is heard on striking with the hammer.



- c. Having prepared the foundation, to create a proper bonding for the gravity dam which is very important, clean the chiseled surface with water. Then sprinkle a thin layer of dry cement onto the still moist rock surface.
- d. Within the same hour, compact a 3 cm thick layer of mortar (1 cement: 3 sand) onto that cement-sprinkled surface. This layer of mortar is left with a rough surface to allow good bonding for the next stage of construction.

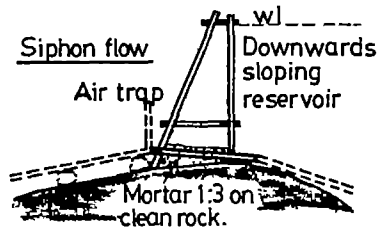
2. **Installing the Draw-off Pipe**

- a. Place a draw-off pipe, 3 metres long and made of 3.8 cm (1.5") galvanized iron pipe with threads at both ends, at the lowest point of the planned dam wall and attach it with mortar (1:3) onto a clean surface of the rock.
- b. The draw-off pipe should slope in order to avoid air bubbles than can block the passage of water in the pipe.
- c. When a rock catchment dam is situated on a rock shelf or in a valley, the floor of the reservoir will be higher than the bottom of the dam wall. In this instance water will flow downwards by gravity without the need of syphon. The draw-off pipe should, therefore, slope down towards the dam wall and the planned tapping station at the foot of the rock.



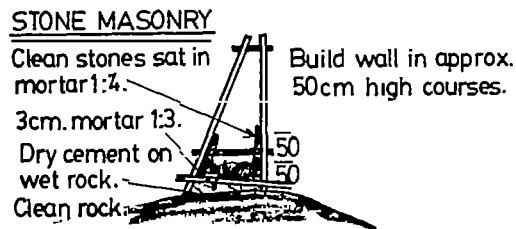
Slope of draw-off pipe.

- d. With some rock catchment dams, part of the reservoir is situated in a depression lower than the bottom of the dam wall, and therefore water must be drawn through a syphon system. In this case therefore the draw-off pipe must slope down away from the reservoir. This prevents the inconvenience of opening the plug inside a filled reservoir.



3. Constructing the Dam Wall

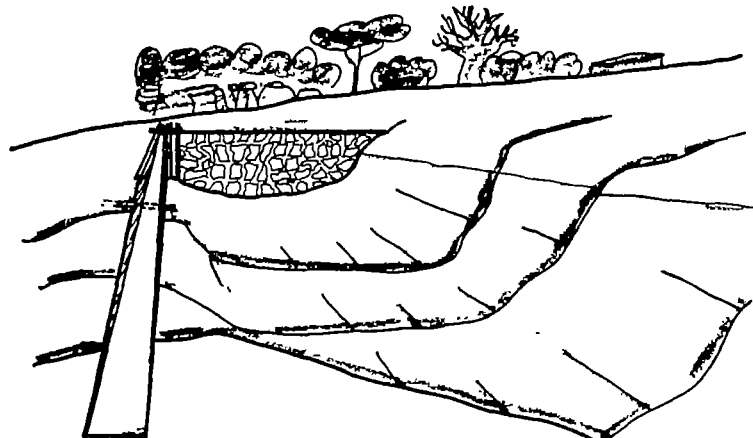
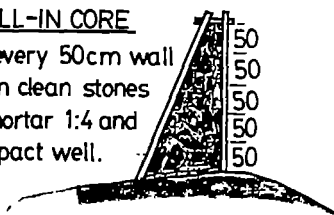
- a. Carefully clean large flat stones (previously prized off the rock) with water and set them in mortar (1:4), exactly along the inner side of the two builders lines marking each side of the wall. Tap the stones with a mason hammer to ensure a firm connection with the mortar. The stones must not touch each other. Mortar must be in between them. Support the stones in place with small sticks until the mortar is hard enough to hold them securely. Build both inner and outer walls up to a height of about 50 cm.



