OBSERVATIONS ON THE "BARE SOIL" METHOD OF GRASSED WATERWAY ESTABLISHMENT

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SUMMARY

Evidence is given that waterways on red volcanic loams possessing a subsoil resistant to erosion when undisturbed may be used to carry run-off water without prior grassing.

Where suitable plants are available, the floor of the waterway is stabilized within a few years by spread of stolons or rhizomes from plantings on the banks. Some erosion of the waterway floor may occur in the interim, but if stabilization is ensured this is of little consequence.

I. INTRODUCTION

Grassed waterways are widely used in order to provide stable conditions for the disposal of surplus run-off water. They depend on a lining of vegetation to protect them from erosion, and the establishment and maintenance of this vegetation is an important consideration in the design of schemes for soil erosion mitigation.

The waterway is usually constructed some time before it is proposed to install contour banks or other interception structures. After construction it is cultivated, fertilized and sown to grass. This grass must be given time to grow into a sward before any run-off water is allowed into the waterway. Under favourable conditions an establishment period of 12 months is usual before the waterway can be used. However, in some years, due to unfavourable seasonal conditions, it is not possible to secure a stand of grass. The occurrence of one dry growing season means that two years will go by before the contour banks can be built and the delay may be even longer. Such delays hinder soil conservation programmes and are frustrating to the farmer.

The resistance of farmers to full waterway stabilization is even more pronounced in red soil areas of Queensland, where the farmer knows by observation and experience that a waterway bare of vegetation will not necessarily turn into a deep gully. To avoid the frustration and delay, a "bare soil" method of waterway establishment has been used on the Atherton Tableland and in the Kingaroy district. This system was introduced in late 1955 and is now almost normal practice in the two districts.

In this article the "bare soil" method is described. An illustrated case history is given of one of the early bare soil waterways on the Atherton Tableland, and the results of a survey made in 1960 of 31 bare soil waterways built at Kingaroy in the seasons 1955-56 and 1956-57 are also presented.

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II. THE BARE SOIL METHOD

It should be pointed out at the outset that the method is suitable only on soil types where the subsoil in the undisturbed stage is resistant to erosion. The red volcanic loams of Atherton and Kingaroy are generally suitable and most of the writer's experience with the method has been gained on these red soils. It involves utilizing the waterway to convey run-off water immediately it is constructed. Grass is planted only on the banks, but stoloniferous or rhizomatous species are utilized. Grassing of the bed of the waterway is dependent upon the spread of grass from the banks, a process that may take several years. The final result is a grassed waterway and the run-off is carried on bare soil for only a few years.

The waterway banks are built with soil graded or dozed from the area between the banks. It is essential that only as much soil as is required for the banks be loosened by ripping or ploughing. All disturbed soil is pushed off, leaving a smooth firm bottom. Depth of excavation is dependent on the width of waterway and size of banks required. A disc or mouldboard plough is preferred to rippers or tined implements for the loosening of soil because it is difficult to excavate to the bottom of tine marks.

Waterway banks are planted on the inside batter with seed, sprigs or sod. Species that spread by stolons or rhizomes must be used, other species being unsuitable. Grasses that have been found to colonize satisfactorily are Rhodes grass (*Chloris gayana*), kikuyu grass (*Pennisetum clandestinum*) and various strains of *Cynodon dactylon,* including common couch and common African star grass.

The channel is not usually planted, because seed or runners are readily washed away, and in any case growth of grass in the undisturbed subsoil is not satisfactory. However, the plants established in the topsoil of the banks send out runners which slowly advance across the waterway. Over a period of years colonization is completed.

Probably the best results are obtained when the waterway is built through an existing stand of grass under conditions of reasonable moisture supply. In such circumstances the grass is rarely killed completely and under favourable conditions regeneration may be rapid.

III. A CASE HISTORY

The waterway chosen for this case history is one constructed on September 10, 1955, near Tolga on the Atherton Tabeland. The particular waterway is chosen because it is one of the first waterways in which the bare soil method was utilized, it carried high-velocity flows soon after construction, and photographs are available to show the progressive establishment of grass.

Soil Type.—The waterway was built on a red volcanic clay loam of basaltic origin typical of the Atherton Tableland. The original vegetation was rain-forest and the soil is known locally as a red "scrub" soil. The average land gradient at the site is 2·5 per cent.

Catchment Area.—Run-off entering the top end of the waterway is contributed by 120 ac of untreated cultivation land varying in slope from 1 to 2½ per cent. In addition, run-off from 60 ac of contour-banked cultivation with average slope of 2½ per cent. enters the waterway from contour banks, making a total area of 180 ac contributing run-off at the bottom end.

Waterway Size.—The waterway is trapezoidal in cross-section, with side slopes of 4:1. The bottom width tapers from 15 ft at the top end to 20 ft at the bottom end. Constructed bank height was 1·7 ft.

Construction Method.—The waterway was built with a large motor patrol grader. The grader's tines were used to loosen the soil. This is an undesirable practice, which resulted in this case in shallow tine marks being left in the waterway floor. These tine marks were obscured by loose soil after construction but they appeared with the first flow of water which washed the loose soil away.

Rainfall.—The average rainfall at Tolga is approximately 55 in. per annum, with a marked summer incidence. The average rainfall for each of the months December to March varies from 6 in. to 10 in., and falls of over 20 in. in any one of these months are not uncommon. Rainfall since the establishment of the waterway in 1955 has been mainly above average, as shown in Table 1.

