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AN OUTLINE OF SOIL CONSERVATION IN KENYA

by

Carl G Wenner
Soil Conservation Extension Unit
Ministry of Agriculture
Republic of Kenya

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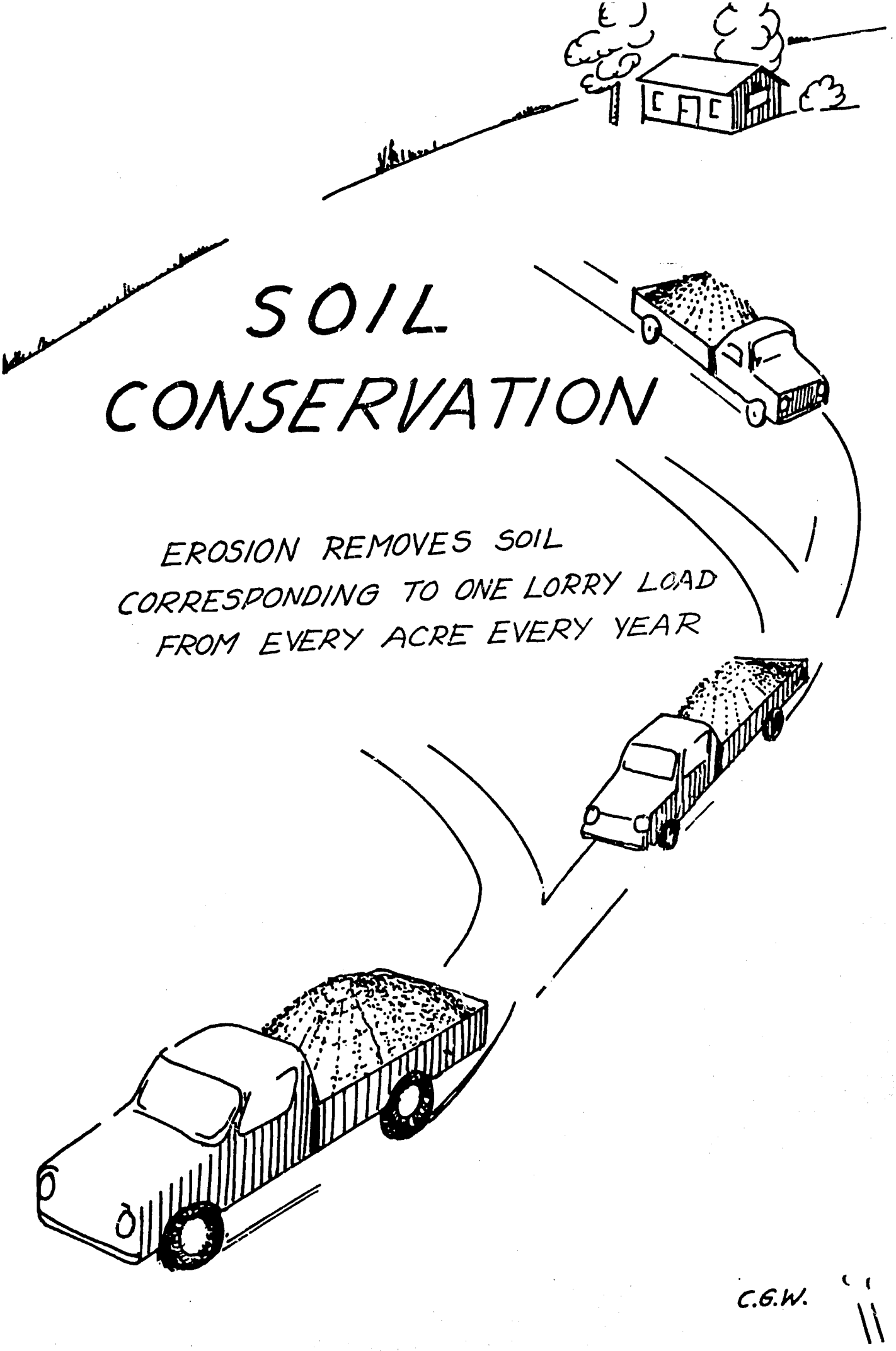
SOIL
CONSERVATION
EROSION REMOVES SOIL
CORRESPONDING TO ONE LORRY LOAD
FROM EVERY ACRE EVERY YEAR
C.G.W.

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1. EROSION

Rain and water flows remove the top soil from arable land and from overgrazed pastures.

The annual loss of top soil is much higher than you think, usually much more than a big lorry load of soil from every acre every year. If not stopped the top soil will get thinner every year and yields will decrease. Rills can develop into gullies dissecting the land, and making it unsuitable for agriculture.

Erosion is more severe in loamy-silty-sandy soils than in clay soils, and it is also more severe on long and steep slopes. Basically erosion is dependent on the pattern of cultivation, especially in regard to the vegetative cover and the structure of the soil.

Erosion (soil loss) consequently depends on several factors:

amount and energy of rainfall	+	erodibility of the soil	+	length and steepness of slope	+	crop and land management

You cannot change the rainfall or the soil, but you can change the length and also the steepness of a slope through "terracing". You can also improve the vegetative cover and the soil structure through good farm management. Let us start with farm management.

2. GOOD FARM MANAGEMENT

Fertility and/or manuring favour the growth of crops, and this results in good protection against rain erosion during the growing season.

During the off-season a continuous layer of crop residue left on the ground reduces erosion, and increases the rate of infiltration, as well as the quantity of water stored in the ground.

All cultivation (ploughing, planting, etc.) shall be along the contour and not up and down the slope. Even on gentle slopes contour farming reduces the soil loss (by a half on slopes of 2 - 7 %).

Maize and other crops should not, if possible, be cultivated year after year. A three-year rotation of maize and grass is recommended for maintaining a soil structure which will decrease the rate of erosion.

On slopes, good farm management by itself is not sufficient and it has to be combined with "terracing".

3. TERRACING

Terraces can be constructed as ditches across the slope, thus decreasing the length of a slope, as ditches divide the slope into shorter stretches (Fig.1 next page). This type of terrace, however, does not influence rain erosion, and rill erosion is only partly affected.

Therefore bench terraces are preferable, as these also change the degree of slope (Fig.2 next page). They also retain eroded soil, moisture and nutrients. Bench terraces can develop from grass strips acting as wash stops (Fig.5, page 4).

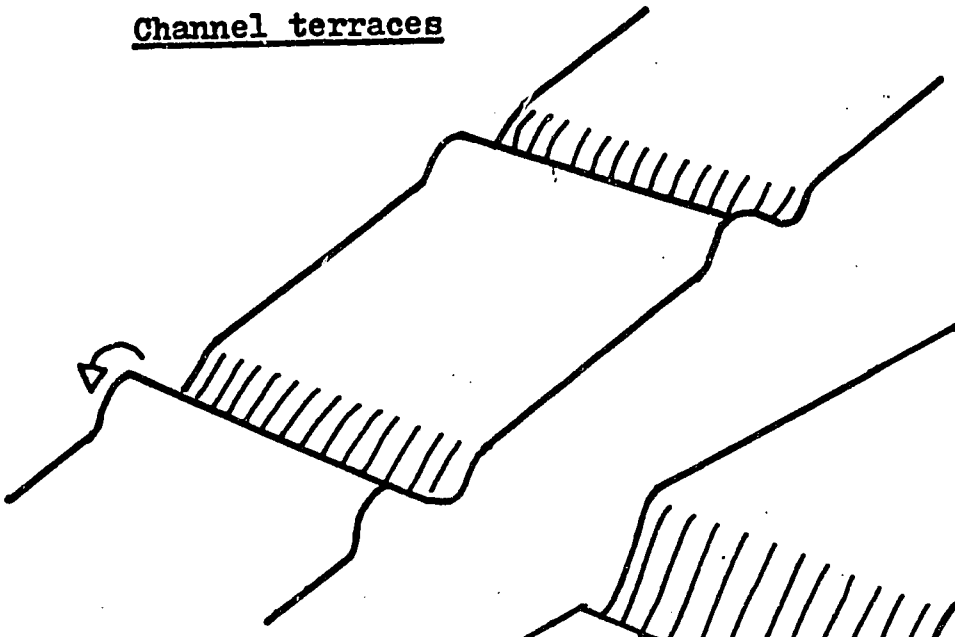
Grass strips can start as:
1) unploughed strips, or 2) grass planted in one or two rows, or 3) trash lines laid along the terrace line (Fig.6 page 5 showing the various alternatives). In the strips water flows will be distributed between the grass stems and most of the water will infiltrate into the ground.

To hasten the formation of a bench terrace you can make a ridge by digging a channel (2 feet wide, 2-3 feet deep) and throwing the soil uphill using the so-called 'Fanya Juu' method (Fig.7 on page 6). Grass should be planted on the ridge to protect it. The channel will be filled up mainly through cultivation and by deposits, but part of it should be maintained as a drain for water passing through the grass strip during heavy rain storms (Fig.8 on page 6). The Fanya Juu terrace is commonly used in Machakos and Kitui Districts, because the risk of drought makes grass strips without ridges unreliable for soil conservation, especially on steep slopes. Besides grass is often eaten by termites.

Mechanized soil conservation can be used on slopes which are not too steep (preferably 2-12 %). Two measures are used in Kenya: 1) the channel type (on slopes of more than 5 %), and 2) the ridge type (on slopes of less than 5 %). See Figs. 1 and 3 on the next page. The V-shaped channel, on one or both sides of a ridge, will usually be filled up by sediment and will thus develop into a bench terrace. But this could as well have developed from a grass strip.

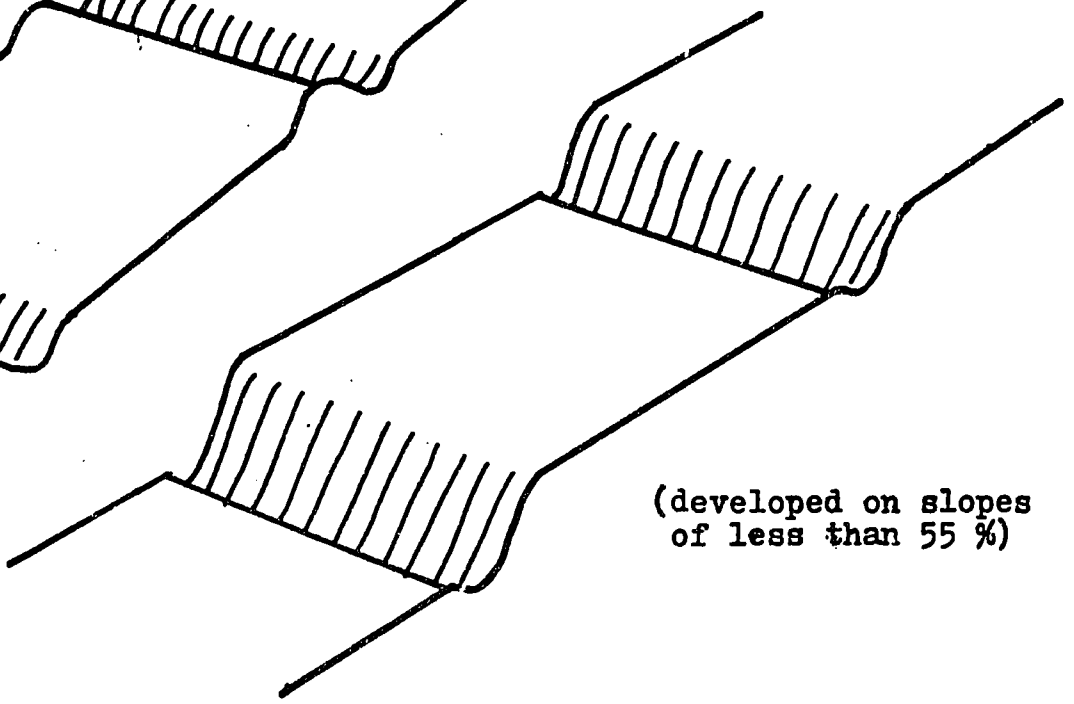
TYPES OF TERRACES

Fig. 1
Channel terraces



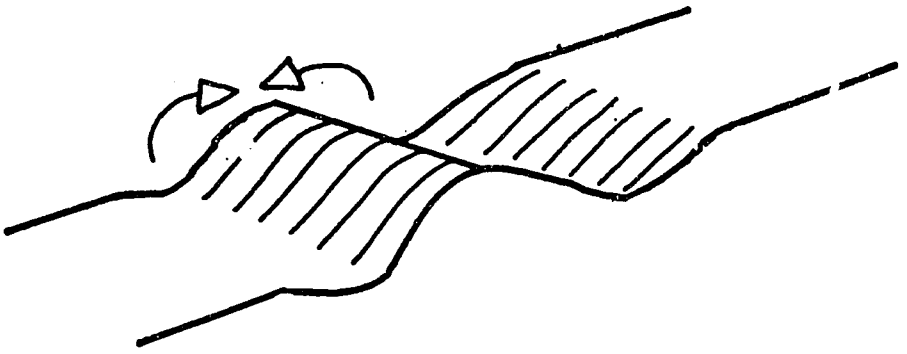
(machine-made on slopes of less than 12 %)

Fig. 2
Bench terraces



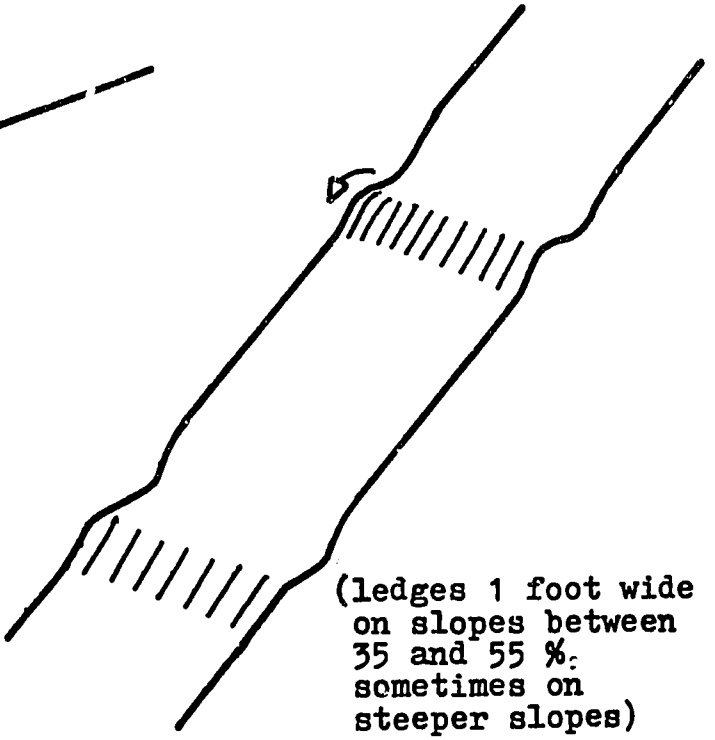
(developed on slopes of less than 55 %)

Fig. 3
Ridge terrace
excavated from two sides



(machine-made on slopes of less than 5 %)

Fig. 4
Modified bench terraces



(ledges 1 foot wide on slopes between 35 and 55 %; sometimes on steeper slopes)

Fig. 5

DEVELOPMENT OF GRASS STRIPS INTO BENCH TERRACES

Pictures showing how the farmer and erosion can work together to develop bench terraces on a slope (here of 35 %)

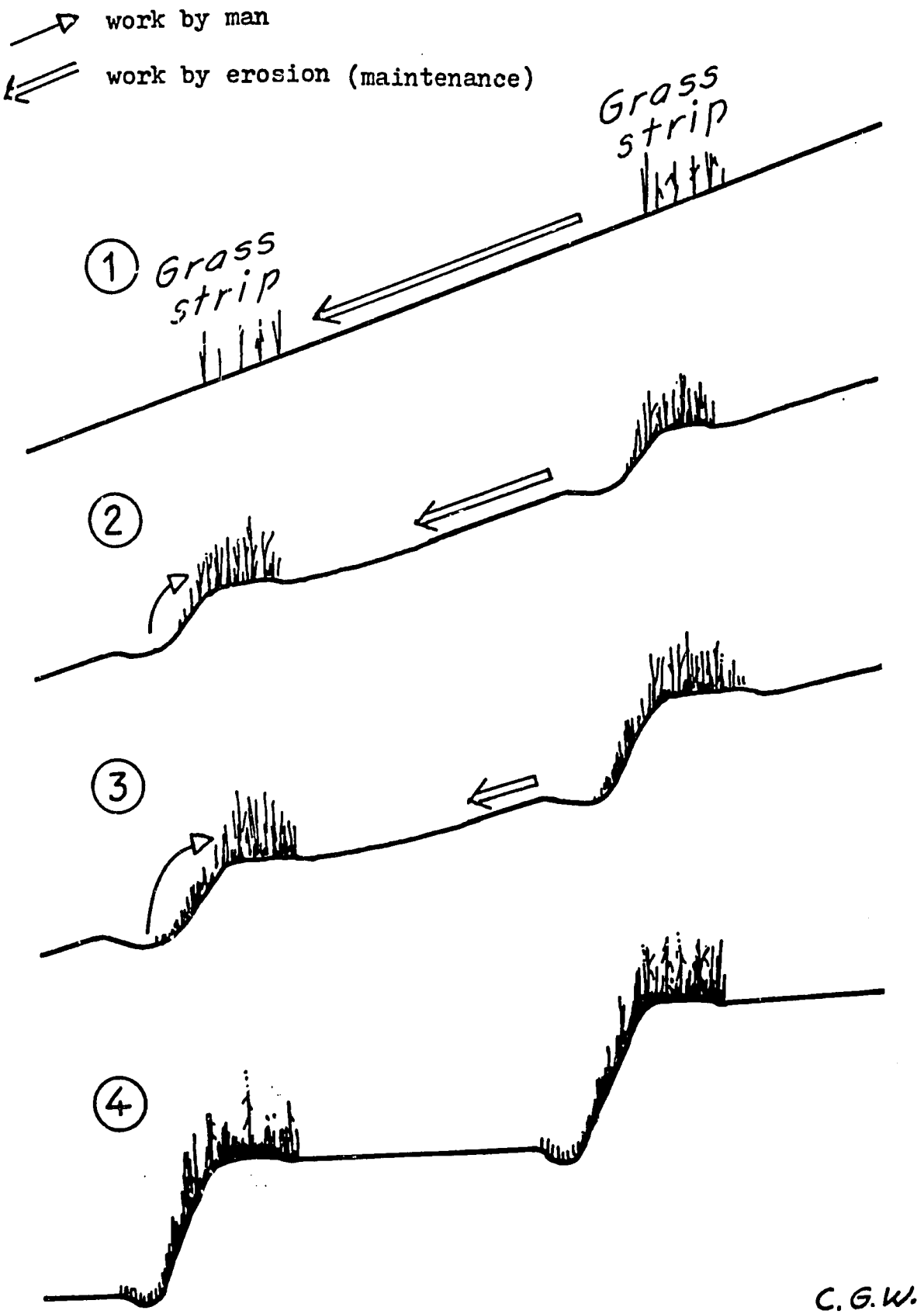
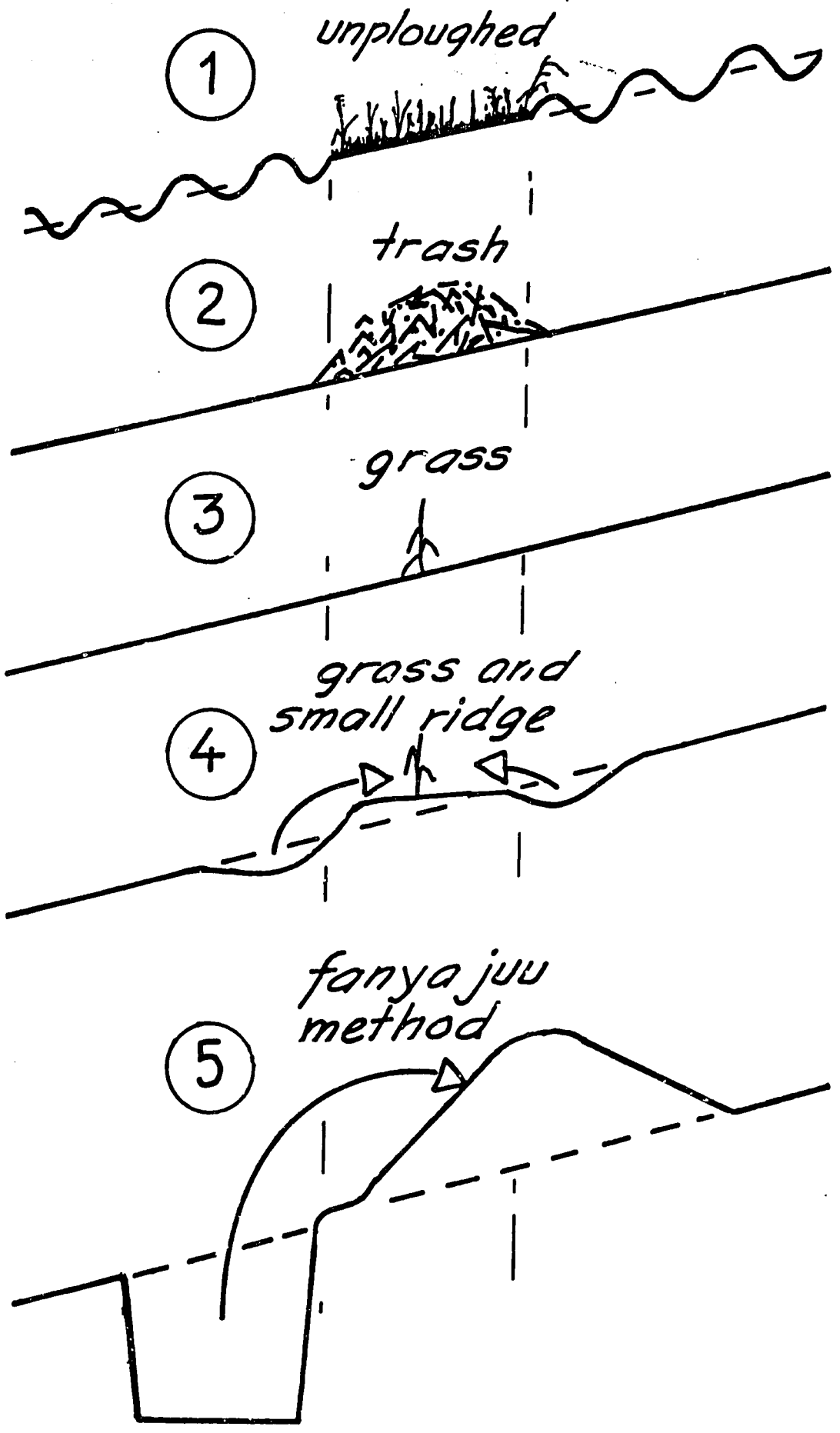


