# REPORT OF THE
# KANSAS STATE BOARD OF AGRICULTURE

## AUGUST, 1941

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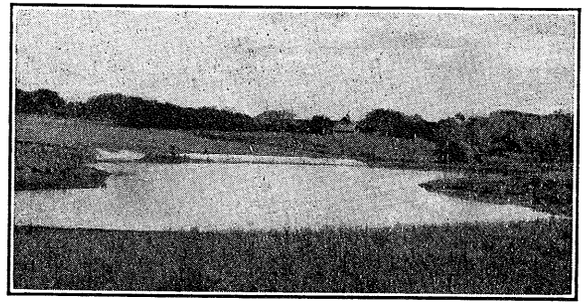
Containing the law relating to

## DAMS ON DRY WATERCOURSES

AND INFORMATION
RELATIVE THERETO



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## 1941

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# DAMS ON DRY WATERCOURSES

## THE KANSAS WATER STORAGE LAW

CHAPTER 400, LAWS OF KANSAS, 1941

SECTION 1. Any landowner owning land in the state of Kansas, not within the corporate limits in any city in this state, who shall lawfully by the construction of a dam across a dry watercourse or any stream or watercourse draining an area not exceeding ten square miles, form upon his own land one or more reservoirs, having along the axis of the dam at the lowest point in the natural bed of a stream or watercourse a depth of not less than ten feet and a storage capacity at spillway level of not less than five acre-feet, for the collection and storage of surface water, and who shall maintain such dam or dams in a condition satisfactory to the chief engineer of the division of water resources in the state board of agriculture, shall be entitled to receive a reduction in the assessed valuation of the entire contiguous acreage owned by the landowner upon which such reservoir is located for ten years of an amount determined according to the following schedule:

| | |
|---|---|
| First ten acre-feet of storage capacity..... | $200 per acre-foot |
| Next five acre-feet of storage capacity..... | 150 per acre-foot |
| Next five acre-feet of storage capacity..... | 100 per acre-foot |
| Next five acre-feet of storage capacity..... | 50 per acre-foot |

*Provided,* That the total amount of any such reduction shall not exceed three thousand five hundred dollars and that in any instance it shall not be more than forty percent of the assessed valuation of the entire contiguous acreage owned by the landowner upon which such reservoir or reservoirs are located.

SEC. 2. In order to be entitled to the compensation provided herein, the landowner must submit to the chief engineer of the division of water resources, complete plans for such dam showing the area of the drainage basin above the dam; plan, profile and cross sections of the dam and spillway; topographic map of the reservoir basin, and such other data and information as the chief engineer of the division of water resources may require, and such plans shall have the approval of the chief engineer and the dam be constructed in accordance with such plans before compensation can be claimed.

SEC. 3. Upon the completion of any such dam to the satisfaction of the chief engineer of the division of water resources, said chief engineer shall certify the completion of the dam and the capacity of the reservoir to the board of county commissioners of the county in which the dam is located, who shall annually make such reduction in the assessed valuation of the land as the owner may be entitled to receive under the provisions of this act, beginning with the first period, following the date of issue of the certificate of completion, on which taxes are regularly levied, and during the years which the landowner is entitled to such reduction, no increase in the assessed valuation of the land shall be made due to the construction of the dam as an improvement on the land: *Provided,* That the owners of all dams for which plans were ap-

proved by the chief engineer of the division of water resources, as provided by section 82a-402 of the General Statutes of 1935, prior to the taking effect of this act and which have been or thereafter are completed and maintained to the satisfaction of the chief engineer, shall be entitled to receive the reduction in assessed valuation as provided by law at the time such dams were constructed: *Provided,* No deductions shall exceed the sum of three thousand five hundred dollars in any year.

SEC. 4. Whenever during periods of drought, it is deemed warranted in the judgment of a majority of the board of county commissioners of any county in this state, the commissioners may by resolution duly adopted, declare a drought emergency to exist and shall determine where surplus water supplies exist and are available in reservoirs constructed in that county under the provisions of this act and may prescribe rules and regulations for obtaining such surplus waters. The owner of any land on which such a water supply has been or may be impounded, shall, upon being notified by the board of county commissioners, permit entry upon his land and access to the reservoir to all persons for the purpose of obtaining water in accordance with the rules and regulations prescribed by the board of county commissioners.

SEC. 5. Any one or more landowners who, in connection with the erection and maintenance of a reservoir for the storage of water, shall donate to the state or to any of its agencies or subdivisions, land for such purposes, shall be entitled to receive for twenty years a reduction in the assessed valuation of the entire contiguous acreage owned by each such landowner of an amount determined according to the schedule set forth in section 1 of this act, for a portion of the reservoir storage capacity in proportion to the amount of land donated by each landowner, and otherwise in accordance with the provisions of this act: *Provided,* That the reduction limitation of three thousand five hundred dollars in assessed valuation as provided in section 1 of this act and that the provision of section 4 of this act shall not apply to reservoirs constructed by the state, its agencies or subdivisions as provided herein.

## GENERAL INFORMATION

This bulletin is offered as a guide to those who may submit plans to the Division of Water Resources, Kansas State Board of Agriculture, for approval under the provisions of the Kansas water-storage law quoted above. The information in this bulletin relates primarily to dams of moderate size and of the class commonly built for farm ponds.

Plans for all dams which are more than ten feet high or which impound more than fifteen acre-feet of water are required by law to be submitted for approval to the chief engineer of the Division of Water Resources. For the purposes of this law the height of a dam is taken to be the difference in elevation between the top of the dam and the lowest point in the natural bed of the stream at the center line of the dam. The capacity of the reservoir is considered to be the volume of water in acre-feet that can be stored in the reservoir basin at spillway elevation.

When selecting the site for a dam the topography and geology should be carefully examined. This includes consideration of the materials available for the construction of the dam and any natural features that can be used to



advantage. All of these things taken together should govern both the choice of location and the type of dam and spillway best suited to the site.

Dams may be built of earth, rock, masonry, concrete, timber or a combination of materials. Earth dams are usually the most economical and are by far the most widely used in this state for small reservoirs. This bulletin therefore deals primarily with the earth-fill type of dam. There are, of course, locations where it may be desirable to build a dam of some other material. For example, all overflow dams must be built of materials such as masonry or concrete.

Earth dams are not a suitable type of structure for sites at which the drainage area is large, unless the reservoir which is created is also large. The size of the reservoir should be in proportion to the size of the drainage area. This ratio will vary between rather wide limits, depending a great deal on various conditions affecting run-off. In general, there should be not less than five to ten acres of drainage area for each acre-foot of storage capacity. As a rule the drainage area should not exceed fifty to sixty acres for each acre-foot of storage.

After selecting the site the next step should be the making of surveys and preparation of plans for the dam. This may be done by any engineer who is qualified by training and experience to do work of that kind. The making of surveys should include an examination of subsurface conditions. Exploration of the abutments, valley floor and spillway location should be made by boring holes and excavating pits.

When the plans have been prepared they should be submitted for approval to the Division of Water Resources of the State Board of Agriculture. If the plans are found to be satisfactory they will be approved. If changes in the plans are necessary they will be returned with suggestions for correction or revision. Where conditions seem to make it advisable an engineer from the Division of Water Resources will examine the site of the proposed dam before final action is taken on the plans. Preliminary plans or sketches may be submitted for examination and comments before the final plans are prepared. If any change is desired after a plan has been approved, an amended plan showing the change must be submitted for approval.

After the plans have been approved an engineer, or someone familiar with the use of surveying instruments, should stake out the location for the dam, spillway, borrow pits, etc. The stakes should be set to enable the workmen to build the dam and spillway at the proper location and to make all dimensions, elevations, etc., conform with the approved plan. All elevations should be referred to a permanent benchmark shown on the plan. As soon as the work has been staked out, construction may be started. All work should conform to the plan as approved. If unanticipated circumstances arise during construction that require changes in design, such proposed changes should be submitted for approval before any change is made.

The Division of Water Resources should be notified when the construction work is completed. Upon receipt of such notice an engineer from the Division of Water Resources will examine the dam to determine if it has been constructed in accordance with the approved plans. If the dam is found to be satisfactory, a certificate of completion will be issued to the board of county commissioners in the county where the dam is located. The reduction in assessed valuation is made by the county commissioners.

In the event that a reduction in assessed valuation is desired by virtue of a dam already constructed, plans of the dam as built showing the area of the drainage basin; a cross section of the dam site; a plan, profile and cross section of the dam; a plan, profile and cross section of the spillway and a topographic map of the reservoir basin should be submitted in the same manner as for a proposed project. These plans will be reviewed and the dam inspected before approval is given. If the plans and dam are satisfactory a certificate of completion will be issued to the Board of County Commissioners the same as above. If the plans or dam are not satisfactory the changes or additions necessary to meet the requirements of the Division of Water Resources will be pointed out and approval will be withheld until those requirements are met.