- b. When these inner and outer walls have cured for a day or two under polythene sheet, fill in the space between them with clean stones and mortar (1:4). All the stones must have mortar between them. Re-use any mortar that has fallen outside the wall and onto the rock immediately. Keep all mortar under shade and use it before it is one hour old. Compact the stones and mortar together by pushing down with a stick. When this section of the wall is filled in, leave it with a very rough surface, with stones sticking up so as to achieve a good bonding with the next section of wall.

FILL-IN CORE

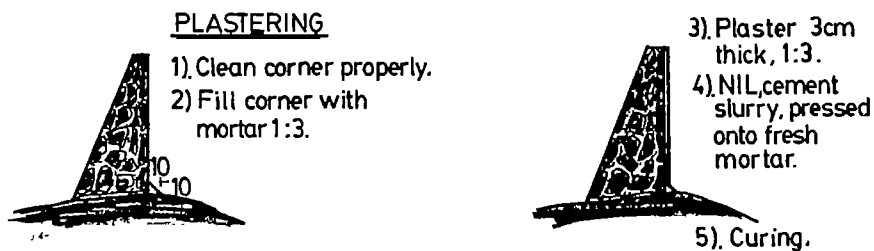
For every 50cm wall fill-in clean stones in mortar 1:4 and compact well.



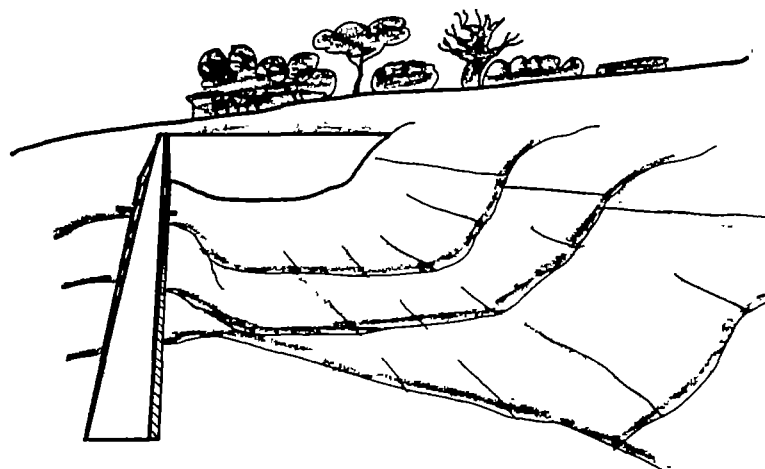
- c. The inner and outer walls are now extended again by 50 cm to 100 cm with flat stones set in mortar (1:4). When these walls are set firm, fill in the space between them with stones and mortar (1:4) as previously described in b. The dam walls should be extended like this until the top of the dam is reached as shown by the templates and builders lines
- d. During the building process and for three weeks afterwards, the stone masonry wall must be kept damp under polythene sheeting for proper curing. When this is complete, remove the templates and store them for use elsewhere.

4. Plastering the Dam Wall

- a. Some skilled artisans can build a wall so water-tight that no plaster is needed at all. However, at most dams, the inner wall facing the reservoir should be plastered.
- b. Chisel the stone masonry wall to a smooth, clean surface free of loose chippings and wash any dust away with water. In particular, thoroughly clean the corner between the inner wall and the rock floor with chisels and water.
- c. Moisten the clean corner with water. Press compact mortar (1:3) into it. This plaster should extend 10 cm up the wall and 10 cm out onto the rock floor. Smooth the mortar with a wooden float until a 45 degree bank of plaster is created.



- d. Moisten the inner side of the wall facing the reservoir with water. Throw a layer of plaster (1:3) onto the wall until it reaches a thickness of 2 to 3 cm. Smooth the plaster off to an even and equal surface with a wooden float.
- e. Within the same day, press a water-tight coat of cement mixed with water (called Nil) onto the still moist plaster with a square steel trowel.

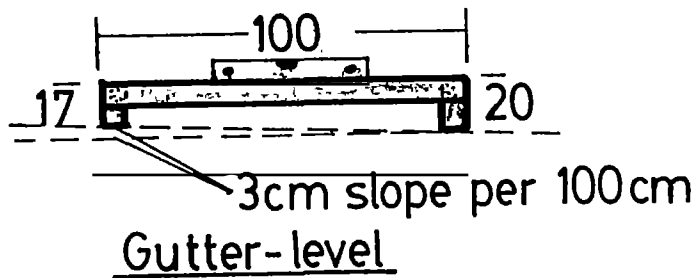


- f. Keep the plastered dam wall damp and covered with polythene sheeting for three weeks in order to obtain a strong, waterproof dam.