Fig. 6

DIFFERENT WAYS TO START TERRACING



FANYA JUU TERRACING

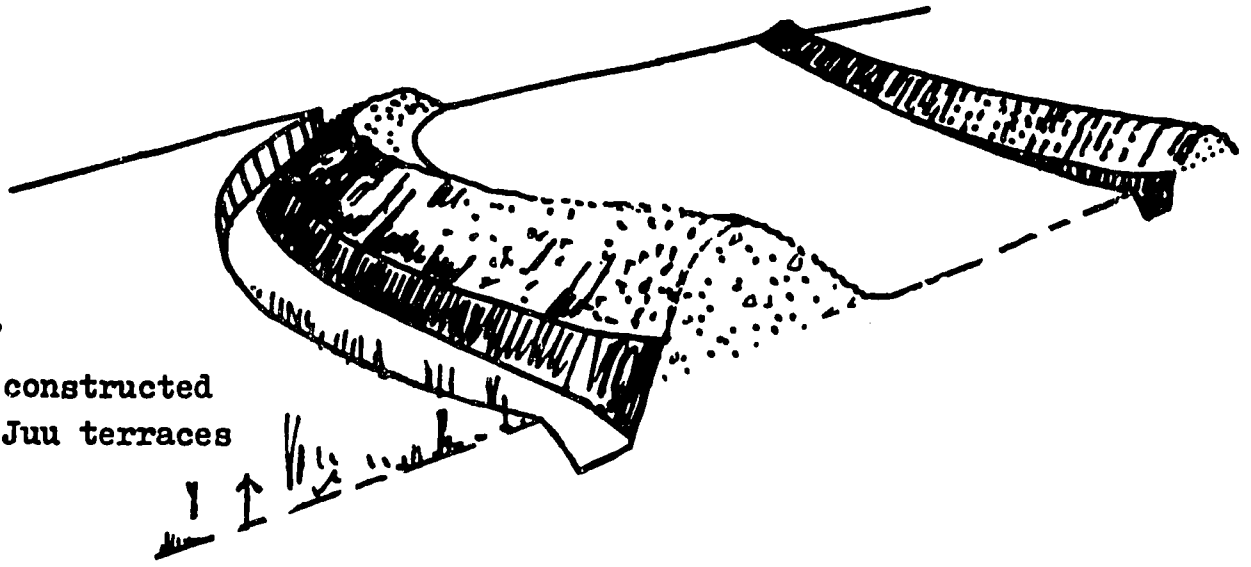


Fig. 7
Newly constructed
Fanya Juu terraces

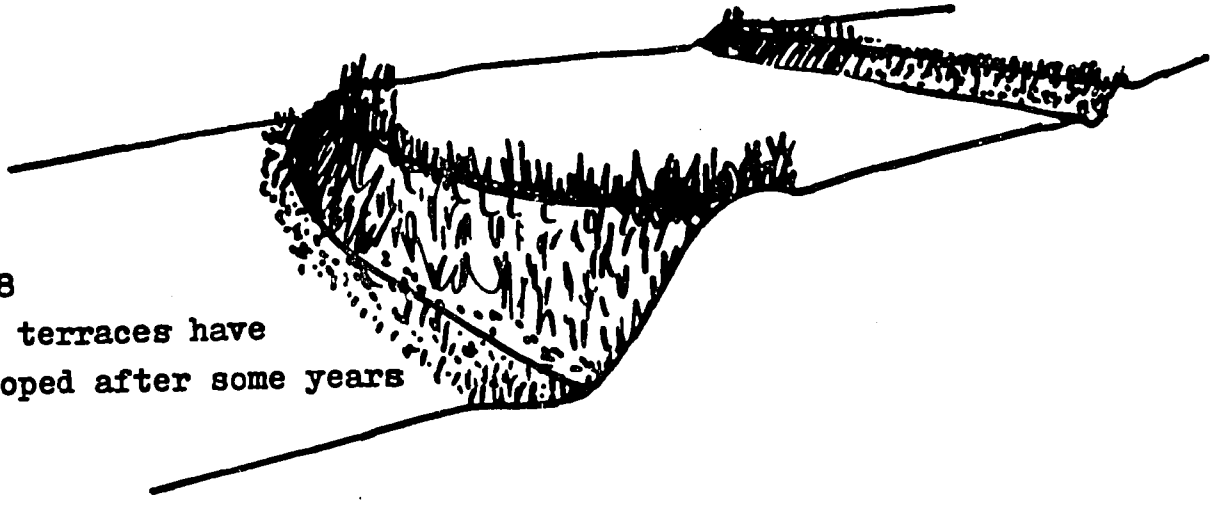


Fig. 8
Bench terraces have
developed after some years

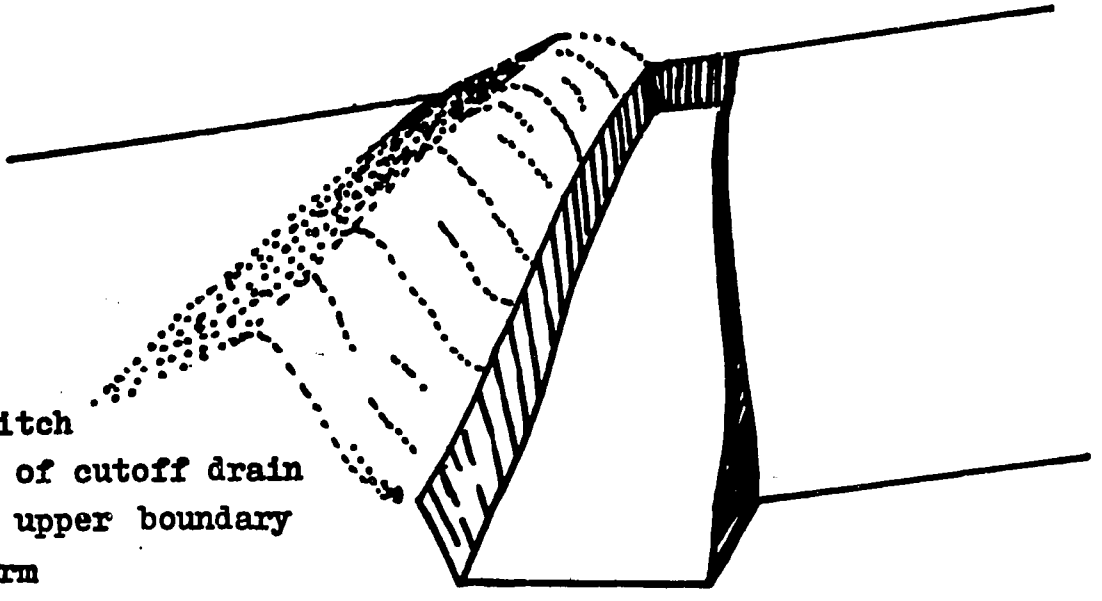


Fig. 9
Up-hill ditch
as a kind of cutoff drain
along the upper boundary
of the farm

4. CUTOFF DRAINS

Large water flows coming from outside a farm have to be diverted from the farm by a cutoff drain, e.g. collecting water from a hillside (Fig.10 on page 8), or preventing water from a plateau from flowing down a terraced slope, or taking care of water from a roadside ditch.

Cutoff drains should be dug only where there is evidence of large waterflows which cannot be stopped through normal terracing. Below the banks of terraces channels can be excavated or increased in size to carry away water.

In the survey of a cutoff drain you should start with the outlet point. If you cannot discharge the water in a safe way, do not dig any cutoff drain. Before measuring and setting out the pegs you should walk along the proposed cutoff drain, checking that the drain is properly sited regarding houses, cultivation, topography, rocky ground and outcrops of bedrock.

Usually only one cutoff drain is needed on a slope. Only on very long slopes might an extra cutoff drain be dug in exceptional cases.

Do not dig any cutoff drain if farmers do not agree to do terracing below the drain and to maintain the channel by removing the soil deposits. Special forms should be used (see page 9).

It is usually wise to dig a cutoff drain (hillside ditch at least 2 feet wide, and 1 foot deep) along the upper boundary of a farm. In Fanya Juu terracing the top terrace should be constructed as a cutoff drain, with the soil being thrown down the slope so that the channel can carry as much water as possible (Fig.9 on page 6).

As to design of cutoff drains see Fig.11 on the next page, and for the approximate dimensions (in feet) of the cutoff channel see Appendix 2. A cutoff drain dug by hand is often 5 feet (1.5 m) wide at the top, 3 feet (0.9 m) wide at the bottom and 2 feet (0.6 m) deep, giving a cross-section of 0.7 sq.m. A cutoff drain constructed by a motor grader often has a V-shaped cross-section and is made 6 - 8 feet wide (1.8 - 2.4 m) and 2.5 feet deep (0.75 m), giving a cross-section of 0.7 - 0.9 sq.m.

CUTOFF DRAIN

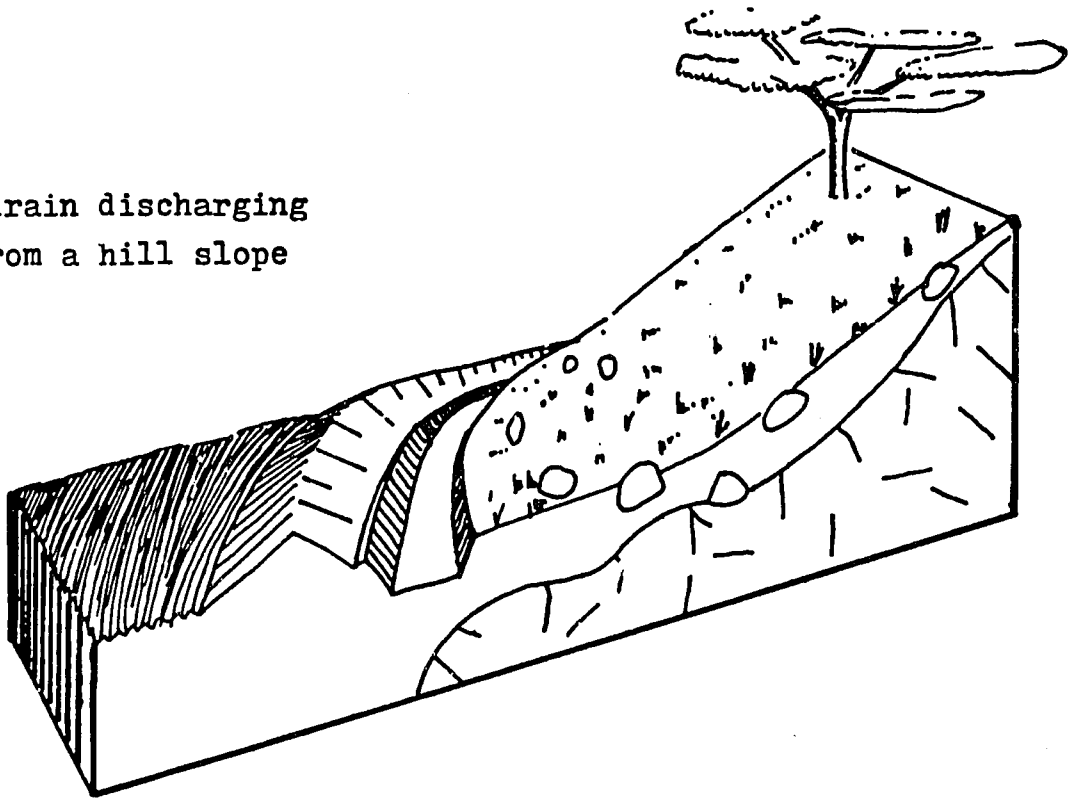
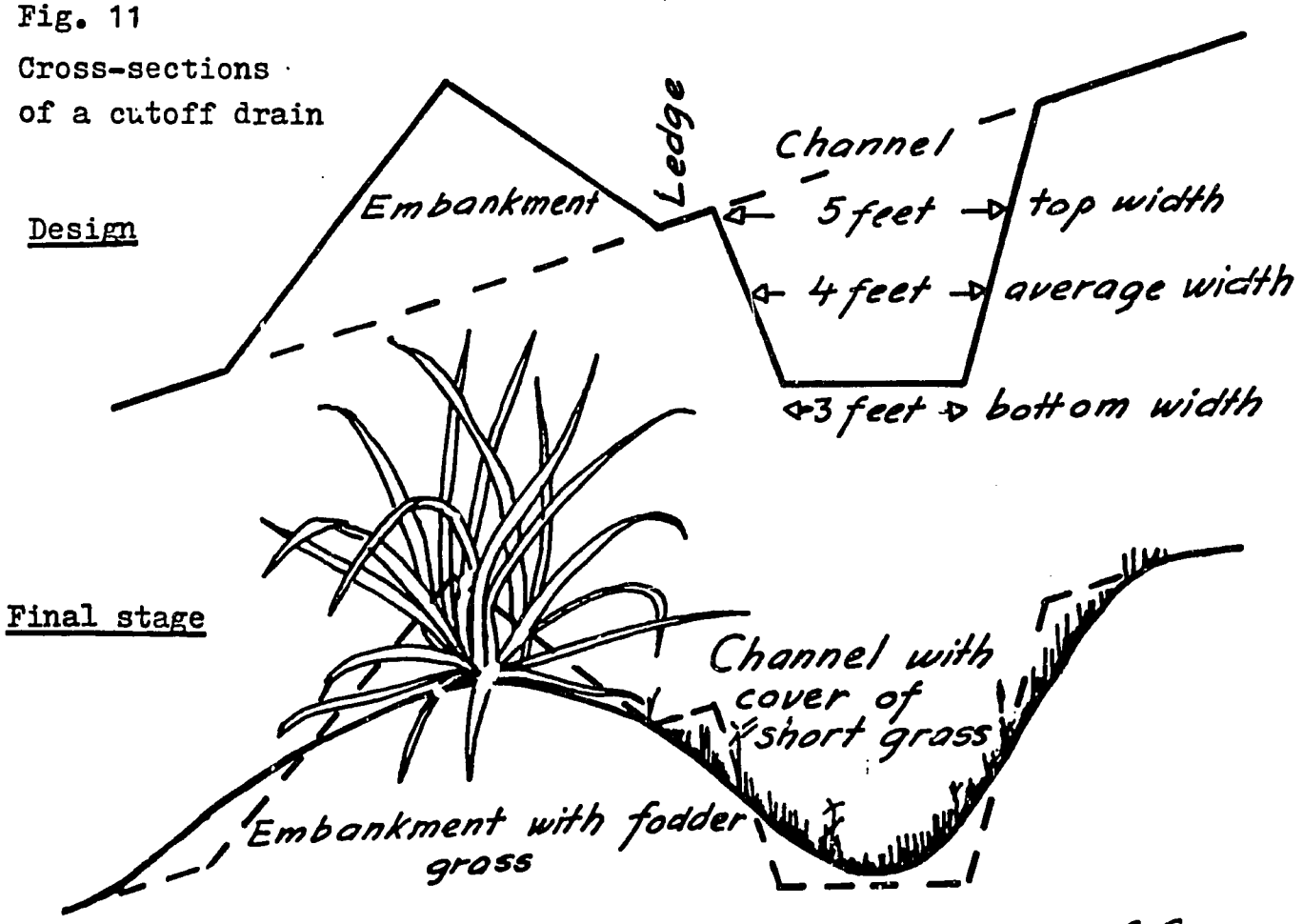


Fig. 10
Cutoff drain discharging water from a hill slope

Fig. 11
Cross-sections of a cutoff drain



MAINTENANCE FORM FOR CUTOFF DRAIN

SITE

Division

Location

Sublocation:

DIMENSIONS OF CUTOFF DRAIN

Length m:

Depth m:

Width at top m: at bottom m:

average width m:

Area of excavated cross-section sq.m:

Total volume cu.m:

WORK

Date of start:

Date of finishing:

Number of workers:

Number of man days

for digging work:

Cu.m dug per man day:

Soil type:

Daily payment per worker Shs/day:

COSTS

Cost of digging work Shs:

of miscellaneous work Shs:

Total cost of the cutoff drain Shs:

Digging cost calculated as

Shs/m length of the cutoff drain:

Shs/cu.m of the cutoff drain:

SKETCH MAP OF THE FARMS BELOW THE CUTOFF DRAIN AND HAVING BENEFIT OF IT

LIST OF THE FARMERS OF THE MAINTENANCE GROUP (No. 1 = the Chairman)

1..... 6.....

2..... 7.....

3..... 8.....

4..... 9.....

5..... 10.....

REMARKS This form has to be completed in 6 copies, of which No. 1 should be distributed to the DAO, No. 2 kept by the assistant and later given to the TO of the division, No. 3 to the Chairman of the maintenance group, No.4 to the DO,No. 5 to the Chief and No. 6 to the Sub-chief.

It is the responsibility of the Sub-chief to make sure that the members of the group set aside 1 - 3 days every year after the long rains for cleaning the cutoff channel.

5. ARTIFICIAL WATERWAYS

The water from cutoff drains as well as from terraces should be discharged into natural watercourses (rivers) or onto non-erodible areas such as stony ground or permanent pasture with a good grass cover. If it is not possible to find such an outlet point within a reasonable distance, the excess water has to be taken down the slope by an artificial waterway (Fig.12 on the next page).

A waterway should be wide (5 feet at least), shallow (1 foot deep) and covered with short grass, all to minimize erosion (Fig.13 :4 on the next page). A difficulty in constructing waterways is that protective grass cannot be established in the first year or two. Consequently it would be reasonable to construct the artificial waterways and plant grass two years before the construction of the cutoff drains and terraces. Another way is to remove the grass before excavating the waterway and afterwards replace the grass as shown in the figure on the next page.

The width can be varied depending on the size of the catchment area and the steepness of the slope. The necessary width in feet of an artificial waterway in erodible soils can be read from the table:

Catchment area of the waterway in acres	The steepness of the slope		
	less than 6 %	6-12 %	more than 12 %
5	5	6	8
10	6	8	10
15	7	11	17
20	8	15	23
30	9	23	34
40	12	30	44
50	16	38	56

In erosion resistant soils such as clay and clay loam, the width as shown in the table can be much less, but not less than 5 feet. If the central 1/3 of the waterways is covered with stones, the widths as shown in the table can be decreased by about a half.

Experience has shown that farmers hesitate to accept even a half of the widths recommended. An alternative then is to construct narrow waterways with check dams as recommended for gully control (Appendix 4).

Fig. 12
Bench terraces discharging water into an artificial waterway

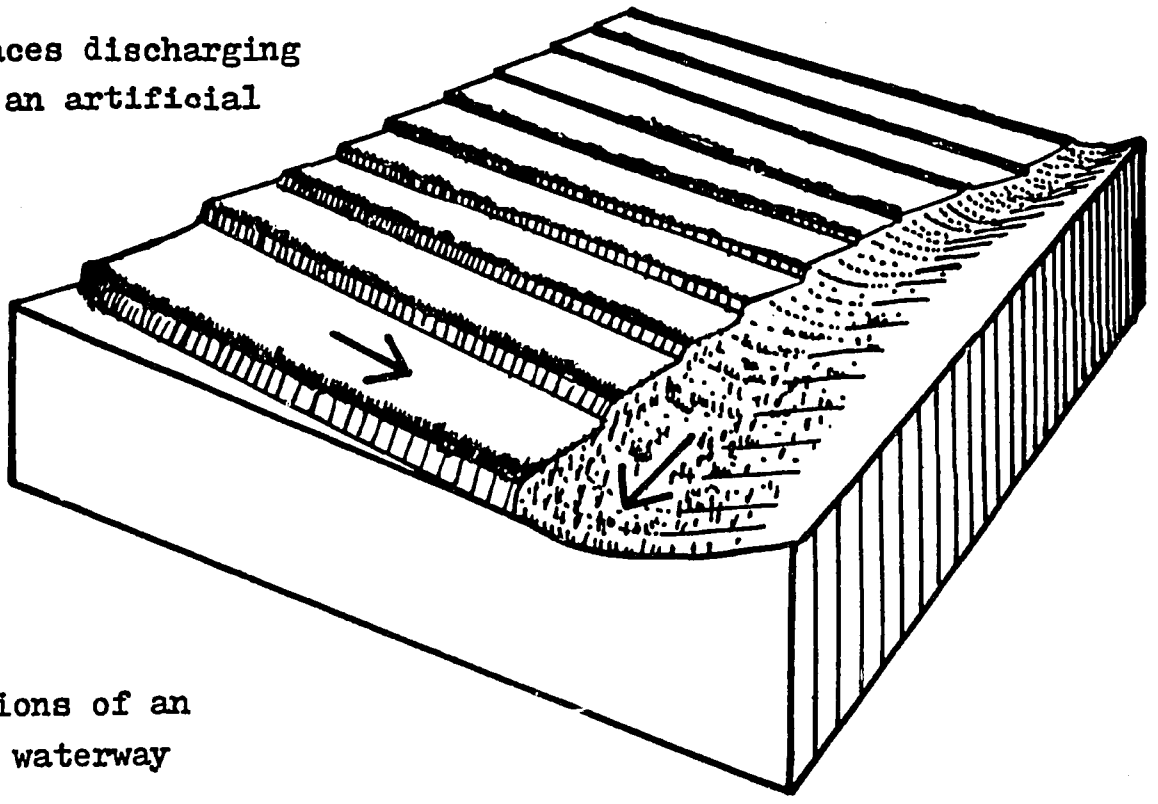
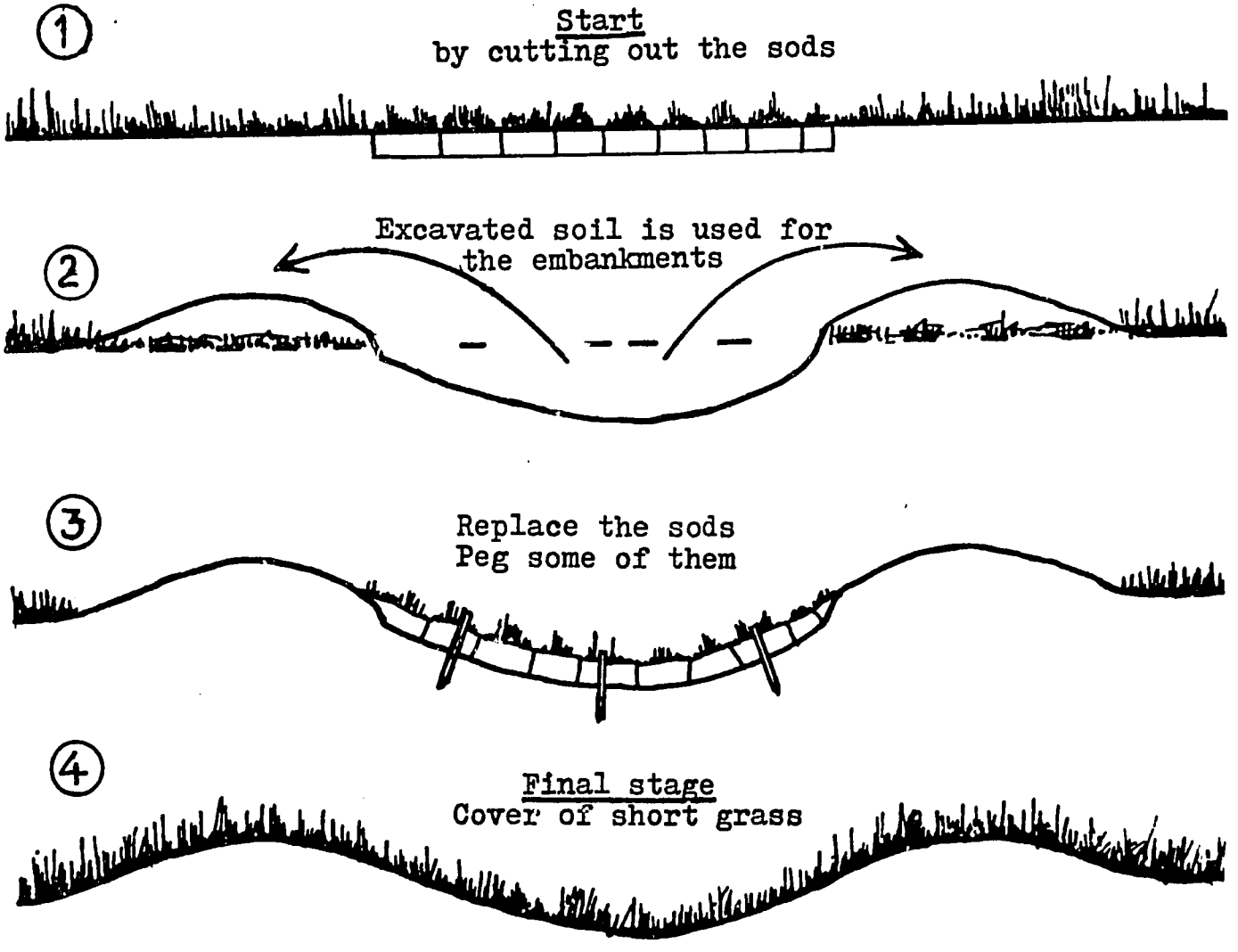


Fig. 13
Cross-sections of an artificial waterway



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6. CLASSIFICATION OF LAND (regarding % slope see Appendix 1,p.30).

