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SCOUR RESISTANCE OF FARM DAM SPILLWAYS WITH GRASS DORMANT

by

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April, 1968

The University of New South Wales
WATER RESEARCH LABORATORY.

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Preface

As part of a programme of research to improve methods for the design and construction of farm dams, the Water Research Laboratory, with the aid of a grant from the Water Research Foundation of Australia, made a study of the protection afforded to farm dam spillways by various low cost surfaces including grass. This work was completed in 1967.

Subsequently, as a laboratory research project, a retesting of the grasses during the winter season was undertaken. At the same time, the extra protection afforded by covering the spillway close to the grass roots with chicken wire was investigated. This report covers the recent work and supplements the information previously published.

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Summary

This report is the fourth in a series dealing with the use of natural grasses and bituminous and soil admixtures for surfacing farm dam bywash spillways. When the work reported here was completed, the test channels were demolished to make way for new construction, and no further tests of this nature are contemplated.

The previous report (Yong and Stone, 1967) dealt with the scour resistance capacity for grasses having a dense even cover, tested at the peak of their growing season. This report covers winter tests with the grass dormant. Once they have established a good root system, the grases withstand high velocities amazingly well, even when dormant, and there is no need to reduce permissible design velocities as given previously for grasses subject to winter floods.

Three channels were available for each grass type, so a test was also made on one channel of each grass of the extra protection that might be afforded by anchoring a layer of chicken wire on the spillway at or near the soil surface and letting the grass grow up through it.

In fact, none of the spillways failed hydraulically, failure due to the structural inadequacy of the channels preceding scour failure in every case, and no definite conclusion could be reached as to the added benefit of the chicken wire.

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1. Introduction

Tests were previously made at the peak of the growing season in channels of continuously varying slope from 10 pc. to 40 pc surfaced with various grasses (Yong and Stone 1967). Before the channels were demolished, an opportunity was available to retest the grasses in the dormant condition during the winter of 1967.

The test programme was started in mid-August 1967 and completed in mid-September 1967. The results, which are the subject of this report, supplement the results for the hydraulic characteristics of grassed spillways tested during the growing season.

2. Test Spillways

A detailed description of the test spillways is given in References 2 and 3. In general terms, a typical test spillway is a 2 ft. wide channel about 60 ft. long and 12 inches high with channel slope varying from 10 per cent at the upstream end to about 40 per cent at the downstream end. A head box with gates was provided at the upstream end to direct flowing water into the test channels individually.

After the completion of the test programme recorded in References 2 and 3, the grassed spillways were repaired and maintained until the winter. Channels which had suffered washaway of their downstream steeper ends were not rebuilt. Instead, a brick wall was built across the channel at the section where the washaway commenced. Some channels were thus foreshortened to as little as 20 feet while others remained at their original 60 feet length.

Three grassed channels (one for each grass type, namely Kikuyu grass, Rhodes grass and a mixture of Mullumbimby couch and couch grass) were selected for special treatment with chicken wire to increase the stability of the grassed spillways against erosion. The longest available channel was chosen for each grass type. The grass was first cut back to about one inch and then a layer of chicken wire with 2 inch openings was carefully pegged down at about $1\frac{1}{2}$ ft. intervals over the grassed surfaces by a series of U-bolts made of 1/8 inch diameter fencing wire. The U-bolts used in channel No. 6 with Kikuyu were 8" long but those in channels 8 and 9 with Rhodes and Couch were considerably shorter than 8 inches because the grass sods had been laid direct on hot mix and macadam respectively. This work was completed in May, 1967 and there was enough time before the tests for the grass to grow through the openings of the chicken wire and establish a satisfactory cover.

3. Conditions of Grassed Surfaces

3.1 Kikuyu Grass

The Kikuyu grass was about $4\frac{1}{2}$ inches in height. The grass was green on top but brownish near the bed. There were patches of dormant grass occupying about 10 per cent of the total surface area. Due to the dense even growth and well matted stem and root system which was established during the growing season, the grassed surface was considered as satisfactory. There were a few bare patches and local depressions. Figure 1 shows the grassed surface covered with a layer of chicken wire.