5. Laying Out and Building Masonry Gutters

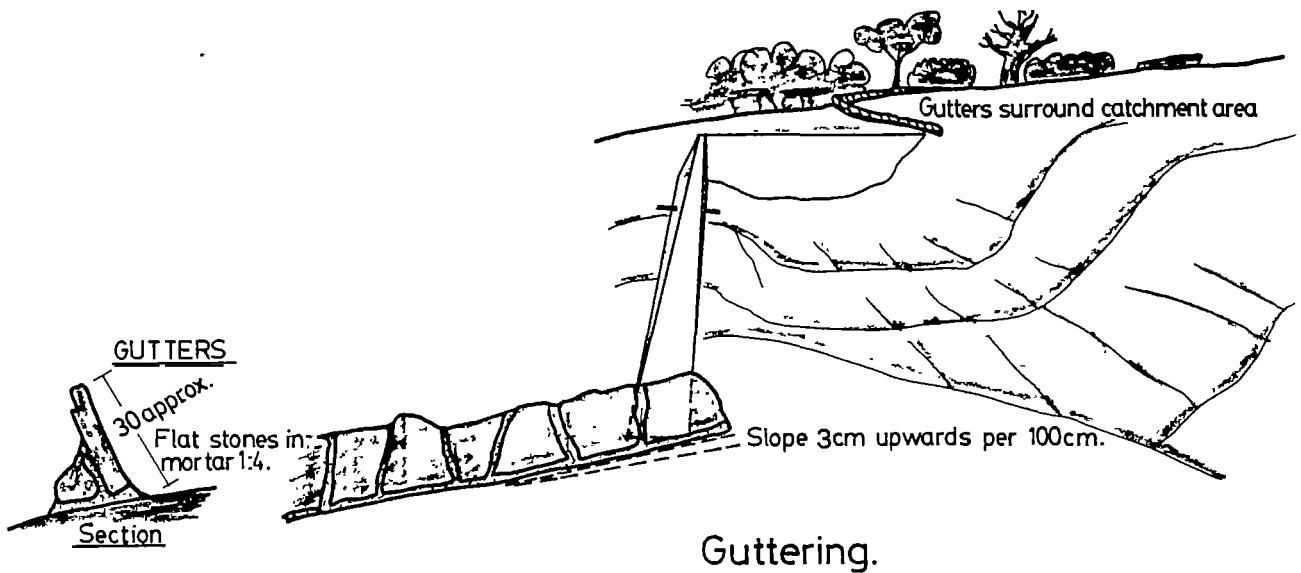
The catchment area draining into the reservoir created by the dam can be increased by constructing gutters out from the ends of the dam wall that catch run-off running down the rock and leads it into the reservoir. Without the gutters it would run-off either side of the dam. On circular rock outcrops, water can even be brought round from the other side of the rock. On steep, flat-topped rock outcrops, gutters can collect the water draining off the flat top and let it run down the cliff directly above the site of the dam.

- a. The gutters can be laid out using a channel layout frame, also called a gutter level, and a spirit level. Notice that one leg is 3 cm shorter than the other leg.



- b. Place the longest leg of the layout frame where the end of the dam wall meets the rock. Place a spirit level on the top of the layout frame. Move the short leg of the frame up or down the rock surface, pivoting around the other leg, until the bubble in the spirit level shows it is horizontal. Mark the point where the short leg is with chalk or a sharp stone. This point is exactly 3 cm higher than the end of the dam over a distance of 100 cm.
- c. Repeat this exercise moving the long leg to where the short leg used to be and finding the next point 3 cm higher with the short leg, marking it again. This marking continues from each end of the dam wall until the edges of the rock outcrop is reached, the lines cross somewhere around the back of a circular outcrop, or when you are sure that you have a large enough catchment area. For a given dam size, the larger the catchment the better because the reservoir should then fill most years. It is better to overdesign the catchment area than undersign the storage volume.

