Division of Agricultural Sciences

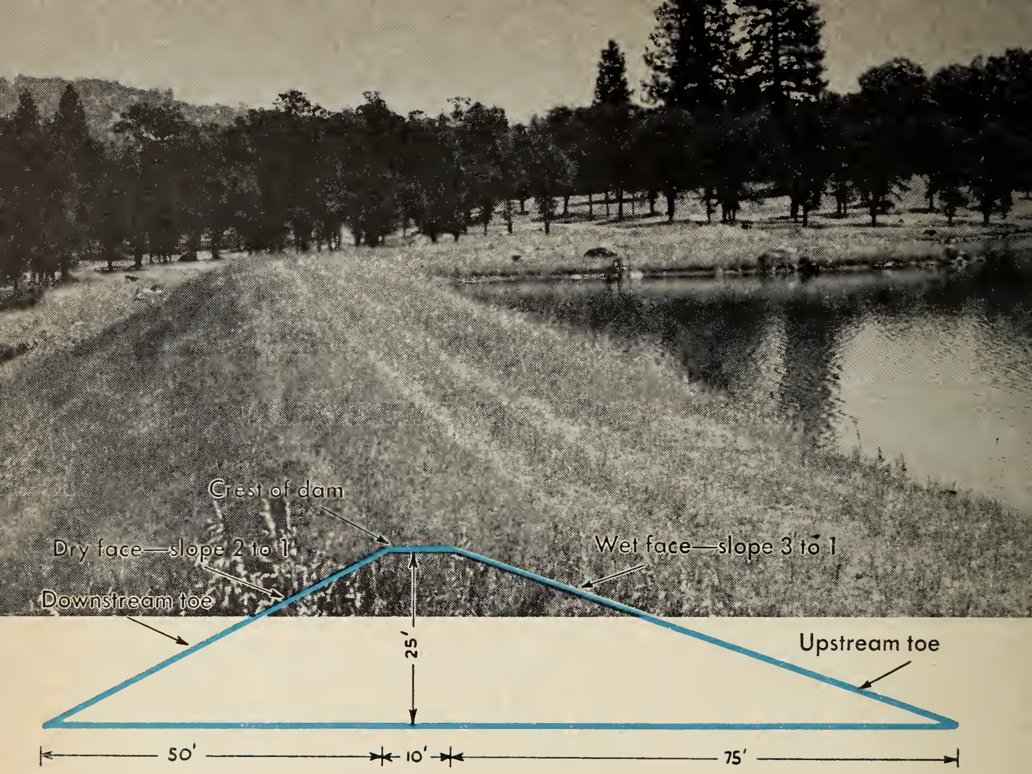
UNIVERSITY OF CALIFORNIA

SMALL EARTH DAMS

LLOYD N. BROWN

CALIFORNIA AGRICULTURAL
Experiment Station
Extension Service

CIRCULAR 467
Revised



Here is a cross section of a typical small earth dam showing the recommended ratios of width to height and naming the main parts.

Dam building is a very involved undertaking. This circular endeavors to supply you with practical suggestions which may be of assistance to you. It is up to you to fit them together as they apply to your situation.

REVISED DECEMBER 1965

THE AUTHOR:

Lloyd N. Brown is Extension Soils Specialist Emeritus in the Agricultural Extension Service, Berkeley.

About 20,000 small earth dams have been built on California farms in the last 25 years and more are being built all the time. While many of the early dams were built primarily as stock-watering ponds, farmers are also deriving benefits from their reservoirs in the way of irrigation water and even recreational purposes.

But dams have disadvantages too. They are expensive to build; they require labor and more expense to maintain properly; they may increase the nearby mosquito population.

So perhaps a dam would be a good investment for you; perhaps not. This circular discusses:

The laws involved—some are restrictive, some are beneficial, but you should know them.

Selection of a site—for the dam, the reservoir, the spillway. You'll undoubtedly have to compromise—you might want to give up the idea of building a dam.

Construction details—there are a lot of things to watch if your dam is to be a good one.

Maintenance practices—for the dam, the spillway, the reservoir, the watershed.

Management practices—for both practical and recreational uses of the reservoir.