3.2 Rhodes Grass

The Rhodes grass was about $3\frac{1}{2}$ inches in height. The grass was dormant throughout the winter period and it was brownish in colour except for about 20 to 30 per cent of the grass which was green on top. Because of the nature of the grass to grow in tufts or tussocks there was little interlocking of surface growth between adjacent plants. This resulted in bare patches scattered over about 40 per cent of the surface area. This surface was considered to have only moderate protection. Figure 1 shows Rhodes grass covered with a layer of chicken wire.

3.3 A Mixture of Mullumbimby Couch and Couch Grass

The grass was about $1\frac{1}{2}$ inches high and it was about 60 per cent green on top, but brownish near the bed. There were patches of dormant grass occupying about 20 per cent of the total surface area. Scattered bare patches were observed along the entire channel. In the channel treated with chicken wire, the grass grew through the openings of the wire and provided a $\frac{1}{2}$ inch cover over the top The surface was considered satisfactory. Figure 1 shows the grass covered with a layer of chicken wire.

4. Flow Conditions

After modification of the head box, a higher flow through the system was possible. A maximum flow rate of 3 c.f.s. per foot width through each channel was obtained compared with the previous maximum of 2.5 c.f.s. per foot width. At maximum flow, the depth of water varied from about 8 inches at the upstream end to about 3 inches at the downstream end of the channel.

As in previous tests, flow in the channel was entirely supercritical and, for the downstream half of the length of the spillway channel, highly aerated.

5. Test Procedure

Tests were carried out at the maximum flow available from the system. Three to four depth measurements were made along each channel and the mean velocity of flow calculated. The flow was maintained at maximum rate either -

(a) until the grassed surface failed either through failure of the grass or structural failure of the channel, or

(b) until adjoining channels were endangered, or

(c) for 24 hours.

The generation of scour holes along the channel bottom and the associated water surface conditions were noted.

6. Test Results

6.1 Mean Velocity and Duration of Flow

Test results - mean velocity and duration of flow - on eight grassed spillway channels are summarized in Table 1. No test result is recorded for a mixture of Mullumbimby couch and couch grass in channel No. 7. The No. 7 grassed channel was so badly affected by 'piping' flow under the channel during the tests on adjacent grassed channels that the testing of this channel had to be abandoned. The test carried out on the channel No. 2 with Rhodes grass lasted for only 3 minutes at 9 f.p.s. before structural failure resulted about halfway along the channel. The No. 1 channel with the Couch and Mullumbimby Couch mixture also failed structurally after 10 minutes.

6.2 Bed Scour in Surfaces covered with Chicken Wire

6.21 General

Three grassed channels (one for each grass type) were selected for observing the effects of chicken wire as a form of reinforcement.

6.22 Kikuyu Grass (Channel No. 6) with Chicken Wire

The grassed channel was subjected to a test for 24 hours at maximum mean velocity of 10 f. p. s. Inspection of the channel bed after the test indicated that the grass surface was generally very satisfactory except at one place where the bed had sunk, due to piping action. Apart from the scour that usually developed along the side walls because of boundary effects, patchy slight scouring was evident in the vicinity of this sunken grass bed.

6.23 Rhodes Grass (Channel No. 8) with Chicken Wire

The grassed channel was subjected to test for $2\frac{1}{2}$ hours at maximum mean velocity of 9 f. p. s. Failure of this channel was due in part to undermining of the test bed during previous tests in adjacent channels. It appeared that the failure was hastened by chicken wire breaking loose at downstream sections and flapping up and down in the flow, creating turbulence and consequent scouring. (As noted in Section 2, the pegs anchoring the chicken wire could not be driven to the full 8 inches in this channel). Apart from these factors, it did appear that the Rhodes grass and chicken wire combination was inherently unsuccessful because of the nature of the grass to grow in separate plants with little interlocking of surface growth between adjacent plants. The naturally poor state of the surface in this channel compared with that in the other channels appeared also to be a factor in the failure of the channel. It is possible that the layer of hot mix prevented penetration of the root system to depth, thereby adversely affecting the growth of the grass which normally has a root system extending down several feet. Scour holes generally developed to sizes approximately 12 inches long by 12 inches wide and 6 inches deep.

