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The Missouri Soil Saving Dam

Low-Cost Structure for Use in Farm Plans for Water Management

J. C. WOOLEY, W. M. CLARK, AND R. P. BEASLEY

A Missouri soil saving dam in place, with wings covered by the backfill and earth puddled-in to the approximate level of the notch.

COLUMBIA, MISSOURI

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J. C. Wooley, M. W. Clark, and R. P. Beasley*

The Missouri low-cost soil saving dam has been developed and tested under a wide range of farm conditions in all parts of the State. It has been widely used and is recommended as an essential part of an economical water management plan for a farm. By such a plan it is possible to control both gully erosion and sheet washing.

Farmers generally are keenly conscious of the damage done to their fields by gully erosion. It is not difficult to secure popular support for a gully control program. A state-wide survey of erosion conditions in 1935 found 11,668,000 acres, or more than one-fourth of the State's entire land area, moderately gullied and 8,027,000 acres seriously gullied.

The damage done by gullying includes more than the loss of the soil and the crops displaced in these channels. Fields are cut up into small, irregularly shaped patches, many of which become waste areas. The ditches grow deeper and cut back into other fields, creating hazards for livestock and man, increasing the erosion on adjacent lands. Rain water runs off quickly leaving a small amount of moisture to mature crops.

Even greater economic losses result from sheet erosion, caused by the less noticeable but much more extensive sheet-like movement of runoff water from entire areas of unprotected land. The survey mentioned above revealed that approximately one-half of the top soil of the State has been eroded away by sheet wash.

In order to control sheet erosion, a water management plan for an entire farm is necessary, but such a plan will at the same time control and erase the gullies. This type of control, therefore, is recommended since it replaces the expensive and laborious measures formerly used on gullies alone.

Using the Missouri Dams in a Water Management System for the Farm

Before any work on mechanical structures for erosion control is begun on a farm, the whole farm should be studied in an effort to plan a system that will effectively and economically

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*The authors acknowledge the cooperation and valuable assistance received from Mr. C. R. Meeker, Missouri Field Representative of the Portland Cement Association, in the development of the Missouri soil saving dam; also in the preparation of that part of the bulletin pertaining to the making of high quality concrete.

control runoff water. This system, when put into effect with proper land use, will solve both the sheet washing and gully problems for the whole farm. Such a system will greatly increase the absorption of rain water and will control the velocity of excess runoff water to such an extent that sheet wash will be cut to an unimportant fraction of former losses, and hillside gully erosion will be completely controlled.

The plan need not be expensive. In fact, more economical control can be accomplished by this system than in any other way. Sometimes the entire job can be done without any gully structures and without more than well sodded terrace outlets, but more frequently two or three concrete dams will be required on the farm to let water form terrace outlets or diversion channels into main stabilized drains. Structures are sometimes required to control main drainageways not stabilized. The use of concrete structures in hillside gullies throughout the field should be avoided. These often are expensive if used in sufficient number to give reasonable control in the individual gullies. They provide little or no real protection from sheet erosion and contribute nothing to the saving of soil moisture between the gullies where the greatest economic losses occur.

By using terraces, dikes and diversion channels, the hillside ditches can be eliminated and all the excess runoff water carried to one outlet at the edge of the field. Frequently the water can be conveyed down the slope on a transversely leveled outlet which has been prepared, treated and seeded and has become heavily sodded.

A set of structures may sometimes be required in the outlet if the slope is steep and a large quantity of water is to be carried. In this case, however, only one set of structures is required instead of the several sets that would be required in the control of individual hillside ditches. With the use of terraces the top soil, lime, manure, fertilizer, or seeding is saved from being washed away by sheet erosion between the ditches and at the same time the ditches are controlled. It is much cheaper to fill hillside ditches with earth and take the necessary steps to prevent the earth washing out than it is to fill the ditch with concrete and steel. Moreover, the concrete in the middle of the field is often an obstacle to the later development of a water management plan. The use of any gully control structures should then be avoided except as located in a well thought-out permanent system.

Several years will usually be required to complete the entire water conservation and disposal system for the farm but with a plan to work toward, each piece of work done can contribute to the completed plan. The dams, terraces, or terrace outlets will not have to be torn down and relocated before a satisfactory system can be completed. See Missouri Extension Circular 433 for further suggestions on planning a complete soil and water conservation system, and Extension Circular 355 for details on constructing and establishing grassed outlets and constructing native rock dams.

Large Dams in Main Drains Are Rarely Justified

The use of large gully control dams in drains which have a well established base grade and drainage area of several hundred acres is generally the poorest investment for erosion control that can be made on any given farm. Rarely there may be an exceptional case where a dam is much needed for a road or for other special purposes.

When dams are to be used in terrace outlets, only permanent or semi-permanent dams are recommended. The same recommendation holds for main drains with the exception that willows will often, after a period of growth and management, prove successful in controlling a wet gully or drain. Seldom can any one of the many forms of temporary dams such as wire, brush, logs, etc., be used to advantage as compared to the cost and results obtained from the use of the Missouri concrete dams and some types of native rock dams. The so-called temporary dams have indeed been very temporary unless repaired almost continuously, particularly after the first two to three years. Their use, in light of other developments, appears to be warranted only as an exception and not as a rule. Their relatively greater labor requirement for proper construction and maintenance places their use at any time on a questionable basis.