The land of a farm can be classified as to slope and soil, with the different classifications needing different considerations:

1) Flat land, sloping less than 2 % can usually be farmed without any special soil conservation measures except contour farming.
2) On gentle slopes between 2 and 12 % terracing is not obligatory according to the present Agriculture Act, but terracing is usually desirable on slopes exceeding 5 %. In semi-arid areas and in areas with erodible soils terracing is usually needed even on slopes less than 5 % (2 - 5 %).
3) For slopes exceeding 12 %, but not exceeding 55 %, terraces (preferably developed bench terraces) should be used if the depth of the soil is more than about 0.75 m. For very steep slopes modified bench terraces are recommended, i.e. narrow ledges cut into the slope, suitable for fruit trees, fodder trees, forest trees and coffee.
4) Slopes exceeding approximately 55 % should be covered with grass and/or forest. Under certain conditions it might be permissible to cultivate tea, sugar cane or bananas with a layer of trash on the ground.
5) Soils which are rocky, stony or shallow, should be used as pasture or for forest or they should have stone terraces.

7. LAYOUT OF CUTOFF DRAINS AND TERRACES

Length

Terraces, as well as cutoff drains, should not, if possible, be many hundreds of metres long. More than 400 m should be avoided, but if it is difficult to find a natural waterway within that distance, it might be better to make the cutoff drain essentially longer than 400 m instead of digging an expensive artificial waterway.

Gradient

A cutoff drain shall always be graded. Terraces can be level or graded. Level terraces can be constructed on gentle slopes in permeable soils in dry areas, but terraces should usually be graded.

For cutoff drains and terraces the following gradients are recommended:

in erosion resistant soils (clay)	1 %
normally	0.5 %

Vertical interval between terraces

A constant vertical interval, corresponding to the eye height of a man (see Fig.15 on page 15), can usually be used on slopes between 5 % and 55 %. The vertical interval will vary with the eye height of the person setting out the terraces, i.e. between 5 and 6 feet (1.5 and 1.8 m). Such variation can be disregarded in setting out terraces.

In some cases variations of the constant vertical interval can be used:

Normal constant V.I. doubled (= 3 - 3.6 m)	Slopes of wheat fields, e.g. Narok and Nakuru Districts, and terracing combined with strip cropping, i.e. rotation of crops between terraces, e.g. Kisii and Kericho Districts
Half of normal constant V.I. (= 0.75 - 0.9 m)	Erodible soils and when oxen are used in cultivation, e.g. Machakos and Kitui Districts

The vertical interval can also be calculated as shown in Appendix 3.

Horizontal interval between terraces

The table on the next page shows the horizontal intervals using a constant vertical interval of 5 1/2 feet (1.65 m). For different percentages of slope the table can be used to find out the width of a terrace.

If the vertical intervals are doubled or halved, the horizontal intervals of the table will also be doubled or halved. In wheat fields, where tractor ploughing along the contour is possible on slopes up to approximately 17 % (with four-wheel drive up to 25 %), graded strips 1 - 2 m wide should be left unploughed. As a rule of thumb the following horizontal intervals can be recommended:

below 5 %	usually no strips
5 %	50 m
15 %	25 m

The horizontal intervals between 5 and 15 % have to be interpolated (estimated).

Horizontal intervals for different percentages of slope with a constant V.I. of 1.65 m:

%	m	feet
2	(82) 24 (x	(273) 80 (x
3	(55) 24	(183) 80
4	(41) 24	(136) 80
5	(33) 24	(110) 80
6	(27) 24	(92) 80
7	23	78
8	21	68
9	18	60
10	16	55
11	15	50
12	14	45
13	13	42
14	12	39
15	11	36
16	10	34
17	9.7	32
18	9.2	30
19	8.7	28
20	8.2	27
21	7.9	26
22	7.5	25
23	7.2	24
24	6.9	23
25	6.6	22

x) In erodible soils the maximum H.I. should be 24 m (= 80 feet)

%	m	feet
26	6.4	21
27	6.1	20
28	5.9	19
29	5.7	18
30	5.5	18
31	5.3	17 1/2
32	5.2	17
33	5.0	16 1/2
34	4.9	16
35	4.7	15 1/2
36	4.6	15
37	4.5	14 1/2
38	4.3	14
39	4.2	14
40	4.1	13 1/2
41	4.0	13
42	3.9	13
43	3.8	12 1/2
44	3.7	12 1/2
45	3.7	12
46	3.6	12
47	3.5	11 1/2
48	3.4	11 1/2
49	3.4	11
50	3.3	11
51	3.2	10 1/2
52	3.2	10 1/2
53	3.1	10
54	3.0	10

Strip cropping

Strip cropping means wide strips with alternating crops under rotation. It should preferably be used on not too steep slopes (less than 20 %) with permeable soils. The maximum width of strips to be recommended:

slope	on clay and loam soil	on fine sand and silt soils
30 %	10 - 12 m	-
20 %	20 - 24 m	10 - 12 m
10 %	30 m	20 - 24 m

LAYOUT OF TERRACES

The technical assistants of the Ministry of Agriculture can help to do the layout and peg the terraces. Sometimes the farmer can do this work himself (see Figs. 14 - 16 below and on the next page).

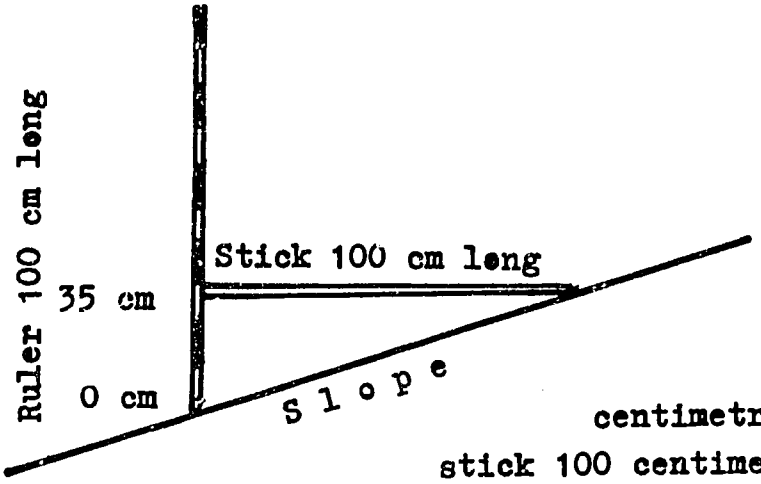


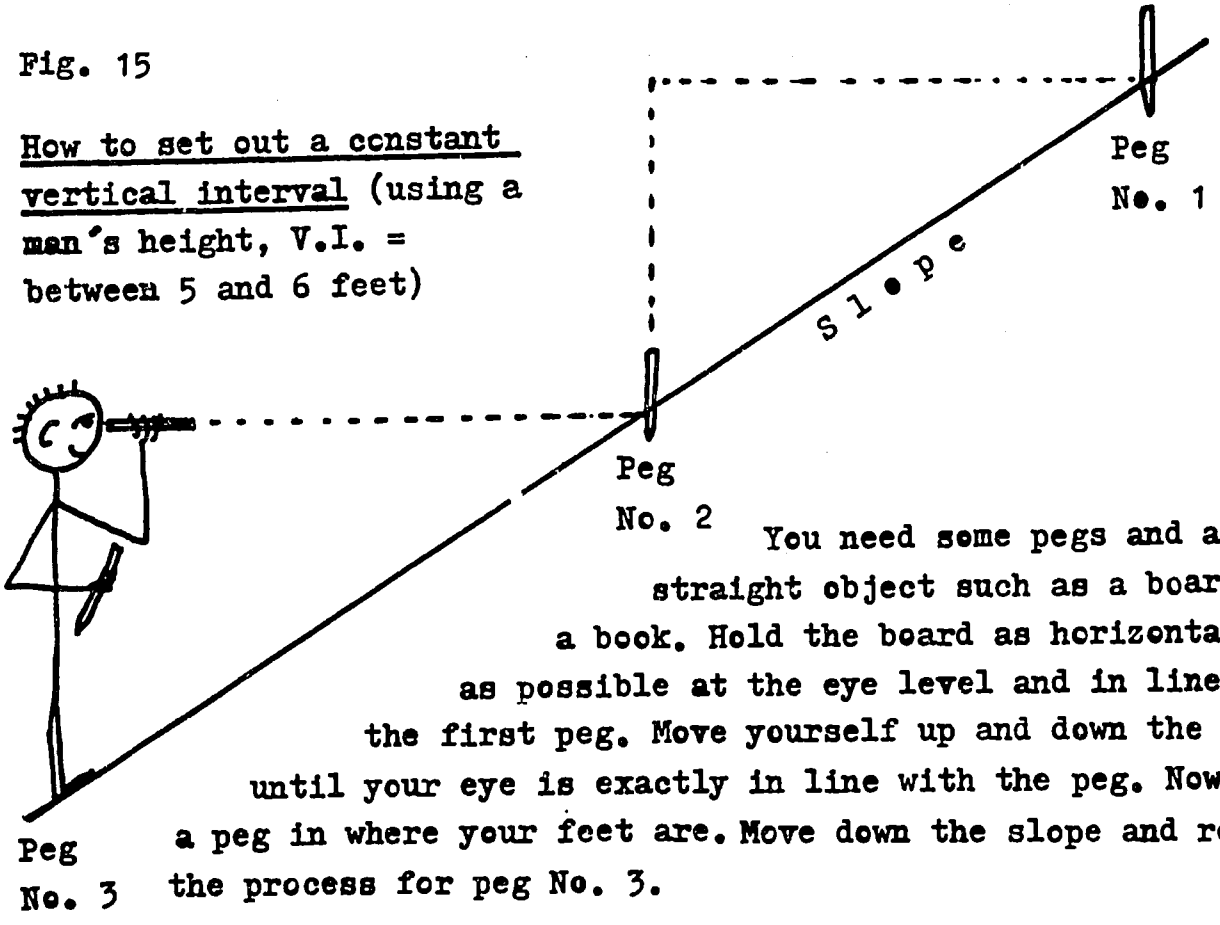
Fig. 14

How to measure the percentage slope

You need a ruler graded in centimetres (or inches). Cut a straight stick 100 centimetres (or 100 inches) long. Lay one end of the stick on the slope, and hold the stick as horizontally as possible. Use the ruler to measure how high the free end of the stick is above the ground. For example a measurement of 35 centimetres in 100 centimetres = 35 %.

Fig. 15

How to set out a constant vertical interval (using a man's height, V.I. = between 5 and 6 feet)

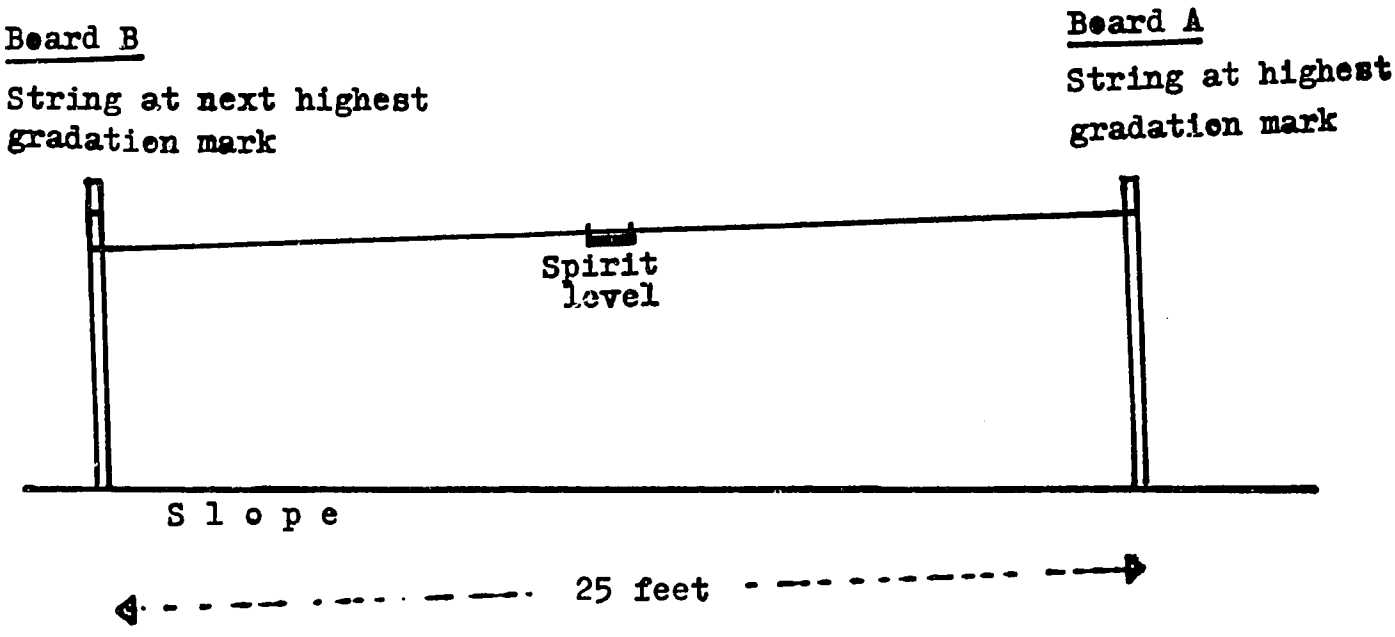


You need some pegs and a flat straight object such as a board or a book. Hold the board as horizontally as possible at the eye level and in line with the first peg. Move yourself up and down the slope until your eye is exactly in line with the peg. Now put a peg in where your feet are. Move down the slope and repeat the process for peg No. 3.

Fig. 16

How to set out a graded terrace line

You need a line level, which consists of two sticks (boards) marked in gradations of 3 inches (7.5 cm) and a string of 25 feet (7.5 m) stretched between the boards. See the figure below. You also need a spirit level, hooked onto the middle of the string, to check that the string is horizontal. This will occur, when the air bubble is in the centre of the spirit level. If you want to peg a terrace to a gradient of 1 %, put the string on board B at the second gradation mark from the top and move the board up and down the slope until the spirit level shows that the string is horizontal.



If you want a gradient of only 0.5 %, put the string between the first and the second gradation marks of the board.

Using boards graduated in the metric system you can have a distance between the boards of 10 m. In this case a difference in height of 10 cm = 1 %, 5 cm = 0.5 % and 2.5 cm = 0.25 %.

8. COSTS OF CUTOFF DRAINS AND TERRACES

A daily worker can dig about 3 cu.m/day. The daily wage is 7.90 shs/day. For normal soils the digging cost varies between 2.05 and 3.25 shs/cu.m. It is preferable to express costs of digging cutoff drains and terraces in shs/cu.m of excavated channel instead of shs per m length of the channel, as this cost depends on the size of the cross-section. This can be seen from the table on the next page showing data as to the cost of digging by hand (1978/79 wage levels):

Cross-sections			Costs in Shs/m if piece work payment is	
Depth	Average width	Area	2.05 Shs/cu.m	3.25 Shs/cu.m
m	m	sq.m		
Fanya Juu terraces:				
0.6	0.6	0.36	0.75	1.05
0.9	0.6	0.54	1.10	1.55
Cutoff drains:				
0.6	1.2	0.72	1.45	2.10
0.6	1.5	0.90	1.85	2.90

As can be seen above, the digging costs of a cutoff drain may vary between 1.45 Shs/m and 2.90 Shs/m. The cost of terracing varies between 0.75 Shs/m and 1.55 Shs/m. The cost per acre of terracing depends on the percentage and the measure used in the layout of the vertical interval. In the table below the cost is assumed to be 1.15 Shs per metre length of terraces:

Slope	Normal formula			Bench formula			Constant V.I.		
%	V.I. feet	H.I. feet	COST Shs/acre	V.I. feet	H.I. feet	COST Shs/acre	V.I. feet	H.I. feet	COST Shs/acre
5	3.25	65	240	1.6	32	480	-	70	218
10	4.5	45	345	2.25	22.5	690	6	60	254
15	5.75	38	40	2.9	19	802	6	40	382
20	-	-	-	3.5	17.5	879	6	30	506
25	-	-	-	4.1	16.5	930	6	24	637
30	-	-	-	4.75	16	950	6	20	762
35	-	-	-	5.4	15.5	990	6	17	895
40	-	-	-	-	-	-	6	15	1,012
45	-	-	-	-	-	-	6	13	1,164
50	-	-	-	-	-	-	6	12	1,243
55	-	-	-	-	-	-	6	11	1,410

Machine-made terraces, only suitable for slopes of up to 15 %, are usually neither cheaper nor better than terraces made by hand. The hourly cost (1979) per productive hour for a Motor grader (Cat 12 or 14) is Shs 190 - 225. Under good conditions a Motor grader can construct approximately 150 m of terraces per hour, i.e. Shs 1.30 - 1.50 charged per metre.

Machine-made terraces have to be paid for in cash in advance, and an order for the work can be placed with the Soil Conservation Station of the Ministry of Agriculture. Hand-made terraces can be dug by the farmers themselves during the off-season, and at a pace which is convenient to the individual farmer.

9. GULLY CONTROL

When rills have increased in size so that they cannot be levelled out through ploughing, they are called gullies. Such channels can rapidly increase in size, especially in silty- fine sandy soils, even if the water flows are small.

Erosion processes in gullies:

At the head of a gully a "waterfall" type of erosion causes a rapid cutting back into the slope (fig. a).

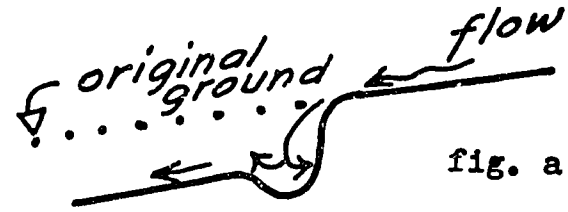


fig. a

If the earth layer is thick enough, the flow over the floor of the gully will deepen the gully. This deepening does not stop until the gully has reached solid rock (fig. b, showing 3 stages of erosion in the longitudinal direction of the gully).

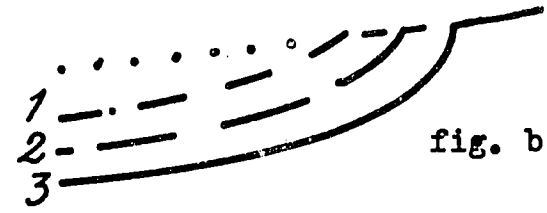


fig. b

The deep erosion makes the sides of the gully unstable and causes movement of the soil from the sides of the gully to the bottom. In this way the gully is not only deepened but also widened (fig. c, showing a cross-section of the gully with 3 stages of erosion).

fig. c

It is not difficult to stop gully erosion in its early stages of development. Unfortunately farmers usually pay little attention to gullies until it is too late, i. e. the gullies have grown so large that they cannot be returned to cultivated land. Small gullies 1-2 feet deep can be filled with trash and soil ploughed over from the sides of the gully. Putting loose brushwood, hay, tree branches, etc into large gullies is useless in stopping erosion, and refilling with earth should be done only in exceptional cases. Other preventive measures are needed, adapted to the local conditions.