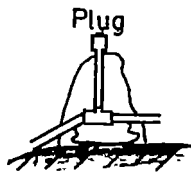
- d. Starting at either end of the dam wall, clean flat stones about 30 cm high with water. Set them in mortar (1:4) along the lines marked out by the layout frame. The smoother side of the stones should be facing upslope so that water passes by them freely. Fill in the space between these flat stones with mortar and smaller flat stones to make the gutter wall a uniform height. The flat stones should be angled slightly downslope. Support them in this position with a line of smaller round stones also set in mortar. Brush all the joints and mortar surfaces with a wet brush so that all the joints are smooth and closed and run-off water can flow smoothly into the reservoir with no leaks.



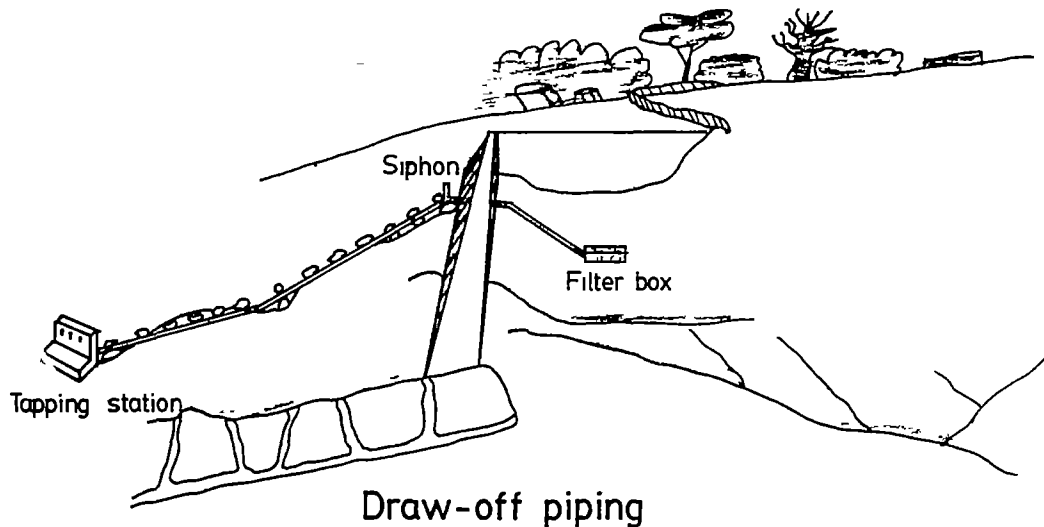
- e. Keep the newly built gutters damp under polythene sheeting for a week or two depending on the weather.

6. Constructing the Draw-Off Pipe and Tapping Station

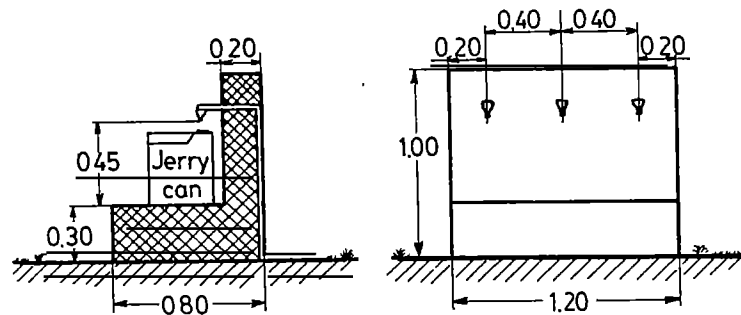
- a. Although some people may prefer to fetch water directly from the reservoir, they should be encouraged to collect their water from a tapping point for reasons of hygiene.
- b. When water has to be drawn by gravity from a reservoir situated at a lower level than the dam wall, as in the example shown in our diagrams, the piping system must be equipped with a syphon device and a tapping point located at a level lower than the floor of the reservoir. Attach the syphon, which consists of a 70 cm length of 3.75 cm (1.5") galvanized iron piping (GI), vertically to the draw-off pipe with a (GI) pipe tee as shown. Close the upper end of the syphon with a removable plug.