Advantages and Disadvantages of the Missouri Dam

The Missouri concrete dam is designed to avoid supporting a vertical wall of earth. The dam is constructed on a slope between 1¼ and 1½ to 1 and thus utilizes the angle of repose of the soil to avoid the necessity of heavy construction.

The cutoff wings are also constructed on a slope extending back into the berm or bank which allows the earth to lie on the sloping wing and thus avoids, to a large degree, the tendency of earth to pull away from the structures in dry weather as it often does with a vertical wall structure. The bad effects of shrinkage or freezing of the soil are minimized. Another feature which seems to be important in the new structure is that it is not anchored deeply in the ground, where different parts would be subjected to different conditions and thus to varying stresses.

The structure also consists of a combination of arches and thus avoids excessive stresses encountered with straight walls and corners. Wood forms, except for the velocity check, are not needed in building this type of structure which again allows for a saving in time and a reduction in construction cost.

The above features all make for lighter, more simple construction and this in turn allows the structure to be properly built at one-third to one-sixth the cost of a conventional type vertical dam. A case is on record where a Missouri dam was constructed at a labor and materials cost of $25.00, which was about one-seventh of the estimated cost of a conventional, vertical type concrete structure strong enough to do the same job. The farm owner in this case pointed out that if one figures 6% interest on the difference in investment, he would save $9.00 per year, or in a three-year period on interest alone he would have saved enough to construct a second Missouri dam.

The economy and performance of this concrete structure have thus far seemed outstanding. However, one point is still undetermined and this is the total length of life of such a structure. The oldest structures of this type were built by the Agricultural Experiment Station of the University of Missouri in 1934. These dams, except for minor additions to improve the wing design, are to all appearances as good as they were the first year after their construction. On some of the larger structures there are minor check cracks, which were expected but have caused no trouble and apparently will be of little or no consequence. Tar can be used to seal these checks as on a road slab if they should ever widen or become troublesome. This has not occurred in any structures to this date.

All structures that have been completed at somewhere near the recommended design have required very little repair. A small amount of maintenance is essential, but this may be expected on any permanent structure. In fact, the amount of maintenance per structure on this type has been much less than with the conventional dams. This, the authors believe, is because of the design of the sloping head wall and curved wings as previously mentioned. A large number of these structures have been placed over the state in the past four years. From a study of these structures in the field, it would seem that where they are maintained the life of the structure will be dependent entirely on the quality of concrete used in the construction.

Design and Construction of the Missouri Dam

The Missouri concrete dam is constructed by cutting into or building up earth as needed in the desired location to make the form for the structure. The reenforcing is then put in place and concrete is floated on the earth forms. The reenforcing mesh is pulled up or blocked two inches above the earth and two inches of concrete is placed above the reenforcing. The concrete is floated (using a wood float) to a uniform thickness of 4 inches, and when it begins to set up it is steel trowled to leave a dense weather resistant finish. The mortar must be a workable mixture and can often be placed better in two layers—one under the reenforcing mesh and one on top. The top layer can follow the first as soon as the first begins to set up and become firm.

Fig. 2.—Downstream side of shaped earth form. This earth form at the end of a terrace outlet is ready to be covered with concrete and will carry water from a terraced field in Scotland County. Notice the heavy hog wire which will be in the middle of the 4-inch layer of concrete.

Fig. 2 shows earth forms and excavation complete with reenforcing placed.

Figs. 3 and 4 show working drawings with dimensions and detailed specifications for building the Missouri dam.

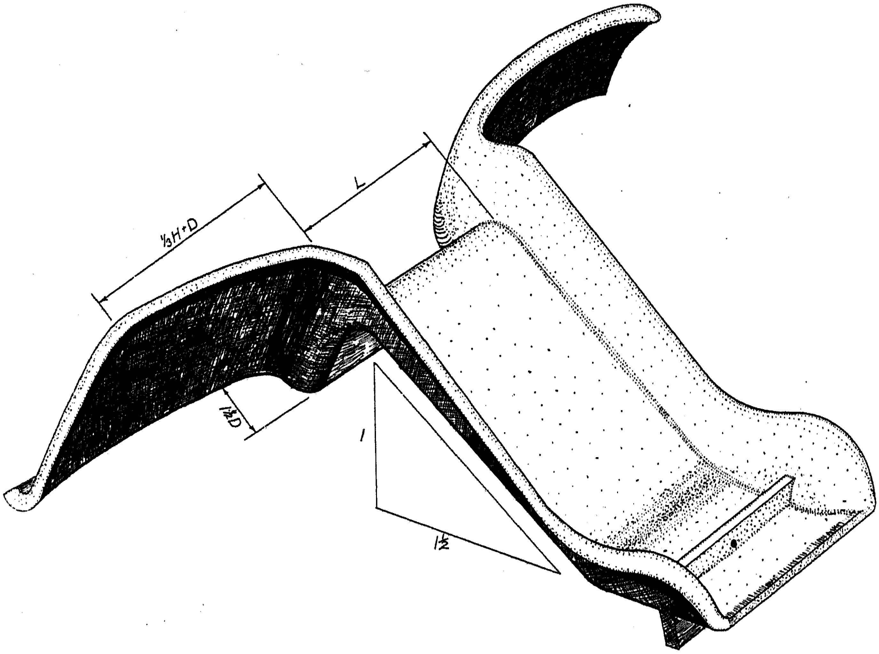


Fig. 3.—Perspective drawing showing completed Missouri dam as it would be removed from the ground. Figure 10 shows a Missouri dam as it is in location, completed with backfill after several years of use.