Measures

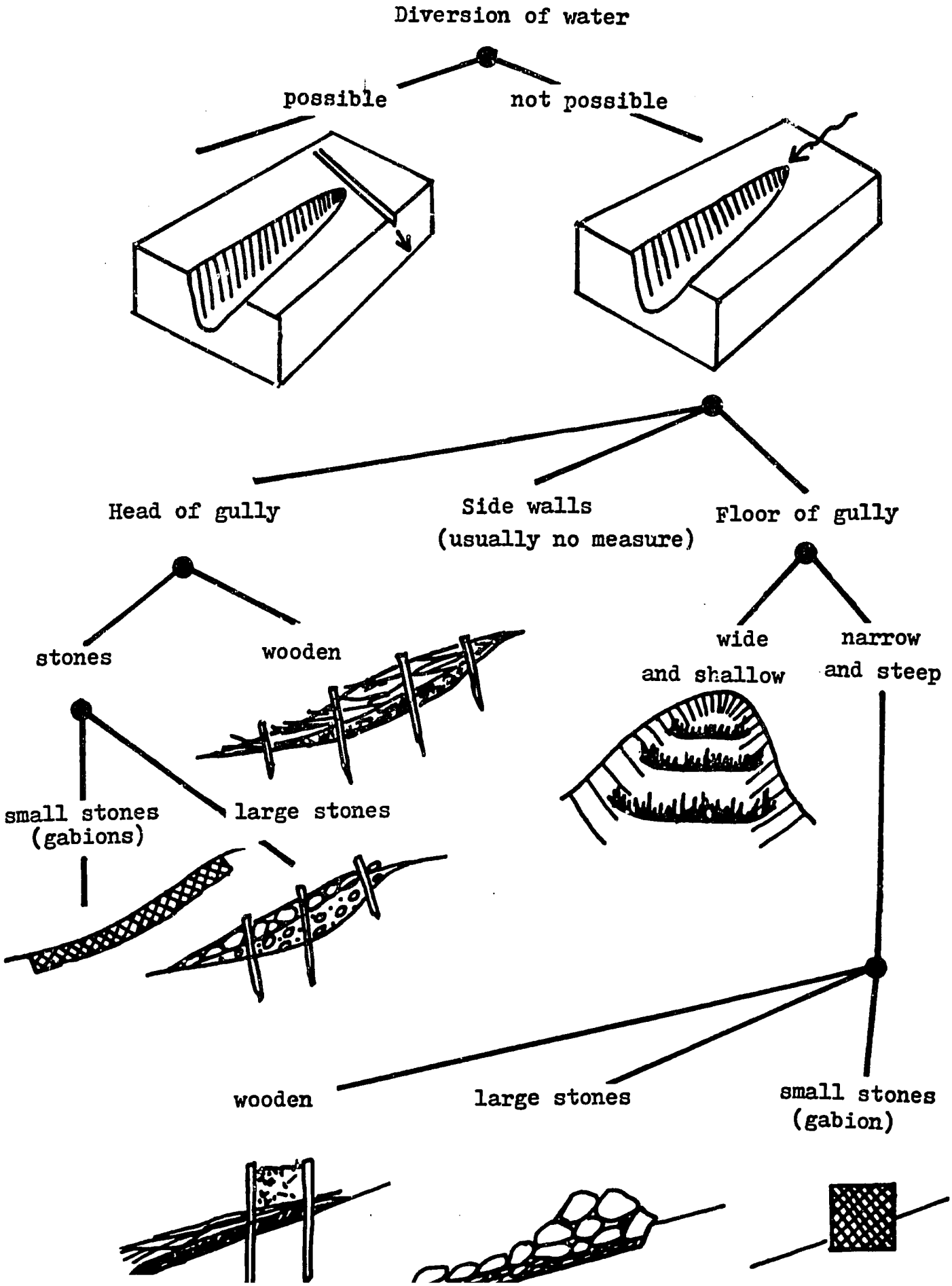
There are two main measures to control gully erosion:

1) Diverting the water which enters the gully by means of a cutoff drain, or a ridge of soil (see the figure on the next page).
2) Preventing the water in the gully from causing erosion by protecting the head and the floor with erosion resistant materials. The measures will differ according to the shape of the gully:
   a) a wide, shallow and not very steep gully, compared to
   b) a narrow and steep gully (with concentrated large water flows).

When choosing the requisite measure it is necessary to consider the availability and cost of construction materials:

a) poles and brushwood
b) stones and boulders
c) only small stones.

The right measure for gully control can be selected from the figures below. For a more detailed design see Appendix 4.



10. PROTECTION OF RIVER BANKS

Most of the transported load in a river comes from soil erosion in the catchment area. However, part of the load comes from erosion in the river bed, and a small part of the transported load originates from erosion of the river banks. The area of those is small compared to the vast areas on both sides of a river. Consequently the erosion of river banks is a minor problem compared with soil erosion on cultivated and grazing land on both sides of a river.

A river cannot erode above its highest water level (flood level). The area below the highest water level (the erosion zone) is not liable to be eroded when there is a wide section of the river and low stream velocity.

However, in narrow sections of a river the stream velocity will increase and cause erosion, especially in the bends (see Figs. 22 and 23 on the next page).

Regarding these facts there are the following rules for the protection of river banks:

1) Natural vegetation up to the extreme high water level should be protected as much as possible, because vegetation prevents erosion by water flows. If the natural vegetation in the flooded zone has been removed by man or erosion, it must be replaced with permanent grass or trees.
2) Cultivation is not permitted on sloping river banks liable to be flooded and eroded by streaming water. Not only should the normal annual high water level be considered but also the extreme high water flow level.
3) Cultivated slopes above the flooded zone should be regarded as ordinary slopes, i.e. terracing between 5 and 55 % and permanent grass and/or trees on slopes exceeding 55 %.
4) It is not permitted to cultivate land to the crest of a high slope. In river valleys, there should be a strip of grass along the crest above the slope.
5) There should be a strip of grass 1 - 2 feet wide along the banks of all small watercourses.

RIVER PROTECTION

Fig. 22

Low river banks in a wide valley

where the ground of the flood zone does not need to be protected

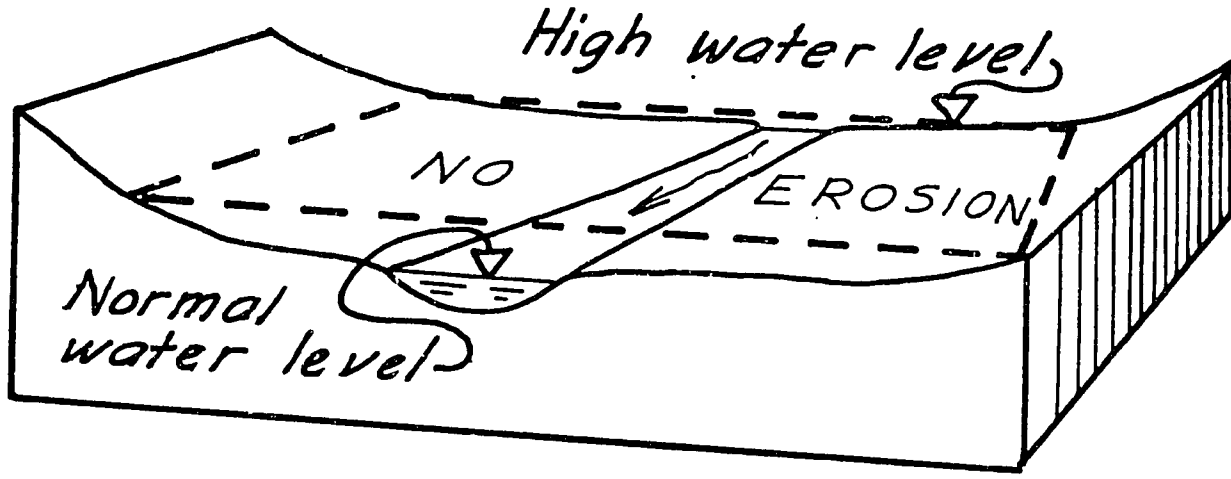
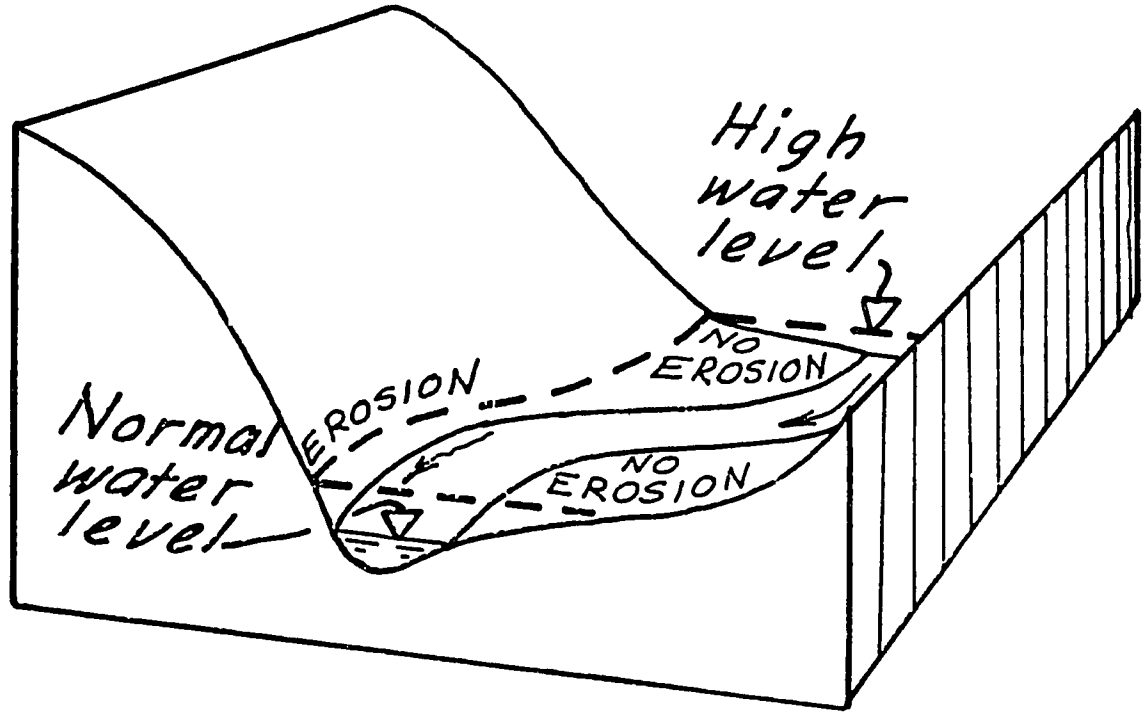


Fig. 23

Narrow and deep valley

where the flow is likely to be sufficient to cause erosion, especially in the steep bends



11. EROSION BY WIND AND PROTECTIVE MEASURES

There are two main types of erosion causing transportation by wind:

1) particles of sand moved more or less along the ground (wind drift)
2) fine particles lifted up into the air (suspended material).

1) Wind drift of sand

Wind drift of sand usually occurs in arid climatic zones and on sandy beaches. It can be stopped through the planting of suitable plants or through the construction of sand catching walls.

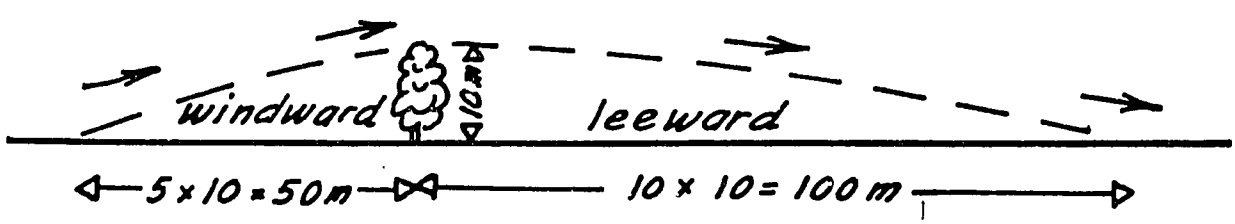
2) Usual wind erosion

Soil particles are detached from the ground by wind, when:

a) the soil is bare and dry
b) soil particles are of sand, silt or loam grade (i.e. loamy fine sand)
c) the velocity of the wind is high enough and eddies occur.

Wind erosion can be disastrous, if the topsoil is removed. This can happen not only in arid and semi-arid areas, but also on cultivated land in high potential areas during parts of the year, when there is no rain and if there is no crop cover or any other protection.

To reduce the velocity of the wind, rows of trees should be planted perpendicular to the prevailing strong winds. Such wind velocity is reduced not only on the leeward side (for a distance of at least 10 times the height of the windbreak) but also on the windward side (for a distance of up to 5 times the height of the windbreak). See the figure below:



Often there is space for only one row of trees as a windbreak. However, the windbreak can be more efficient, if smaller trees and/or bushes are planted on the windward side, or on both sides (a shelter belt).

12. SOIL CONSERVATION ON GRAZING LAND

Development of erosion on grazing land

How the erosion develops is well known. Overgrazing, in combination with droughts, causes bare spots increasing in size. Perennial grasses are replaced by annual grasses and coarse weeds. The trampling of cattle year after year compacts the surface of the bare ground. The rain water is not infiltrated into the soil but runs off on the surface. Rain and rill erosion remove the topsoil. On bare ground wind erosion may commence.

On slopes gully erosion can start. The gullies cut deeper down to the bedrock and backwards to the solid rocks of the hills, or their crests. The land will be dissected by more or less parallel gullies. Later on branches develop from the gullies so that they will have a treelike ramification. This is the final stage and the definite end to cultivation and good grazing.

Measures

The most important soil conservation measure in such areas is grazing control (destocking, if necessary, and rotational grazing). Deep and loamy soils are best suited for rehabilitation (sandy loam, silt loam and loam). The rainfall should preferably be more than 300 mm/year.

Rehabilitation should start with:

1) closing the area to grazing and thereby allowing natural grasses to establish a cover all over the ground (grazing control) or
2) reseeding with suitable species of grasses, after some land preparation (vegetation modification).

1) Closing an area

To increase the infiltration, ploughing can be done along the contour (horizontally), thereby retaining the water. There can be a spacing of one to three metres between the plough furrows (pasture furrows), one metre on completely denuded land and three metres in areas with some grass and weeds. It is recommended to burn the area as soon as sufficient combustible vegetation is available, before grazing is permitted again.

2) Closing and reseeding

Usually scratch ploughing, by ox-plough or jembe, is needed. Harrowing after seeding should not be done except in areas of high rainfall.

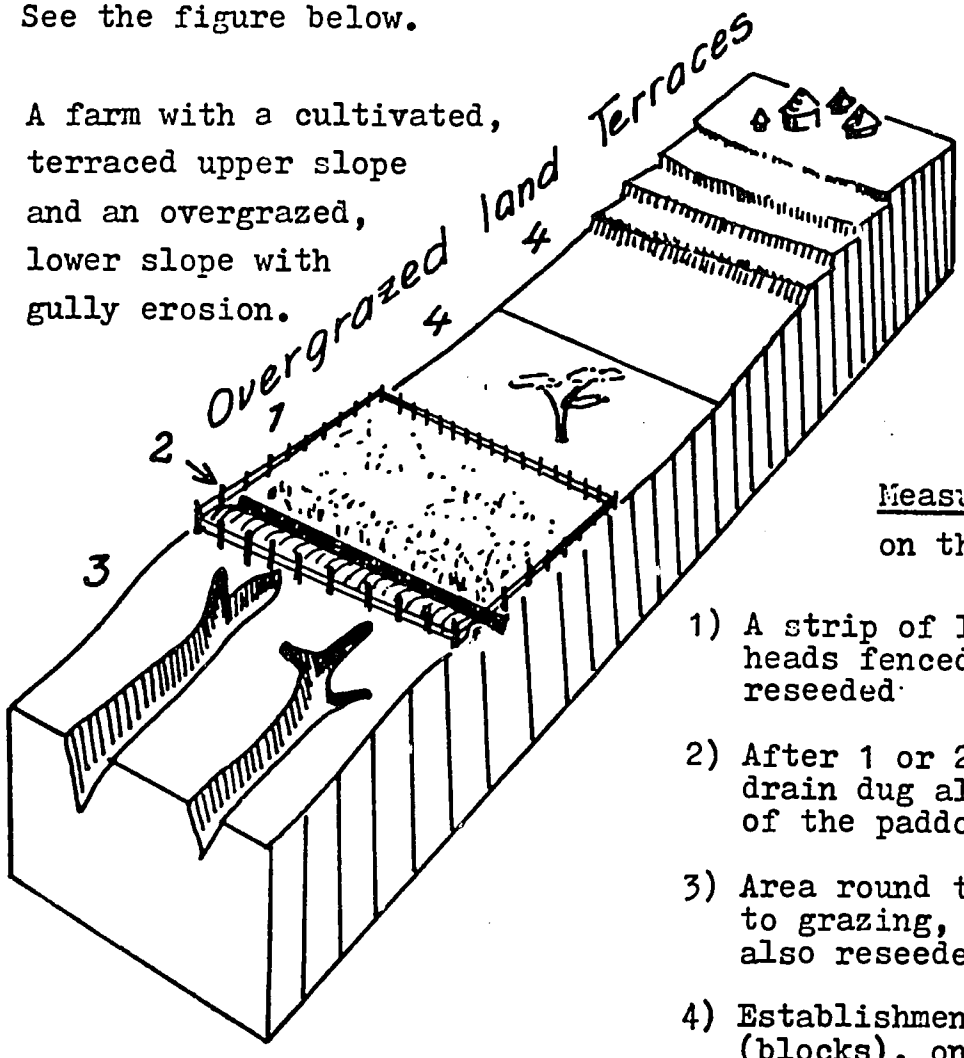
As to the time of seeding it is best to reseed at the beginning of a rainy season and preferably that one followed by the less pronounced dry season, if there are two dry seasons.

About 100 seeds per square metre are needed for broadcasting by hand, as the germination rate is often only 10 %. However, the rate varies for different species.

Perennial grasses should be used, as they usually live for up to 6 years. In drier climatic zones the proportion of annual grasses increases, and below 250 mm of annual rainfall no perennial grasses survive. The table on the next page shows recommended species for different natural conditions (mainly after Bogdan and Pratt).

On communal land there are difficulties in closing (and fencing) areas for establishing better grass, and having these areas respected by more or less nomadic people. On farms something has to be started. See the figure below.

A farm with a cultivated, terraced upper slope and an overgrazed, lower slope with gully erosion.



Measures to be taken on the overgrazed slope:

1) A strip of land above the gully heads fenced, ploughed and reseeded

2) After 1 or 2 years a cutoff drain dug along the lower side of the paddock, if needed

3) Area round the gullies closed to grazing, alternatively also reseeded

4) Establishment of other strips (blocks), one by one for rotational grazing

5) Control measures against erosion in the gullies, if necessary (see Gully Control pages 18-19).

Two rules to remember:

1) Measures against erosion without grazing control are useless.
2) Cutoff drains, especially in silt and sandy soils, are useless without grazing control and establishment of grass cover on the ground round the gullies.

Annual rainfall requirement in mm	Species of grass	Soils preferred	Occurrence in Kenya	Seed rate per acre
750 or more	Cynodon dactylon (Star Grass)	Sand and silt	Up to 2,400 m	5-8 oz.
700-675	Chloris gayana (Rhodes Grass)	Silt, sand, loam but not heavy clay	Common 600-2,100 m	8 oz.
	Panicum maximum (Guinea Grass)	Sand, silt, loam	Common in all semi-arid areas	1-1.5 lb.
	Themeda triandra (Red Oat Grass)	Sand and loam, black cotton soil	Above 1,500 m	5 oz.
	Botriochloa insculpta (Sweet pitted Grass, Creeping blue Grass)	Both red and black soils	e.g. Nairobi area and Machakos District	1 lb.
700-450	Cenchrus ciliaris (African Foxtail, Buffel Grass)	Sand, silt, loam	Widespread in dry areas	2.5-3 lb.
600-550	Enteropogon machrostachysus (Bush Rye)	Sand and loam, also rocky ground	300-1,500 m, e.g. Baringo District	6 lb.
	Eragrostis superba (Masai Lovegrass)	Sand and loam,	Used in Kitui and Machakos Districts	10 lb.
500	Eragrostis caespitosa (Cushion Lovegrass)	Poor sand	Up to 1,500 m, e.g. from Yatta Plateau to Embu	0.5 oz.
300-200	Eragrostis cilianensis (Grey Lovegrass)	Alluvial soils	Northern Kenya	2 oz.
	Latipes senegalensis (Hook Grass)	Also on eroded slopes and rocky ground	Found in Machakos District and towards Voi	3 lb.
	Panicum coloratum (Coloured Guinea Grass)	Best on heavy soils	Northern and south-eastern Kenya	1 lb.

13. REHABILITATION OF DESERTIFICATION AREAS

In many parts of the medium and low potential areas the top soil has been lost, and the ground is bare, dry and compacted. Methods for rehabilitation are:

1) planting fast growing trees
2) grazing control
3) water conserving measures on arable land.

These measures are most reliable in areas with loam soils (including sand and silt loam), and with an annual rainfall exceeding 250 mm.

Trees

The aim is to restore soil fertility, decrease erosion and improve the micro climate. All this can be achieved by planting trees, either scattered or as shelter belts. The trees will "pump" nutrients from great depths and return them to the ground litter. The shade and the reduced wind will increase the humidity. Decreased ground temperature will favour moisture and preservation of humus. Soil loss through wind and rain erosion will decrease.

If planted as shelter belts there should be 1-6 rows of trees, preferably 4 rows with trees 3 m apart. The seedlings usually need protection against goats and other animals for at least 2-5 years.