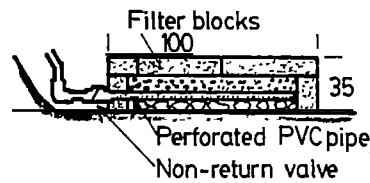
- c. From the syphon tee, reduce the piping from 3.8 cm (1.5") GI to 2.5 cm (1") GI down to the tapping point which is usually situated at the foot of the rock outcrop on which the dam is built. Lay this piping on the rock so that it bends to fit its profile. Support the GI pipe every 100 cm with a large stone laid in mortar which should also cover the pipe and secure it to the stone.



- d. Build the tapping station of stones or blocks under a shady tree. Divide the 2.5 cm GI pipe with tees to feed three water taps. Build the tapping station so there is room for three jerrycans to stand under the three taps at the same time.
- e. In the reservoir, reduce the draw-off pipe in the dam wall from 3.8 cm (1.5") to 2.5 cm (1") and extend it down to the deepest point in the reservoir. Connect a perforated PVC pipe, 100 cm long to the 2.5 cm GI pipe with a horizontal non-return valve. Build a box of filter blocks (made of a mixture of cement and small stones) around the PVC pipe but with the lid of the non-return valve just outside the box.



- f. Remember that all the joints in the syphon pipe system must be screwed together properly, otherwise air will enter the piping and prevent the system from working.
- g. Normally, the syphon system begins working by itself as soon as the reservoir is filled with water and a water tap is opened at the tapping station. However, if it does not begin working, unscrew the removable plug in the syphon pipe and let out any air which might be blocking the flow. If the reservoir is not completely full, then close the water tap and screw the plug and fill up the syphon pipe with water. In both cases, re-screw the plug with sealing material so that it cannot let in air.



7. Quality Control and Maintenance

If the instructions given are not followed closely then the dam may not prove water-tight and the take-off system will not function. The most important are as follows;

- a. If the foundations are not prepared properly, then the dam will leak and the reservoir will rapidly empty. The rock surface must be cleared, washed and chiseled and a good base of cement applied.
- b. The packing of mortar and ballast within the dam should be tight, with stones and mortar pushed in hard and the stones wetted beforehand. A piece of wood should be used to poke the mortar in between the stones to fill all the airholes. If this is not done effectively, the dam could leak.
- c. The facing of the wall needs to be formed of flat stones bound with mortar. There should be no gaps, and an even finish.
- d. The draw-off pipe must be at the lowest point in the reservoir to allow as much water as possible to be drained out through it. If sediment is washed into the dam it should be cleaned out if the dam dries up so that the filter box is not buried and draw-off prevented.
- e. The syphon point, if fitted, should be at the highest point of the draw-off pipe and filter box because otherwise water may not leave the dam.

It is important that all the above requirements are satisfied. If there are problems, then these questions and answers should help spot and solve them;

Does water leak from the base of the dam?

If it does this is probably due to a poor seal between the dam foundations and the rock. If the inside of the dam has not been plastered the corner between the rock surface and the dam wall must be cleaned thoroughly and plastered.

Does water leak from the face of the dam?

If it does there is a weak spot in the wall where the facing, and/or the fill have not been properly constructed. If the dam is to be enlarged with the building of another stage, this fault can be ignored because building the dam upward and outward will provide an effective seal. If it is not to be enlarged, then once the water level has dropped below the leak, the facing should be chiseled away within a large radius of the leaking area and a layer of plaster added with water-proofing.

Does water flow over part of the dam wall outside the spillover when the reservoir overfills?

If it does, the crest of the dam is not level all the way round. Using the hosepipe the top should be leveled with mortar and small stones. This prevents concentrated overflow and erosion forming downslope.

Does the dam fail to fill up over most years even though your design calculations say it should?

If so, check your volumetric calculations again to see if you have not overdesigned your storage. If they are correct, check along the gutters for breaks or leaks and if possible, extend the gutters to catch run-off from a large area.

Is the plaster lining the dam cracked and flaking?

If so, the curing was not carried out properly, or else the plaster and waterproofing mixtures were incorrect. If the dam does not leak, then the plaster can be left. Otherwise, a second coat can be applied (with the first removed in the worst places) and cured properly.