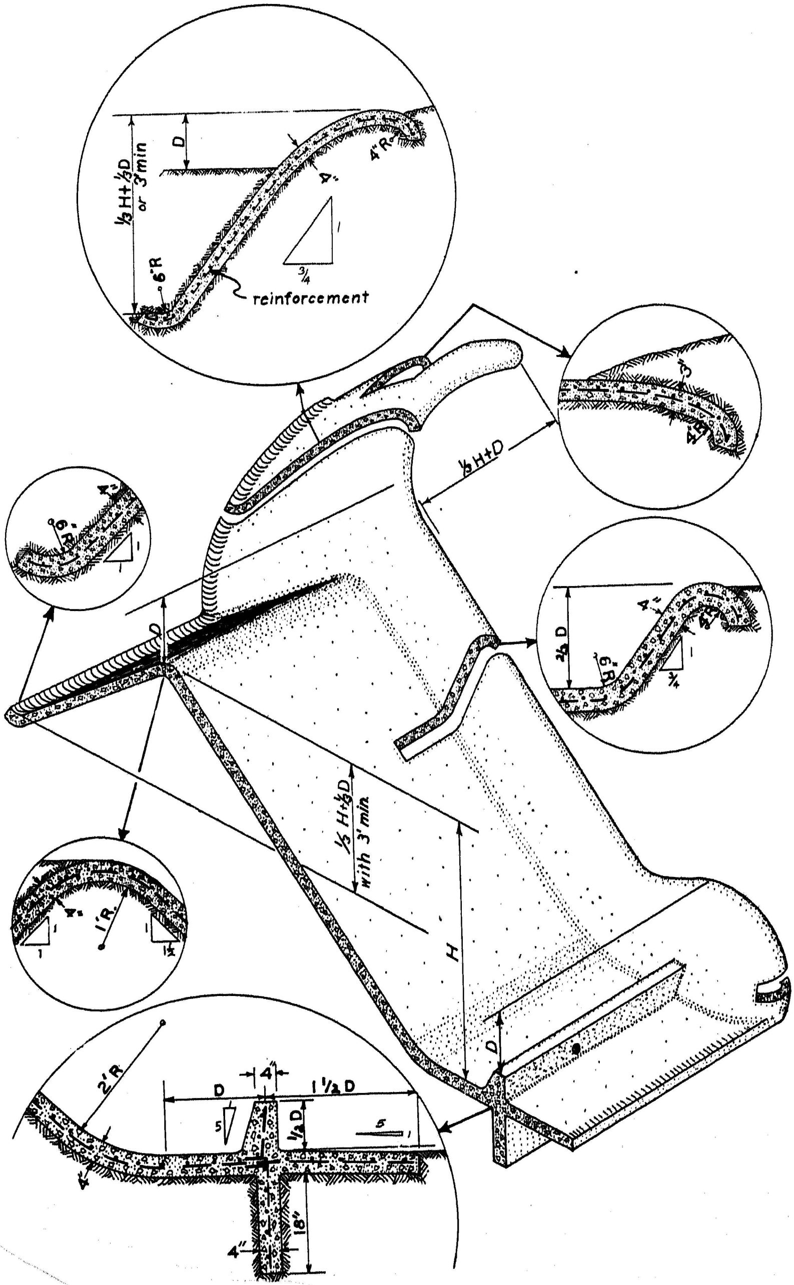


Fig. 4.—Working drawing of Missouri dam showing construction details and enlarged cut-a-way sections.

Structures Placed in the Terrace Outlets

When structures are used for complete control of an outlet or waterway, they are placed to allow the apron of one structure to be almost level with the notch of the structure below. A 4 to 6 inch grade per 100 feet is permissable between the structures if some effort is made to encourage vegetation to grow between the structures. If the outlet is to be controlled entirely by mechanical means and the channel between structures is narrow and barren of vegetation, the apron of one should be placed level with the notch of the one below. Fig. 5 shows a cross section of a completely controlled outlet or drainageway.

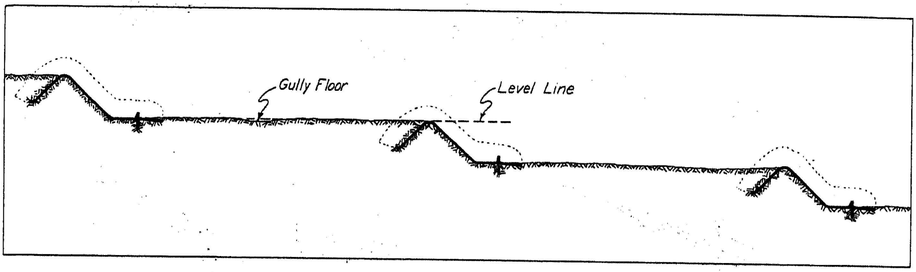


Fig. 5.—Cross section view of Missouri dams used in a series to give complete mechanical protection in a gully or terrace outlet. A combination of grassed outlet and structures is usually preferable to complete control by structures.