Flow Observations.—Records of run-off are not complete but some details of flows are available for early 1956, when the waterway was still quite bare:—

On December 29, 1955, the waterway ran 1·25 ft deep.

On January 3, 1956, the waterway ran 0·75 ft deep.

On January 13, 1956, maximum surface velocity of 7 ft/sec was measured with a float. Maximum depth of flow was 0·3 ft.

On January 14, 1956, maximum surface velocity of 9 ft/sec was measured with a float. Maximum depth of flow was 0·6 ft.

On February 3, 1956, the waterway flowed 1·5 ft deep. From measurement of cross-sectional area and hydraulic radius of flow it is calculated that approximately 300 cu. ft. of water flowed down the waterway per second at an average velocity of 11 ft/sec. At this stage the waterway was still quite bare.

Table 1

TOLGA RAINFALL (INCHES), 1955–1960

—	1955	1956	1957	1958	1959	1960
January	2·89	15·12	18·99	11·91	12·49	9·74
February ..	17·45	22·48	15·72	14·88	4·98	9·48
March	25·31	15·57	5·77	13·55	16·94	2·64
April	2·80	2·05	1·58	4·71	1·88	·32
May	4·39	2·75	1·72	1·82	3·49	..
June	2·21	1·59	3·49	1·07	1·44	..
July	·70	·70	1·30	Nil	·76	..
August	·31	·59	·58	·54	1·74	..
September ..	1·09	2·29	Nil	Nil	1·71	..
October	1·56	3·88	·30	·06	Nil	..
November ..	·95	2·69	6·37	·66	4·97	..
December ..	5·36	7·90	1·23	4·35	9·66	..
Total ..	65·02	77·61	57·05	53·55	60·06	..

Although the records of flow are not complete, it is known that other flows did occur from time to time. The five flows which were recorded between December 28, 1955, and February 3, 1956, are sufficient to indicate that the waterway survived above-average flow conditions in the early stages.

Establishment of Vegetation.—The waterway was planted on January 11, 1956. A single row of sprigs was planted on each waterway bank at about original ground level. Species used were common couch (*Cynodon dactylon*) and kikuyu grass (*Pennisetum clandestinum*). Twelve months later, although these grasses were all well established, some sprigs of common African star grass (*Cynodon dactylon*) were also planted in the same position. The top and outside batter of the banks was planted with green panic (*Panicum maximum*).

Rates of Colonization.—Figures 1-4 show four stages in the grassing of this waterway. The most recent, taken in May 1959, shows the grasses meeting in places—and a bare patch 5 ft wide still to be covered in others. Had common African star grass been used from the outset, colonization would probably have been quicker. In any case, it is clear that nearly four years after establishment the waterway is still quite stable and well on the way to complete colonization by the grasses.

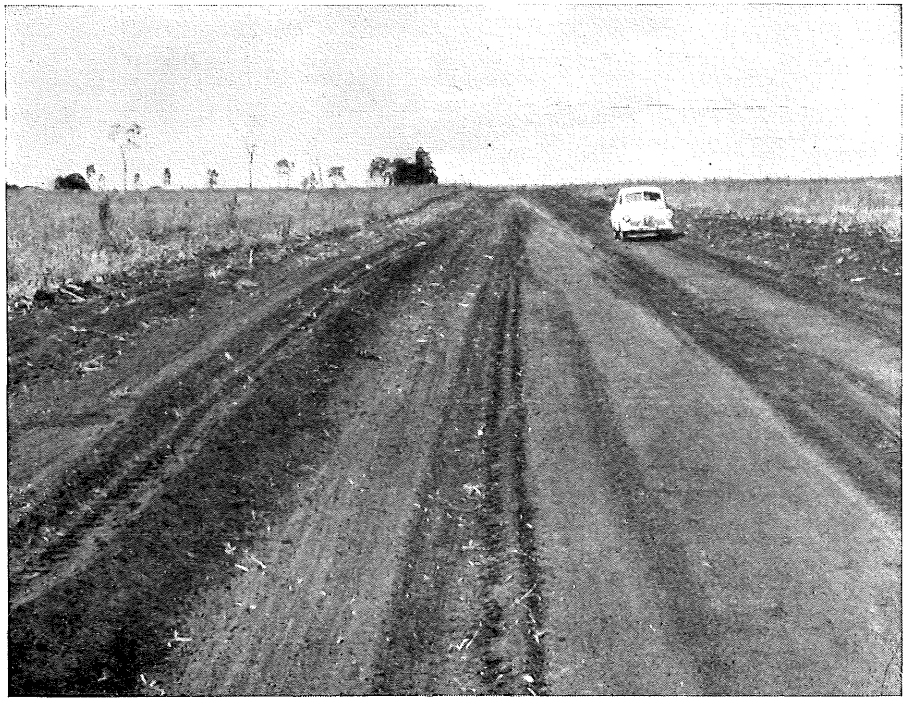

Fig. 1.—Waterway near Tolga on 10.ix.1955 after construction.