Trees suitable for planting in rows:

Cassia siamea	for fuel and poles, not eaten by termites; seeds sown in situ; on well drained soils up to 1,200 m above sea level and more than 500 mm annual rainfall
Eucalyptus camaldulensis	fast growing with high timber yields (4-10 years); a disadvantage is competition with crops
Azadirachta indica (neem tree)	fast growing with valuable timber; found even on stony or saline soils, below 1,200 m above sea level and annual rainfall more than 300 mm
Casuarina equisetifolia	a fuel tree found on the coast; the roots must reach subsoil water; does not like inundation or clay soils

If trees are planted scattered, they can increase the yields of crops and grasses:

Acacia albida	ideal fodder tree with foliage during the dry season; best on alluvial soils and in depressions; altitude less than 2,800 m above sea level and annual rainfall preferably more than 500 mm
Prosopis	valuable timber, nutritious pods eaten by humans and cattle; found on poor sandy and rocky soils even if the annual rainfall is less than 500 mm; up to 1,500 m above sea level

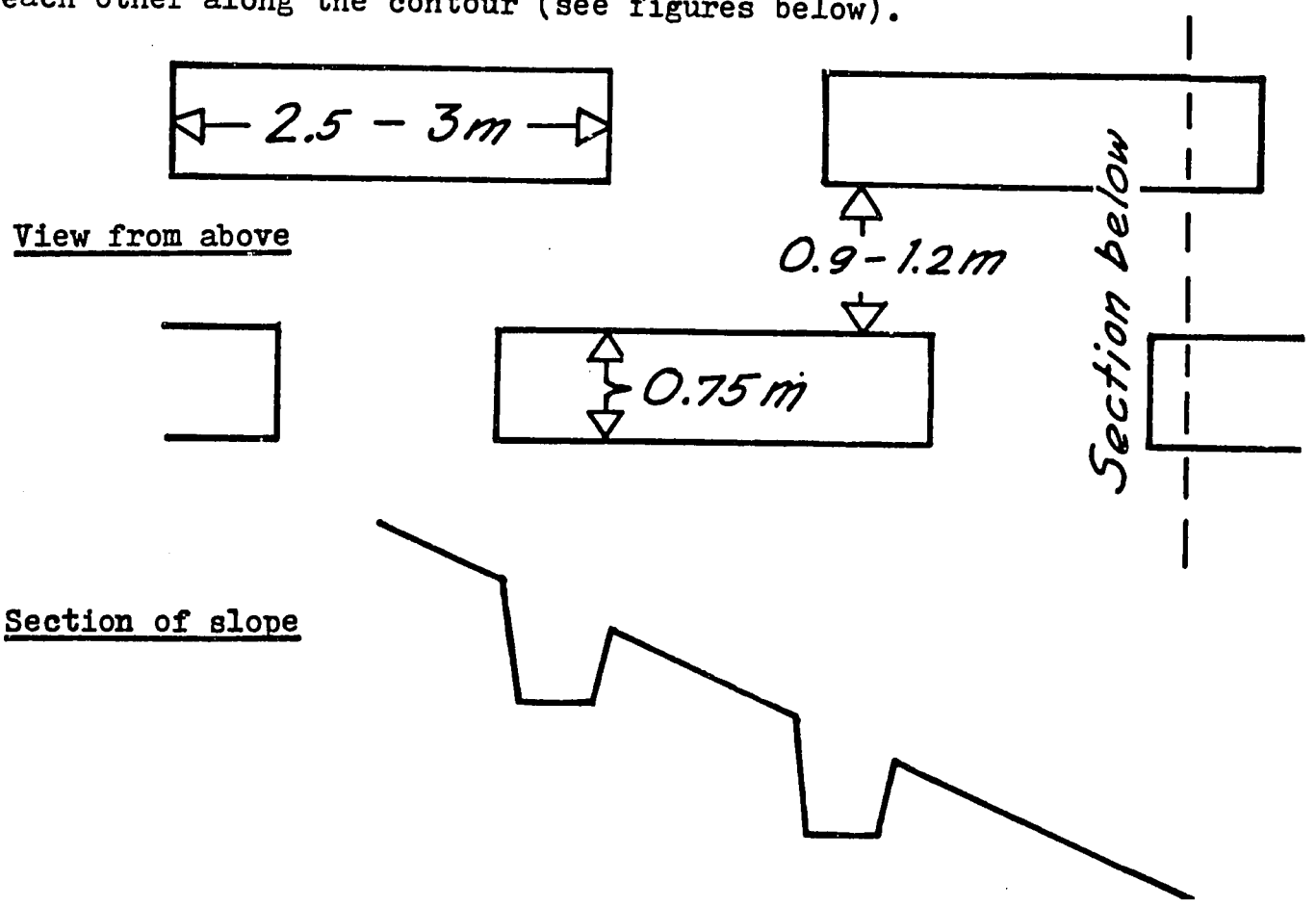
Leucaena leucocephala (=glauca)	quick growing fodder tree with deep roots, fodder cut every 6 - 8 weeks; not suitable for acid soils ; more than 250 mm rainfall
Conocarpus lancifolius	fast growing evergreen fodder tree with good timber yields; found on deep soils and heavy clay along river beds up to 4oo m above sea level

Grazing control

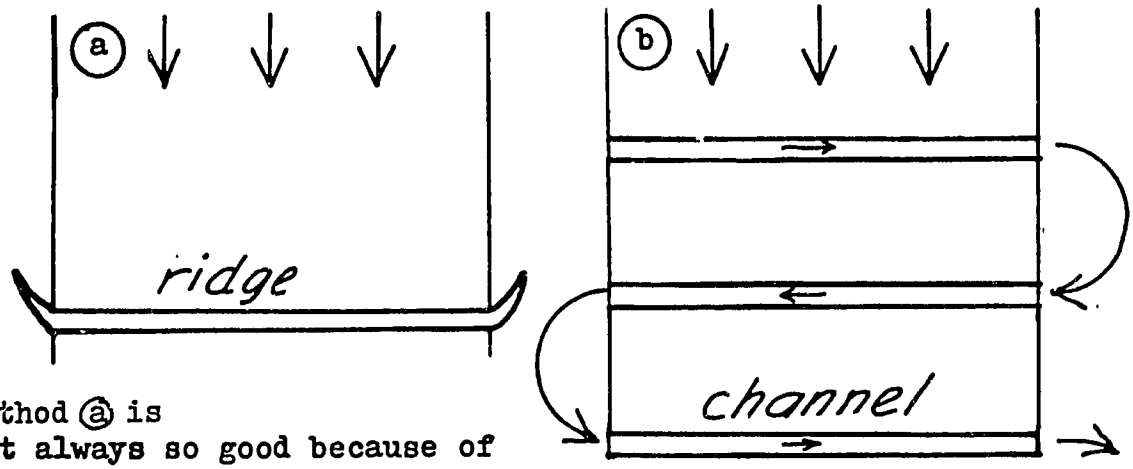
How to establish and maintain grass is described on page 23. Digging narrow cutoff drains or channel terraces is often a waste of money, as such excavations will be filled up with sediment, unless a grass cover has been established.

Water conserving measures on arable land

On fine- and medium textured soils contour ploughing is a simple and efficient method of conserving water in the ground.
On erodible (sandy-silty) slopes, not too steep (preferably less than 10 - 15 %), sisal can be planted in rows along the contour to develop bench terraces, which will retain nutrients and increase the moisture in the ground.
To collect water, even on steep slopes, pitting can be used, i.e. a series of short trenches (2.5 - 3 m long), 0.75 m deep and 0.75 m wide. The trenches should have a spacing of 0.9 - 1.2 m and overlap each other along the contour (see figures below).



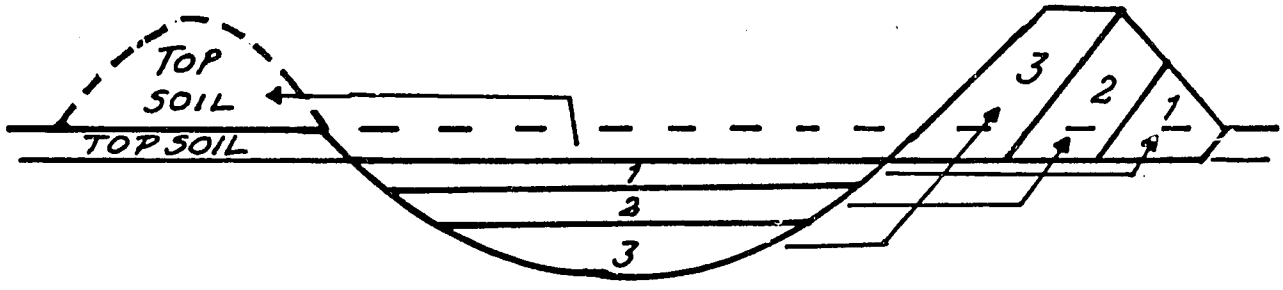
Water spreading a) through construction of dam embankments, or b) leading the water zig-zag down the slope from terrace to terrace, terraces separated by ridges or channels leading the water:



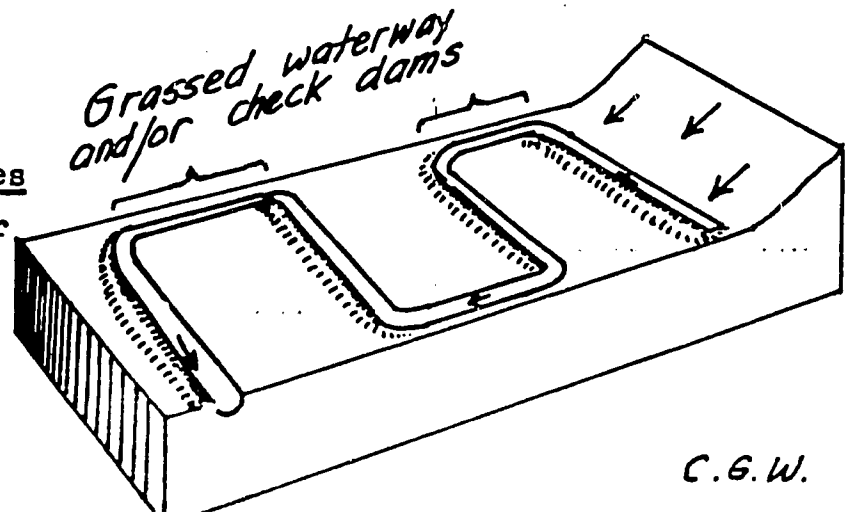
Method ⓐ is not always so good because of sedimentation of clay, and the risk of increased salinity on clay soils.

Dam embankment

When constructing a good wall (measure ⓐ above) the topsoil should be removed. After that excavation and subsequent filling-up should be done in layers (see the figure below). The idea is that the layers should be perpendicular to the seepage, thus reducing it. Every layer should be well compacted, if possible with some moisture.



View of channel terraces connected to each other



13. GOVERNMENTAL POLICY FOR SUBSIDIES

In principle the Governmental policy is that soil conservation on individual farms should be done by the farmers themselves. The main contribution of the Government is the digging of cutoff drains, which will take care of excess water flowing from areas outside the farms (plateaux, large hill-sides, road side ditches) or which will divert water from large and growing gullies which devastate the land.

Mechanized soil conservation is best suited to large-scale farming, or vast and semi-arid areas without steep slopes. In such areas the cost of mechanized soil conservation can be subsidized by the Government up to 50 %.

The Government can also provide farmers doing terracing with cuttings of fodder grass and tree seedlings free of charge. Fruit tree seedlings should be distributed at low, subsidized cost.

In overgrazed areas, where farmers agree upon rehabilitation, seeds can be provided free of charge.

14. BENEFITS OF SOIL CONSERVATION

Terraces and cutoff drains do not mean any loss of land, as the terrace edges and the cutoff embankments can be used for planting fodder grass and trees. Grass strips will promote more and/or better cattle.

Eroded soil is irreplaceable. The terraces will save the soil for the future. Yields will not decrease but will increase by 10 - 50 %. Cultivation operations will be easier on level benches than on a steep slope.

WHAT IS PERCENTAGE SLOPE ?

Usually the inclination of a slope is expressed in degrees of the angle between the slope and a horizontal line (Fig. a below). In soil conservation, however, the steepness of a slope and the gradient (inclination) of a terrace in its longitudinal direction are expressed as the height in percent of the length, e.g. a drop of 18 feet in 100 feet horizontally = 18 % (Fig. b below).

Fig. a

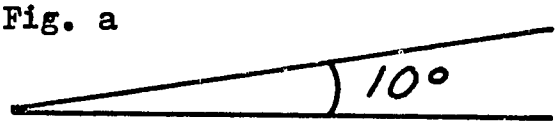
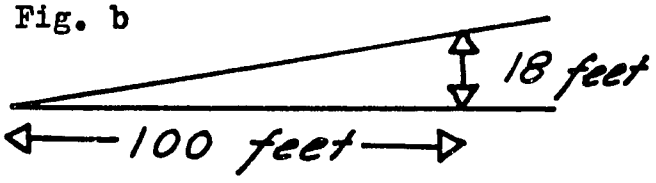
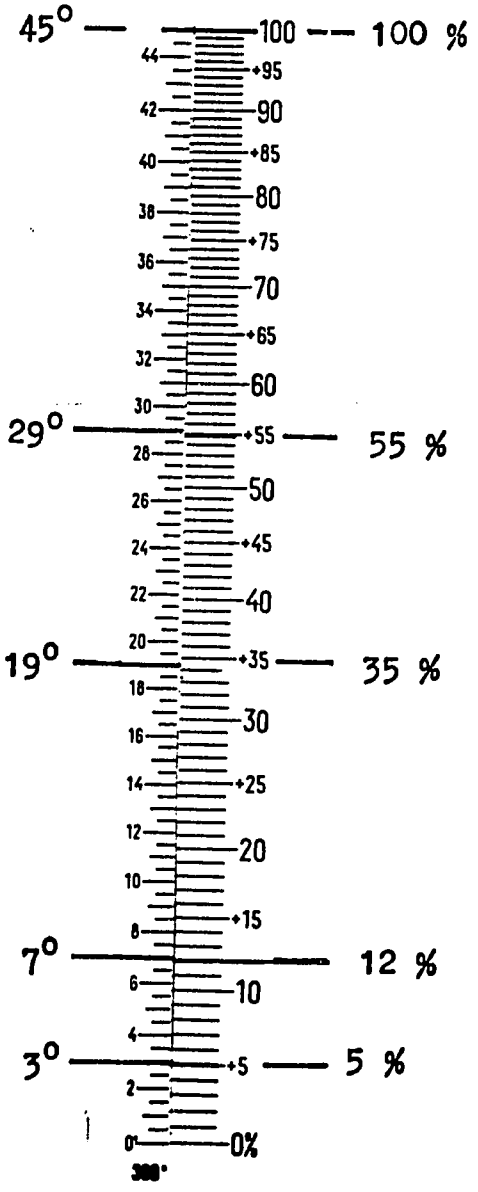


Fig. b





The table on the right shows the conversion of degrees into percentage and vice versa.

How to measure the percentage slope practically see Fig.14 on page 15.

HOW TO CALCULATE THE DIMENSIONS OF A CUTOFF DRAIN

1. How to calculate surface runoff (Cook's method)

The size of a catchment area (runoff area) can be measured either on a map or in the field, or usually just estimated.
Under African conditions there are high rainfall intensities even in dry areas. The runoff is much more influenced by the local surface conditions within the runoff area, than by rainfall intensity. Consequently rainfall can be disregarded in the calculation work.

The calculation of the runoff is based on the following characteristics of the area: 1) vegetative cover, 2) infiltration rate of water into the ground, and 3) topography inclusive of slopes. The table below shows the numerical values for these three characteristics under African conditions:

1) Vegetative cover		2) Infiltration rate		3) Topography	
Forest or thick grass cover	10	Well drained soils, e.g. sand	10	Flat land or gentle slopes (0-5 %)	5
Scrub or medium grass cover	15	Moderately pervious soil, e.g. silt	20	Moderate slopes (5-10 %)	10
Cultivated land	20	Slightly pervious soil, e.g. loam	25	Rolling or hilly land (10-30 %)	15
Bare or sparse cover	25	Shallow soils with impeded drainage	30	Steep slopes (exceeding 30 %)	20
		Clay or rock	40	Mountainous	25
		Impervious soils and waterlogged areas	50		

From each of the three columns the most appropriate value should be selected, and the values should be added to give the summarized characteristics.
Now the runoff in cusecs can be read from a table using: a) the runoff area in acres and b) the characteristics. Dependent on the shape of the runoff area one of three tables should be used: A) square (p.32), B) broad and short (p.33) or C) long and narrow area (p.34).

The differences between different shapes can be seen from the drawings below.

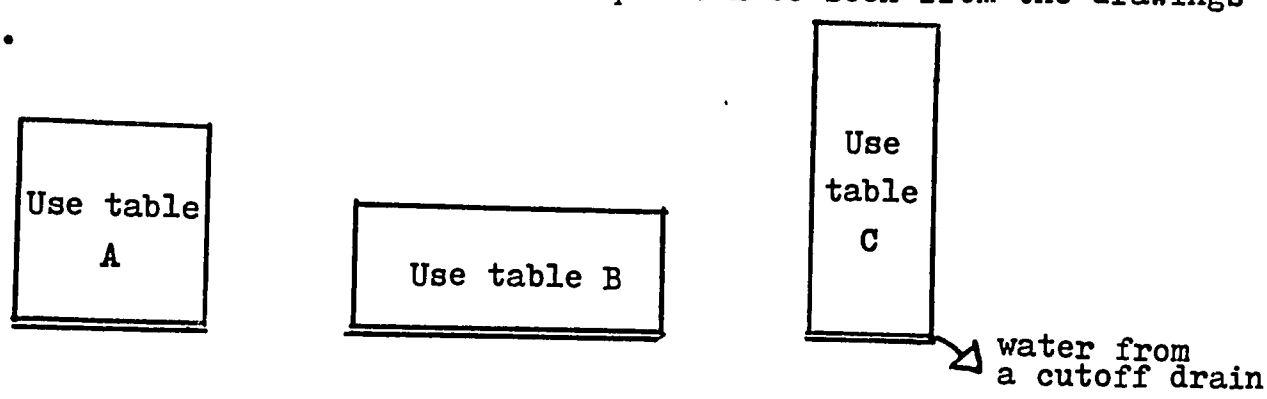


Table A. Runoff in cusecs from a square runoff area (more or less square)

Runoff area in acres	Summarized characteristics of the runoff area											
	25	30	35	40	45	50	55	60	65	70	75	80
5	3	5	7	9	11	13	15	17	19	21	25	30
10	5	8	11	14	17	21	25	30	35	40	46	52
15	7	11	15	20	25	30	35	42	50	58	66	75
20	10	15	20	25	30	38	46	55	65	75	85	95
30	12	18	25	33	42	52	64	76	90	105	120	135
40	15	20	30	40	50	65	80	95	110	130	150	175
50	17	25	35	50	65	80	100	120	140	165	190	215
75	20	35	50	70	90	115	140	170	200	235	270	310
100	25	45	65	90	120	150	180	220	260	300	350	400
150	35	60	90	125	165	210	260	310	365	425	500	580
200	40	80	120	170	220	270	330	400	470	550	640	750
250	50	90	140	190	245	310	385	470	565	670	785	910
300	60	100	150	210	280	360	450	550	660	780	910	1050
350	70	120	180	240	330	430	540	640	760	890	1030	1160
400	80	140	200	280	370	490	600	710	860	990	1160	1280
450	90	150	220	300	410	540	660	780	940	1090	1280	1390
500	100	160	240	330	450	590	720	850	1030	1200	1390	1520

Example: A hillside in Machakos District

First estimate the width and the length of the runoff area, e.g. width 200 m and length 200 m, giving an area of 40,000 sq.m, to be divided by 4,000 sq.m (= 1 acre) to get the area in acres = $\frac{40,000}{4,000}$ = 10 acres.

After that find out the characteristics:

1) scrub and grass 15
2) shallow soil 30
3) steep slopes 20

summarized 65

Now read off from the table above:

a) Runoff area in acres 10

b) Summarized characteristics 65

giving a runoff of 35 cusecs.

Table B. Runoff in cusecs from a broad and short runoff area (more or less rectangular and along the contour)

Runoff area in acres	Summarized characteristics of the runoff area											
	25	30	35	40	45	50	55	60	65	70	75	80
5	4	6	8	10	12	15	18	21	24	27	31	35
10	7	10	12	15	20	26	32	38	44	51	58	65
15	9	14	19	25	32	40	48	57	66	75	85	95
20	12	18	25	32	40	50	60	70	80	95	110	125
30	16	25	35	45	55	70	85	100	115	135	155	175
40	19	30	42	55	70	90	110	130	150	175	200	225
50	23	35	50	65	85	110	135	160	185	210	240	275
75	30	50	70	95	120	150	185	220	255	295	340	390
100	35	60	85	120	160	205	250	295	345	395	450	510
150	45	85	125	170	220	280	340	410	485	560	640	725
200	55	100	150	205	280	360	445	535	630	730	830	935
250	65	125	190	260	340	440	550	665	780	900	1020	1145
300	80	145	220	300	390	490	600	720	850	990	1150	1350
350	100	170	260	340	460	580	700	830	980	1160	1340	1510
400	110	210	290	400	520	670	800	920	1120	1300	1500	1660
450	120	220	320	440	580	740	880	1020	1240	1420	1670	1810
500	130	230	340	470	630	800	960	1110	1350	1560	1800	1970

Example: Width 500 m and length 200 m,
giving an area of 100,000 sq.m = 25 acres.
The same characteristics as on p. 32 = 65.
Now read off from the table above:
The runoff area in acres is 25 (i.e. between 20 and 30 in the table).
Summarized characteristics = 65.
The runoff for 20 acres will be 80 cusecs, and for 30 acres 115 cusecs.

Thus $\frac{20 + 30}{2}$ = 25 acres and $\frac{80 + 115}{2}$ = 98 cusecs.

Table C. Runoff in cusecs from a long and narrow runoff area (more or less rectangular along the slope, which is the most common shape of a small farm)

Runoff area in acres	Summarized characteristics of the runoff area											
	25	30	35	40	45	50	55	60	65	70	75	80
5	3	4	5	6	8	10	12	14	16	19	22	25
10	4	6	9	12	15	18	22	26	30	35	40	45
15	6	9	12	16	20	25	30	35	41	47	53	60
20	7	11	16	21	27	33	39	46	54	62	70	80
30	9	15	21	28	36	46	56	66	76	88	100	115
40	12	20	28	36	46	58	70	85	100	115	130	145
50	15	25	35	45	60	75	90	105	120	135	155	175
75	20	32	45	60	80	100	120	145	170	195	225	255
100	25	40	55	75	100	130	160	190	220	255	290	330
150	32	55	80	105	140	180	225	270	315	360	410	470
200	40	70	100	135	180	235	290	345	405	470	540	615
250	45	80	120	160	215	280	345	415	490	570	660	760
300	50	90	135	190	250	320	400	480	570	670	780	900
350	60	100	150	200	280	370	470	550	660	770	890	1000
400	70	120	170	240	330	420	520	610	740	860	1000	1100
450	80	130	190	260	360	470	570	670	820	940	1100	1200
500	90	140	200	280	390	510	620	740	890	1040	1200	1320

Notes

1 cusec (cubic foot per second) = 28.3 litres/sec.

If the runoff area in the first column of the tables is read in hectares instead of in acres and if the figures for the runoff in cusecs are divided by 0.07, the runoff values of the tables will show cubic metres per second instead of cusecs.

The tables are computed for a period of 10 years, which is the period usually used for the design of soil conservation works. For shorter or longer periods the following conversion factors should be used:

2 years	0.90	10 years	1.00	25 years	1.25
5 years	0.95			50 years	1.50

The tables on pages 32-34 are from Norman Hudson's textbook "Soil conservation", 1971.

2. How to find the cross-sectional dimensions of cutoff drains by use of four tables and two calculations (Durbach's method)

1. A table for finding the maximum velocity of water flow in ft/sec (the fastest water flow without erosion) from: a) the soil type and b) the degree of grass cover in the channel (expected after 2 years):

Table 1

Soil type	Grass cover expected in the channel: Sparse cover (suggested for dry areas)	Medium cover (for normal use)	Very good cover (suggested for highlands)
Silty sand	1.0	2.5	4.5
Sand	1.5	3.0	5.0
Coarse sand	2.5	4.0	5.5
Sandy soil	2.5	4.5	6.5
Loam	3.0	5.0	7.0
Clay loam	3.5	5.5	7.5
Clay	4.5	6.0	8.0
Gravel	5.0	6.0	
Soft rock, hardpan	6.0	7.0	

2. A table for finding the channel factor $\left(= V \times \sqrt{\frac{L}{H}}\right)$ from: a) the gradient of the channel expressed in Height:Length or in % slope, and b) the maximum velocity in feet/second found in table 1 above:

Table 2

Gradient Height:Length		%	Maximum velocity in feet/sec 1.0	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0
1:50	=	2.0	-	-	14	21	28	35	42	50	57
1:100	=	1.0	-	15	20	30	40	50	60	70	80
1:200	=	0.5	14	21	28	42	56	71	85	99	113
1:400	=	0.25	20	30	40	60	80	100	-	-	-

3. A table for finding the depth of the channel using the channel factor found in table 2:

Table 3

Channel factor from table 2	Depth of the channel in feet	
20	0.25	in view of the risk of silting up if possible not less than 1 foot
32	0.50	
42	0.75	
50	1.00	
58	1.25	
65	1.50	
72	1.75	
79	2.00	
86	2.25	
92	2.50	
98	2.75	
104	3.00	

4. A table for finding the discharge (in cusecs per foot width of channel) from a) the depth of the channel (in feet) and b) the channel gradient (as a percentage):

Table 4

Depth of channel in feet	Gradient as %			
	2.0	1.0	0.5	0.25
0.25	1.0	0.7	0.5	0.3
0.5	3.1	2.2	1.6	1.1
0.75	6.0	4.3	3.0	2.2
1.0	9.7	6.8	4.8	3.4
1.25	13	10	7.0	5.0
1.5	16	13	9.5	6.7
1.75	19	17	12	8.6
2.0	21	21	16	11
2.25	24	24	19	13
2.5	27	27	23	16
2.75	29	29	26	18
3.0	32	32	32	22

5. The width of the channel in feet (of trapezoid or parabolic section) can be calculated by dividing the runoff (in cusecs) by the discharge figure arrived at from table 4.
For a rectangular section reduce the width by 1/3 as shown in the figure on page 37.