Structures can be used to reduce the grade in a terrace outlet or drainageway say from a 10 per cent slope to a 4 per cent slope, using vegetation to control the 4 per cent grade between structures. Care must be exercised here, however, to prevent water from flowing too deep between structures and washing out the grass. Also the slope between structures must be treated as recommended in Circular 355, "Terrace Outlets for Missouri", to secure a completely vegetated outlet. This treatment includes leveling, plowing under a heavy application of manure, fertilizing with complete fertilizer, and protecting from runoff water until the grass is well established. Combination of the two methods of control seldom is advisable, however, since it usually requires extremely wide structures and inconvenient areas for seeding to vegetation.

Figs. 6 and 8 show two views of a structure complete except for backfill, and Figs. 7 and 9 show the same structure after earth backfill is completed. Fig. 6 also shows an up-stream view of cutoff and wing construction.

Fig. 6.—The upstream side of a dam in Boone County with the structure completed except for the earth backfill. Notice the low portion in the center known as the "notch", which will carry the water over the structure. The wings are to be covered with earth and a small terrace like dyke is to be placed along the fence to divert water through the notch.

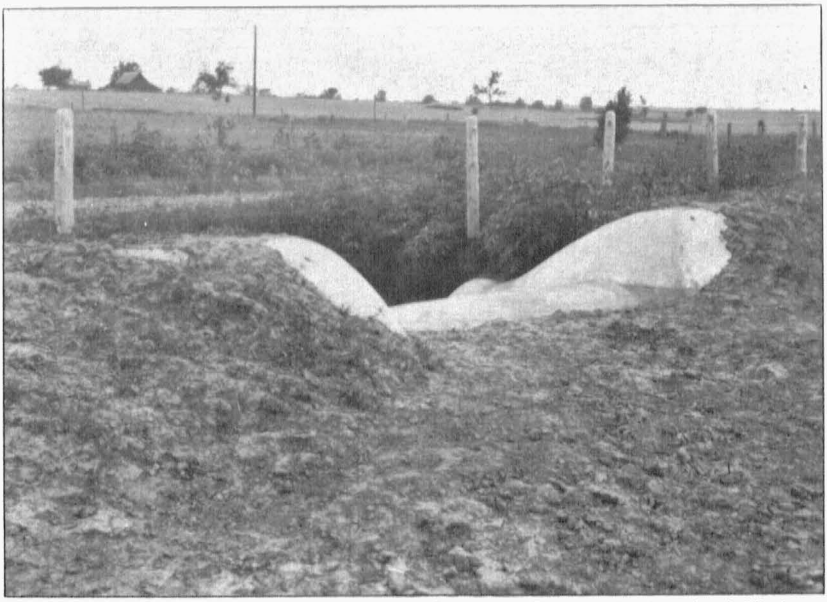


Fig. 7.—The same structure as shown in Figure 6 after backfill is properly made. Note the wings are completely covered and the earth is puddled in to the approximate level of the notch.

Fig. 8.—The downstream side of the same structure as in Figures 6 and 7, with baffle and stilling basin shown. Notice the rolled edges of the structure and the flat apron on which the water will fall after striking the baffle velocity check. This structure will carry water from approximately 40 acres of terraced land coming from a wide grassed outlet to be constructed along the fence seen on the left and not from out in the field where the old gully was located.

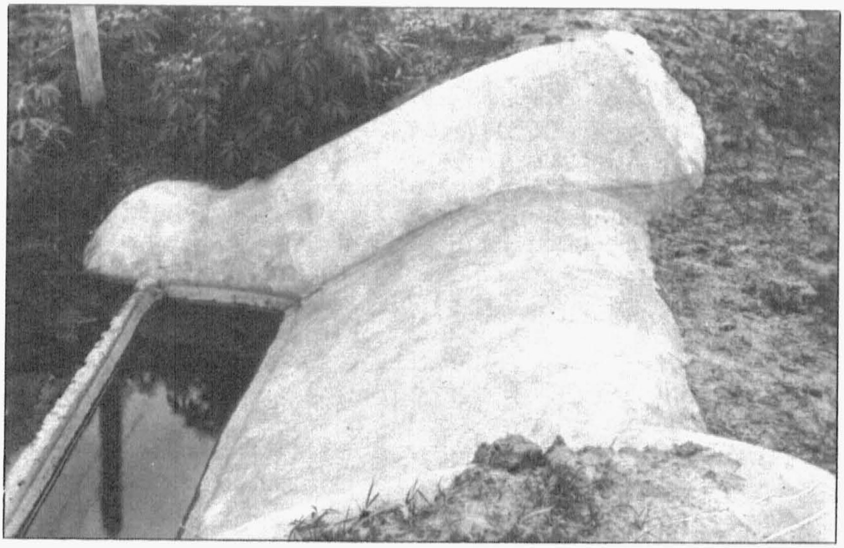


Fig. 9.—Looking down on the same structure as shown in preceding figures after one winter's use. Note the water in the stilling basin although the baffle has a drain through it. The apron was placed slightly lower than the base grade of the drainageway below the structure. This prevents any cutting or overfall as water leaves the structure.