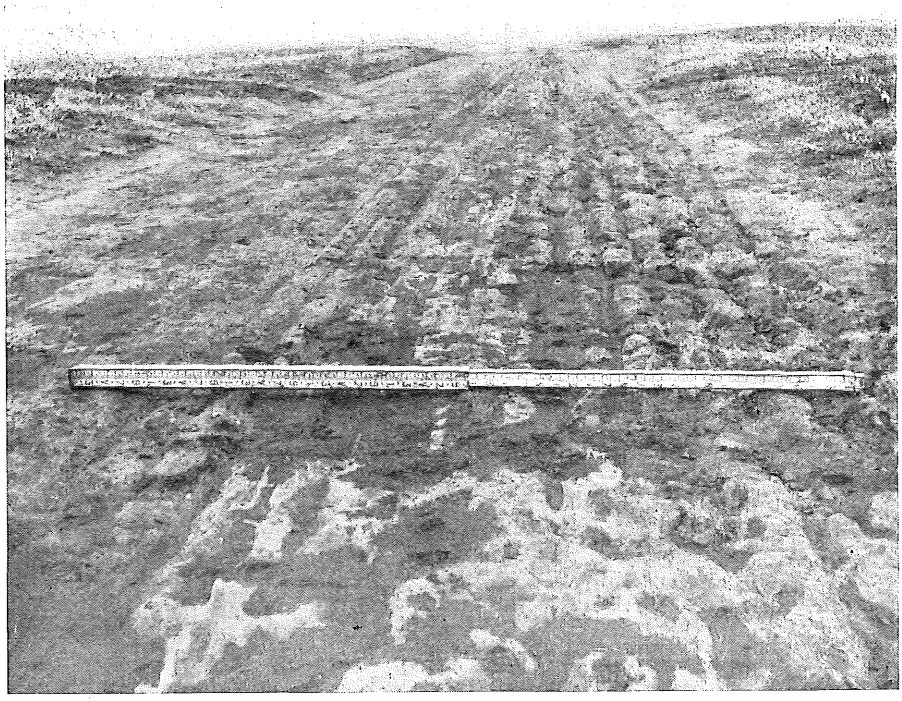

Fig. 2.—Same waterway as Fig. 1 on 16.i.1956 after four flows.

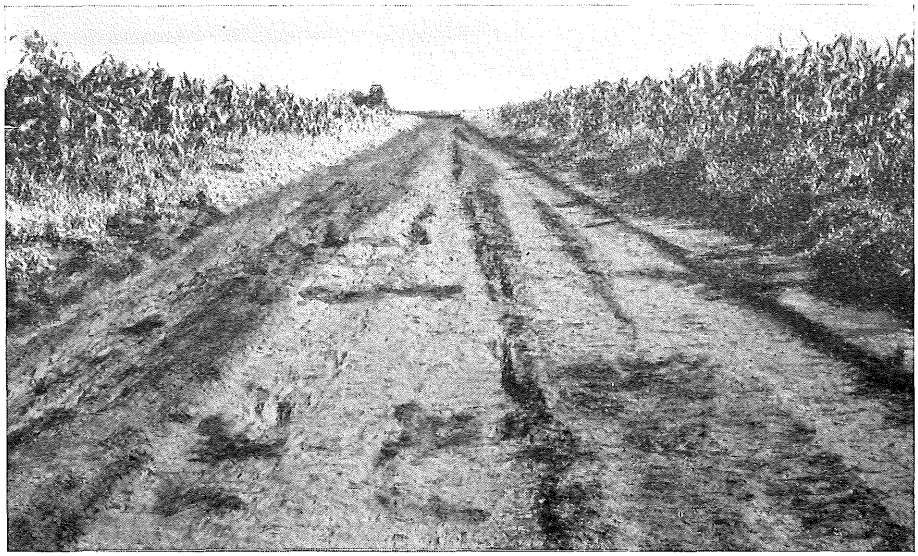

Fig. 3.—Same waterway as Fig. 1 on 17.ii.1956 after a fifth flow in which the waterway flowed at full capacity at a calculated average velocity of 11 ft./sec. The waterway floor is quite bare and perennial grasses planted on the banks have made little growth.

Fig. 4.—Same waterway as Fig. 1 on 30.v.1959. Waterway is still in good order and colonization has proceeded to the stage where grass will shortly meet in the centre.

IV. SURVEY OF 31 KINGAROY WATERWAYS

A survey of 31 waterways in the Kingaroy area was made in May 1960. The waterways had all been constructed in the period between October 1955 and November 1957, so all were at least 2½ yr old and some were 4½ yr old.

The waterways inspected represented all that could be traced from records kept at the Kingaroy office of the Department of Agriculture and Stock and are believed to represent the majority of all "bare soil" waterways constructed during this period.

Observations were made on soil type, area contributing run-off during the establishment period, waterway slope, species planted, method of planting, management, grass composition, distance of advance of grass across the waterway floor, percentage of waterway floor covered by grass, and depth of washes in waterway, if any. These aspects are listed in Tables 2 and 3 together with a record of the date of construction and a general assessment of the stability of each waterway at the date of survey. Observations were made on the last 10 chains of each waterway or on the whole waterway if it was less than 10 chains long.

Soil Types.—The waterways were located on two main soil types, red "scrub" soils and red "forest" soils. Both are red loams formed from basaltic parent material. The scrub soils are associated with rain-forest and the forest soils with sclerophyll forest. The scrub soils invariably occur on the more elevated areas of the undulating landscape and the forest soils on the lower slopes. Though both soil types have a high level of fertility, the productivity of the scrub soils is in general greater than that of the forest soils.

Considerable variation in colour, texture and apparent fertility was noted, particularly in regard to the scrub soil waterways. This may account for some of the differences both in colonization rate and in degree of erosion in the waterways.

Twenty-four of the waterways were on scrub soils and seven on forest soils.

Catchment Areas.—The catchment areas listed are those contributing at the time of establishment of the waterway. They range from 12 ac to 1,500 ac. In some cases an additional area was added at a later stage.