## REQUIREMENTS OF THE DIVISION OF WATER RESOURCES

All plans submitted to the Division of Water Resources for approval should be prepared on standard size sheets, 22 by 36 inches outside dimensions. Border lines should be arranged to provide a binding margin two inches wide at the left end of the sheet. There should be a one-half-inch margin on the remaining sides. Complete plans for small dams can usually be prepared on a single sheet. At least two copies of each plan should be submitted for approval. One copy will be retained for the files of the Division of Water Resources and the others, with official approval indicated thereon, will be returned. The following information should be shown on the plans:

1. Map of the drainage area above the dam site.
2. Topographic map of the reservoir basin.
3. Plan of the dam and dam site.
4. Cross section of the dam site and longitudinal section of the dam.
5. Cross section of the dam.
6. Plan, profile and cross section of the spillway.
7. Reservoir data.
8. Description, elevation and location of a permanent benchmark.
9. Identification of plan.
10. Legal description of the land.

### Map of Drainage Area Above Dam Site

A map of the drainage area should show the location of the watercourse across which the dam is to be built and its tributaries above the dam site. The location of the dam and the approximate outline of the reservoir should also be shown. The boundary of the watershed should be accurately shown by a line enclosing the entire area that will drain into the reservoir.

### Topographic Map of Reservoir Basin

An accurate topographic map of the reservoir basin is needed in order that the capacity of the basin can be determined. The location of the dam should be shown on this map. Topography for shallow reservoirs should be shown by contours at one-foot intervals. Topography for the deeper reservoirs can be shown by contours spaced at greater intervals, but not exceeding five feet. A two-foot interval will be found satisfactory in most instances. The elevation of each contour should be clearly noted on the plan. When the top of the dam is within the stream banks, topography should be shown at least to the top of the dam. When the top of the dam is above the stream bank, topography should be shown at least up to the top of the bank at the dam site.



### Plan View of Dam and Dam Site

The plan view of the dam and dam site can usually be shown in connection with the topographic map of the reservoir basin. The topography should show accurately and in detail the natural features of the entire area in which the dam and spillway are to be located. This should include an area on both sides of the dam as well as some distance downstream. Where topography at either or both ends of the dam is so flat that it cannot be clearly shown by contours, actual elevations of the ground surface should be given and, if necessary, explanatory notes added to make the plan more understandable. Elevations shown by contours at the dam site must correspond with elevations on the cross section of the dam site. The following details are needed:

1. Toe of upstream and downstream slopes.
2. Location of berms.
3. Location of slope protection.
4. Location of borings or test holes.
5. Location of outlet pipes, intakes, valves, valve well, etc.

### Cross Section of Dam Site and Longitudinal Section of Dam

The cross section of the valley at the dam site should be taken along the center line of the dam. The details of a longitudinal section of the dam can be given on this section. They should show the top of dam; the amount allowed for settlement; the bottom of the stream bed; elevation of spillway; elevation of berms; the original surface of the ground; bottom of the cut-off trench; top of core wall and the location of the outlet works. The location of test holes should be shown and a log of the material encountered in each hole should be noted on the plan.

### Cross Section of Dam

A cross section of the dam shows many of the details of its construction and is, therefore, an important part of the plan. A section of the dam at the deepest point is generally typical and as a rule includes all the essential details. If the cross section is variable, several typical sections should be shown. In most cases it will be desirable to show an additional section of the dam along the line of the outlet pipe. Cross sections of the dam should include the following information:

1. Width and elevation at the top of dam.
2. Width and elevation of berms.
3. Width and elevation at bottom of dam.
4. Elevation of crest of spillway.
5. Rate of side slopes.
6. Kind and location of slope protection.
7. Position and dimensions of manholes, outlet pipes, intakes, valves, etc.

8. Dimensions to which the dam must be built to make adequate allowance for settlement.
9. Dimensions of cut-off trench and core wall.

### Plan, Profile and Cross Section of Spillway

The plan should show the location of the spillway with respect to the dam, the location of the control section, riprap or other spillway protection and stationing along the center line. Often it can be shown together with the plan of the dam on the topographic map of the reservoir basin.

A cross section of the spillway can most always be shown on the cross section of the dam site. In addition to this it is desirable that the details be shown on a separate sketch. The information given should include dimensions of the spillway, such as bottom width, and depth and side slopes. The maximum capacity of the spillway should be given in cubic feet per second.

A profile taken along the center line of the spillway and extending down to stream bed should be shown. The stationing should correspond to that on the plan view. This profile should show the grade along the bottom of the spillway, the elevation of riprap along the sides, the depth of excavation and the nature of the material through which the spillway is cut.

If the spillway is in any way affected by conditions such as back water, submergence or temporary storage, the effect should be fully described and clearly illustrated. When special designs are used additional details may be needed to clearly show the construction desired.

### Reservoir Data

The number of acres enclosed by each contour within the reservoir basin and the total storage capacity of the reservoir in acre-feet at the elevation of each contour should be determined and tabulated on the plan. Where the top of the dam is within the stream banks this data should be computed up to the elevation of the top of the dam. Where the top of the dam is above the stream bank it should be computed up to the elevation of the top of the banks at the dam site. Computations of capacity must be based on the natural topography of the reservoir basin. No allowance is made for quantities of material excavated from the reservoir basin during the construction of the dam.

When the reservoir is divided between more than one landowner the property lines must be shown on the topographic map of the basin. Separate tables of reservoir data should be given showing the amount of water stored on the land of each.

### Bench Mark

When surveys of the dam site and reservoir basin are being made at least one permanent bench mark should be set for future reference, since it is necessary that the dam be checked before certifying its completion to the county commissioners.

The bench mark should be conveniently located for use, both during and after construction. It should be placed where it will not be destroyed or be under water after the reservoir fills. A three- or four-foot piece of pipe or



steel driven flush with the ground makes a good bench mark. Wood stakes, nails or marks in trees, etc., are not considered as permanent bench marks. The location of the bench mark should be shown on the plan and its description and elevation given. It should be properly referenced so that it can be easily found in the field from the information given on the plans. Elevations for small dams may be referred to any assumed datum.

### Identification of Plan

A space approximately five inches long and three inches high should be reserved in the lower right-hand corner of the plan for the following information:

1. Name and address of landowner.
2. Location of dam by section, township and range to the nearest quarter section.
3. County in which dam is located.
4. Name and address of the engineer.
5. Date of plans.

### Legal Description of Land and Adjoining Landowners

When certifying the completion of a dam it is necessary to have a legal description of all the land on which the reduction in assessed valuation is to be made. This information should be given by showing the location of the land on the map of the drainage area and listing in a table the description of each piece in exactly the same manner as it is given in the county records.

Where more than one landowner is involved, separate tables should be provided for each owner entitled to a reduction in the assessed valuation of his land. In instances where the building of a dam will affect the land of others, whether public or private property, it is customary to require the owner to show that satisfactory arrangements have been made with proper officials where public property is involved and with individual persons where private property is involved. The approval of a plan does not convey any property right or right to tresspass on land of other owners.

### Specifications

Ordinarily specifications are not needed other than notes that can be placed on the plans. In special cases, however, a separate and complete set of specifications may be required. When no other specifications for the items covered are submitted to and approved by the Division of Water Resources, the owner should be guided in the construction of the dam by the general specifications set forth at the end of this bulletin.

### Remarks and Specimen Plan

Figure 1 shows a specimen plan which is intended to show the scope and nature of the information required on plans for earth dams. It is not a plan for any individual dam and is not intended to indicate a preference for any particular type of construction.

## DESIGN DATA

The following data and information are intended principally for the use of engineers in connection with the design of earth dams proposed to be built according to the Kansas water-storage law.

### Top of Dam

The width across the top of the dam is frequently fixed by requirements for a roadway. When this is not the limiting factor, the top width is generally goverened by the maximum height of the dam. A study of a large number of dams in different parts of the United States indicates that the general practice is to make the top width equal to approximately one-half the maximum height. For dams less than fifteen feet high this ratio is too small. The top width for such dams should not be less than that given by the relation—

$$W = 5 + 0.2H$$

where $W$ = top width in feet
and $H$ = maximum height in feet

The top of the dam should be sloped towards the reservoir, in order that rain which falls on it will drain off on the upstream side, which is usually protected by riprap.

### Allowance for Settlement

The amount that should be added for settlement will depend upon the nature of the material of which the dam is built as well as the manner in which the material is placed. For most dams a minimum allowance of ten percent of the height should be made. This allowance should be provided by steepening the side slopes during construction and adding to the height of the embankment as needed along the length.

### Side Slopes

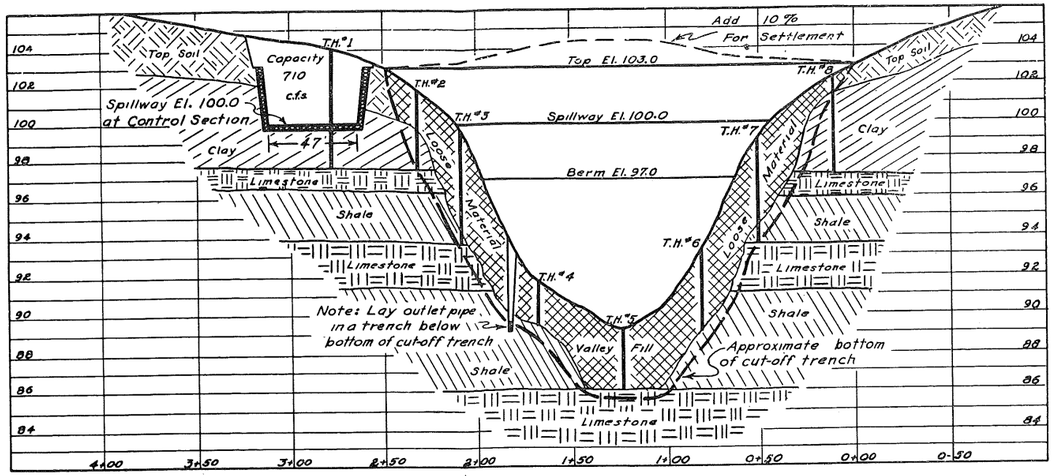
Side slopes of earth dams vary with the materials of which the dam is built as well as with the height of dam and nature of the foundation. With the materials that are most commonly available and foundation conditions that most frequently prevail the downstream slope should not be steeper than 2 horizontal to 1 vertical. In many instances a flatter slope may be required.