Before you start you should know the law

When you build a dam to impound water for your own use, in California, you should be familiar with the regulations of a number of public agencies. They are:

The State Water Rights Board

To legally impound water for deferred use, a water right must be secured from this board and anyone proposing to build a dam would do well to write to this agency for information. The address is 1140 Resources Building, Ninth and O Streets, Sacramento.

The Department of Water Resources

By California statutes, the State Director of Water Resources must approve the design and construction or enlargement of all dams over a certain size and/or storage capacity. The reason for this is to assure that sound design principles and construction procedures are used for larger dams, to minimize failures. This procedure not only protects the public from floods due to dam failure, but makes available to builders of large dams valuable technical advice.

This publication, however, is concerned primarily with small dams that are exempt from supervision by the Department of Water Resources. Such dams are described as follows:

1. All dams 6 feet or less in height, regardless of storage capacity.
2. All dams storing 15 acre-feet of water or less, regardless of height.
3. All dams less than 25 feet high which have a storage capacity of less than 50 acre-feet of water.

(See pages 6 and 7 for directions on measuring the height of a dam and storage capacity of a reservoir.)

For dams exceeding the above limitations, construction of a new dam or the enlargement of any dam above these limitations MUST NOT BE COMMENCED until the owner has applied for and obtained from the department written approval of plans and specifications. Otherwise severe penalties are involved. The department's address is P.O. Box 388, Sacramento.

Enlarging small dams. Occasionally small dams are built with the idea of later enlarging them to a size that will bring them under the supervision of the Department of Water Resources. The builder of such a dam would be wise to consult the department in the beginning and use specifications for the larger dam to save expensive alterations later.

For instance—the department usually requires that the outlet pipe in large dams be laid in a trench and backfilled with concrete, rather than using concrete collars (which are allowed in smaller dams). If specifications for the larger dam were used from the start a considerable saving could be effected.

Agricultural Conservation Program—USDA

If you comply with the regulations of this agency when you build a dam, you may be entitled to financial help toward the cost of construction. The agency has offices in most California counties.

It is not anticipated that there will be any material differences between the technical recommendations in this publication and the requirements of the ACP.

State Department of Fish and Game

The reservoir behind your dam may be big enough to provide good fishing and thus bring you into contact with the regulations of the Fish and Game department.

Two kinds of ponds are recognized: recreational ponds in which the owner, his family, and friends may fish for fun, but license and bag regulations of the

State Fish and Game Department apply; commercial ponds in which fish are raised for sale to restaurants, fishermen, pond owners, etc. Consult with the Fish and Game Department about regulations that apply to this type of pond.

Trout ponds can be successful only where the water temperature does not rise above 70° F for any length of time. They will be stocked free by the state, provided the public is allowed to fish there. The department will provide a list of trout dealers and a transportation permit without charge to owners of ponds who do not wish to open them to the public.

Warm-water ponds are those in which the summer temperature of the water rises above 70° F for several weeks or more, and in which bass, bluegills (also known as bream, sunfish, or perch), and crappie, will thrive. The state will provide free an initial stocking for such ponds if they are less than 25 surface acres in size but not less than one-quarter acre. For warm-water ponds larger than 25 acres, the state will stock them only if they are open to the public for fishing. Since these fish will reproduce in reservoirs, restocking may not be necessary.

There is no closed season on warm-water fish in California.

Before you turn over a shovelful of earth on construction of a dam,
KNOW THE LAW.

Selecting a site may call for a compromise

It is possible to build a dam across a watercourse almost anywhere, but it may be practical to build one only when the three major elements (the dam, the spillway, and the reservoir) will function as a satisfactory whole. It is rare indeed where optimum conditions for all three elements occur together—therefore the selection of a site is nearly always a compromise.

If no satisfactory compromise between these elements can be made it may be impractical to build a dam.

But in looking for a site for your dam, consider all of the elements separately and collectively. Here are some pointers:

For the dam

Do not locate a dam on springs, seeps, or old landslides—all of these indicate unstable soil conditions. Avoid boulders and outcroppings of rocks on the damsite, as they are difficult to work around.

A dam should be as short as possible—such as in the narrow part of a canyon. A long dam requires more fill material and is thus more expensive.