Are there wet patches or marshy ground alongside the draw-off pipe to the tap station?

If so, there is a leakage in the pipe which wastes water and may effect the syphon action by leaking air into the pipe. Each connection should be checked and properly sealed.

CONTRACTORS MANUAL ON SELF-CLOSING WATER TAP

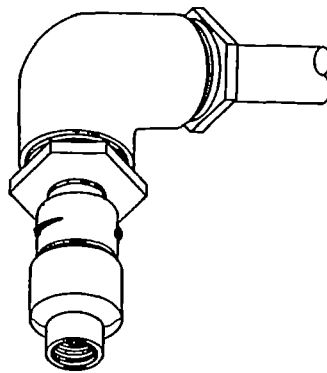
C O N T E N T S

	PAGE
CONTRACTORS MANUAL ON SELF-CLOSING WATER TAP	34
1. Self-closing Water Tap	35
2. Materials and Cost	36
3. Making the Self-closing Water Tap	37
4. Installing the Water Tap	39
5. Making a Fixed Spanner for the Caretaker	40

1. Self-Closing Water Tap

Below is a drawing of a self-closing water tap. Fitting a tap such as this to draw-off pipe from a rock-catchment, spring protection, tank or sand-dam will provide a major saving in water use in ASAL environments. Rural people will often leave taps running and unattended, wasting large quantities of water. The sight of running water gives the impression of unlimited supply and just as people in more humid regions leave a tap running when washing hands or doing dishes, ASAL rural people will do the same.

By having a tap that turns itself off by the downward force of the water and the weight of the handle once the upward pressure on the tap head is released by the user this problem is successfully solved. In addition, the use of a rubber ball valve is a robust design with little maintenance requirements and has few moving parts that can be broken or worn down.



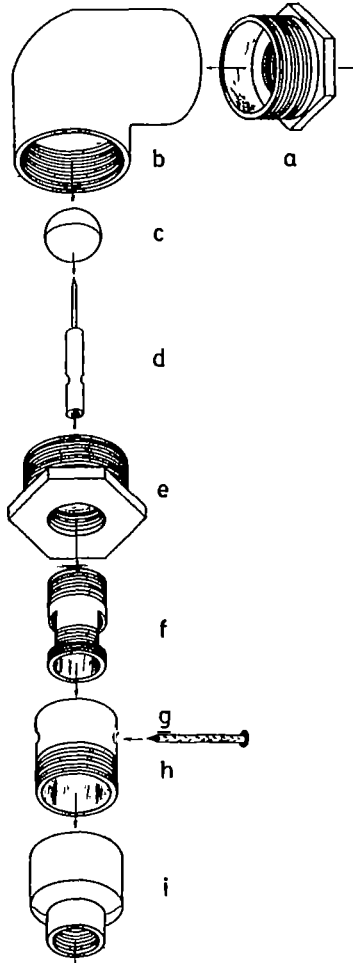
The tools needed for manufacturing the tap include;

- 1 engineering vice
- 1 pipe wrench
- 1 flat file
- 1 bench drilling machine (hand or power driven)
- 1 4mm drill bit
- 1 19 mm drill bit
- 1 28 mm drill bit
- 1 hacksaw
- 1 hammer

The total cost of the tap, not including labour is approximately US \$7.0.

2. Materials and Cost

The materials required to manufacture a self-closing tap are illustrated in sequence and include;

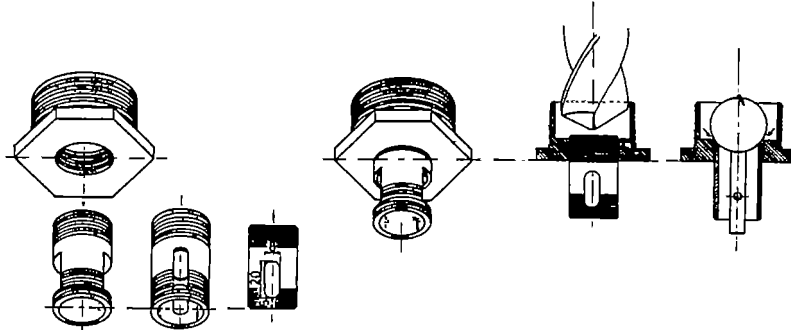


- a. Reducing bush, galvanized iron (G.I.), 1.5" to 3/4"
- b. Elbow pipe, G.I. 1.5"
- c. Rubber ball with 2mm diameter
- d. 75 mm length of 8 mm diameter iron bar
- e. Reducing bush, G.I., 1.5" to 3/4"
- f. Nipple, G.I., 3/4"
- g. Round 2" nail
- h. 4 cm length of 1" G.I. pipe with one thread
- i. Socket, G.I., 1" to 1/2"