The upstream slope, under ordinary circumstances, should be made somewhat flatter than the downstream slope since it becomes saturated and is subject to the action of waves and ice. Small dams as a rule should not have upstream slopes steeper than 3 horizontal to 1 vertical.

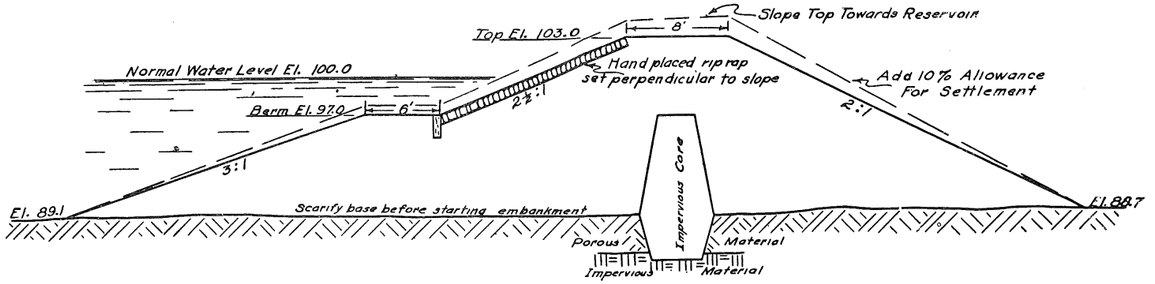
### Slope Protection

All dams should be protected against the action of waves by placing revetment on the upstream slope. Such protection is required on all dams that are exposed to more than about five acres of water surface. Revetment may consist of handlaid stone riprap, a covering of loosely dumped stone or a reinforced concrete slab. Slope protection of logs, timbers, brush, wire, snowfence and the like should not be used.

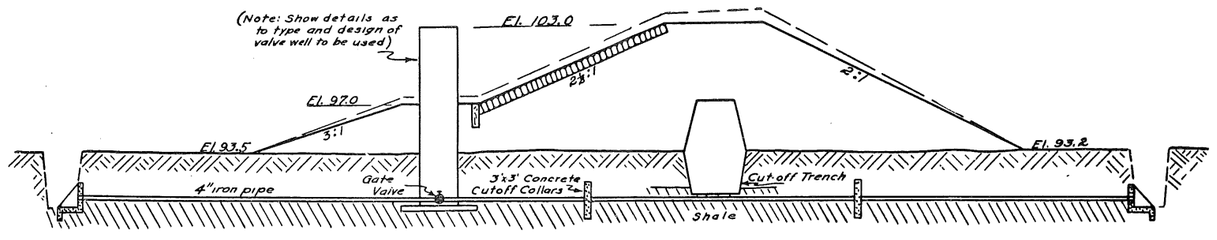
Where no suitable revetment is available the upstream slope of dams of moderate size may be flattened. Although this will not be equivalent to covering the slope with rock or concrete, it may reduce somewhat the amount of maintenance required.



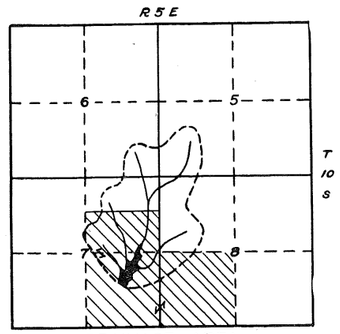

SECTION A-A
SHOWING CROSS SECTION OF DAM SITE & SPILLWAY
AND LONGITUDINAL SECTION OF DAM




MAXIMUM CROSS-SECTION OF DAM
SHOWING TYPICAL DETAILS
SCALE —




CROSS-SECTION OF DAM
SHOWING OUTLET WORKS
SCALE —




DRAINAGE AREA
0.56 SQ. MI.
SCALE —

LAND DESCRIPTION

| Fraction | Sec. | Twp | Rg. |
|---|---|---|---|
| S½ of NE¼ | 7 | 10s | 5e |
| SE¼ | 7 | 10 | 5 |
| SW¼ | 8 | 10 | 5 |
| | | | |

(Note: List all land to which the reduction in assessed valuation is to apply, describing it as given on the county tax rolls.)

LOGS OF TEST HOLES

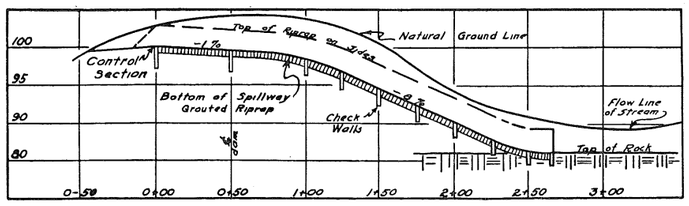
| Hole | Elev. of Top | LOG | | |
|---|---|---|---|---|
| #1 | 104.0 | Top Soil 0-2.5' | Clay 2.5'-6.2' | Limestone at 6.2' |
| #2 | 102.0 | Top Soil 0-2.0' | Clay 2.0-4.1' | Limestone at 4.1' |
| #3 | 99.8 | Top Soil + Rock 0-5.3' | Shale 5.3-6.0' | Limestone at 6.0' |
| #4 | 91.8 | Top Soil + Gravel 0-1.0' | Clay + Rock 1.0-2.3' | Shale at 2.3' |
| #5 | 89.1 | Silt 0-1.5' | Sand + Gravel 1.5-3.2' | Limestone at 3.2' |
| #6 | 93.5 | Top Soil 0-1.8' | Clay + Rock 1.8-4.0' | Shale at 4.0' |
| #7 | 99.2 | Top Soil + Rock 0-4.3' | Shale 4.3'-5.4' | Limestone at 5.4' |
| #8 | 102.3 | Top Soil 0-0.8' | Clay 0.8'-5.0' | Limestone at 5.0' |

RESERVOIR DATA

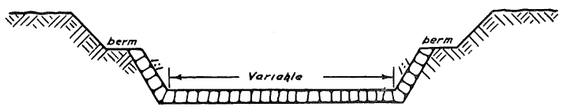
| Elevation | Area Acres | Capacity Acre Feet |
|---|---|---|
| 89 | 0 | 0 |
| 90 | .09 | .05 |
| 92 | 1.07 | 1.21 |
| 94 | 1.85 | 4.13 |
| 96 | 2.67 | 8.65 |
| 98 | 4.25 | 15.37 |
| 100 W.L. | 6.70 | 26.52 |
| 102 | 8.80 | 42.02 |
| 104 | 12.20 | 63.02 |

QUANTITIES

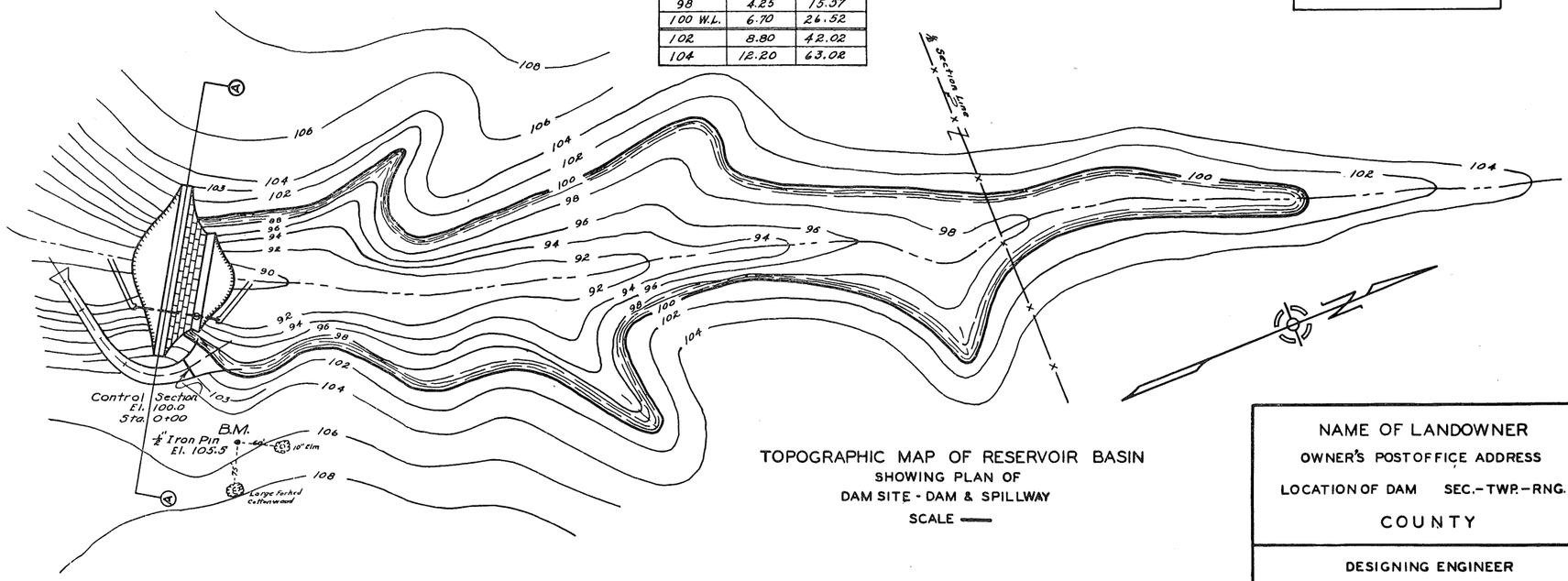
| | |
|---|---|
| Spwy. Excavation | 500 cu.yds. |
| Embankment | 2,000 cu.yds. |
| Rock for Riprap | 150 cu.yds. |
| | |