Consider the elevation of the proposed dam and reservoir—is it higher than the area in which the water is to be used? Can you take water out by gravity or will it have to be pumped? Pumping may be expensive.

Locate the dam as close as possible to a supply of medium-textured soil for construction. Fine-textured clay is likely to crack when drying; coarse-textured sand may not hold water.

Is the proposed damsite accessible by an existing road? If not, is it practical to build an access road? It may be the cost of such a road would preclude some damsites.

If, like some people, you are "disaster-minded," you may want to consider the site of the dam in relation to dwellings.

Would possible failure of the dam endanger lives or property below it?

How is the site for the dam with reference to the proposed spillway and reservoir? (See below.)

For the Reservoir

Will the reservoir hold all the water you will need? (See page 7 for directions for calculating the reservoir volume.)

Will the watershed above the dam furnish enough runoff to fill the reservoir? This is sometimes a guess because rainfall and runoff will vary from year to year, but if the stream you are damming is a well-established watercourse this will indicate an appreciable amount of runoff.

Sometimes the water in the dammed stream can be augmented by diverting water into it from an adjacent stream, using a contour grade ditch. Such a ditch can be made by several trips with a plow. It would probably be impractical to make the ditch large enough to carry peak flows, so you should avoid diverting water during periods of high runoff.

Avoid locating the reservoir on material that may allow excessive seepage—shale and similar formations are frequently very porous and even solid material such as granite may have cracks that will allow water to escape. The best reservoir bottom would be a natural layer of fine-textured soil.

Since trees and shrubs should be removed from the reservoir site (for reasons given later), consider how dense this vegetation is. If it is very dense, the cost of clearing might be excessive.

For the spillway

A spillway can be located in any of several positions relative to the dam, but in any event a wide, shallow spillway is usually preferable to a deep narrow one (see page 15).

The spillway bottom for at least part of its length should be through material that will not wash, such as solid rock. In most instances rock can be found which can be excavated with a bulldozer. In some cases it may be necessary to use dynamite. Here are four possible locations of a spillway, arranged in order of ease and probable economy of construction.

If you can locate your dam just upstream from the confluence of two streams you can usually build the spillway to the undammed stream (see diagram page 15). Where possible, it is well to run such spillways along the contour and bring them into the undammed fork well upstream. This will slow down the flow of the spillway water and prevent erosion.

Occasionally it is possible to construct a spillway through a saddle upstream from the dam, into another watercourse that drains an adjacent basin.

Many spillways are built around one end of the dam. When this is done, the water must be led into the stream below the dam without washing the dam itself—this may be very difficult in a steep-sided canyon.

As a last resort it might be necessary to put a concrete spillway over the center of the dam but such structures are very expensive, difficult to maintain, and not infrequently wash out.

It should also be pointed out that a dam of less than 25 acre-feet storage capacity, built on a major stream, will require such a large spillway that it may make the cost of the project out of line with any benefits to be derived.

For the watershed

Check the watershed area for soil erosion. Excessive erosion will silt up your reservoir in a relatively short time and perhaps make the whole project economically unsound.

How to Measure the Storage Capacity of the Reservoir

To make sure your proposed dam will comply with state regulations, and store enough water to meet your needs, you will want to know the capacity of the reservoir. To get this information, make the following measurements:

Height of dam. The state defines the vertical height of a dam as the distance between "the level of the natural stream-bed at the downstream toe (of the dam) to the crest (bottom of spillway) of spillway," or to the crest of any barrier built in the spillway.

Area of proposed reservoir. Starting at the crest of the proposed spillway, use a level (hand-held or surveyor's) and outline the reservoir with lath stakes. Drive stakes at intervals of no more than 100 feet.

Using the line between the stakes at either end of the proposed dam as a base, lay out lines parallel to this base, with one end of each line at an angle in the shoreline (see diagram, below).

Lay out as many of these parallel lines as necessary. You will then have a series of strips and one triangle, the areas of which can be computed as follows:

To get the area of W (in the diagram) measure Lines AB, CD, and P_1. Then:

$$\frac{\text{Length of AB} + \text{Length of CD}}{2} \times \text{Length}$$

of P_1 = sq. ft. in strip ABDC.