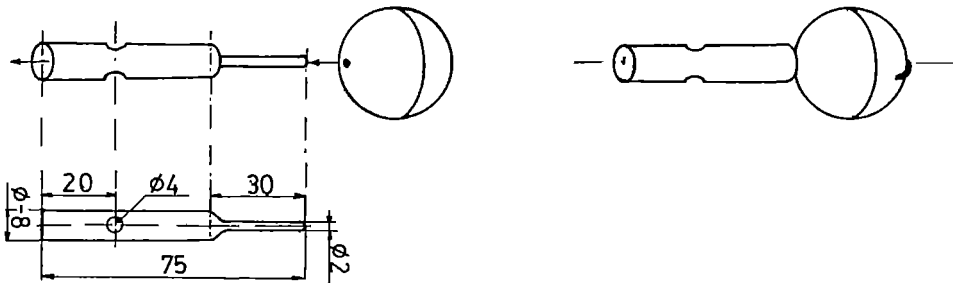
3. Making the Self-Closing Water Tap

The Valve

- a. Wind a few rounds of sealing tape clockwise around one end of a thread 3/4" G.I. nipple and screw it into a reduction bush of 1.5" to 3/4" G.I.
- b. Cut two 5 mm wide and 20 mm long slot in the nipple with a 4 mm drill bit and file.
- c. Drill a seat for a 22 mm rubber ball in the joint of the nipple and reduction bush using firstly a 19 mm drill bit, and then a 28 mm drill bit.
- d. Remove most of the thread on the free end of the nipple with a file.



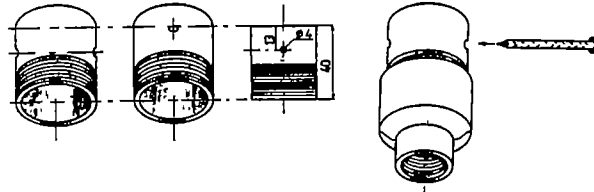
- e. Cut a 75 mm long piece of 8 mm diameter round iron bar. Drill a 4 mm hole through it at 20 mm from one end. reduce 30 mm of it at the opposite end to a thickness of about 3 mm with a file.
- f. Drill a 2 mm hole through the centre of a 22 mm rubber ball. Fit the thinned-down end of the iron bar (the pin) through this hole and bend the end of the pin over the rubber ball on the other side.



- g. Test the water-tightness of this valve with water. If it leaks, then the seat in the reduction bush needs to be re-drilled to get a more even, better seat.

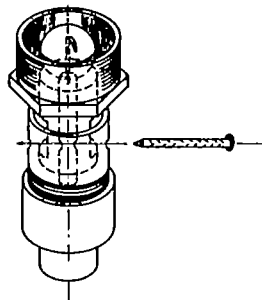
The Handle

- a. Cut a 40 mm long piece of 1" G.I. pipe with thread at one end.
- b. Drill a 4 mm hole through the G.I. pipe at 13 mm from its unthreaded end.
- c. Wind a few rounds of sealing tap clockwise around the threads on the 1" G.I. pipe and screw it into a reducing socket of 1" to 1/2" G.I.