Waterway Slopes.—These varied from 1 to 8 per cent. Waterways with steeper gradients usually have the smaller catchments and those with small gradients have the big catchments.

Waterway Size.—Bottom widths of the waterways are recorded in Tables 2 and 3. The 24 scrub soil waterways range in bottom width from 6 ft to 38 ft, with an average of 16 ft. The seven forest soil waterways range in bottom width from 16 ft to 120 ft, with an average disturbed area of 21 ft. Three of these forest soil waterways of 100–120 ft bottom width were built with a centre strip of undisturbed grass.

Table 2

KINGAROY SCRUB SOIL WATERWAYS

Waterway No.	Date Constructed	Catchment Area (ac)	Waterway Slope (%)	Bottom Width (ft)	Species and Method of Planting	Management				Grass Composition					Percentage of Waterway Floor Grassed (%)	Distance of Advance across Waterway Floor (ft)	Depth of Gullies (ft)	Assessment of Stability
						Grazed betweed Crops	Grazed Heavily	Waste Area	Mowed	Rhodes (%)	Couch (%)	Paspalum (%)	Kikuyu (%)	African Star (%)				
1	Aug. 1957	30	5	12	Rhodes harrowed in	*			*	95	5				100	6	0–0·2	Stable
2	Sept. 1956	35	6	10	Self-sown	*				99					95	5	0–1	Only last 100 ft gullied (should heal)
3	Sept. 1957	61	7½	10	Couch and African star hand-planted. Rhodes broadcast	*				30	70			Patch	80	2–5	·5–1·5	Couch grass established in rill ; expected to heal
4	Dec. 1955	46	5	12	Self-sown	*						99			95	6	0–2·5	Three short gullies ; may need treatment
5	Sept. 1956	53	3	10	,, ,,	*				55		45			99	5	0–1·5	Grass established in rills ; expected to heal
6	Aug. 1956	124	2½	12	Rhodes broadcast, not covered ..	*				55	45				95	6	·5–3	Rills carrying grass and partly filled with silt ; should heal
7	Aug. 1957	77	2	18	Self-sown	*				30	10		60		60	0–9	·2– ·4	Stable
8	Nov. 1957	35	3	16	Nil	*				50	50				1	0–8	0–2·5	Unstable
9	Oct. 1956	75	6	24	Rhodes broadcast ; strike poor ..	*			*	50	25		25		70	3–12	·3– ·9	Expected to heal
10	Nov. 1956	20	3	10	Self-sown	*				99					100	5	0– ·2	Stable
15	Oct. 1957	50	5	24	Rhodes broadcast	*				95	5				100	12	0– ·5	,,
17	May 1956	37	3	10	Self-sown	*				10	90				100	5	0– ·3	,,
18	Oct. 1956	19	4	16	,, ,,	*				99					100	8	none visible	,,
19	Nov. 1956	28	6	6	,, ,,	*				99					95	3	·2–1	Short rill caused by plough furrow at one place only ; stable
20	Oct. 1956	16	7	10	Spread by grader	*							99		95	5	0–2	Short rill at one place only ; now grassed up ; stable
21	Nov. 1956	200	2	24	Self-sown	*				99					50	4–12	·1– ·5	Grassing up well
22	Oct. 1955	200	2	38	,, ,,	*				80		10	10		90	14–19	0– ·5	Stable
23	Nov. 1956	110	7	20	,, ,,	*				80	20				20	0–9	·5–3	Unstable
25	Oct. 1957	45	8	16	Rhodes runners hand-planted on 10 ft grid			*		99					70	0–8	1·5–4	Unstable, but grass in bottom of gully and contour banks not affected yet
27	Nov. 1955	12	5	8	Rhodes broadcast, not covered ..	*				5		95			50	2–4	·2–1	Unstable ; needs earth weirs and couch to heal
28	Oct. 1957	12	8	8	Rhodes runners hand-planted ..		*			20	80				80	2–4	0– ·7	Stable
29	Sept. 1956	88	5	36	Rhodes broadcast, not covered ..		*			70	30				45	0–18	1–1·7	Needs weirs to heal centre rill
30	Nov. 1956	72	6	24	Rhodes broadcast	*				90	5	5			90	12	0–1	Rill caused by trickle flow after grass established
31	Nov. 1955	146	5	10	Self-sown			*		99					75	2–5	0–1	Stable ; grass growing in bottom of rill

Table 3

KINGAROY "FOREST" SOIL WATERWAYS

Waterway No.	Date Built	Catchment Area (ac)	Waterway Slope (%)	Bottom Width (ft)	Species and Method of Planting	Management				Grass Composition					Percentage of Waterway Floor Grassed (%)	Distance of Advance on to Waterway Floor (ft)	Depth of Gullies (ft)	Assessment of Stability
						Grazed between Crops	Grazed Heavily	Waste Area	Mowed	Rhodes (%)	Couch (%)	Paspalum (%)	Kikuyu (%)	African Star (%)				
11	Sept./57	1500	1	120 (24)	No record	*				5	5	90			25	3–12	0– ·6	Expected to colonize and become stable
12	Nov./56	110	3	20	Rhodes broadcast and disc harrowed on banks	*				80	20				20	0–9	·1– ·8	May eventually colonize. Gaps in grass even on banks
13	Nov./56	1500	1	110 (25)	Self-sown		*				50	50			1	0–3	0– ·3	No deep gullies but grass making little headway under present management
14	Nov./56	35	2	16	,, ,,	*				99					70	3–8	0– ·2	Stable
16	Oct./57	75	3	30	Rhodes broadcast	*				99					15	0–10	·2– ·5	Erosion very slow but Rhodes grass not making much headway
24	Sept./56	42	4	16	Self-sown	*				85	15				25	0–8	·3–1·6	Unstable
26	Jan./56	650	1·3	100 (20)	,, ,,	*					10	70			99	10	0– ·5	Stable
										(plus 20% forest grasses)								