PROFILE ALONG CENTER-LINE OF SPILLWAY




TYPICAL CROSS-SECTION
OF SPILLWAY
SCALE —




TOPOGRAPHIC MAP OF RESERVOIR BASIN
SHOWING PLAN OF
DAM SITE - DAM & SPILLWAY
SCALE —

NAME OF LANDOWNER
OWNER'S POST OFFICE ADDRESS
LOCATION OF DAM SEC.-TWP.-RNG.
COUNTY

DESIGNING ENGINEER
ADDRESS DATE

Revetment may be placed on the entire upstream face; however, slope protection is usually provided only for the upper portion of the dam beginning at a point some distance below spillway elevation. A support for the base of the revetment is necessary when it does not extend to the bottom of the dam. This is best provided by widening the embankment to form a berm at the elevation where the revetement is to start. A berm of this kind should have a width approximately equal to the minimum required for the top of the dam, but in general should not be less than about six feet. When the water level is subject to great fluctuations, it is desirable to protect a larger portion of the slope than when the water level remains more nearly constant.

Revetment cannot be considered as adding anything to the imperviousness of a dam. Its value lies wholly in the protection that is provides to the upstream slope against the action of waves.

The unprotected portion of the upstream slope is generally made flatter than the portion covered by revetment. The downstream slope can be protected against erosion from wind and rain by covering the slope with a rich loam and seeding it to grass.

### Freeboard

For dams designed according to information given in this bulletin the freeboard is considered to be the difference in elevation between the spillway crest and the top of the dam. The amount of freeboard needed is usually governed by spillway requirements. When the height of waves is the governing factor the freeboard needed can be estimated by the formula:

$$H = 1.5\sqrt{D} + (2.5 - \sqrt[4]{D})$$

where $D$ = length of exposure in miles

and $H$ = height of water in feet

This formula gives H a value of 2.5 feet when D equals zero. The minimum value of H given by this formula is 2⅓ feet when D equals one-eighty-first of a mile or about 65 feet. Consequently, the freeboard should never be less than about three feet. For larger exposure this will need to be increased.

### Cut-off Trench

The purpose of a cut-off trench is to prevent leakage of water through porous material underneath and at the ends of a dam. The degree to which leakage can be prevented depends altogether on the extent to which the cut-off trench is excavated into impervious material. So far as safety and stability are concerned a dam can be built with a cut-off trench through only the top soil or surface layers of loose material. If the base is properly prepared a safe dam can in some cases be built without any cut-off trench at all. However, if it is desired to maintain a supply of water in the reservoir, a cut-off trench should be provided along the axis of the dam and extend through all loose, porous and broken layers to some sound impervious material below.

Plans of the cut-off trench should provide for a trench at least five feet in width at the bottom. The sides of the trench can be made as steep as the material will stand. The trench should be backfilled with a material that is impervious to water. The backfilling can be done by puddling or by sprinkling and rolling the material in thin layers.

Sometimes all or part of the cut-off is made by using a concrete wall or by driving sheet piling through the porous material.

### Spillway

More dams fail because of inadequate spillways than from any other cause. For that reason the design of the spillway should receive particular attention. The capacity of the spillway should be large enough to safely discharge the maximum flood that may be expected to occur on the stream at the dam site. The rate of flow at any section of a stream varies, among other factors, with the size of the drainage area above that section. The first two columns in the table beginning on page 16 shows a probable maximum rate of discharge for drainage areas up to ten square miles. Unless local conditions introduce factors which will materially affect run-off, spillways must be designed to safely discharge run-off with a maximum rate of inflow into the reservoir of not less than that given in the table.

The spillways most frequently used for small dams are essentially either some form of a weir or a canal. The capacity of a rectangular weir may be determined by the formula—

$$Q = CLH^{3/2}$$

where Q = capacity in cubic feet per second
L = length of weir in feet
H = height of water surface above crest of weir
C = a coefficient ranging from 2.63 to 3.88 depending on the shape of the weir crest, and varying with the height of the water surface above the crest of the weir.

When the spillway is a channel around one end of the dam is can usually be considered as a short canal with a steep slope or free discharge. Under such conditions the maximum capacity of a spillway of rectangular cross section is given with reasonable accuracy by the formula—

$$Q = 3.09\ CBD^{3/2}$$

where Q = capacity in cubic feet per second
B = width of canal in feet
D = depth of canal in feet
C = a coefficient depending on entrance conditions and varying from unity for perfect entrance with well-rounded corners to about 0.8 where all corners at entrance to the canal are sharp.

The maximum capacity of a spillway of triangular cross section is given by the formula—

$$Q = 2.30\ CZD^{5/2}$$

where Q = capacity in cubic feet per second
Z = rate of side slopes expressed as a ratio of horizontal to vertical
D = depth of canal in feet
C = a coefficient of entrance as before.

A triangular section is seldom practical. The formula for such a section is useful, however, in determining the capacity of a trapezodial section which



is the most common form used in spillway design. For all practical purposes a trapezodial section can be considered as a rectangular section with one-half of a triangular section at each end. By combining the expressions for rectangular and triangular sections the following practical formula for maximum discharge through a trapezodial section is obtained—

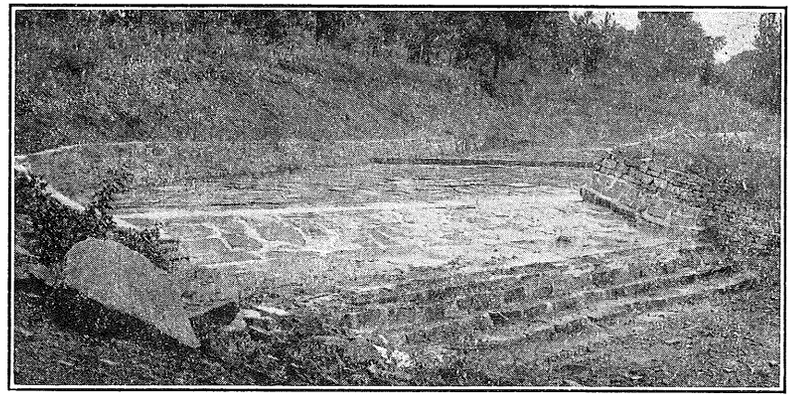
$$Q = 3.09\ CBD^{3/2} + 2.30CZD^{5/2}$$

if $B = KD$

then $Q/C = 3.09\ KD^{5/2} + 2.30\ ZD^{5/2}$

or $Q/C = D^{5/2}\ (3.09K + 2.30\ Z)$

Values of "B" for trapezoidal sections with depths ranging from 1 to 6 feet and for conditions where $C = 0.9$ and $Z = 1$ are given in the table beginning on page 16. In applying this table it must be borne in mind that depth, which is represented by the factor "D," is measured above the level of the crest of the spillway and just upstream from the control section.



SPILLWAY PAVED WITH CEMENT-GROUTED RIPRAP

The formulas given here, and the table derived from them, all give the maximum rate at which water can enter a canal. They take account of the fact that for maximum discharge there is a definite loss of head used in producing velocity at entrance. For a rectangular section this velocity head for maximum discharge is equal to one-third the depth. For a triangular section it is equal to one-fifth the depth. The velocity head at entrance for maximum discharge through a trapezodial section will vary from one-fifth to one-third of the depth, depending upon the ratio of width to depth.

The discharge given by these formulas or by the table can be taken as the actual capacity of the spillway only when the water has an unrestricted approach to the control section and a free flow away from it.

The spillway entrance is considered to be located at that section passing through the point where, in plan, the center line of the spillway intersects the contour having an elevation equal to that of the top of the dam. The spillway should be designed so that the control will be at this section. A one percent slope from the control section will usually be adequate to get the water away. If the slope is too flat there will be a backwater effect which will reduce the capacity of the spillway.