3. Example of a calculation

The soil is clay loam and the grass cover of the cutoff channel is not expected to be very good.
According to Table 1 the maximum velocity of the water flow will be 5.5 feet/sec.

The gradient of the channel is 0.5%. As the maximum velocity is 5.5 feet/sec, the channel factor will be between 71 and 85 according to Table 2 = $\frac{71+85}{2}$ = 78.
As the channel factor of 78 is the closest figure to 79 in the first column of Table 3, the depth of the channel should be read as 2 feet in the right hand column of Table 3.

In Table 4 a channel depth of 2 feet and a gradient of 0.5 % gives a discharge of 16 cusecs per foot width of channel.

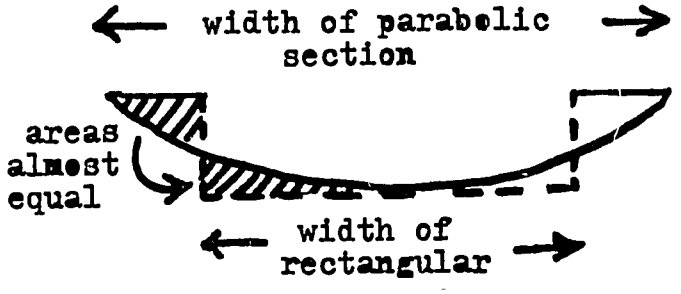
The catchment area is estimated to be 500 m wide across the slope and 200 m long down the slope, i.e. 100,000 square metres. By dividing this figure by 4,000 square metres (= 1 acre) it gives a runoff area of 25 acres.

The hillside above the cutoff drain consists of scrub with some grass (value for vegetative cover = 15 according to the table on p.31). The soil is a shallow clay loam (value for infiltration rate = 30). The hillside is steep (value for slope = 20). The summarized characteristics: 15 + 30 + 20 = 65.

As the runoff area is broad and short; Table B on p. 33 should be used. An area of 25 acres and summarized numerical characteristics of 65 give a runoff of $\frac{80 + 115}{2}$ = 98 cusecs.

The width of the channel in feet is obtained by dividing the runoff (= 98) by the discharge (= 16 according to p.36): $\frac{98}{16}$ = 6 feet.

Result: The size of the cutoff drain will be 2 feet (0.6 m) deep and 6 feet (1.8 m) wide.
If a rectangular cross-section is desired, perhaps simpler to dig by hand, the width will be $\frac{2 \times 6}{3}$ = 4 feet (1.2 m).



4. <u>Summary of how to find the size of a cutoff drain</u>

A. Calculate the amount of water (runoff) from the runoff area

1) Size of runoff area:

a) width (along the contour) in metres =

b) length (down the slope) in metres =

Area in sq.m: width x length =

Area in acres: $\frac{\text{area}}{4{,}000}$ =

2) Summarize the characteristics of the runoff area (p. 31):

a) vegetation =

b) soil =

c) topography =

Summarized =

3) Read from one of 3 tables (p. 32, 33, 34)

Use table A p. 32	Use table B p.33	Use table C p. 34

to find the runoff in cu.secs =

B. Select the gradient of the channel as a percentage (0.5 or 0.25 %).

C. Read from four tables (p. 35 - 36):

1) Table 1, maximum velocity =

2) Table 2, channel factor =

3) Table 3, <u>depth</u> in feet =

4) Table 4, discharge =

D. Make two calculations to find the <u>width</u> (p. 36 and 37):

1) Width in feet $= \frac{\text{Runoff (A 3 above)}}{\text{Discharge (C 4 above)}} =$

2) Reduced width in feet for a rectangular cross section

$\frac{2 \times W}{3} =$

HOW TO CALCULATE INTERVALS BETWEEN TERRACES

Vertical interval between terraces

The vertical interval is defined as the difference in height between two terraces. The vertical interval (V.I.) between terraces depends on the slope and has been calculated in three different ways in Kenya:

A The ordinary formula - V.I. (in feet) = $\frac{\text{percentage slope}}{4} + 2$

B The bench formula - V.I. (in feet) = $\frac{\text{percentage slope}}{8} + 1$

C A constant V.I. of 5 - 6 or 2.5 - 3 feet (1.5 - 1.8 or 0.75 - 0.9 m).

The method selected depends on the slope:

5 - 12 %	A, B or C, but the horizontal interval is never greater than 80 feet (24 m) on erodible soils
12 - 35 %	B or C
35 - 55 %	C or modified bench terraces.

As shown above a constant vertical interval can always be used between 5 % and 55 %, and this method is indeed the simplest one to use for setting out vertical intervals between terraces. The vertical intervals will vary with the eye height of the person setting out the terraces, i.e. between 5 and 6 feet (1.5 and 1.8 m).

For slopes between 2 % and 5 % the vertical intervals will be less than the height of a person, because the horizontal interval should be a maximum of 24 m (80 feet):

Slope %	Vertical interval in metres	Horizontal interval in metres	Horizontal interval in feet
2	0.5	24	80
3	0.7	24	80
4	1.0	24	80
5	1.2	24	80

Horizontal intervals between terraces

The width of a terrace is expressed as the horizontal interval (H.I.) between terrace edges (grass strips). It is calculated as

$$\text{H.I.} = \frac{\text{V.I.} \times 100}{\%\ \text{slope}}$$

If the V.I. is expressed in feet, the H.I. will be in feet. If the V.I. is expressed in metres, the H.I. will be in metres.

DESIGNS FOR GULLY CONTROL

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2. Not possible to divert the water	
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2.1.2 Stone materials	
2.1.2.1 Low head	42
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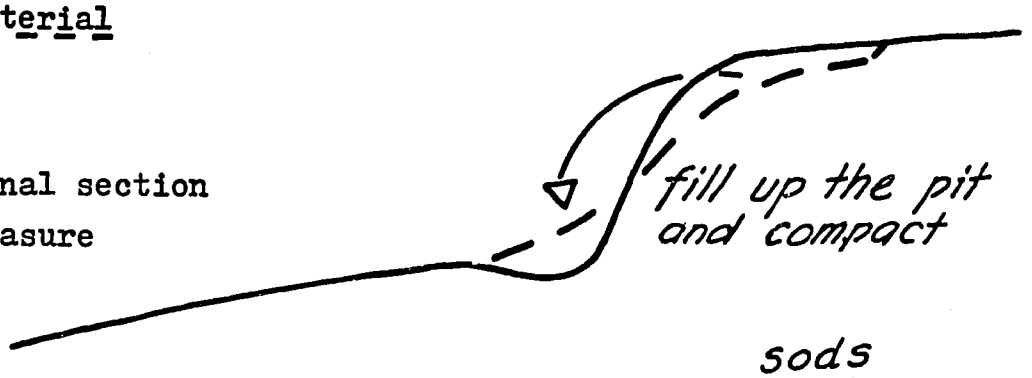
Head of gully

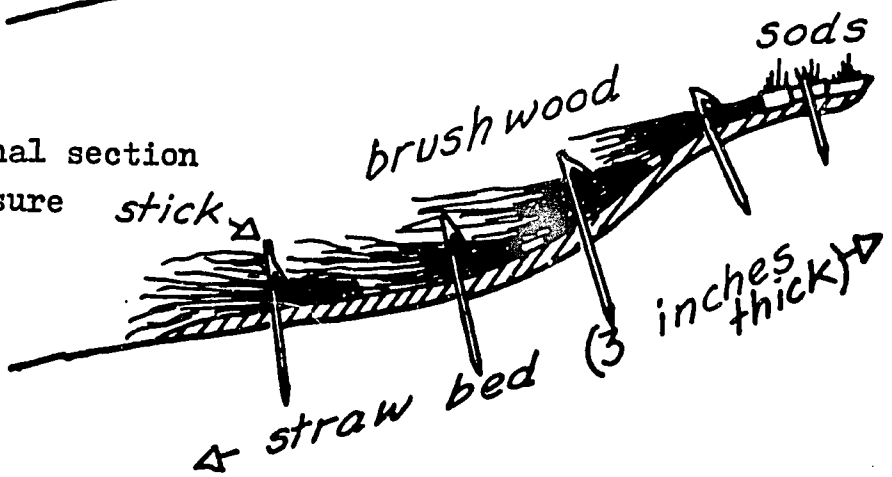
The "waterfall erosion" of the water flow can be stopped through a protecting carpet of piled beds of straw and brushwood (see below) or stones (pages 42-43).

Wooden material

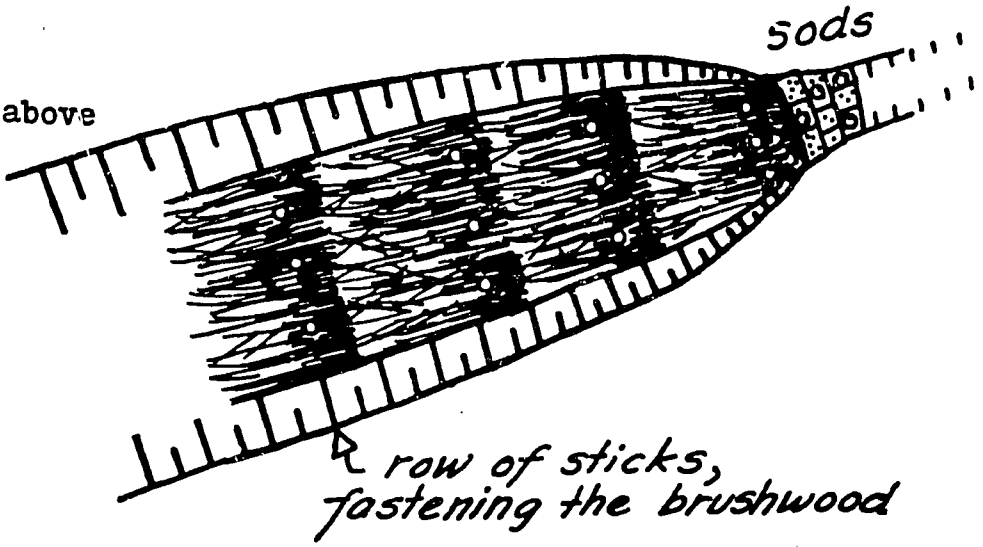
Longitudinal section before measure



Longitudinal section after measure



View from above



Cross-section

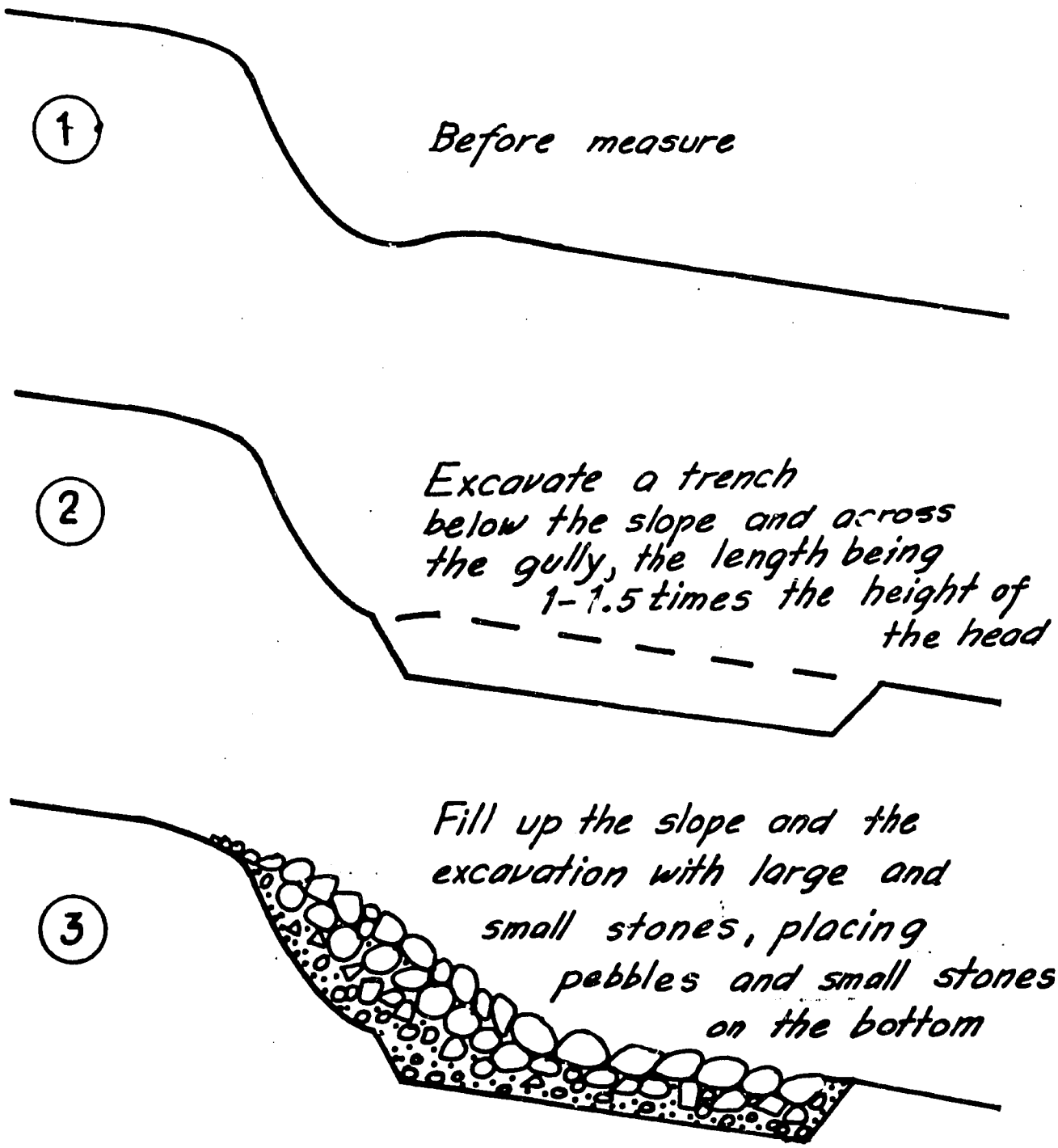
C.G.W.

Stone material

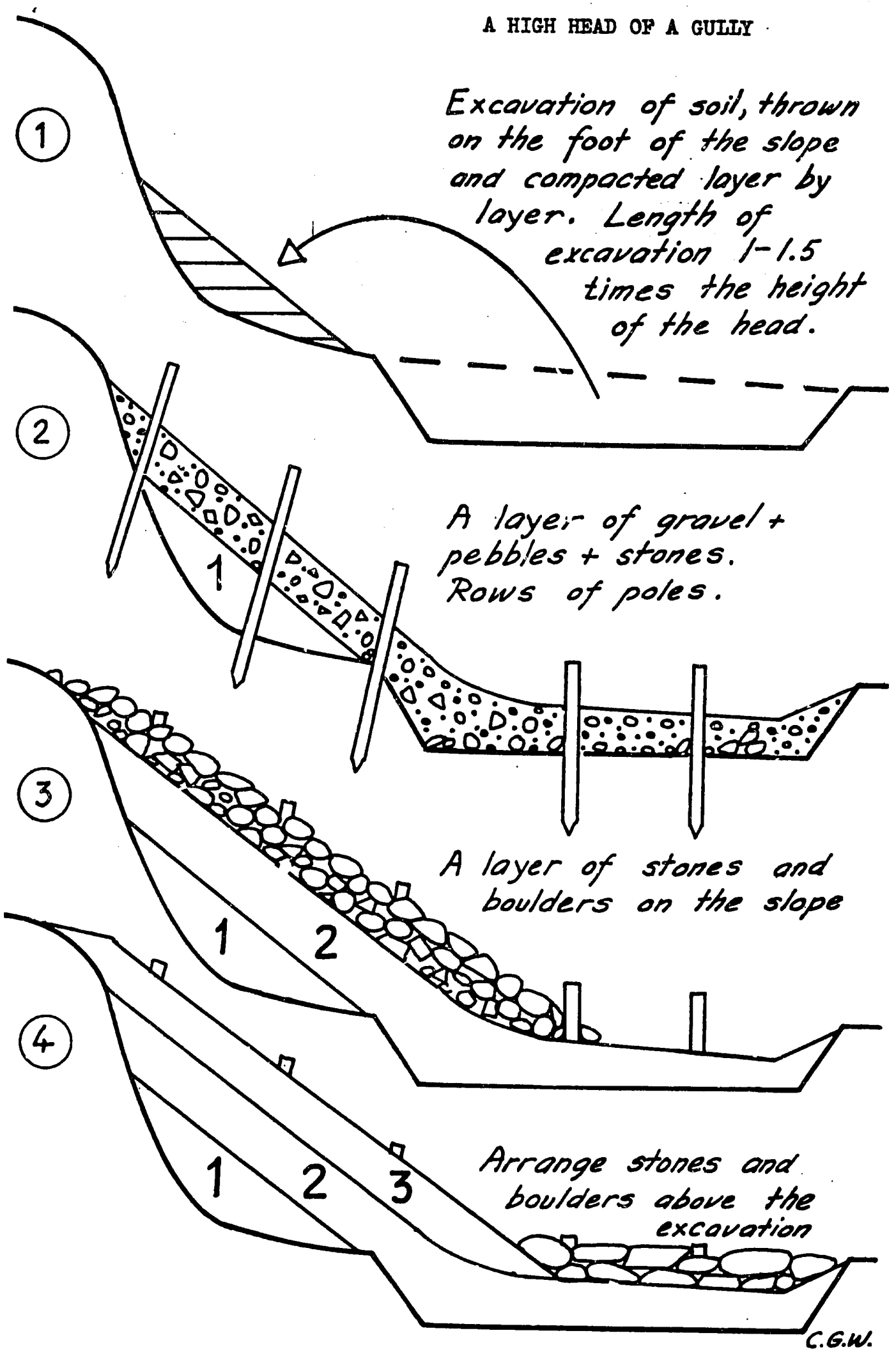
The stone protection (figures below) is stronger than the wooden one, and can be especially strong by filling up in layers (figure on the next page). If only small stones are available, gabions can be used (i.e. prefabricated iron cages filled up with stones), see page 49.

A LOW HEAD OF A GULLY

Longitudinal sections



A HIGH HEAD OF A GULLY



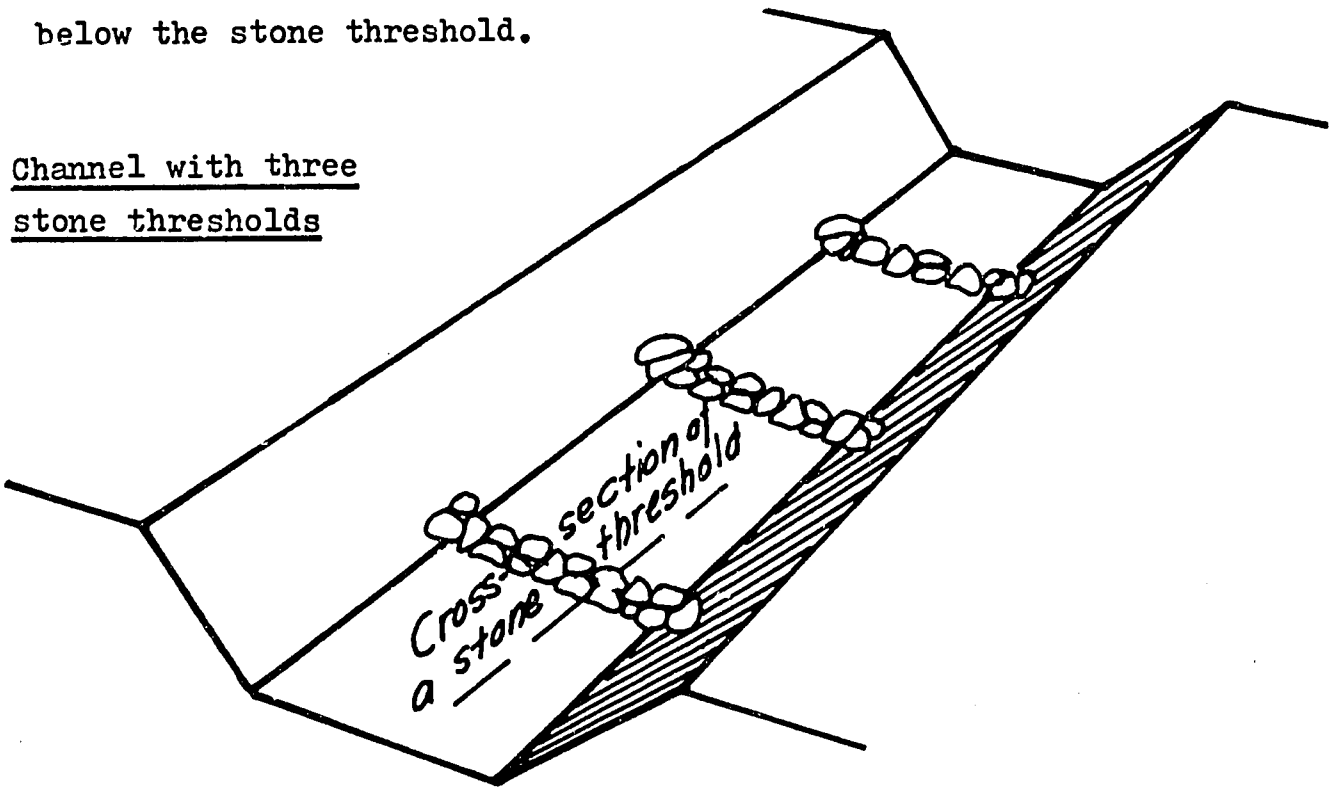
Floor of gully, wide and shallow

Erosion on the floor of a gully can often be stopped by strips of grass or turves (in arid areas sisal), placed at every 2nd, 4th or 6th metre.