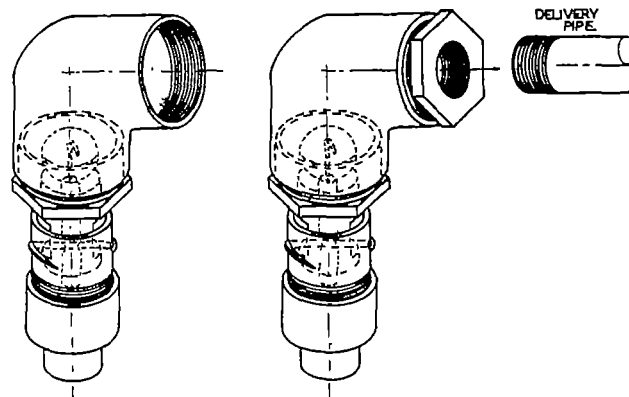
Assembly of the Water Tap

- a. Place the rubber ball with its attached pin onto the seat of the valve with the hole in the pin pointing towards the slits in the nipple.
- b. Place the handle over the nipple so that the hole in the handle is in line with the hole in the pin and slits.
- c. Put a 2" round nail through these holes and slits and bend the end of the nail sharply and firmly against the outside of the handle.



- d. Test this valve again for water-tightness and perfect functioning. When the handle is pushed upwards it will lift the rubber ball off its seat thereby allowing water to flow. When the handle is released it will drop under the force of the water and through gravity until the rubber ball rests in its seat causing the water flow to stop.

- e. Wind sealing tape around the threads of the free end of the reduction bush and screw it into a G.I. 1.5" elbow.
- f. Wind sealing tape over the reads of a G.I. reducing bush of 1.5" to 3/4" G.I. and screw it into the other end of the 1.5" elbow.



- g. The self-closing water tap is now ready to be fitted onto the 3/4" pipeline from the water source.

4. Installing the Water Tap

- a. Train three people living near the water point to which the taps are fitted on how the self-closing taps function. They will be the caretakers of the tap station.
- b. Fix the water tap to the draw-off pipe or feeder pipe leading off the water reservoir.
- c. The caretakers should be trained in replacing the self-closing water taps if there are any problems. They can do this with a fixed spanner (see below). If the tap should stop working they should remove it and fit a spare tap which they are given with the spanner.
- d. The caretakers can get the faulty tap replaced by another tap by the manufacturers.

5. Making a Fixed Spanner for the Caretaker

The materials needed to make a fixed spanner include;

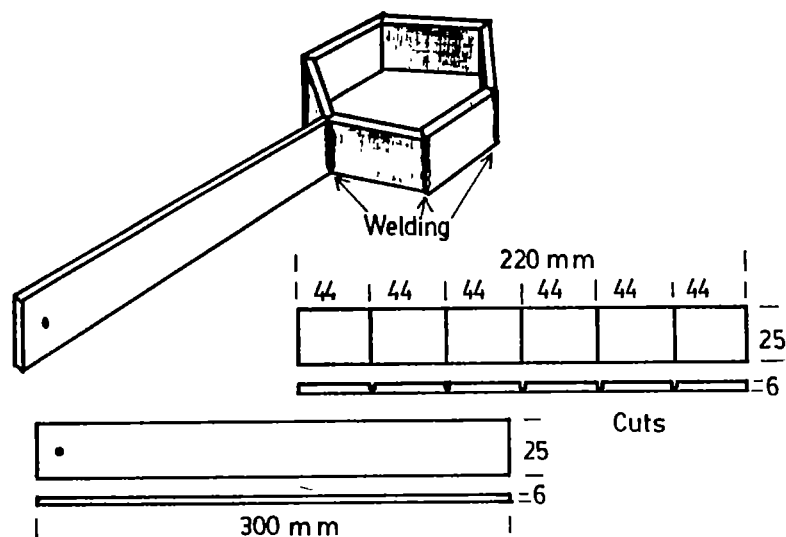
30 cm of flat iron, 30 mm x 6 mm

22 cm of flat iron, 25 mm x 6 mm

Total Cost of Fixed Spanner

The fixed spanner is the tool the caretaker will use to take the tap off the pipe if there are any problems.

- a. Cut a 22 cm long piece of flat iron 25 mm x 6 mm. Slit the iron bar at 5 places corresponding to the six sides of the hexagonal reducing bush of 1.5" to 3/4" used to connect the tap to the pipe. Bend it tightly around this shape. Weld the iron bar at each of the slits and at the join between the two ends.
- b. Cut a 300 mm length of flat iron 30 mm x 6 mm and weld one end of it onto the hexagonal spanner end as a handle.



Fixed Spanner for Watertap