## WIDTH OF SPILLWAY REQUIRED

### At Different Depths for Discharge of Runoff from Various Size Drainage Areas

Values based on C = 0.9 and Z = 1
in formula $Q/C = D^{5/2}$ (3.09 K + 2.30 Z)

| Drainage area, sq. miles | Probable maximum discharge, sec.-ft. | Depth "D" (feet) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 |
| .03 | 70 | 25 | 13 | 8 | 5 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| .04 | 88 | 31 | 16 | 10 | 6 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| .05 | 105 | 37 | 19 | 12 | 8 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| .06 | 121 | 43 | 23 | 14 | 9 | 6 | ..... | ..... | ..... | ..... | ..... | ..... |
| .07 | 137 | 49 | 26 | 16 | 11 | 7 | ..... | ..... | ..... | ..... | ..... | ..... |
| .08 | 152 | 54 | 29 | 18 | 12 | 8 | ..... | ..... | ..... | ..... | ..... | ..... |
| .09 | 167 | 60 | 32 | 20 | 13 | 9 | ..... | ..... | ..... | ..... | ..... | ..... |
| .10 | 182 | 65 | 34 | 22 | 15 | 10 | 7 | ..... | ..... | ..... | ..... | ..... |
| .11 | 197 | 70 | 37 | 24 | 16 | 11 | 8 | ..... | ..... | ..... | ..... | ..... |
| .12 | 211 | 75 | 40 | 25 | 17 | 12 | 9 | ..... | ..... | ..... | ..... | ..... |
| .13 | 225 | 80 | 43 | 27 | 19 | 13 | 10 | ..... | ..... | ..... | ..... | ..... |
| .14 | 239 | 85 | 46 | 29 | 20 | 14 | 10 | 8 | ..... | ..... | ..... | ..... |
| .15 | 252 | 90 | 48 | 31 | 21 | 15 | 11 | 8 | ..... | ..... | ..... | ..... |
| .16 | 265 | 95 | 51 | 32 | 22 | 16 | 12 | 9 | ..... | ..... | ..... | ..... |
| .17 | 278 | 100 | 53 | 34 | 24 | 17 | 13 | 9 | ..... | ..... | ..... | ..... |
| .18 | 291 | 105 | 56 | 36 | 25 | 18 | 13 | 10 | ..... | ..... | ..... | ..... |
| .19 | 304 | 109 | 58 | 37 | 26 | 19 | 14 | 11 | ..... | ..... | ..... | ..... |
| .20 | 316 | 113 | 61 | 39 | 27 | 20 | 15 | 11 | 9 | ..... | ..... | ..... |
| .21 | 328 | 117 | 63 | 40 | 28 | 20 | 15 | 12 | 9 | ..... | ..... | ..... |
| .22 | 340 | 122 | 65 | 42 | 29 | 21 | 16 | 12 | 10 | ..... | ..... | ..... |
| .23 | 352 | 126 | 68 | 44 | 30 | 22 | 17 | 13 | 10 | ..... | ..... | ..... |
| .24 | 365 | 131 | 70 | 45 | 31 | 23 | 17 | 13 | 11 | ..... | ..... | ..... |
| .25 | 377 | 135 | 73 | 47 | 32 | 24 | 18 | 14 | 11 | ..... | ..... | ..... |
| .26 | 389 | 139 | 75 | 48 | 34 | 25 | 19 | 14 | 12 | ..... | ..... | ..... |
| .27 | 400 | 143 | 77 | 50 | 35 | 25 | 19 | 15 | 12 | ..... | ..... | ..... |
| .28 | 412 | 148 | 79 | 51 | 36 | 26 | 20 | 16 | 13 | 10 | ..... | ..... |
| .29 | 424 | 152 | 82 | 53 | 37 | 27 | 21 | 16 | 13 | 10 | ..... | ..... |
| .30 | 436 | 156 | 84 | 54 | 38 | 28 | 21 | 17 | 13 | 10 | ..... | ..... |
| .31 | 447 | 160 | 86 | 56 | 39 | 29 | 22 | 17 | 14 | 11 | ..... | ..... |
| .32 | 458 | 164 | 89 | 57 | 40 | 29 | 23 | 18 | 14 | 11 | ..... | ..... |
| .33 | 469 | 168 | 91 | 58 | 41 | 30 | 23 | 18 | 15 | 11 | ..... | ..... |
| .34 | 480 | 172 | 93 | 60 | 42 | 31 | 24 | 19 | 15 | 12 | ..... | ..... |
| .35 | 491 | 176 | 95 | 61 | 43 | 32 | 24 | 19 | 15 | 12 | ..... | ..... |
| .36 | 501 | 180 | 97 | 63 | 44 | 33 | 25 | 20 | 16 | 12 | ..... | ..... |
| .37 | 512 | 183 | 99 | 64 | 45 | 33 | 25 | 20 | 16 | 13 | ..... | ..... |
| .38 | 523 | 187 | 101 | 65 | 46 | 34 | 26 | 21 | 17 | 13 | 11 | ..... |
| .39 | 534 | 191 | 104 | 67 | 47 | 35 | 27 | 21 | 17 | 14 | 11 | ..... |
| .40 | 545 | 195 | 106 | 68 | 48 | 35 | 27 | 22 | 17 | 14 | 11 | ..... |
| .41 | 556 | 199 | 108 | 70 | 49 | 36 | 28 | 22 | 18 | 14 | 11 | ..... |
| .42 | 567 | 203 | 110 | 71 | 50 | 37 | 28 | 22 | 18 | 14 | 12 | ..... |
| .43 | 578 | 207 | 112 | 72 | 51 | 38 | 29 | 23 | 19 | 15 | 12 | ..... |
| .44 | 589 | 211 | 114 | 74 | 52 | 38 | 30 | 23 | 19 | 15 | 12 | ..... |
| .45 | 599 | 215 | 116 | 75 | 53 | 39 | 30 | 24 | 20 | 16 | 13 | ..... |
| .46 | 609 | 218 | 118 | 76 | 54 | 40 | 31 | 24 | 20 | 16 | 13 | ..... |



WIDTH OF SPILLWAY REQUIRED—Continued

| Drainage area, sq. miles | Probable maximum discharge, sec.-ft. | Depth "D" (feet) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 |
| .47 | 619 | 222 | 120 | 77 | 54 | 41 | 31 | 25 | 20 | 16 | 13 | ..... |
| .48 | 629 | 226 | 122 | 79 | 55 | 41 | 32 | 25 | 21 | 17 | 13 | ..... |
| .49 | 639 | 229 | 124 | 80 | 56 | 42 | 32 | 26 | 21 | 17 | 14 | ..... |
| .50 | 650 | 233 | 126 | 81 | 57 | 43 | 33 | 26 | 22 | 17 | 14 | 12 |
| .51 | 660 | 237 | 128 | 82 | 58 | 43 | 34 | 27 | 22 | 17 | 14 | 12 |
| .52 | 670 | 240 | 130 | 84 | 59 | 44 | 34 | 27 | 22 | 18 | 15 | 12 |
| .53 | 680 | 244 | 132 | 85 | 60 | 45 | 35 | 28 | 22 | 18 | 15 | 12 |
| .54 | 690 | 248 | 134 | 86 | 61 | 45 | 35 | 28 | 23 | 18 | 15 | 12 |
| .55 | 700 | 251 | 136 | 87 | 62 | 46 | 36 | 28 | 23 | 19 | 15 | 13 |
| .56 | 710 | 255 | 138 | 89 | 63 | 47 | 37 | 29 | 24 | 19 | 16 | 13 |
| .57 | 720 | 258 | 140 | 90 | 64 | 47 | 37 | 29 | 24 | 20 | 16 | 13 |
| .58 | 730 | 262 | 142 | 91 | 65 | 48 | 38 | 30 | 25 | 20 | 16 | 13 |
| .59 | 740 | 265 | 144 | 93 | 66 | 49 | 38 | 30 | 25 | 20 | 17 | 14 |
| .60 | 750 | 269 | 146 | 94 | 67 | 50 | 39 | 31 | 25 | 21 | 17 | 14 |
| .61 | 760 | 273 | 148 | 95 | 67 | 50 | 39 | 31 | 25 | 21 | 17 | 14 |
| .62 | 770 | 276 | 150 | 96 | 68 | 51 | 40 | 32 | 26 | 21 | 17 | 14 |
| .63 | 780 | 280 | 152 | 98 | 69 | 52 | 40 | 32 | 26 | 21 | 18 | 15 |
| .64 | 790 | 284 | 154 | 99 | 70 | 52 | 41 | 33 | 26 | 22 | 18 | 15 |
| .65 | 800 | 287 | 156 | 100 | 71 | 53 | 41 | 33 | 27 | 22 | 18 | 15 |
| .66 | 810 | 291 | 158 | 101 | 72 | 54 | 42 | 33 | 27 | 22 | 18 | 15 |
| .67 | 820 | 294 | 160 | 103 | 73 | 54 | 42 | 34 | 28 | 23 | 19 | 16 |
| .68 | 830 | 298 | 162 | 104 | 74 | 55 | 43 | 34 | 28 | 23 | 19 | 16 |
| .69 | 840 | 302 | 164 | 105 | 75 | 56 | 43 | 35 | 28 | 23 | 19 | 16 |
| .70 | 850 | ..... | 166 | 107 | 76 | 57 | 44 | 35 | 29 | 24 | 20 | 16 |
| .71 | 860 | ..... | 168 | 108 | 77 | 57 | 45 | 36 | 29 | 24 | 20 | 17 |
| .72 | 870 | ..... | 170 | 109 | 77 | 58 | 45 | 36 | 30 | 24 | 20 | 17 |
| .73 | 880 | ..... | 172 | 110 | 78 | 58 | 46 | 37 | 30 | 25 | 20 | 17 |
| .74 | 890 | ..... | 174 | 112 | 79 | 59 | 46 | 37 | 30 | 25 | 21 | 17 |
| .75 | 900 | ..... | 176 | 113 | 80 | 60 | 47 | 38 | 31 | 25 | 21 | 18 |
| .76 | 910 | ..... | 178 | 114 | 81 | 61 | 47 | 38 | 31 | 26 | 21 | 18 |
| .77 | 920 | ..... | 180 | 115 | 82 | 61 | 48 | 38 | 32 | 26 | 21 | 18 |
| .78 | 930 | ..... | 182 | 117 | 83 | 62 | 48 | 39 | 32 | 26 | 22 | 18 |
| .79 | 940 | ..... | 184 | 118 | 84 | 63 | 49 | 39 | 32 | 27 | 22 | 19 |
| .80 | 950 | ..... | 186 | 119 | 85 | 63 | 50 | 40 | 33 | 27 | 22 | 19 |
| .81 | 959 | ..... | 188 | 120 | 86 | 64 | 50 | 40 | 33 | 27 | 23 | 19 |
| .82 | 968 | ..... | 190 | 121 | 87 | 65 | 51 | 41 | 33 | 28 | 23 | 19 |
| .83 | 977 | ..... | 192 | 123 | 87 | 65 | 51 | 41 | 34 | 28 | 23 | 19 |
| .84 | 986 | ..... | 193 | 124 | 88 | 66 | 52 | 41 | 34 | 28 | 23 | 20 |
| .85 | 995 | ..... | 195 | 125 | 89 | 67 | 52 | 42 | 34 | 28 | 24 | 20 |
| .86 | 1004 | ..... | 197 | 126 | 90 | 68 | 53 | 42 | 35 | 29 | 24 | 20 |
| .87 | 1013 | ..... | 198 | 127 | 91 | 69 | 53 | 43 | 35 | 29 | 24 | 20 |
| .88 | 1022 | ..... | 200 | 128 | 91 | 69 | 54 | 43 | 35 | 29 | 24 | 21 |
| .89 | 1031 | ..... | 202 | 130 | 92 | 70 | 54 | 43 | 36 | 30 | 25 | 21 |
| .90 | 1040 | ..... | 203 | 131 | 93 | 70 | 55 | 44 | 36 | 30 | 25 | 21 |
| .91 | 1049 | ..... | 205 | 132 | 94 | 71 | 55 | 44 | 36 | 30 | 25 | 21 |
| .92 | 1058 | ..... | 207 | 133 | 95 | 71 | 56 | 45 | 37 | 30 | 25 | 21 |
| .93 | 1067 | ..... | 209 | 134 | 95 | 72 | 56 | 45 | 37 | 31 | 26 | 22 |
| .94 | 1076 | ..... | 211 | 135 | 96 | 72 | 57 | 45 | 37 | 31 | 26 | 22 |
| .95 | 1085 | ..... | 213 | 136 | 97 | 73 | 57 | 46 | 38 | 31 | 26 | 22 |
| .96 | 1094 | ..... | 215 | 138 | 98 | 73 | 58 | 46 | 38 | 32 | 26 | 22 |