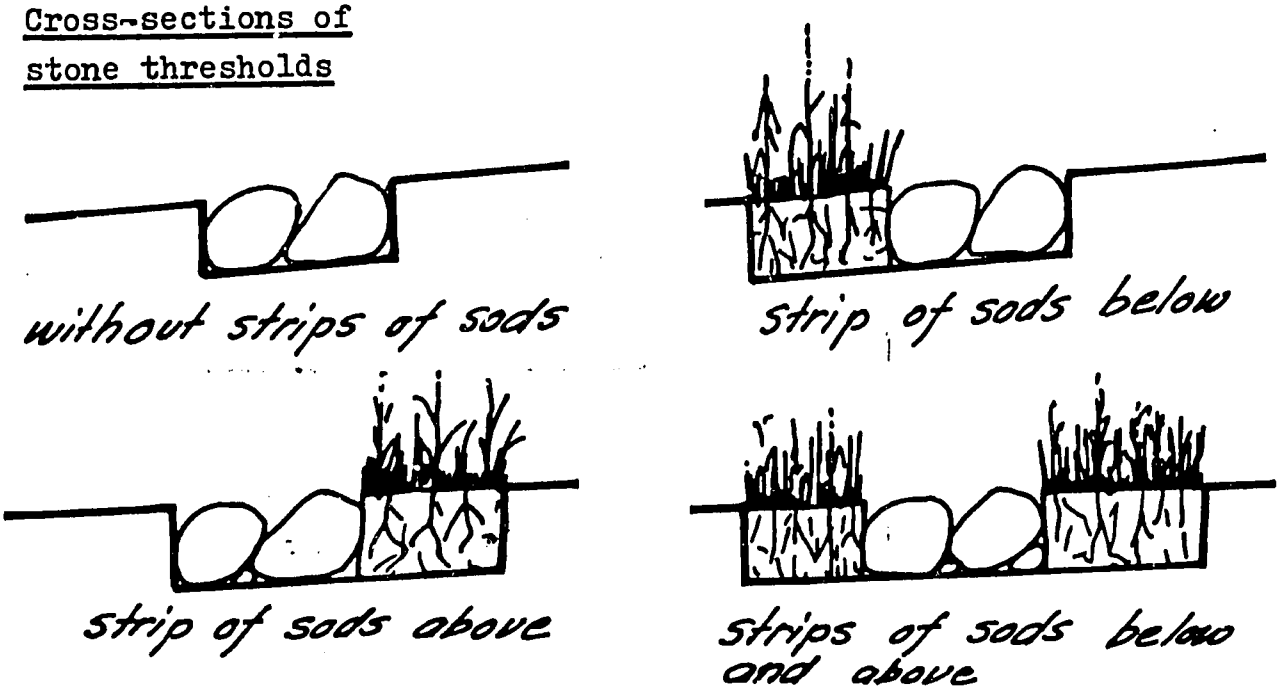
Alternatively thresholds of stones can be arranged across the floor instead of vegetation. The stones should be put into an excavation (approximately 0.5 feet deep), so the upper parts of the stones are level with the floor of the gully.

It is also possible to combine the two types of materials: 1) a grass strip above the stone threshold, 2) a grass strip below the stone threshold, or 3) grass strips both above and below the stone threshold.

Channel with three stone thresholds



Cross-sections of stone thresholds



C.G.W.

Floor of a gully, narrow and steep

In steep and narrow gullies the check dams have to be more solid to reduce the fall of the slope and to resist the velocity of the water. The ends of a check dam should be somewhat higher to prevent water from cutting round them. It is better to construct several low dams than a few high dams. The filled-up dams (steps of silt) are recommended to have a small percentage inclination. Consequently the number of check dams depends on the gradient of the gully (see the table below).

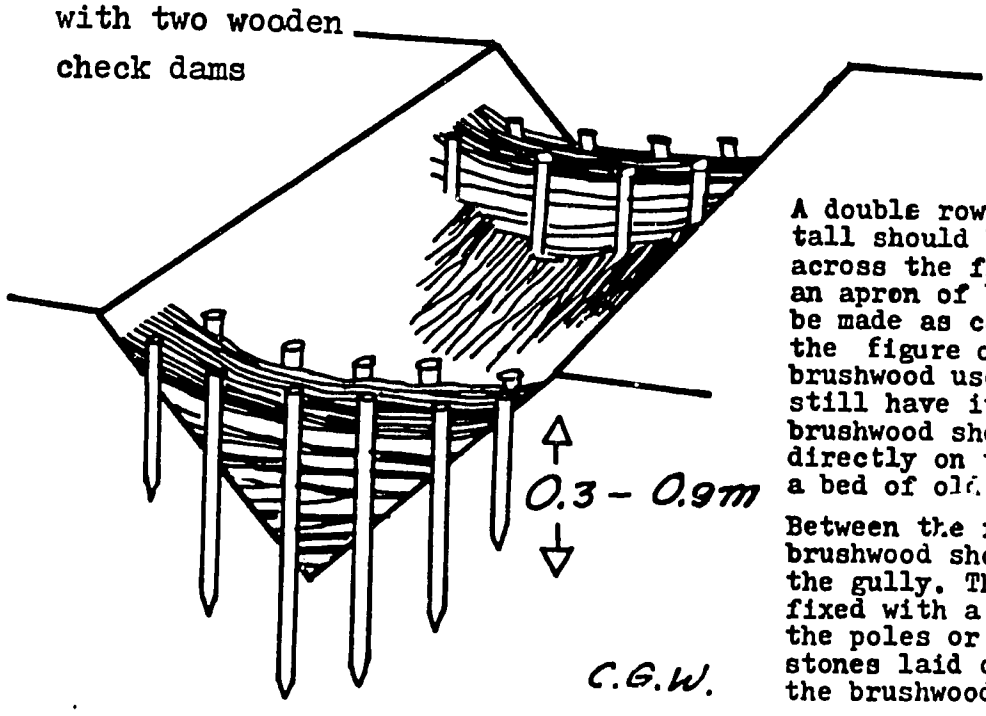
Table showing spacings in metres between check dams

Gradient %	Height of check dam 0.3 m		0.6 m		0.9 m		1.2 m	
2	15		30		45		60	
4	15		30		45		60	
6	7.5		15		23		30	
8	5.2		10.3		15		20	
10	4.0		7.7		11.5		15	
12	3.2		6.3		9.3		12	
14	2.7		5.3		7.8		10	
16	2.3		4.6		a)6.7	b)7.4	a)8.9	b)10.0
20	1.8		a)3.7	b)4.5	5.4	6.7	7.1	8.5
24	1.6		3.1	3.9	4.5	6.1	5.9	8.0
28	a)1.4	b)1.7	2.7	3.4	3.9	5.4	5.1	6.6
32	1.2	1.6	2.3	3.2	3.3	4.6	4.3	6.0
36	1.1	1.5	2.1	3.0	3.0	4.4	3.9	5.7
40	1.0	1.3	1.9	2.9	2.7	4.2	3.5	5.5
44	0.9	1.2	1.7	2.8	2.4	4.0	3.1	5.2

a) wood and gabion constructions b) stone wall with slopes 1:1

Wooden material (if stones are not available)
For detailed design see the next page

View of an eroded channel with two wooden check dams

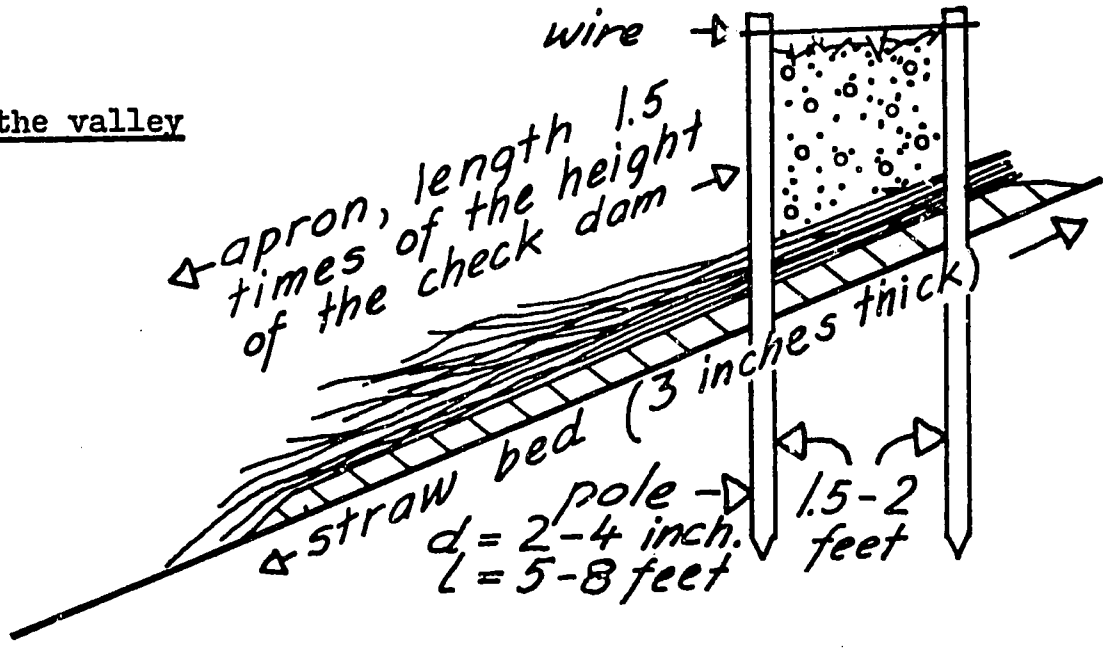


A double row of poles 5-6 feet tall should be hammered down across the floor. After that an apron of brushwood should be made as can be seen from the figure on the left. The brushwood used should preferably still have its leaves on. The brushwood sho not be laid directly on t ground but on a bed of old grass or weeds.

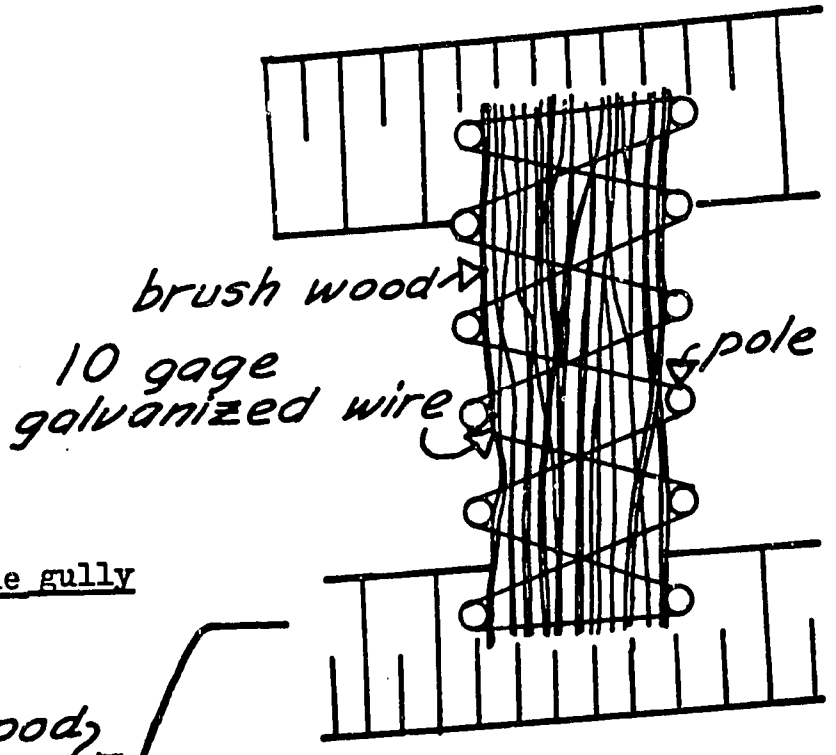
Between the rows of poles brushwood should be laid across the gully. The brushwood can be fixed with a wire connecting the poles or with large flat stones laid on the surface of the brushwood fill.

CHECK DAM, USING WOODEN MATERIAL

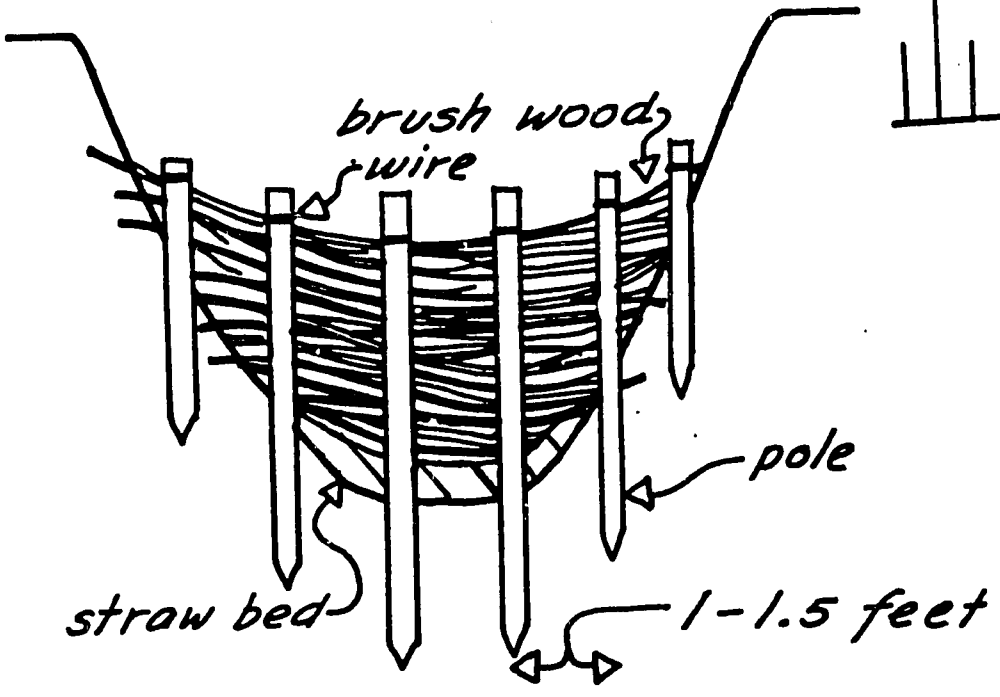
View across the valley



View from above



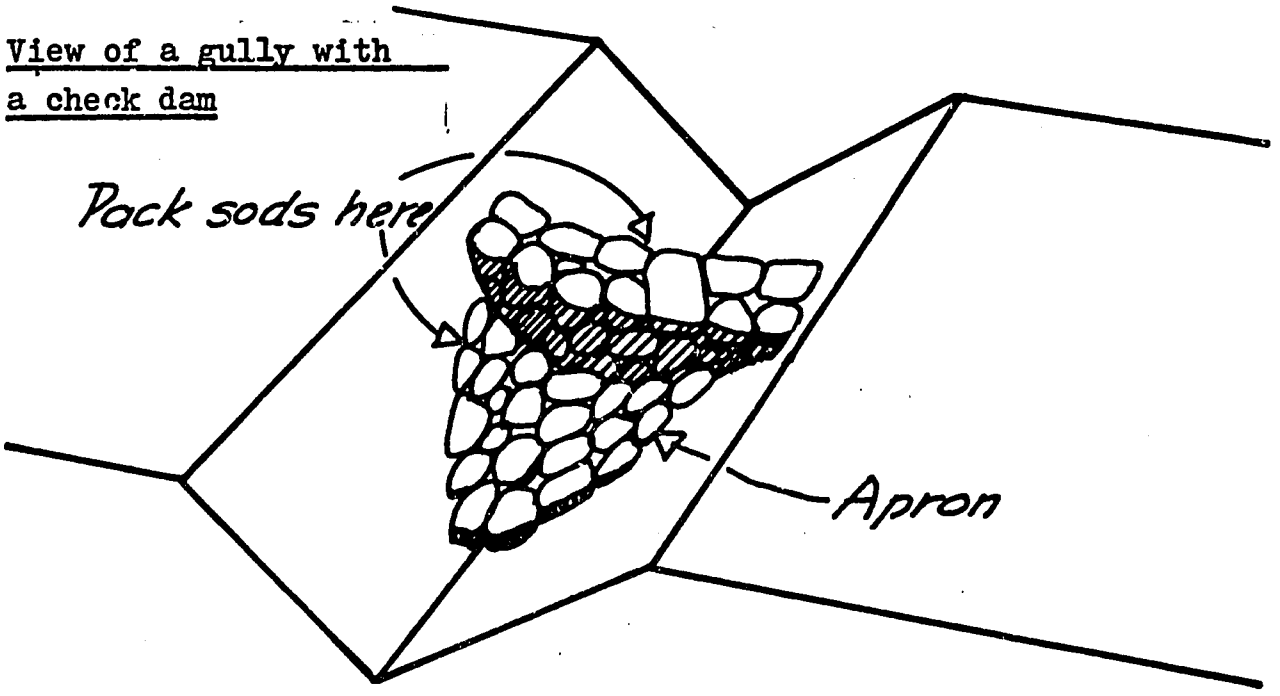
View in the direction of the gully



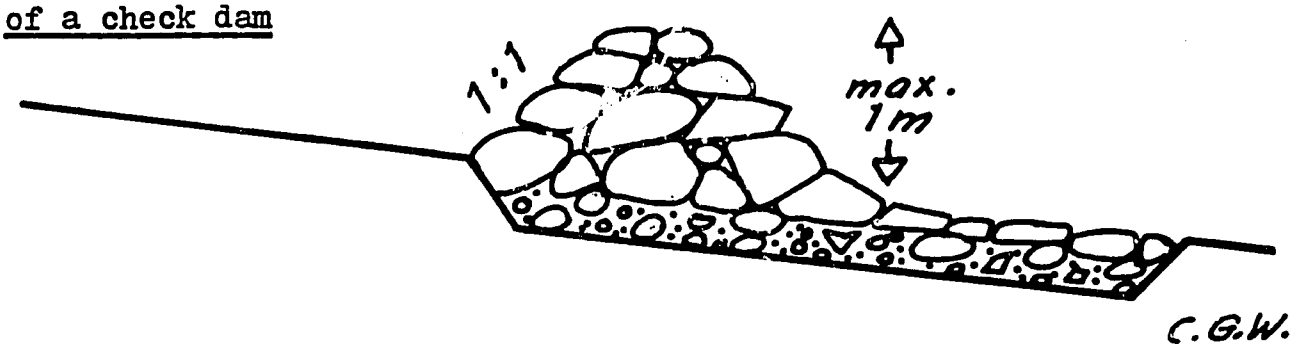
Stone material, large stones available

CHECK DAM USING STONE MATERIAL

View of a gully with a check dam



Cross-section of a check dam

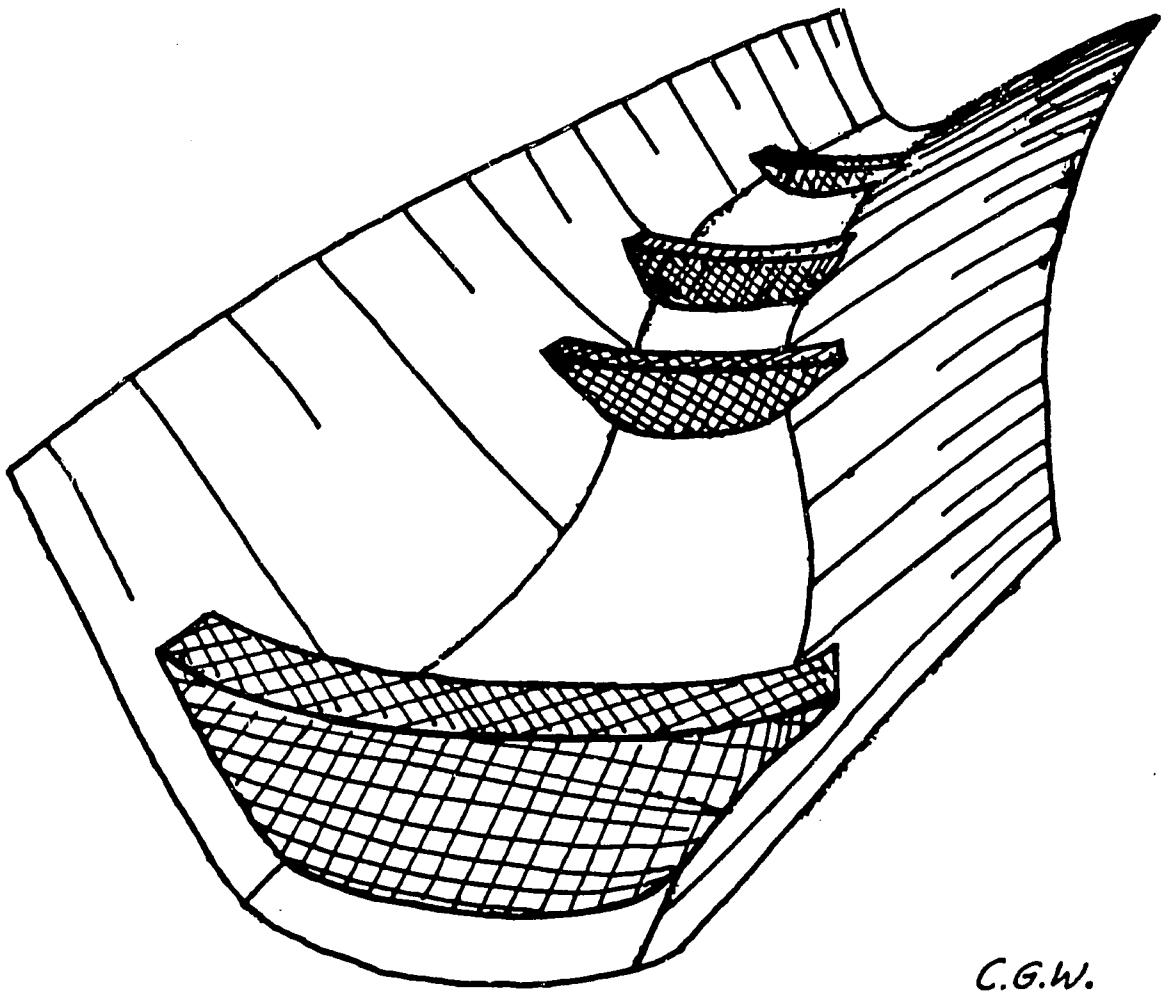


The construction work should start with a shallow excavation, 0.5-1 feet deep, across the floor. The bottom of the excavation should be covered with a layer of gravel, pebbles and small stones. Above this layer the largest boulders and stones are laid as a ridge across the floor. Small stones and pebbles should fill up the spacings in the ridge to create stable slopes on both sides of the ridge. Stone check dams should not be higher than 0.5-1 m, in the latter case 1.5 m wide at the bottom and 0.5 m wide at the top. Below the stone ridge there should be an apron of large flat stones of the same width as the ridge. This apron should also be laid on excavated ground as shown in the figure above. The length of the excavated trench is 1-1.5 times the height of the ridge.

Stone material, large stones not available

In such a case gabions can be used (see the example below). Gabions can be made by the staff (see the following two pages), or they can be bought prefabricated from Greenham Ltd, Nairobi. However, they tend to be expensive. The following are examples of sizes and prices (in 1979):

Gabions 2 x 1 x 1 m with one central diaphragma	shs. 335
2 x 1 x 0.5 m with one central diaphragma	shs. 215
Mattresses 6 x 2 x 0.23 m with nine diaphragma at 0.6 m intervals	shs. 745
Mattresses 6 x 2 x 0.29 m with nine diaphragma at 0.6 m intervals	shs. 765

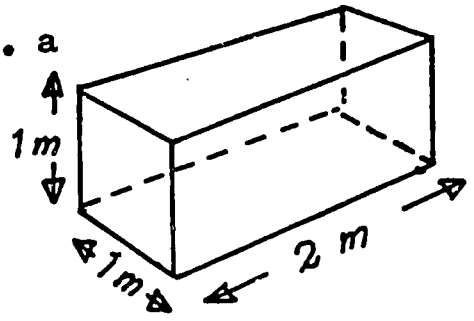


Gabions

Gabions are boxes of galvanized wire mesh. Such boxes can be filled with even small stones, and the mesh will prevent a water flow from removing the stones. The boxes are heavy enough to resist movement even by large water flows and high stream velocities. Unlike concrete they do not crack.