Do the same for Area X by Lines CD, EF and P_2.

$$\frac{\text{Length of CD} + \text{Length of EF}}{2} \times \text{Length}$$

of P_2 = sq. ft in strip CDFE.

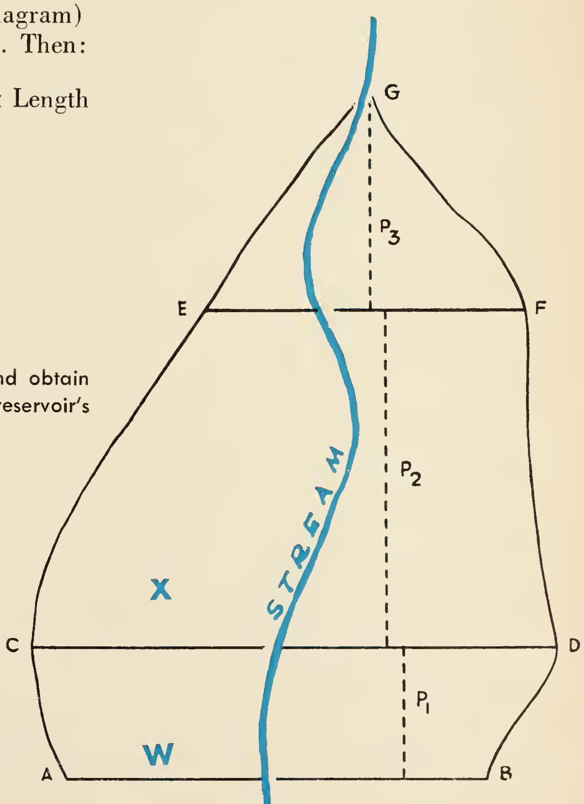
In the triangle EFG, find the area as follows:

$$\frac{\text{Length of EF}}{2} \times \text{Length of } P_3 = \text{sq. ft. in}$$

triangle EFG.

Add figures for the sq. ft. of all strips and the triangle; divide this total by 43,560 (the sq. ft. in an acre) to get the number of *surface* acres in the proposed reservoir.

A widely used formula assumes that the average depth of the reservoir is one third of the maximum depth. So to estimate the capacity in *acre-feet,* multiply the number of surface acres by one third the maximum depth in feet of the proposed reservoir.



You can step off the lines shown and obtain a fairly accurate estimate of your reservoir's capacity.

Line AB is level with bottom of proposed spillway.

Building the dam takes careful preparation

Whether you build the dam yourself or hire the work done, you should have the details of the completed structure well in mind; have a carefully planned construction program by steps. Material and equipment should be available as needed.

Stake out the damsite

The upstream, or wet face of the dam should have a slope of at least 3 feet horizontally to 1 foot vertically. The downstream, or dry face, should have a slope of at least 2 feet horizontally to 1 foot vertically. The crest of the dam should be 10 feet wide so as to provide a roadway if necessary.

So assuming an almost level streambed, a dam 25 feet high will occupy 135 feet horizontally.

Upstream slope	75 ft.
Downstream slope	50 ft.
Crest of dam	10 ft.
Total	135 ft.

A dam 20 feet high would occupy 110 feet horizontally—and so on.

Prepare the site very carefully

Remove all rocks greater than 6 inches in diameter from the entire damsite. Uproot and burn or remove all trees and stumps. Push off or burn all brush, heavy grass and weeds, decaying logs and other debris. Any of this material that cannot be burned should be removed *downstream*—not upstream into the reservoir site.

The soil under the dam should be practically free of coarse vegetative matter before you start building.

Next, disk the entire damsite. Mix the soil enough so that there will be no layer of trash or vegetation that will seep water when the dam is filled. This loose soil will also make a good bond with the fill material placed over it when building the dam.

Cut-off trench

Most watercourses have gravel in them and there are likely to be gravel strata buried in the banks and below the streambed. Since they will leak water these strata must be broken up. Bulldoze a trench across the streambed directly below the crest of the proposed dam. The trench need only be about the width of the dozer blade and should extend both ways from the watercourse and to a depth that will insure interruption of all gravel strata and other pervious material. (See sketch, page 9.)