WIDTH OF SPILLWAY REQUIRED—CONTINUED

| Drainage area, sq. miles | Probable maximum discharge, sec.-ft. | Depth "D" (feet) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 |
| .97 | 1103 | ..... | 217 | 139 | 98 | 74 | 58 | 47 | 39 | 32 | 27 | 23 |
| .98 | 1112 | ..... | 219 | 140 | 99 | 74 | 59 | 47 | 39 | 32 | 27 | 23 |
| .99 | 1121 | ..... | 221 | 141 | 100 | 75 | 59 | 47 | 39 | 33 | 27 | 23 |
| 1.0 | 1130 | ..... | 223 | 142 | 101 | 76 | 60 | 48 | 39 | 33 | 27 | 23 |
| 1.1 | 1220 | ..... | 238 | 153 | 109 | 82 | 65 | 52 | 42 | 35 | 30 | 25 |
| 1.2 | 1310 | ..... | 256 | 165 | 117 | 88 | 70 | 56 | 46 | 38 | 32 | 28 |
| 1.3 | 1400 | ..... | 273 | 176 | 126 | 94 | 75 | 60 | 49 | 41 | 35 | 30 |
| 1.4 | 1480 | ..... | 289 | 186 | 133 | 100 | 79 | 63 | 52 | 44 | 37 | 32 |
| 1.5 | 1560 | ..... | 305 | 197 | 140 | 105 | 83 | 67 | 55 | 47 | 39 | 34 |
| 1.6 | 1640 | ..... | ..... | 207 | 147 | 111 | 87 | 71 | 58 | 49 | 42 | 36 |
| 1.7 | 1720 | ..... | ..... | 217 | 155 | 116 | 92 | 74 | 61 | 52 | 44 | 38 |
| 1.8 | 1800 | ..... | ..... | 227 | 162 | 122 | 96 | 78 | 64 | 54 | 46 | 40 |
| 1.9 | 1880 | ..... | ..... | 237 | 169 | 128 | 101 | 81 | 67 | 57 | 48 | 42 |
| 2.0 | 1960 | ..... | ..... | 247 | 177 | 133 | 105 | 85 | 70 | 59 | 51 | 44 |
| 2.1 | 2040 | ..... | ..... | 258 | 184 | 139 | 109 | 89 | 74 | 62 | 53 | 46 |
| 2.2 | 2120 | ..... | ..... | 268 | 191 | 144 | 114 | 92 | 77 | 64 | 55 | 47 |
| 2.3 | 2195 | ..... | ..... | 277 | 198 | 149 | 118 | 96 | 79 | 67 | 57 | 49 |
| 2.4 | 2270 | ..... | ..... | 287 | 205 | 154 | 122 | 99 | 82 | 69 | 59 | 51 |
| 2.5 | 2345 | ..... | ..... | 296 | 211 | 160 | 126 | 102 | 85 | 72 | 61 | 53 |
| 2.6 | 2420 | ..... | ..... | ..... | 218 | 165 | 130 | 106 | 88 | 74 | 63 | 55 |
| 2.7 | 2490 | ..... | ..... | ..... | 225 | 170 | 134 | 109 | 90 | 76 | 65 | 57 |
| 2.8 | 2560 | ..... | ..... | ..... | 231 | 174 | 138 | 112 | 93 | 79 | 67 | 58 |
| 2.9 | 2630 | ..... | ..... | ..... | 237 | 179 | 142 | 115 | 96 | 81 | 69 | 60 |
| 3.0 | 2700 | ..... | ..... | ..... | 244 | 184 | 146 | 118 | 98 | 83 | 71 | 62 |
| 3.1 | 2770 | ..... | ..... | ..... | 250 | 189 | 149 | 121 | 101 | 85 | 73 | 63 |
| 3.2 | 2840 | ..... | ..... | ..... | 257 | 194 | 153 | 125 | 104 | 87 | 75 | 65 |
| 3.3 | 2910 | ..... | ..... | ..... | 263 | 199 | 157 | 128 | 106 | 90 | 77 | 67 |
| 3.4 | 2980 | ..... | ..... | ..... | 269 | 203 | 161 | 131 | 109 | 92 | 79 | 69 |
| 3.5 | 3050 | ..... | ..... | ..... | 276 | 208 | 165 | 134 | 112 | 94 | 81 | 70 |
| 3.6 | 3118 | ..... | ..... | ..... | 282 | 213 | 168 | 137 | 114 | 96 | 83 | 72 |
| 3.7 | 3186 | ..... | ..... | ..... | 288 | 218 | 172 | 140 | 117 | 99 | 85 | 74 |
| 3.8 | 3254 | ..... | ..... | ..... | 294 | 222 | 176 | 143 | 119 | 101 | 87 | 75 |
| 3.9 | 3322 | ..... | ..... | ..... | 300 | 227 | 180 | 146 | 122 | 103 | 89 | 77 |
| 4.0 | 3390 | ..... | ..... | ..... | ..... | 232 | 184 | 149 | 124 | 105 | 90 | 79 |
| 4.1 | 3457 | ..... | ..... | ..... | ..... | 236 | 187 | 152 | 127 | 107 | 92 | 80 |
| 4.2 | 3524 | ..... | ..... | ..... | ..... | 241 | 191 | 155 | 130 | 110 | 94 | 82 |
| 4.3 | 3591 | ..... | ..... | ..... | ..... | 246 | 195 | 158 | 132 | 112 | 96 | 83 |
| 4.4 | 3658 | ..... | ..... | ..... | ..... | 250 | 198 | 161 | 135 | 114 | 98 | 85 |
| 4.5 | 3725 | ..... | ..... | ..... | ..... | 255 | 202 | 164 | 137 | 116 | 100 | 87 |
| 4.6 | 3790 | ..... | ..... | ..... | ..... | 259 | 205 | 167 | 139 | 118 | 102 | 88 |
| 4.7 | 3855 | ..... | ..... | ..... | ..... | 264 | 209 | 170 | 142 | 120 | 103 | 90 |
| 4.8 | 3920 | ..... | ..... | ..... | ..... | 268 | 213 | 173 | 144 | 122 | 105 | 92 |
| 4.9 | 3995 | ..... | ..... | ..... | ..... | 273 | 217 | 176 | 147 | 125 | 107 | 93 |
| 5.0 | 4050 | ..... | ..... | ..... | ..... | 277 | 220 | 179 | 149 | 127 | 109 | 95 |
| 5.1 | 4113 | ..... | ..... | ..... | ..... | 282 | 223 | 182 | 152 | 129 | 111 | 96 |
| 5.2 | 4176 | ..... | ..... | ..... | ..... | 286 | 227 | 185 | 154 | 131 | 112 | 98 |
| 5.3 | 4239 | ..... | ..... | ..... | ..... | 290 | 230 | 187 | 156 | 133 | 114 | 99 |
| 5.4 | 4302 | ..... | ..... | ..... | ..... | 295 | 234 | 190 | 159 | 135 | 116 | 101 |
| 5.5 | 4365 | ..... | ..... | ..... | ..... | 299 | 237 | 193 | 161 | 137 | 118 | 102 |
| 5.6 | 4426 | ..... | ..... | ..... | ..... | ..... | 240 | 196 | 163 | 139 | 119 | 104 |