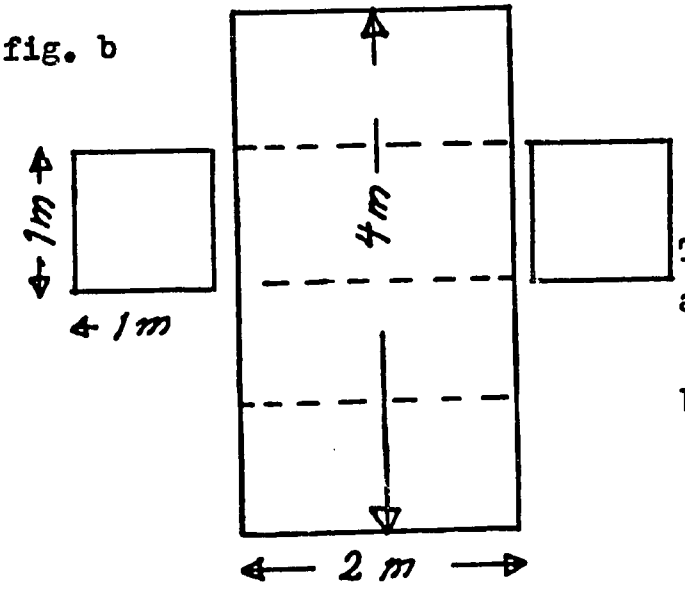
Fabrication should be done on the site.

fig. a



A normal size is 2 x 1 x 1 m (fig.a)

fig. b

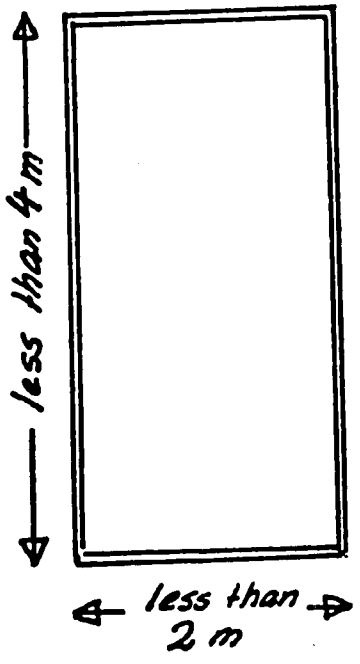


This size needs (fig.b):

a) for 4 sides 4 x 2 m = 8 sq.m of wire mesh

b) for 2 ends 2 pieces of 1 x 1 m = 2 sq.m.

fig. c



An iron rod (d = 5 - 7 mm) is needed for reinforcement round the 4 sides = 4 + 2 + 4 + 2 = 12 m (fig. c and d).

fig. d

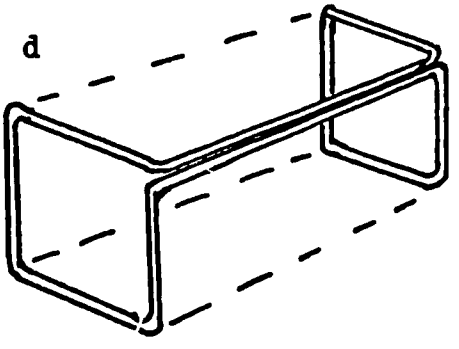
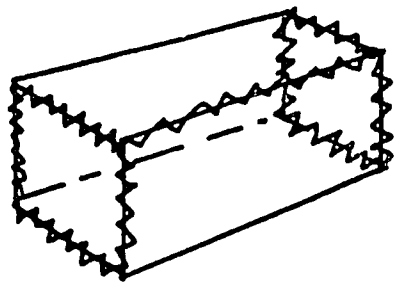
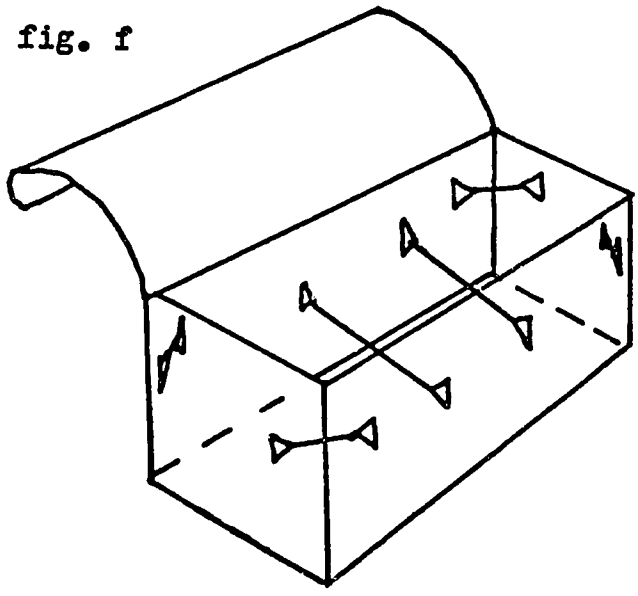


fig. e



For "sewing" the wire mesh into the box approx. 10 m of wire is needed (fig. e).

fig. f



During the filling of the gabion box with stones, cross-ties can help to stabilize the box, the ties being across the box, as well as diagonally in the corners (fig. f).
Fill the gabion with stones to 1/2 (or 1/3) of the height. Fix the horizontal cross-ties above the level of the stone filling. Repeat filling (and cross-ties). The level of the filled up gabion box can be 1 - 2 inches too high to allow some settlement.

If several gabions are placed beside or on top of each other, they should be connected by thick galvanized wire. Gabions should be laid in small excavations in the ground to prevent undercutting by erosion.

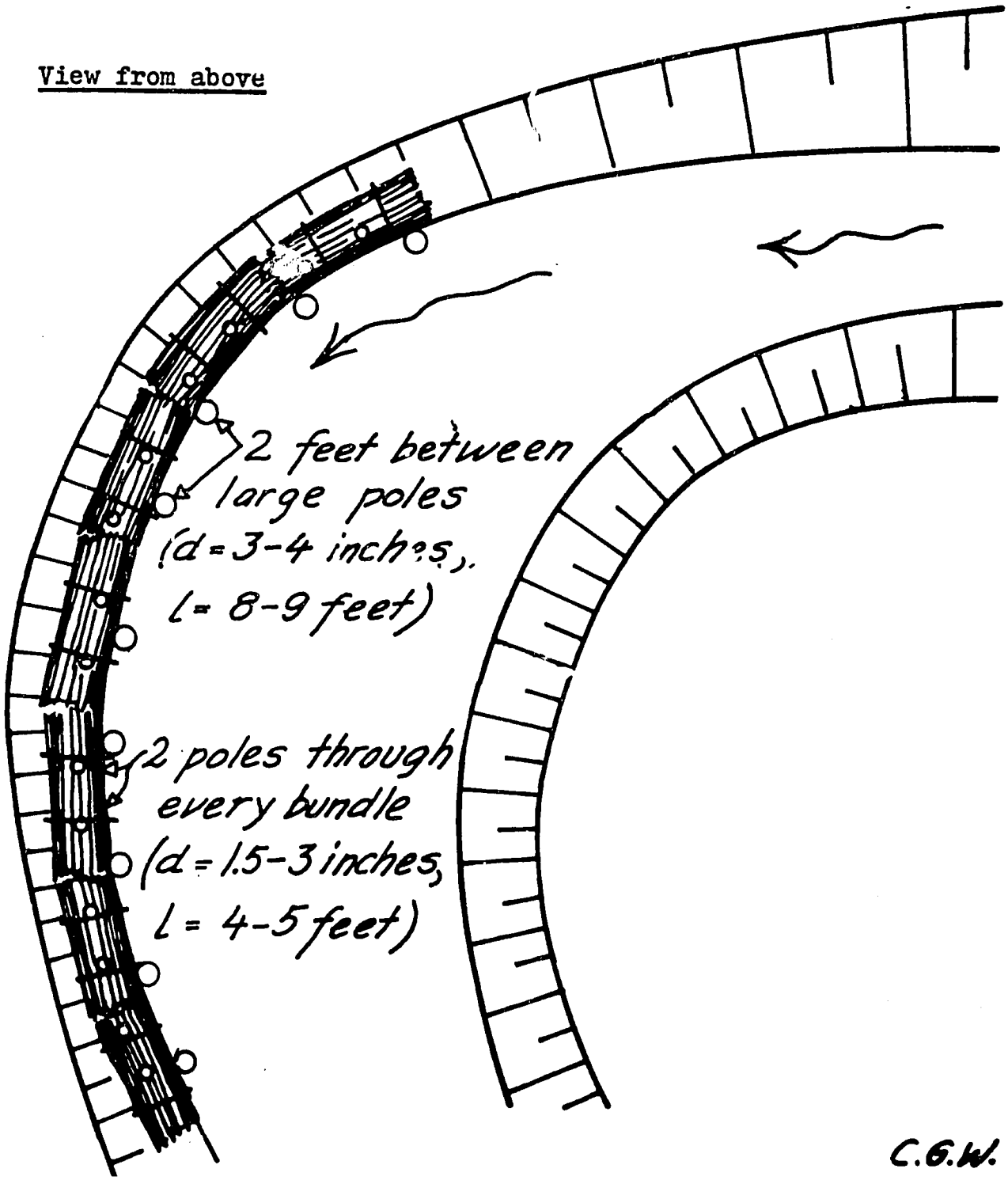
Side walls of a gully

There is usually no reason to make the side walls less steep through digging. This will happen by itself, and when the side walls start to stabilize, vegetation will come in by itself. However, if the walls are not very steep, the stabilization can be helped by planting trees and/or grass.

Bank erosion in a bend, wooden materials used

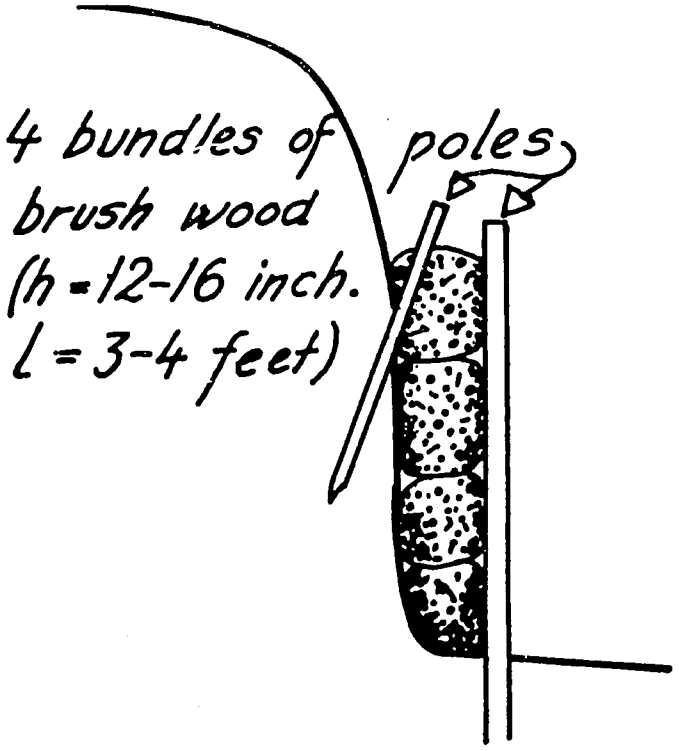
Sometimes the water flow erodes the bend of a gully. In a small gully this can be stopped by a row of poles with brushwood between the poles and the gully wall. However, in a large gully (or river) the construction has to be stronger. See design below and on the next page.

View from above

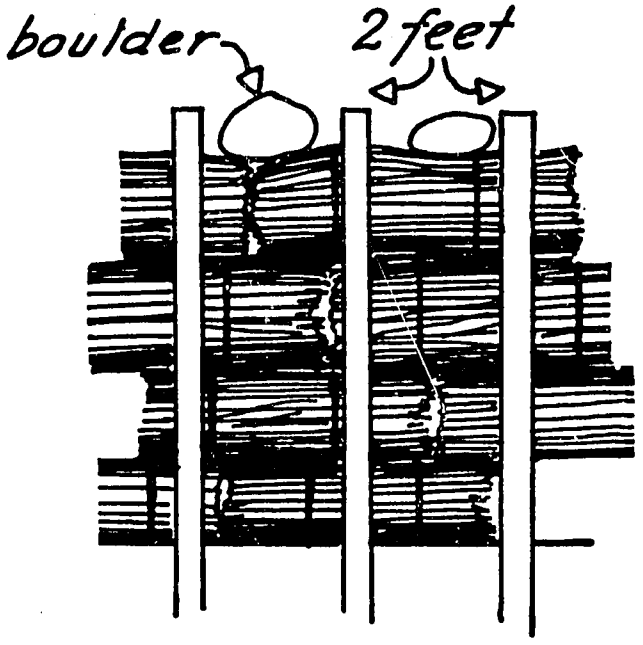


C.G.W.

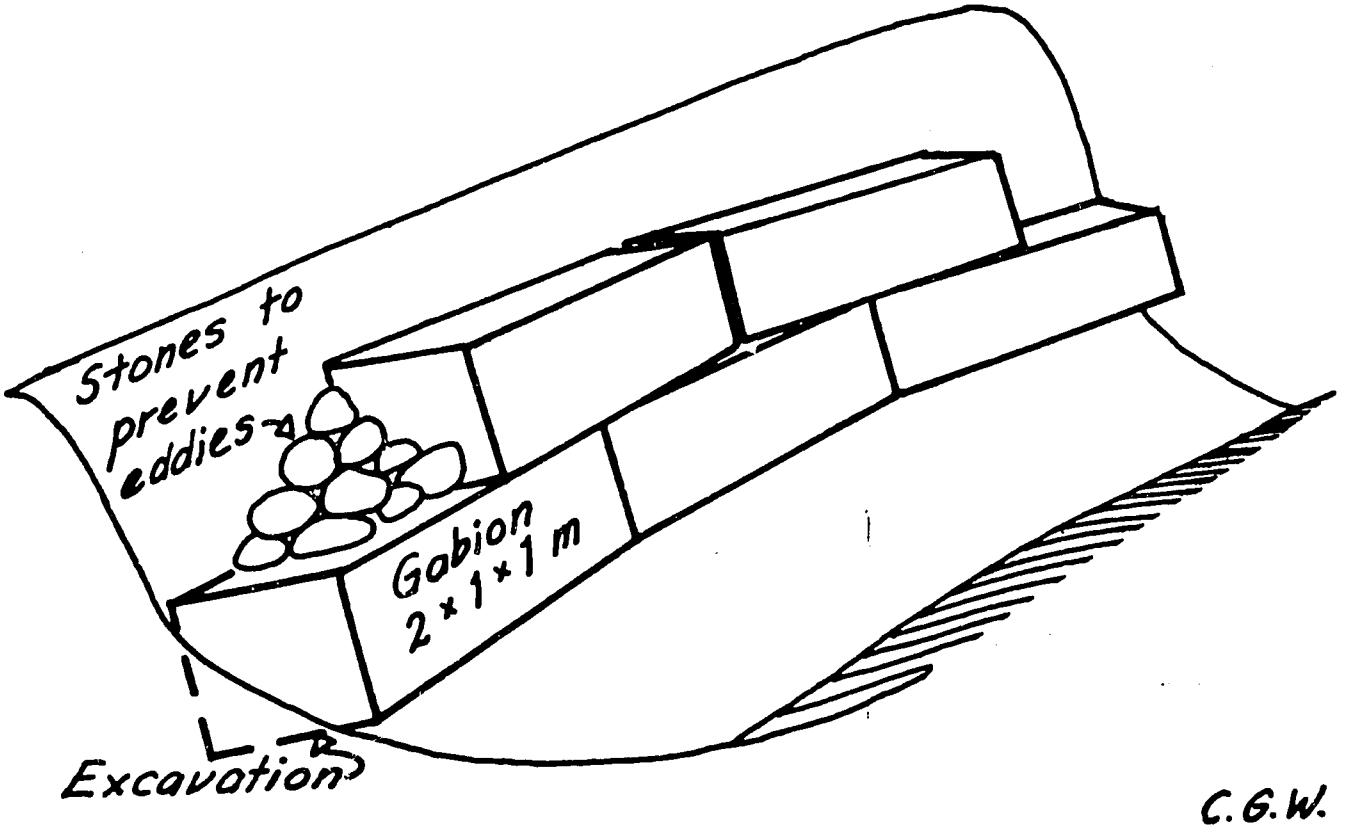
View along the bank



View towards the bank



Bank erosion in a bend, gabions used



C.G.W.

INSTRUCTIONS TO TECHNICAL ASSISTANTS

Soil conservation is a part of farm planning, and in this respect farm planning has to consider:

1. Areas available for cultivation, livestock and trees
2. Ground conditions as to the type of soil, occurrence of rock outcrops, infiltration rate, and erodibility
3. Present erosion on slopes and along watercourses, and existence of gullies and damaging sedimentation
4. Existing soil conservation measures, including the usage of different areas considering the soil conservation
5. New proposals for soil conservation measures, including the usage of different areas under the proposed soil conservation measures.

It is necessary that the soil conservation programme for a farm is recognized by the farmer as his own programme. In any approach to farmers it is important to listen to their points of view. Make your own proposals tentatively, when you are walking round the farm. Discuss with the farmer, and listen to what the farmer thinks is possible.

If you think terracing is the right measure, do not ask if he/she is willing to do that. Propose alternatives. In most cases the farmer will agree to the simplest alternative from his point of wiew.

If the farmer is hesitant, try to make the programme flexible, e.g. if the farmer does not want to plant grass strips at vertical intervals of 1.8 m, try starting with 3.6 m and leaving the remaining strips for future action.

Try to involve the sub-shief as much as possible in the field work for the following tasks:

a) organizing farmers to be present
b) finding helpers for field work (pegging)
c) helping to explain matters to the farmers, and
d) organizing the digging of cutoff drains and the maintenance groups for cutoff drains.

You have not finished your work after the layout work. You have to check not only that the pegs are not removed, but also that the measures agreed to, are carried out.

If the field has been planted with maize before or shortly after the layout and the pegging, and grass cannot be planted immediately for some reason, the layout must be marked in a better way than only by pegs. It is recommended that

1) small ridges be constructed along the pegged lines, or
2) trash from the weeding be placed along the pegged line, or
3) some plants other than grass be planted provisionally.

Every case of the removal of pegs should be reported immediately to the chief and/or to the DLFMO for further action.

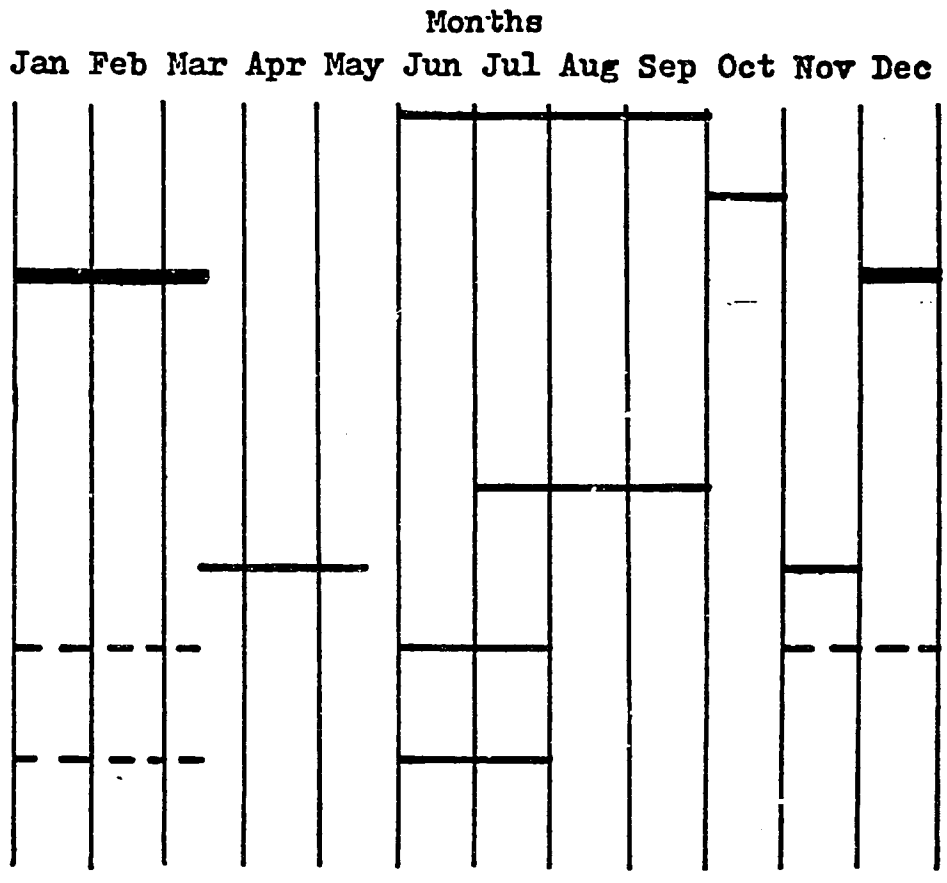
The best time for the layout and construction of terraces is the off-season between harvesting and planting. This means that the technical assistants should concentrate on soil conservation for 3 - 5 months during every year. Some work can also be done during other months of the year. A time schedule for soil conservation has to be varied for different parts of the country because of changing climate conditions:

1. Most districts p. 55
2. Machakos and Kitui Districts etc p. 56
3. Narok District and the higher parts of Nakuru District etc. p. 57

TIME SCHEDULE FOR SOIL CONSERVATION

A. MOST DISTRICTS

Activities	Action by
1. Barazas on soil conservation	Chiefs, TAs, Farmers
2. Checking line levels etc for accuracy	TAs
3. Visits to farms for farm planning including soil conservation Layout and construction of cutoff drains, artificial water ways and terraces	TAs, farmers
4. Checking and pushing forwards farmers' soil conservation	Chiefs, TAs
5. Planting on terraces and cutoff drain embankments	TAs, farmers
6. Maintenance of cutoff drains, artificial waterways and terraces	Chiefs, TAs, farmers
7. Gully control, cutoff drains and artificial waterways	TAs, farmers



the main field work

obligatory supplementary activities

supplementary activities when possible

Other publications from the Soil Conservation Extension Unit of the Farm Management Branch, Ministry of Agriculture:

1. "Soil conservation in Kenya, specially in small-scale farming in high potential areas using labour intensive methods". - Handout in 250 pages, 6th edition, Nairobi 1980. (for teaching agricultural staff at all levels)

2. "Soil conservation. Pocket book for technical assistants". - Nairobi 1980. (summarizing facts from publication No. 1)

3. "Soil erosion and soil conservation". - Booklet with 17 coloured pictures plus text, Nairobi 1980. (for agricultural and administrative staff, teachers and farmers)

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