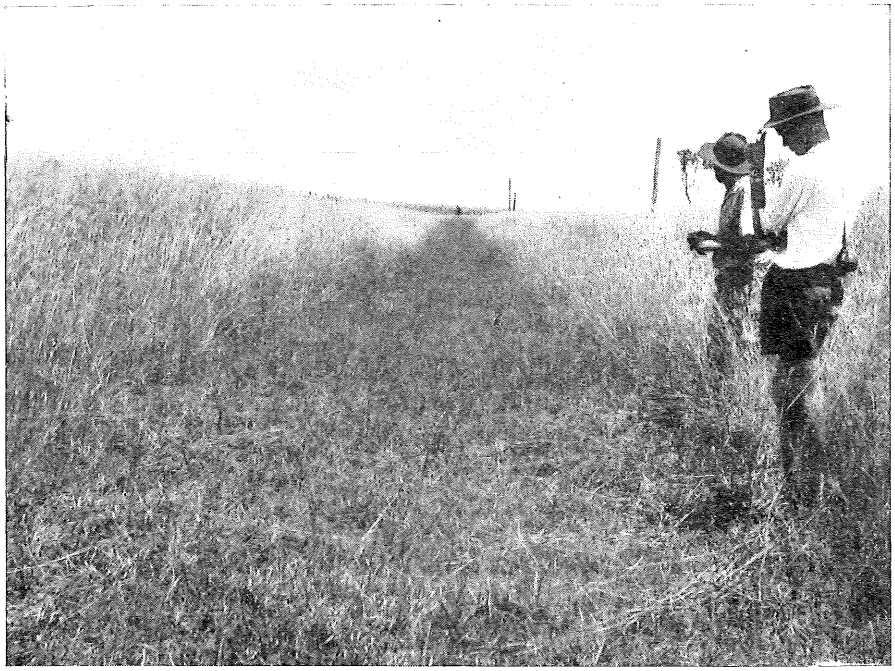

Fig. 5.—Well-managed Rhodes grass waterway at Kingaroy established by "bare soil" method. Photographed 2½ years after construction. Waterway 1 in Table 2.

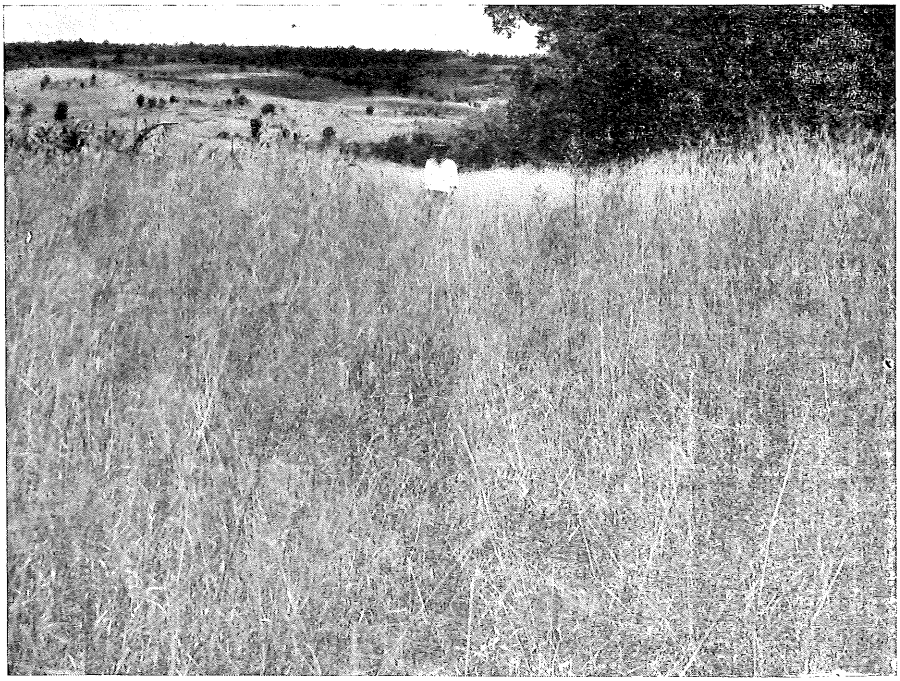

Fig. 6.—Rhodes grass waterway established by "bare soil" method. Constructed in September, 1956, in a Rhodes grass paddock. Photographed 3½ years after construction. Waterway 2 in Table 2.

Fig. 7.—Scrub soil waterway stabilized by couch and Rhodes grasses. Centre rill 0.5–1.5 ft deep has common couch grass growing in the bottom. Photographed 2½ years after construction. Waterway 3 in Table 2.