6.24 A mixture of Mullumbimby Couch and Couch Grass (Channel No. 9) with chicken wire

This grassed channel was subjected to flow with maximum mean velocity 9 f. p. s. for 12 hours and subsequently to flow with maximum mean velocity of 10 f. p. s. for 24 hours. Inspection of the bed after test indicated that the top loose soil was completely washed away. There were a few scour holes developed in the downstream portion of the channel, generally of size approximately 15 inches long by 6 inches wide and 4 inches deep. In addition there were scattered bare patches, some exposing the root system. Despite these, the bed was still very firm after the test.

6.3 Bed Scour in Surfaces not treated with Chicken Wire

6.31 Kikuyu Grass

Testing of Kikuyu grass in channels Nos. 4 and 5 had to be discontinued after 4 hours and $7\frac{1}{2}$ hours respectively, not because of failure of the surface but because of increasing danger to adjacent channels caused by leakage under the brick dividing walls. The grass itself withstood the flow with no appreciable deterioration.

6.32 Rhodes Grass

Rhodes grass in channel No. 3 had likewise to be stopped short in testing after $4\frac{1}{2}$ hours because of possible damage to adjoining channels. The grass surface did not fail. Structural failure in channel No. 2 occurred about halfway down the channel after 3 minutes of flow. The grass upstream of the failure was still in good condition.

6.33 A Mixture of Mullumbimby Couch and Couch Grass

Neither channel could be properly tested, Channel No. 7 was too damaged from the tests on adjoining channels and Channel No. 1 failed structurally after 10 minutes.

6.4 Indication of Initiation of Scour by Surface Flow Conditions

Along the portion of the grassed channels where the flow was not aerated due to the steep slope, it was observed that the initiation of scouring on the bed could be detected by observing the surface flow conditions. This surface flow condition took the form of a local depression entraining air into the surface flow. This sudden depression of the water surface was due to the changing bed form caused by local erosion of the bed.

7. Discussion and Conclusions

Although cursory examination of the figures in Table 1 might indicate that channels protected by chicken wire stand up better than others, this must be regarded as unproven. In fact, as before, failure of the grass surfaces did not occur in any case except where precipitated by other factors such as structural failure. The fact that the two channels that withstood maximum flow for 24 hours were treated with chicken wire could be merely a result of the initial choice of channel.

As pointed out in W. R. L. Report No. 95 Section 2. 2, floods on farm dam spillways normally pass within 2 or 3 hours and the dormant Kikuyu and Rhodes grasses without chicken wire withstood flows of 9 feet per second for comparable times. There is no reason to suppose that the couch grass, had testing been possible, would not have withstood similar flows. There is therefore no reason to vary the design figures previously given so as to cater for winter flooding. Once the grasses are well established they withstand velocities up to 9 ft. per second (comparable to a discharge of 3 c. f. s. per foot width) even when dormant.

Due care in the initial planting of the grasses and while they are re-establishing on the spillway is the significant factor in producing the strong stem and root system that enables the surface to withstand high velocity flows for long durations even when the grass is dormant. Subsequent maintenance, such as infilling and, if necessary, re-sodding of any substantial scour holes left after a flood, is also important; for, if the surface is allowed to deteriorate, heavy rainfall even without reservoir outflow can gradually lead to gully erosion. Failure of the spillway surface at much lower overflow velocities will ensue, starting from areas of naked soil which can be eroded by velocities as low as 2 feet per second.

As to the likely benefits to be derived from chicken wire reinforcement, although these tests were not sufficient to prove or disprove the advantages in quantitative terms, it did appear to observers that the chicken wire was helpful in restricting the spread of damage in the Kikuyu and Couch grass tests especially where long durations at high flow were encountered. Particularly, its use may be worthy of consideration for Kikuyu grass, for, once broached at a point of weakness, entire surfaces planted with this grass have been known to slide off and roll up in a mat at the bottom of the spillway channel, (Yong and Stone, 1967). Chicken wire could help to prevent such an occurrence. Rhodes grass, which grows in separate clumps with less interlocking of surface growth, did not appear to benefit from the chicken wire. If chicken wire is used, it should be anchored well into the soil, as it can prove deleterious rather than beneficial if it does not remain firmly anchored.