Structures Placed at the End of Terrace Outlet

If the structure is built as is often advisable at the end of a grassed waterway, the notch can be placed at the level of the waterway. If the waterway is 30 feet wide and 6 inches deep and must converge into a notch 10 feet wide and 18 inches deep, the notch level may be placed slightly higher than the incoming outlet floor to allow the grade to be flattened where the water will flow deeper just before entering the structure notch. Unless this is done or the grade in the outlet flattens materially as is often the case when it approaches the stream bank, the intensified flow of water and velocity of approach entering the structure may cause the grass sod just above the structure to be damaged. To build the structure 30 feet wide to avoid this deepening of flow would be unnecessarily expensive and, in general, it can be avoided as suggested. Fig. 10 shows a structure that is located at the end of a broad grass outlet.

Fig. 10.—This Missouri dam carries water from approximately 30 acres of terraced land. The water comes to it through a broad constructed grassed outlet 34 feet wide along the field boundary to the left. Notice the water standing in the stilling basin below. The velocity check which is here submerged has prevented the discharge flow from scouring out the channel of the main drain below.

The apron of the structure over which the water is discharged should be placed slightly below the stabilized grade of the main drain. Usually 6 inches to 1 foot is sufficient. An apron placed several feet below the grade line of the main drain with the expectation that the main drain will in time cut out to a much deeper grade is usually wasteful of labor and materials. Oftentimes the interest on the additional investment will pay for several extensions when and if such extension have to be used. Structures can not be forgotten after they are installed, and one will always have plenty of time to add an extension or a new unit to the structure if the base grade of the drainageway downstream is being changed.

Structures for field drains entering the main channel should be placed well back into the banks of the main channel to avoid any trouble from cross currents, drifts, etc. Usually if a structure is placed back 10 to 15 feet into the bank of a branch or drainageway, it will be found satisfactory. However, if water is being lowered to the grade line of a large creek or a river, placing the structure back from the stream 100 feet or more is sometimes desirable.

Choosing the Notch Size for the Structure

The period of frequency for which the notch is designed will depend upon the accessibility of a satisfactory emergency outlet, the damage excessive overflow through the emergency outlet might do to either the structure, the property below, or the emergency outlet itself. These must be balanced against the extra first cost of the larger structure and the interest on the added investment for the infrequent use of the extra notch size. For example, it has been a common practice in the past to construct a soil saving dam with a concrete spillway to carry runoff from the hardest rain expected in a 50-year period. Such a structure requires a rather high investment for the average farm and its advisability in many locations is questionable even if money is available.

If the concrete spillway is designed to carry the hardest rain in a two-year period, it will cost about one-half as much per structure and will carry 95% of all rains designated as intense rains. The 5% of intense rains that the concrete structure will not carry completely will flow through the emergency sod spillway and in the short period of time that both spillways are required to carry the runoff, little or no damage will be done. This avoids paying the extra first cost and interest on the larger structure.

In like manner it is possible to use a design in which the capacity of the concrete spillway may be exceeded once in 5, 10 or 25 years. In all cases the emergency spillway will be located far enough from the structure and made large enough so that the runoff from the hardest rain in 50 years will not damage the structure.

It is usually the more frequent long periods of smaller flow that would destroy the grassed spillway, and the concrete or tile structure designed for this purpose will carry all of this flow—making a very practical combination of the two used together. Structures placed in large watersheds where the emergency spillway would need to carry the excess runoff for perhaps several hours would be very likely to cause too much damage to the emergency spillway to give complete satisfaction. It is not often, however, that the damming of such a stream will be found practical for any individual farm, solely for erosion control.

Table 1. -- TO BE USED IN DETERMINING CUBIC FOOT OF RUNOFF FROM DIFFERENT SIZES AND TYPES OF WATERSHEDS FOR DIFFERENT STORM PERIODS

Calculations based on rainfall intensity study by Yarnall and local Missouri weather records.

RUNOFF - CUBIC FEET PER SECOND

50 Year Frequency

Type of Watershed	Acres in Drainage Area													
	3	5	7½	10	15	20	30	40	50	75	100	125	150	200
	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.
Rolling Timber	7	11	15	20	28	35	49	60	70	95	118	142	165	205
Hilly Timber	8	13	18	24	34	43	60	75	90	125	160	193	225	285
Rolling Pasture	13	21	30	39	54	68	92	114	135	186	237	285	330	410
Hilly Pasture	16	25	37	47	67	85	118	148	180	250	320	385	450	565
Cultivated (Terraced)	15	25	36	46	70	88	116	170	205	287	364	437	502	624
Rolling Cultivated	21	35	50	64	91	114	151	187	226	315	400	480	550	685
Hilly Cultivated	28	43	63	82	116	146	200	250	305	435	550	665	770	980

Structure designed for runoff shown in this section of the table will carry the runoff from the heaviest rain occurring in a 50-year period.