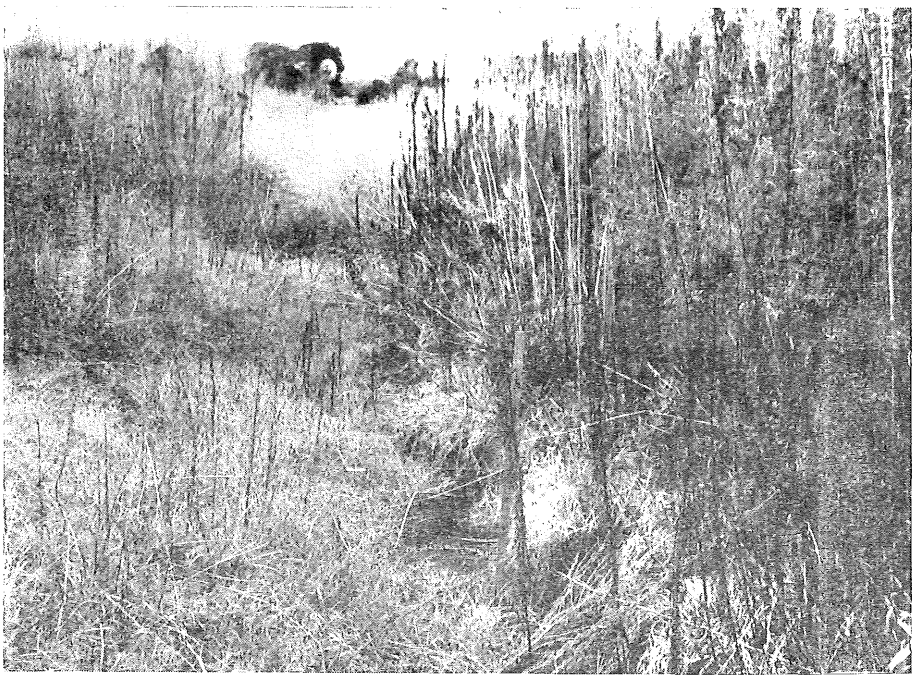

Fig 8.—This scrub soil waterway has a centre gully 0.5–3.0 ft deep. Common couch grass is stabilizing the gully, which is now partly filled with silt. Waterway 6 in Table 2.

Fig. 9.—Grass was not planted in this scrub soil waterway. Some kikuyu grass plants were accidentally established on the left bank during construction and have now spread to the centre. Waterway 7 in Table 2.

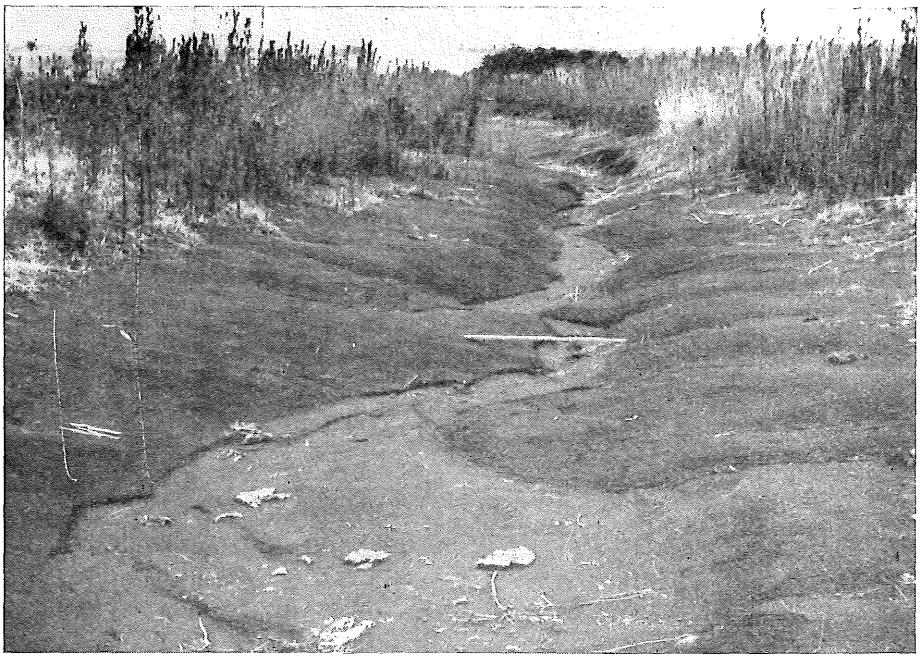

Fig. 10.—Grass was not planted in this scrub soil waterway nor has self-sown grass appeared. The centre gully is up to 2½ ft deep. Waterway 8 in Table 2.

Fig. 11.—Exposed stump roots show gradual loss of soil in a forest soil waterway. Rhodes grass is colonizing slowly in this soil type. The waterway is 2½ years old. Waterway 16 in Table 3.

Fig. 12.—A wide forest soil waterway catering for run-off from a 1,500 ac. catchment. Excavation is confined to a strip 25 ft wide on each "side." Waterway 13 in Table 3.

Fig. 13.—Of the 31 waterways inspected, this waterway showed the most serious gully development, including a gully 4 ft deep. Predominance of gravel in the profile suggests that the soil type was atypical and unsuited to the bare soil method. Waterway 25 in Table 2.

Rainfall.—Monthly rainfall for the years 1955 to 1960, together with monthly averages for a period of 54 years, are given in Table 4. It will be noted that 1955, 1956, 1958, and 1959 were years of above-average rainfall, while 1957 was a drought year.

Runoff.—No records of run-off are available. Most owners interviewed could remember waterways running strongly at some time or other in the early stages. It is reasonable to assume from rainfall figures that normal run-off occurred.