References

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2. Yong, K. C. and Stone, D. M. "Resistance of Low Cost Surfaces for Farm Dam Spillways" Report No. 95, Water Research Laboratory, University of New South Wales, April 1967.

3. Yong, K. C. "The effects of channel flow of water over steeply sloping grassed spillways" M. Eng. Sc. Thesis, University of New South Wales, 1967.

Table 1: Summary of Test Results on Grassed Spillway Channels

Channel No.	Grass Type	Discharge per ft. width cfs/ft.	Mean Velocity (fps)	Duration of Flow (hours)	Remarks
1	A mixture of Mullumbimby Couch and Couch	3.0	9.3	10 minutes	The test on this channel was not successful because the bare soil downstream of the end wall, located at half way of the grassed channel, was badly eroded at start of test. As a result, the end wall collapsed under flow, causing failure of the grassed channel. No further test was attempted on this channel so as to pres-erve the adjacent grassed channels from being affected by undermining from the sides.
9	A mixture of Mullumbimby Couch and Couch grass	2.6	9	12	With 2" opening chicken wire pegged down over grassed channel
		3.0	10	24	
6	Kikuyu	3.0	10	24	With 2" opening chicken wire pegged down over grassed channel.
5	Kikuyu	3.0	9	$7\frac{1}{2}$	Test stopped to prevent danger to adjacent channels.

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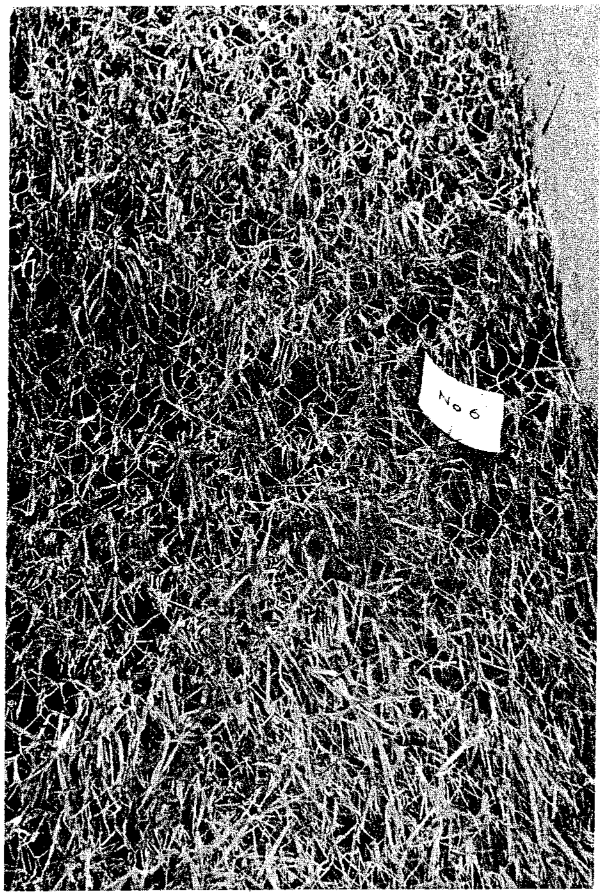
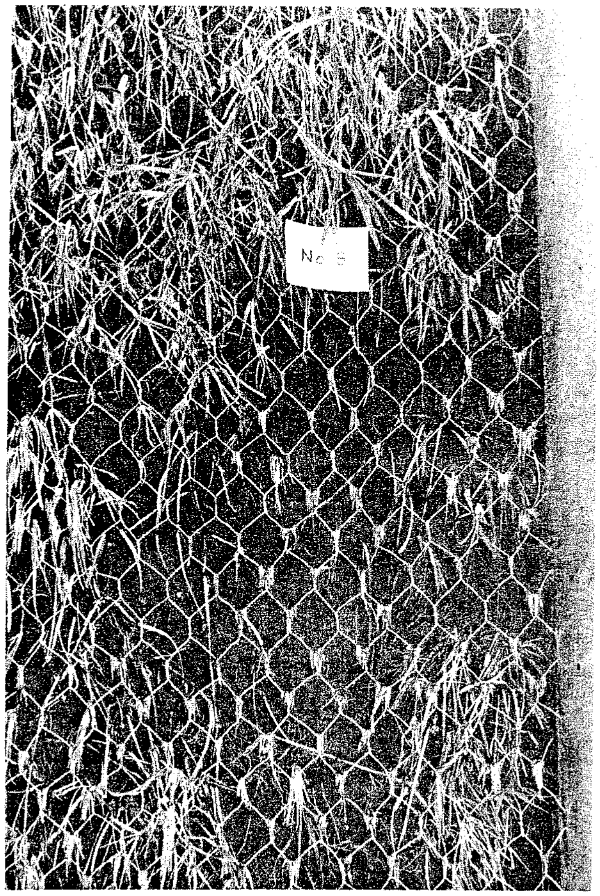
Table 1 (cont'd): Summary of Test Results on Grassed Spillway Channels