25 Yr. Frequency

Type of Water Shed	Acres in Drainage Area													
	3	5	7½	10	15	20	30	40	50	75	100	125	150	200
	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.
Rolling Timber	6	10	14	18	25	31	39	49	60	82	105	129	150	188
Hilly Timber	8	12	17	22	30	38	50	64	79	110	145	175	205	262
Rolling Pasture	12	20	28	36	49	61	80	100	122	170	215	255	295	372
Hilly Pasture	16	24	34	42	59	75	100	130	158	222	290	350	405	
Cultivated (Terraced)	15	24	34	43	63	77	100	148	180	255	323	382	446	
Rolling Cultivated	21	34	48	60	82	102	130	163	198	280	355	420	490	620
Hilly Cultivated	25	40	56	72	102	127	175	218	270	380	490	590	680	860

A structure with notch designed for runoff shown in this section of the table will carry the largest rain in the average 25-year period. There will be on the average only 2 storms in the 50 years which will exceed the notch capacity of the structure.

10 Yr. Frequency

Acres in Drainage Area.

Type of Watershed	3	5	7½	10	15	20	30	40	50	75	100	125	150	200
Rolling Timber	6	9	12	15	21	26	35	43	52	72	92	110	128	161
Hilly Timber	7	10	15	19	27	33	46	58	70	97	125	150	174	220
Rolling Pasture	11	17	24	31	43	53	69	85	102	140	180	217	252	317
Hilly Pasture	13	20	29	37	53	67	92	115	140	192	250	298	348	440
Cultivated (Terraced)	13	20	29	40	55	69	100	132	159	218	275	330	382	483
Rolling Cultivated	18	28	41	52	72	89	118	145	175	240	303	363	420	531
Hilly Cultivated	23	36	50	65	90	114	150	192	236	335	428	510	592	747

A structure designed for runoff shown in this section of the table will carry runoff from all the intense rains occurring in the average 10-year period. There will be only 5 storms in the average 50-year period with runoff which will exceed the structure capacity.

5 Yr. Frequency

Acres in Drainage Area

Type of Watershed	3	5	7½	10	15	20	30	40	50	75	100	125	150	200
Rolling Timber	4½	7	10	14	19	23	30	37	45	64	82	95	110	135
Hilly Timber	5	9	13	17	24	30	42	52	60	85	110	130	150	190
Rolling Pasture	9	15	21	27	38	46	60	76	90	125	160	190	215	275
Hilly Pasture	11	17	24	32	47	59	79	100	120	170	215	260	300	380
Cultivated (Terraced)	11	17	25	33	48	60	80	116	136	190	245	290	330	415
Rolling Cultivated	16	24	35	45	62	76	102	128	150	210	270	320	365	455
Hilly Cultivated	18	30	42	54	74	92	123	153	180	250	325	385	440	550

A structure designed for runoff in this section of the table will carry runoff from all the intense rains occurring in the average 5-year period. In 50 years' time such a structure would use an emergency spillway on the average of 10 times to assist in carrying runoff.

2 Yr. Frequency

Acres in Drainage Area

Type of Watershed	3	5	7½	10	15	20	30	40	50	75	100	125	150	200
Rolling Timber	3½	6	9	11	16	19	28	33	40	56	70	85	97	118
Hilly Timber	4½	7	11	14	20	25	32	41	50	73	92	112	130	163
Rolling Pasture	8	13	18	23	31	38	50	62	76	108	135	163	190	235
Hilly Pasture	9	15	23	29	40	49	65	83	100	143	185	221	258	323
Cultivated (Terraced)	10	15	22	28	40	48	68	98	118	164	207	250	288	358
Rolling Cultivated	14	21	31	39	52	63	88	108	130	180	228	275	318	395
Hilly Cultivated	16	26	38	49	68	84	116	148	178	247	315	384	442	560

In a 50-year period the emergency spillway would be used on the average of 25 times to assist in carrying the flood water. A structure designed for runoff shown in this section of the table will carry runoff of all the intense rains occurring in the average 2-year period.

*A rain storm designated as "intense" is taken from the U.S. Weather Records as meaning .25 inch of rain falling in 5 minutes to 1.0 inch falling in 80 minutes and all rains of higher intensity.

Table 2. -- TO BE USED IN DETERMINING SIZE OF NOTCH FOR MISSOURI DAM

Notch Capacities - Cubic Feet Per Second

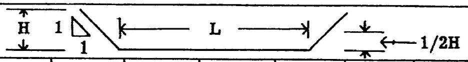
Depth of Notch	Length of Notch - Ft. - Measured Thus: 												Computed from Notch Formula $Q = 3.85\ LH^{3/2}$			
	2	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24
1 - 0	8	12	15	19	23	27	31	35	39	46	54	62	69	77	85	92
1 - 4	12	18	24	30	36	42	47	53	59	71	83	95	107	119	130	142
1 - 8	17	25	33	41	50	58	66	74	83	99	116	132	149	166	182	199
2 - 0	22	33	44	54	65	76	87	98	109	131	152	174	196	218	240	261
2 - 4	27	41	55	69	82	96	110	123	137	165	192	219	247	274	302	329
2 - 8	33	50	67	84	101	117	134	151	168	201	235	268	302	335	369	402
3 - 0	40	60	80	100	120	140	160	180	200	240	280	320	360	400	440	480
3 - 4	47	70	94	117	141	164	187	211	234	281	328	375	422	469	515	562
3 - 8	54	81	108	135	162	189	216	243	270	297	324	351	378	406	433	460
4 - 0	62	92	123	154	185	216	246	277	308	339	370	400	431	462	492	524