Grass Species.—Most of the waterways were found to be partly or wholly colonized by Rhodes grass (*Chloris gayana*) and/or common couch (*Cynodon dactylon*). A few carried paspalum (*Paspalum dilatatum*) and a few kikuyu grass (*Pennisetum clandestinum*). One had a section with common African star grass (*Cynodon dactylon*). A rough estimate of the percentage of each species present was made by visual observation.

Annual grasses and weeds were sometimes present on the banks but were usually in the minority on the waterway floor.

Table 4

KINGAROY RAINFALL (INCHES), 1955–1960

——	1955	1956	1957	1958	1959	1960	54 Year Average 1906–1959
January ..	1·27	5·97	1·28	4·54	9·64	2·40	4·53
February ..	4·98	8·51	1·97	7·24	4·34	1·81	3·93
March	9·18	5·98	2·70	4·83	2·32	1·53	3·36
April	4·57	3·00	·21	3·17	·11	1·88	1·76
May	5·77	6·01	·20	·37	2·51	1·38	1·35
June	1·44	2·90	1·29	7·54	·19	..	1·91
July	1·55	1·28	2·98	·07	2·32	..	1·49
August	·03	·26	·97	1·97	·08	..	·96
September ..	1·28	·22	·20	1·04	3·09	..	1·49
October ..	2·86	1·90	1·79	1·84	7·99	..	2·36
November ..	1·33	1·75	·94	1·41	9·96	..	3·00
December ..	9·86	6·53	1·53	3·16	3·04	..	4·12
Total ..	44·12	44·31	16·06	37·18	45·59	..	30·26

Method of Planting.—Rhodes grass was usually planted by broadcasting seed on the banks. In most cases it was left uncovered and few good strikes were reported.

Many of the waterways were not planted at all. Where these were built through an existing stand of grass an adequate grass cover was readily established. Where they depended on spread of grass seed from adjacent areas by wind or water, results were not so satisfactory. Where paspalum was observed in waterways it could be traced to stands which grew on the waterway site. Kikuyu grass was not usually planted, but in several cases where the waterway had been constructed through a patch of this grass it was well distributed along the waterway banks, having been carried there by the graders during construction. Common couch grass is a common weed in the area and many of the waterways had it in spite of the fact that none was planted.

Management.—Few of the waterways were fenced. Most received a good spell from grazing while the adjacent area was under annual summer crops, with some grazing after the crops were harvested.

Three of the waterways appeared to be overstocked and grazed most of the time. This would be detrimental to grass colonization. A few waterways were not grazed at all at any stage. Two were mowed as required but most lacked this attention.

Extent of Colonization.—The extent of colonisation was judged by measurement of the distance of advance of the grass into the waterway floor and by an estimate of the percentage of the waterway floor covered by vegetation. As there appears to be a difference in behaviour between the scrub and the forest soils, results are discussed separately in a later section.

Distance of Advance.—Distance of advance of the grass from the waterway banks across the waterway floor was obtained by measurement. In most cases this represents growth of grass by runner from the banks but in some cases, particularly in low-gradient waterways, grass appeared to have germinated on the waterway floor.

In many cases grass had become established over the full width of the waterway. Maximum distance of advance was then taken as half the waterway width.

Percentage of Waterway Floor Covered by Vegetation.—This figure was obtained by visual observation aided by measurement of bare patches in relation to the waterway width. In the case of very wide waterways, where the grass in the centre had not been disturbed in construction, colonization figures relate to the disturbed area only.

Of the 24 scrub soil waterways, 15 had 80 per cent. or more of the bottom covered by grass; five were 100 per cent. grassed. Six more had 50–80 per cent. grassed and only three had less than 50 per cent. of the bottom covered by grass.

Of the seven forest soil waterways, one had 99 per cent. of the bottom covered by grass, one had 70 per cent. and five had less than 50 per cent. covered by grass.

Reasons can readily be found for the poor grassing of the three scrub soil waterways which were less than 50 per cent. grassed. Two had not been planted, nor had self-sown seed contributed to grass establishment; unsatisfactory grass establishment was noted on the banks. The third waterway was overgrazed.

In the case of the five forest soil waterways where less than 50 per cent. of the bottom was covered by grass, lack of suitable grass on the banks accounts for two and overgrazing for one. There is no obvious reason why grass is not better established in the other two waterways and one waterway shows clear indication that Rhodes grass is making only slow progress towards colonization (Figure 11).

All grasses appeared able to colonize the scrub soil waterways satisfactorily. Of the 21 scrub soil waterways with 50 per cent. or more of the floor colonized,

14 had Rhodes grass predominant, three common couch grass, two paspalum, and two kikuyu grass. The paspalum appeared to have germinated and established on the waterway floor rather than to have spread from the banks.

Erosion in the Waterways.—Erosion was judged by inspection and measurement of the depth of rills with line level and measuring rod. The range of depth of rills is given in Tables 2 and 3. In most cases rills were intermittent in character and in all cases gullying was confined to the centre of the waterway. In no cases had gullying reached the stage where the gully head had started to cut back into the contour banks which discharge into the waterway.

The forest soil waterways seem to have more resistance to erosion than those on scrub soils. Six out of the seven showed rilling no more than 1 ft deep and three of these had rills no more than 6 in. deep. Fifteen out of 24 scrub soils showed rilling no more than 1 ft deep, and eight of these were no more than 6 in. deep. Nine scrub soil waterways and one forest soil waterway showed rilling over 1 ft deep. Of these, five (all scrub) had rills over 2 ft deep. Maximum depth of gullying was 4 ft.