WIDTH OF SPILLWAY REQUIRED—CONCLUDED

| Drainage area, sq. miles | Probable maximum discharge, sec.-ft. | Depth "D" (feet) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 |
| 5.7 | 4487 | ..... | ..... | ..... | ..... | ..... | 244 | 198 | 166 | 141 | 120 | 105 |
| 5.8 | 4538 | ..... | ..... | ..... | ..... | ..... | 247 | 201 | 168 | 143 | 122 | 107 |
| 5.9 | 4609 | ..... | ..... | ..... | ..... | ..... | 250 | 204 | 170 | 145 | 124 | 108 |
| 6.0 | 4670 | ..... | ..... | ..... | ..... | ..... | 254 | 207 | 173 | 147 | 126 | 110 |
| 6.1 | 4731 | ..... | ..... | ..... | ..... | ..... | 257 | 209 | 175 | 149 | 128 | 111 |
| 6.2 | 4792 | ..... | ..... | ..... | ..... | ..... | 260 | 212 | 177 | 151 | 130 | 113 |
| 6.3 | 4853 | ..... | ..... | ..... | ..... | ..... | 264 | 215 | 180 | 153 | 131 | 114 |
| 6.4 | 4914 | ..... | ..... | ..... | ..... | ..... | 267 | 218 | 182 | 154 | 133 | 116 |
| 6.5 | 4975 | ..... | ..... | ..... | ..... | ..... | 271 | 220 | 184 | 156 | 135 | 117 |
| 6.6 | 5036 | ..... | ..... | ..... | ..... | ..... | 274 | 223 | 186 | 158 | 136 | 119 |
| 6.7 | 5097 | ..... | ..... | ..... | ..... | ..... | 277 | 226 | 189 | 160 | 138 | 120 |
| 6.8 | 5158 | ..... | ..... | ..... | ..... | ..... | 281 | 229 | 191 | 162 | 140 | 122 |
| 6.9 | 5219 | ..... | ..... | ..... | ..... | ..... | 284 | 231 | 193 | 164 | 141 | 123 |
| 7.0 | 5280 | ..... | ..... | ..... | ..... | ..... | 287 | 234 | 196 | 166 | 143 | 125 |
| 7.1 | 5339 | ..... | ..... | ..... | ..... | ..... | 291 | 237 | 198 | 168 | 145 | 126 |
| 7.2 | 5398 | ..... | ..... | ..... | ..... | ..... | 294 | 239 | 200 | 170 | 146 | 128 |
| 7.3 | 5457 | ..... | ..... | ..... | ..... | ..... | 297 | 242 | 202 | 172 | 148 | 129 |
| 7.4 | 5516 | ..... | ..... | ..... | ..... | ..... | 300 | 245 | 205 | 174 | 150 | 131 |
| 7.5 | 5575 | ..... | ..... | ..... | ..... | ..... | ..... | 247 | 207 | 176 | 151 | 132 |
| 7.6 | 5634 | ..... | ..... | ..... | ..... | ..... | ..... | 250 | 209 | 178 | 153 | 134 |
| 7.7 | 5693 | ..... | ..... | ..... | ..... | ..... | ..... | 253 | 211 | 180 | 155 | 135 |
| 7.8 | 5752 | ..... | ..... | ..... | ..... | ..... | ..... | 255 | 213 | 181 | 156 | 136 |
| 7.9 | 5811 | ..... | ..... | ..... | ..... | ..... | ..... | 258 | 216 | 183 | 158 | 138 |
| 8.0 | 5870 | ..... | ..... | ..... | ..... | ..... | ..... | 261 | 218 | 185 | 160 | 139 |
| 8.1 | 5928 | ..... | ..... | ..... | ..... | ..... | ..... | 263 | 220 | 187 | 161 | 141 |
| 8.2 | 5986 | ..... | ..... | ..... | ..... | ..... | ..... | 266 | 222 | 189 | 163 | 142 |
| 8.3 | 6044 | ..... | ..... | ..... | ..... | ..... | ..... | 268 | 224 | 191 | 164 | 144 |
| 8.4 | 6102 | ..... | ..... | ..... | ..... | ..... | ..... | 271 | 227 | 193 | 166 | 145 |
| 8.5 | 6160 | ..... | ..... | ..... | ..... | ..... | ..... | 274 | 229 | 195 | 168 | 146 |
| 8.6 | 6218 | ..... | ..... | ..... | ..... | ..... | ..... | 276 | 231 | 196 | 169 | 148 |
| 8.7 | 6276 | ..... | ..... | ..... | ..... | ..... | ..... | 279 | 233 | 198 | 171 | 149 |
| 8.8 | 6334 | ..... | ..... | ..... | ..... | ..... | ..... | 281 | 235 | 200 | 173 | 151 |
| 8.9 | 6392 | ..... | ..... | ..... | ..... | ..... | ..... | 284 | 238 | 202 | 174 | 152 |
| 9.0 | 6450 | ..... | ..... | ..... | ..... | ..... | ..... | 287 | 240 | 204 | 176 | 154 |
| 9.1 | 6506 | ..... | ..... | ..... | ..... | ..... | ..... | 289 | 242 | 206 | 177 | 155 |
| 9.2 | 6562 | ..... | ..... | ..... | ..... | ..... | ..... | 292 | 244 | 208 | 179 | 156 |
| 9.3 | 6618 | ..... | ..... | ..... | ..... | ..... | ..... | 294 | 246 | 209 | 181 | 158 |
| 9.4 | 6674 | ..... | ..... | ..... | ..... | ..... | ..... | 297 | 248 | 211 | 182 | 159 |
| 9.5 | 6730 | ..... | ..... | ..... | ..... | ..... | ..... | 299 | 250 | 213 | 184 | 160 |
| 9.6 | 6786 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 252 | 215 | 185 | 162 |
| 9.7 | 6842 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 255 | 217 | 187 | 163 |
| 9.8 | 6898 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 257 | 218 | 188 | 165 |
| 9.9 | 6954 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 259 | 220 | 190 | 166 |
| 10.0 | 7010 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 261 | 222 | 191 | 167 |

Sometimes the spillway may be on a rock ledge which may have no slope, or even dip in an upstream direction. Under such circumstances the dimensions of the spillway must be increased to compensate for the lower velocities that will result.

Most frequently the spillway consists of a channel around one end of the dam. Under such conditions the best plan is to keep the spillway entirely in cut beyond the end of the dam. When the topography makes it necessary to have the spillway directly against the end of the dam, a dike should be extended downstream far enough to prevent water from cutting back along the downstream toe. Once in a while it is possible to cut the spillway through to an adjoining watercourse and thus divert the water entirely away from the dam.

All spillways should be protected against erosion. The most effective protection is to keep the water confined to a concrete or masonry channel discharging at stream bed elevation some distance below the dam. When this cannot be done riprap grouted with cement or clay can be used effectively when properly placed. Protection below the outlet of a spillway can be provided by planting willows or bushes Another way is to make wash checks out of wire and brush held in place by posts strung in rows over the area to be protected. Flaring the outlet to spread the water out in a thin sheet will reduce velocities.

Two spillways sometimes can be used to advantage—one a paved or riprapped spillway to care for wet-weather flow and small freshets, the other an unsurfaced spillway at a slightly higher elevation to discharge excess flood waters over sod or adjacent land. The combined capacity of the two must be equal to the probable maximum run-off from the drainage area. The temporary storage in the reservoir may be sufficient to permit some reduction in the maximum spillway capacity.

Each reservoir presents an individual problem in spillway design. There is no rule by which all spillways can be governed. It is well to bear in mind that the safety of a dam depends greatly on the spillway, so particular attention should be given to its design and construction.

### Fish Screens and Other Obstructions

The spillway for a dam must always be open so as to have the full capacity for which it was designed. Fish screens or flash boards should never be placed across the spillway. Approval is not given to dams where they are used. Piers, supports for crossings, etc., are obstructions in a spillway and should not be used unless the spillway has been designed especially for them.

### Outlet Pipe

Every dam should be equipped with a suitable outlet pipe through which water from the reservoir can be easily drawn off. When a pipe is used it should be laid in a trench excavated so that the pipe will lay in original undisturbed ground throughout. Suitable cut-off collars should be placed around the pipe to prevent water from following along the outer surface and opening up a hole through the dam that might result in its destruction.