Table 3. -- TO BE USED IN DETERMINING THE SIZE OF AN EMERGENCY SPILLWAY FOR A CONCRETE OR AN EARTH SOIL SAVING DAM

Spillway Capacities -- Cubic Feet Per Second

Head on crest of spillway	Length of Spillway in Feet													
	4	6	8	10	12	16	20	25	30	40	50	60	80	100
0.5	5	7	9	11	14	18	23	28	34	45	56	68	90	113
1.0	13	19	26	32	38	51	64	80	96	128	160	192	256	320
1.5	24	35	47	59	71	94	118	147	177	236	294	353	471	589

Computed by formula $Q = 3.2\ LH^{3/2}$

Use of Tables to Select Notch Size

By studying Tables 1 and 2, the designer may choose the size of notch desired to carry a certain percentage of all rains from the acreage and kind of drainage area involved. For example, suppose 100 acres of tillable land are terraced, draining over the structure in question where a good emergency sod spillway can be provided. A structure notch that would carry on the average the hardest rain in five years or 98% of all intense rains occurring in 50 years' time would need to carry 245 cubic feet per second as shown in Table 1 for 5-year frequency.

The dam would need to have a notch depth of 3 feet and a length of 12 feet or a notch length of 18 feet if the depth was only 2 feet, 4 inches. In a similar manner a 4-foot depth of notch would need to be only 8 feet long as is shown by Table 2.

The emergency or side spillway would need to carry at least the difference between the 245 and the 364 cubic feet per second expected in 50 years, which storm might occur the next day after construction. This spillway would need to be 40 feet wide and 1 foot deep or a spillway 110 feet wide and 6 inches deep could be used if conditions permitted it as shown by Table 3.

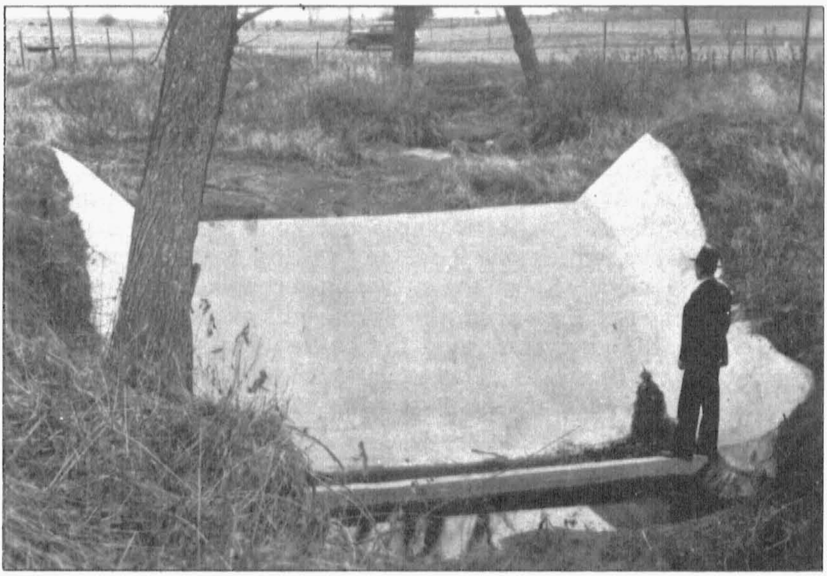


Fig. 11.—A Missouri dam constructed in 1939 carrying water from approximately 90 acres of terraced land and 30 acres of unterraced land, lowering it approximately 8 feet into a large stabilized drainageway. Several feet of soil have been deposited above the structure.

The bottom of the emergency spillway would be 6 inches or one foot below the top of the wings of the concrete structure for protection of the structure, but the bottom of the emergency spillway should be placed at a level which will allow the notch in the concrete structure to be loaded almost to normal capacity before any water flows around the emergency overflow. This is the reason for the shallow design on the emergency spillway. If in this example there is an overfall of 4 feet to be controlled, it would require approximately 26 sacks of cement, 3 yards of gravel and 2½ yards of sand to construct a Missouri concrete dam for the location and watershed just discussed.

Figure 11 shows a large Missouri dam of 25-year frequency design after several years of operation.

Details of Construction

Staking Out the Dam.—A simple, yet satisfactory method of staking the dam is to place two grade stakes marked at the proposed notch level and located at each end of the notch. Proceed from the mark on the notch stakes to slope down on a 1½ (or, if desired, a 1¼) to 1 slope. The immediate question is how to determine a 1½ to 1 slope. After taking a reading at the desired notch level and another in the bottom of the ditch below, subtract the two readings to determine the overfall to be protected. Then add to this figure the depth below the grade of the drain to which it is desired to place the apron.