Channel No.	Grass Type	Discharge per ft. width cfs/ft.	Mean Velocity (fps)	Duration of Flow (hours)	Remarks
4	Kikuyu	3.0	9	4	Due to lateral enlargement of scour hole at downstream end of channel, the test had to be stopped since adjacent channels were in danger of being undermined by this scouring.
3	Rhodes	3.0	9	$4\frac{1}{2}$	Channel in poor condition at start of test as a result of winter weathering. Failed half way down channel.
8	Rhodes	3.0	9	$2\frac{1}{2}$	With 2" opening "chicken wire" pegged down over grassed channel.
2	Rhodes	3.0	9	3 mins.	Test had to be terminated since the brick side wall of the channel collapsed near the downstream end, due to scour from Channel No. 1, undermining a section of the wall.

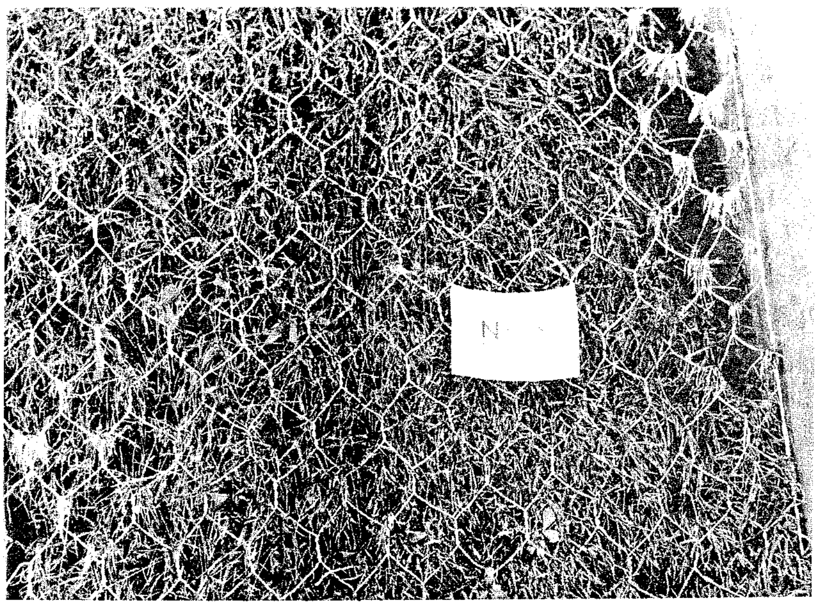
Note : A mixture of Mullumbimby couch and couch grass in Channel No. 7 was so badly affected by piping flow underneath the channel during the testing of adjacent channels that testing of this channel was abandoned.





Kikuyu Grass

Rhodes Grass



A mixture of Mullumbimby Couch and Couch Grass