A valve should be placed in the line, preferably in a manhole or well at a point upstream from the center of the dam. This keeps most of the pipe



through the dam free from internal pressure except when in use. On small dams where the valve is sometimes located near the downstream end of the outlet pipe, it should be set at a point sufficiently well back in the body of the dam to protect it from damage by freezing.

## GENERAL CONSTRUCTION SPECIFICATIONS

The followng specifications are intended primarily to serve as a guide to aid individuals who are engaged in constructing a dam to properly perform the various operations involved in doing the work.

### Preparation of Site

The entire area which is to be occupied by the embankment shall be cleared of all trees, shrubs, brush, sod and vegetation of all kinds; also all trash, debris and perishable matter. All stumps within this area shall be grubbed out and all roots shall be removed to a depth of at least three feet. All mud and muck shall be cleaned out of the bed of the stream After the area is prepared in this manner, furrows shall be plowed parallel to the axis of the embankment at intervals not exceeding three feet. The base shall be sprinkled with water immediately before depositing material for the embankment.

### Cut-off Trench

The cut-off trench shall be excavated along a line across the dam site at the location and to the dimensions, cross sections and elevations shown on the plans. The bottom of the trench shall be excavated to the full width shown on the plans and shall extend through all top soil, loose fill, sand and gravel and broken ledges of stone to a minimum of six inches into sound, undisturbed, impervious material.

### Rolled Fill

Material for rolled fill shall consist of selected earth and clay, impervious to water and free from all clods, large lumps of soil, roots, stumps, sod, rocks, and debris of any kind. The material shall be deposited in the embankment and be mixed and spread in layers which are not more than six inches in thickness before being compacted by rolling or by teams, wagons and trucks which may travel over it. The surface of the embankment shall be sprinkled with water immediately before spreading material for each lift. Each layer shall be thoroughly compacted and bonded to material previously placed by rolling and by distributing the travel of wagons and trucks uniformly over all parts of the embankment. Teams or machines shall not be permitted to "track" across the embankment, but their travel shall be directed in such a manner as to secure a thorough and uniform compaction of the material which has been placed. The material shall contain the proper amount of moisture to permit maximum compaction. The embankment shall be maintained as nearly level as possible in the direction of the axis of the dam, and the outer edges of the embankment shall be kept higher than the central portion. Berms shall be built to a uniform width and side slopes shall be kept full at all times. Dumping of material over the edges and onto the side slopes shall not be permitted. In finishing the embankment sufficient material shall be added to allow ten percent of the vertical height at any point for shrinkage

or settlement. No borrow pits shall be made closer than twenty feet from the toe of the slope of the finished embankment.

### Puddled Fill

The material for puddled fill shall be the same kind as specified for rolled fill. Puddled fill shall be made by depositing quantities of this material into water in such amounts as can be thoroughly puddled with the methods and equipment that are employed for that purpose. The puddled fill shall be constructed in lifts not exceeding twelve inches in depth. Sufficient quantities of water shall be used so that all material is inundated and a quanity of free water stands at the surface of the fill at all times. The material in each lift shall be thoroughly slaked in order to completely break down the structure of all soïl particles. The slaked material shall be mixed to the consistency of stiff mud, and shall be stirred and agitated until all entrained air is expelled in order to secure a mixture of maximum density. The puddled fill shall be made as continuously as possible but when, for any reason, it is necessary to stop, care shall be taken to prevent material which has been placed in the fill from drying out and shrinking. In that event the surface of the wet mixture shall be covered with a sufficient quantity of dry, pulverized material in order to seal the top and prevent the evaporation of moisture. When the process of puddling is resumed the puddled fill shall be flooded and the dry pulverized material on the top shall be thoroughly mixed with the other puddled material.

### Installation of Outlet Pipe

The bottom of the trench for the outlet pipe shall be at the same elevation as the bottom of the cut-off trench at the point of intersection and no backfill shall be permitted under any portion of the pipe. Concrete cut-off collars shall be placed around the outlet pipe as indicated on the plans and shall be poured directly against excavation in the sides of the trench without forms.

### Riprap

Riprap shall consist of stones laid on edge in parallel courses, one against the other with ends in contact and joints broken. The long dimension of each stone shall be parallel to the axis of the dam when used on the embankment and normal to the centerline of the channel when used in the spillway. The spaces between the larger stones shall be filled with spalls of suitable size and all spalls shall be rammed firmly into place so that the finished surface of the riprap is tight and even. All stones for riprap shall be of sound, hard and durable material which show no signs of weathering or disintegration. The minimum dimensions of individual stones which are used shall be not less than eight inches in width or five inches in thickness and shall be equal in length to the required thickness of the riprap, provided, that exclusive of spalls, no stones shall be less than one-third cubic foot in volume. The thickness and length of individual pieces of stone shall not exceed the required thickness of the riprap and the maximum width may be as large as can be conveniently handled.



### Clay-grouted Riprap

When clay-grouted riprap is required the spaces remaining between the stones after spalls have been driven shall be filled with stone dust or finely pulverized clay or shale which material shall all pass a fifty-mesh sieve. This material shall be spread in quantities just sufficient to cover the surface of the stones and shall be brushed and washed into the spaces between the stones. This procedure shall be repeated until the spaces between the stones are completely filled so that the finished surface of the riprap is tight and impervious to water.

### Cement-grouted Riprap

When cement-grouted riprap is required the spaces remaining between the stones after spalls have been driven shall be filled with cement grout consisting of one part Portland cement and three parts sand, mixed wih sufficient water to form a plastic mortar which shall be worked into the voids between the stones until they are completely filled so that the finished surface of the riprap is tight and impervious to water.

### Masonry

All rock for masonry walls or structures shall consist of sound, hard and durable pieces of stone which show no indication of weathering or disintegration. Thin edges and projecting pieces shall be struck from each piece of stone and it shall be roughly squared. Before being laid all stones shall be thoroughly cleaned and shall be sprinkled with water for such a period of time as may be necessary to absorb sufficient moisture to permit proper bonding with the mortar. Material for mortar shall be proportioned by volume and shall consist of one part Portland cement to one-fourth part of slaked lime and three parts sand, mixed with sufficient water to make a plastic mortar. Each stone shall be laid on a full flat bed of mortar. Joints shall be not more than three-fourths of an inch thick and each joint shall be completely filled with mortar. The stones shall be laid in courses on their natural beds with joints broken and bonded with header stones evenly distributed throughout the mass of masonry.

### Rock Fill

Material for rock fill shall consist of random size pieces of stone of such size as can be conveniently handled. This material shall be deposited and spread in horizontal lifts not exceeding twelve inches in thickness. Following the placing of each lift, the spaces between the larger stones shall be filled with smaller stones and spalls of suitable size. Each lift shall be finished in this manner before material is placed for the succeeding lift.

### Concrete

Concrete shall consist of a mixture of Portland cement mineral aggregates and water. For mixed sand and gravel aggregate the proportion of materials by volume shall be approximately one part cement to four parts of aggregate. For aggregate consisting of sand and crushed rock, with maximum size not exceeding three-fourths inch, the proportion of materials by volume shall be approximately one part cement to two parts sand and two and one-half parts crushed rock. In either case the amount of water used for mixing shall not

exceed seven and one-half gallons per sack of cement. The exact proportion of aggregates shall be determined by trial and shall be adjusted so as to produce a workable mixture, such that with light troweling all spaces between pebbles are filled with mortar.

### Sheet Piling

Each piece of piling shall consist of three timbers which shall be fastened together with spikes driven alternately from opposite sides along both edges in staggered rows, spaced not more than ten inches apart and tightly clinched. In addition to spiking, bolts shall be placed near the bottom of each pile. Each piece of piling shall be sharpened and coped and all edges shall be chamfered. The long edge of each pile shall be placed against the last pile driven so that the drift will be toward the piling already in place. The maximum allowable variation from the vertical in driving shall not exceed one tenth of an inch per foot of length of pile. All piling shall be securely braced and supported while being driven to insure proper alignment. All piles improperly driven or those which broom, splinter, split or are otherwise damaged in driving shall be pulled and replaced with a new pile which shall be driven into place before proceeding with additional piling.

## MAINTENANCE

Every dam can be expected to require a certain amount of maintenance, depending upon how well it may have been constructed in the first instance and also on how promptly any needed repairs are made. In order to keep maintenance at a minimum, the dam should be inspected frequently while the reservoir is filling and thereafter at regular intervals, particularly following heavy rains or periods of wet weather.

In examining the dam it should be observed whether any cracks appear in the embankment due to shrinkage or settlement and whether the embankment may have settled below grade at any point. The condition of the side slopes should be noted to determine whether the upstream slope is satisfactory withstanding the action of water in the reservoir and whether the downstream slope is dry and suitably protected from erosion by wind and rain. The spillway should be carefully checked in order to discover any serious erosion which might be taking place, or where riprap is used, to determine whether any pieces of stone may have been dislodged or loosened. Any seepage which may occur should be observed and its relative amounts should be noted with respect to various stages of water in the reservoir. Ordinarily, it is not necessary to be concerned with seepage unless it results in the loss of needed water from the reservoir or is affecting the safety of the dam.

A dam can be kept in good condition by giving prompt attention to a small amount of maintenance from time to time as may be necessary. In this manner serious damage to the dam may be averted and only minor repairs may be required occasionally.

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