Backfill the trench with the same material that will be used for building the dam. Be sure to get good compaction of this material.

Moving the soil

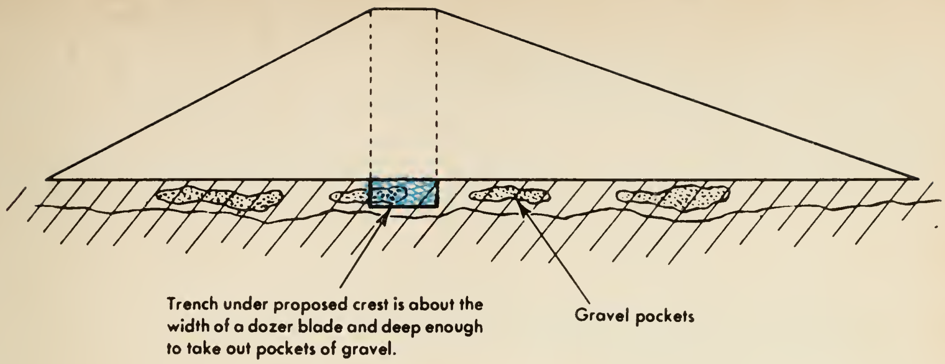
You are now ready to start bringing in soil to build the dam and it is assumed that the site has been chosen with an ample supply of medium-textured soil nearby. *Do not take soil from the reservoir site* if the underlying strata are not watertight.

Bring in the soil and spread the fill in shallow layers—not over 6 inches thick. The equipment passing over these layers should result in satisfactory compaction.

If you can build the dam late in the spring, while the soil is still damp (but not wet), you will obtain best results. If the dam is built with dry soil it may be necessary to haul in water and sprinkle—a costly procedure.

Slope gauge. To maintain the slopes you want on both wet and dry faces of the dam you can use a gauge similar to the one shown in the illustration (page 10). Use a 3-for-1 gauge on the wet side; a 2-for-1 gauge on the dry side.

Reseeding your cuts. If you use soil from a hillside above the dam for your fill, you will probably leave a bare area



that will erode badly during winter rains. Best protection against this is to push the top, shallow layer of soil and debris to one side, then push it back over the cut after the dam is built. If this does not provide sufficient cover, haul in straw or manure. A little seed and fertilizer will then start growth in the scraped bare area and avoid erosion.

The outlet pipe

An outlet pipe can be used for draining water from your reservoir for irrigation, watering stock, making repairs on the dam, locating leaks in the reservoir, disposing of floating debris, getting rid of undesirable fish or vegetative matter.

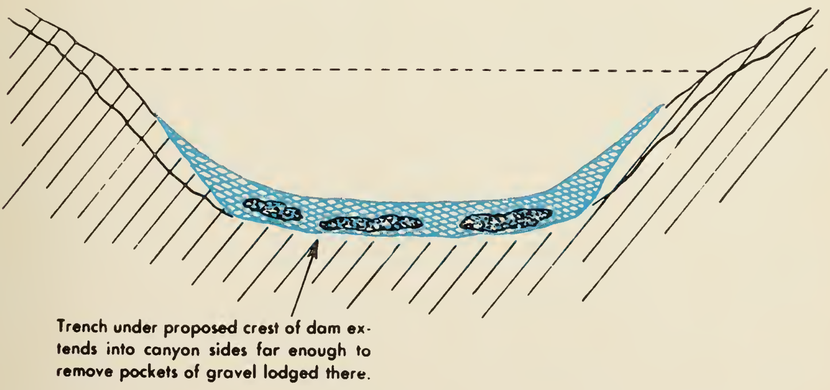
A siphon over the dam can be used as an alternate to an outlet pipe but priming is necessary to start a siphon flowing.