Suppose the distance from the notch level to the grade below is 5 feet and you decide to go below the grade level 1 foot with the apron, this gives a total of 6 feet of overfall. If you want a 1½ to 1 slope, measure out 1½ times the total fall of 6 feet, or 9 feet, and place two more stakes here the same distance apart as the notch stakes. A slope from the mark on the notch stakes straight to points one foot under the ground on these stakes, which are 9 feet away and 6 feet down gives the 1½ to 1 slope. From these two lower stakes, which mark the upper edge of the apron, the apron will extend 18 inches to the baffle and 27 inches beyond the baffle (Fig. 4), if the notch depth is to be 18 inches. The excavation will need to be made sloping enough to allow at least a ½ to 1 slope on the sides. This then would allow the 6 foot side banks to slope out 3 feet from the stakes at the deepest point. Grade stakes can then be set on the top of the side banks 3 feet horizontal distance outward from the apron stakes and the side bank sloped to these stakes. A trench will be excavated for the toe wall as indicated in Fig. 4.

Excavating, Shaping Earth and Placing Reenforcing.—While excavating for the lower part of the structure, the earth taken out can be put out for wing fill which usually has to be built up above the gully bank or outlet floor. Also earth taken from excavations for the wings and cutoff wall can be used. Notice the cutoff wall extends in this case 3 feet (1/3H+1/3D) below the notch level and out to each side 5 feet, if a 3-foot depth of notch is chosen. (Fig. 4 shows 1/3H+D). Loose earth used to build up the wing fill must be tamped. It will require water to thoroughly tamp dry soil. Whole structures are being successfully built on new fill when the fill is thoroughly tamped before floating on the concrete.

After the earth is carefully shaped as described above and shown in Fig. 2, reenforcing is placed on the earth forms. Heavy, *new* hog wire is most often used for reenforcing and is cut in strips long enough to reach from the end of the apron over the notch hump and back down into the cutoff wall. The strips of hog wire should be lapped at least one stay and short or irregular pieces cut as needed to cover the entire structure. Usually the wire mat is allowed to lie on the earth and is raised up 2 inches from the ground as concrete is poured and floated with a wooden float. The density and uniformity of the concrete will depend to a large degree upon the consistency and workability of the concrete mix.

Making and Placing the Concrete for the Missouri Dam.—Because of the comparatively thin layer of concrete and exposure to the elements, it is essential that high-quality, watertight, workable concrete be made. If the following suggestions are carried out, good concrete will be assured:

1. Sand and gravel should be clean, free of dirt and organic matter. Gravel should be well graded; good, sharp sand should be used. The gravel or crushed rock should not be more than 1 to 1½ inches in diameter for the largest particles and should grade from that down to ½ inch.
2. The mixing water should be clean.
3. To insure water-tight concrete, care must be taken to use not more than 6 gallons of mixing water to each sack of cement. This amount of water includes the water in damp sand. Ordinarily damp sand contains about 1 quart of water per cubic foot.
4. The proper proportions of sand and gravel or crushed rock should be used to make a workable mix. There must be sufficient sand in the mix so it will spread easily and produce a dense concrete free from honeycomb. Where sand and gravel are separate, a mix of 1 part of cement, 2¼ to 2½ parts of sand and 3 parts of crushed rock or gravel will be satisfactory. When a bank run material is used—that is a mixture of sand and gravel as it comes from the creek—about 1 part of cement to 4 or 4½ parts of the bank run material will usually be needed.

The first batch or two made are trial batches, and it may be necessary to change the amounts of sand or gravel slightly to secure a smooth, workable mix. The consistency of the concrete must be a slightly mushy mix. If too wet, it will not stay in place; and if too stiff, it cannot be worked properly. A few trial batches will show what proportions of sand and gravel finally to use with the 6 gallons of water to secure a mixture of proper workability and consistency.

5. Mix thoroughly at least one minute if a machine mixer is used—1½ minutes would be better.

6. Moisten the fill ahead of placing the concrete so the ground will not absorb the water out of the concrete. Shovel the concrete in place and spread it out evenly with a wood float. Take care to get the reenforcing embedded in the concrete. Raise the wire and push the concrete under.

7. Floating is usually started on the notch and the back side moving down and out to the wings and cut-off walls. The art of placing the concrete on these side slopes is acquired by some practice. However, the dam will be a success if the builder starts with a workable mix, makes good use of the reenforcing, and places the concrete in the desired location on the dam, allowing it to slide from a shovel, covering the dam from the top down as in plastering a room, and applying a little pressure with an upward movement of the float. Often the layer of concrete below the reenforcing will be allowed to set up slightly before the layer on top the reenforcing is added.

8. After the second layer is put on, the surface may be steel troweled for further smoothness if desired, a thin finish coat of 1 part of cement to two parts of sand may be troweled on. This finish coat must go on immediately while the lower concrete is still green. Many farmers use no finish coat—just float and trowel the concrete smooth.

9. As soon as the concrete hardens and before it dries it must be covered with a layer of earth, straw or wet sacks and kept damp for 6 or 7 days. This is important if concrete is to reach the proper strength.

Making the Backfill.—After the concrete has been kept damp for at least a week, earth backfills are made. Earth is puddled in the trench above the structure to a level with the notch and is carried out to the sides of the notch and over the wings as shown in Fig. 7. If care is exercised, part of this earth backfill can be made a few hours after the structure is completed and if thoroughly wet down, will cure the concrete—thus reducing the area to be covered with straw or sacks and kept watered for proper cure.

Well tamped and puddled backfills are essential to insure the success of any type of soil saving dam.