Discussion.—The 10 waterways that have developed gullies over 1 ft deep provide evidence that the method is not perfect. On the other hand, 21 waterways either have no rills or the rills are not more than 1 ft deep. Seventeen of these have more than 50 per cent. of the waterway floor grassed. Stabilization of these 17 waterways is well advanced. The four that are not grassed are forest soil waterways and the low erosion losses indicate that there is ample time available for grass establishment. It may be desirable to establish different grass species.

Of the 10 waterways with rills over 1 ft deep, five have 80 per cent. or more of the waterway floor grassed and in most cases grass is well established in the bottom of the rills. These must be conceded a good chance of stabilizing with little or no further attention.

Of the remaining five waterways which have rills over 1 ft deep and less than 80 per cent. grass, three (two scrub and one forest) were not planted and even now have large areas on the banks with no suitable grass. One is overgrazed. One has a soil profile showing a considerable amount of gravel and should not be regarded as typical red scrub soil.

V. DISCUSSION

There is sufficient evidence to demonstrate the practicability of the "bare soil" method under field conditions on red volcanic soils in Queensland. In the Atherton Tableland case reported here, erosion was limited and colonization of the waterway occurred eventually. In the Kingaroy survey, not every waterway inspected was entirely satisfactory in relation to degree of erosion and extent of

colonization, but it must be remembered that these waterways were not all given ideal treatment. For example, grass was planted in only about half of them. That a reasonable proportion was found to be completely satisfactory and that most were at least reasonably satisfactory is evidence enough that the method is practicable.

Advantages of the method are that there is no delay in the installation of contour banks and that there is no need for costly alternative waterways in lower parts of the catchment which would otherwise be necessary while grass is being established in the prepared waterway.

The advantage of being able to use the waterway immediately is based on a human failing but it is no less real and applies not only in areas where soil conservation work is in the pioneering stage. Even while they admit that the prior building and grassing of a waterway is a better method of waterway establishment and results in a superior waterway, many experienced soil conservation farmers still prefer to leave the building of the waterway until very late. They rarely plan waterway construction until they are ready to install contour banks in the paddock to be served by the waterway. The main reason is that they prefer to use the funds available in building contour banks. These provide immediate practical benefits, but a waterway is non-functional until it is used to dispose of run-off water from the contour banks.

Consideration is also given to the fact that a long delay is likely where the orthodox method of waterway establishment is adopted. Once the waterway floor is loosened to provide satisfactory conditions for seeding it cannot be used for water disposal until reasonable grass cover has been established. The time required for the establishment cannot always be predicted.

In cases where waterways are constructed in depressions already carrying run-off water, the usefulness of the "bare soil" method can be readily appreciated. No special stabilizing structures or temporary diversion banks are needed and there is no erosion outside the waterway due to run-off water that is temporarily carried there.

The main disadvantage of the method is that the waterway has little grazing value for several years. Moreover, the grass that eventually establishes on the subsoil in the waterway is rarely as vigorous or as productive as grass that is planted in a well-prepared and fertilized seedbed. On the typical Queensland cash-crop farm, where livestock production is not developed to any great extent, the waterway is not valued for its production and this disadvantage is then relatively unimportant.

A minor disadvantage is the increased cost of waterway maintenance during the initial years. Silt deposits will occur in places where velocity is reduced, e.g. where a change from high to low land gradient occurs. Removal of this silt is necessary during the establishment period.

A further disadvantage is that a rough, uneven waterway floor can develop. Small washes occur during the establishment period and although grass ultimately establishes in these rills they remain an undesirable feature, making mowing difficult and constituting a potential source of erosion in the waterway.

The successful practice of this method of waterway establishment is limited to certain soil types and to non-eroded waterway sites. Climatic conditions and availability of suitable grasses may also be limiting factors.

The basic requirement of the soil type is that it should have a firm subsoil capable of carrying water at high velocity without eroding deeply. A gradual soil loss during the establishment period is probably unavoidable and even the formation of shallow gullies over a period does not eliminate the soil type from consideration. Soils that readily form deep, sharp-sided gullies should be avoided.

Rate of erosion must be balanced against rate of colonization. Provided colonization will proceed and eventually stabilize the waterway, some erosion in the establishment period wil not matter in the long-term view.

Rate of colonization will depend on soil fertility, climate and the availability of suitable grasses. It can be expected to vary widely in different localities. The survey of Kingaroy waterways has shown that the more fertile scrub soils colonize more rapidly than do the forest soils, which are generally regarded as being less fertile.

With regard to suitable grasses, it will almost certainly be found that the grass most suitable for advancing across the waterway floor will also be equally ready to advance in the other direction, i.e. onto the cultivation. The answer to this problem lies in choosing from the species available the one that is most easily controlled by cultivation. For example, in the Kingaroy area kikuyu grass, although an excellent waterway grass in most respects, is not generally favoured by farmers because control of encroachment is difficult on the red soils. Most farmers prefer to use one of the other species mentioned earlier.

It will be obvious from the description of the method that gullied waterway sites are not suited to the "bare soil" method. Unless special precautions are taken, washing out of the gully "fill" is almost inevitable. Where possible, waterways on such sites should be grassed before use. Where this is not practicable, success can be achieved by compacting the fill, using moist soil.

VI. ACKNOWLEDGEMENT

The author wishes to express his thanks to Mr. H. S. Pink (Senior Adviser, Soil Conservation), whose careful office records enabled the older "bare soil" waterways to be selected from the large number of waterways in the Kingaroy area.

(Received for publication September 27, 1960)