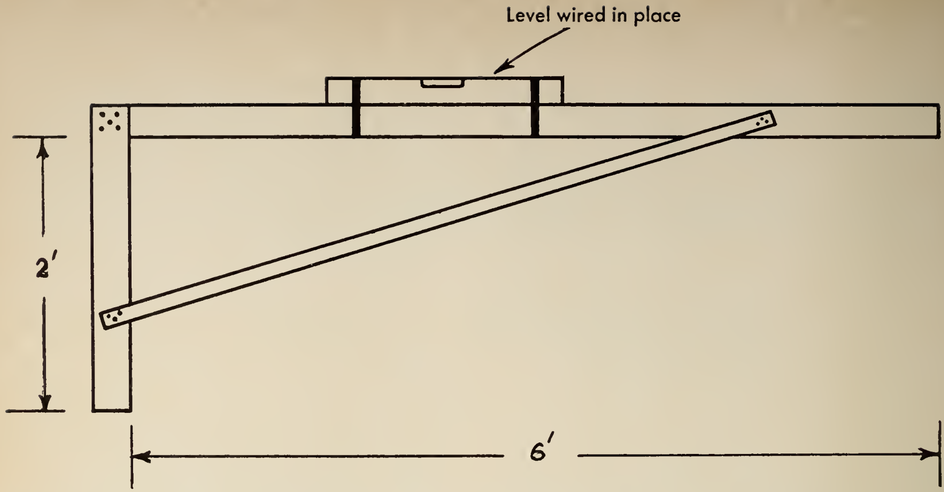
Priming consists of removing the air with a common suction pump or with a suction pump operated off of and by your auto engine.

Then, of course, water can always be pumped directly from the reservoir to any place that it is needed, but this may be expensive.

Assuming that an outlet pipe will be wanted, here are some pointers on installation.

The pipe should be large enough to deliver all the water you will need, whatever your intended use. The minimum pipe size—even for a watering trough—should be 1½ inches in diameter. Anything smaller would be too difficult to clean if it got plugged.





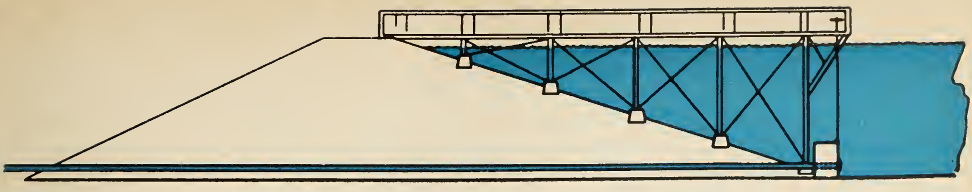
Two feet high—6 feet horizontal gives a 3–1 gauge; 3 feet high—6 feet horizontal gives a 2–1 gauge.

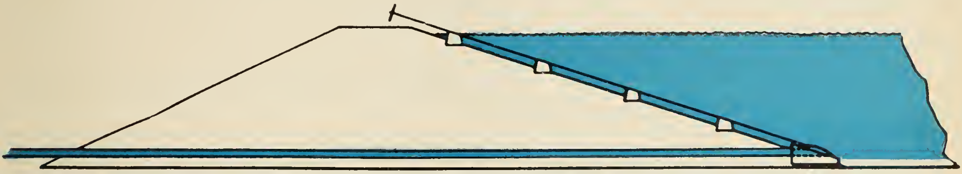
For irrigation, a 6-inch pipe might be required. In any case, galvanized water-pipe is the most commonly used.

The intake end of the pipe should be high enough above the upstream toe of the dam so that subsequent settling of silt and debris will not clog it, but low enough so that usable irrigation water is not left in the reservoir. In a shallow reservoir the pipe might be almost on the bottom; in a deep reservoir it might be 5 or 6 feet above the bottom. The most favorable condition for laying the outlet pipe is in a trench dug in the fill material used for the dam as described below.

When to install. Build the dam 2 feet above the point you have selected for the position of the outlet pipe, then dig a

The hillside in the background would have been benefited by seeding. This reservoir is already starting to silt up—note the fan forming at the far end of the dam.





Two ways of operating the valve on an outlet pipe.

trench about 2 feet deep in the partly constructed dam. Lay the pipe in the trench.

Concrete collars should be poured around the outlet pipe in the upstream two thirds of its length. These collars should be at least 8 inches thick, extend out from the pipe 18 inches, and be not more than 15 feet apart. After constructing the collars, the backfill around both pipe and collars should be tamped thoroughly.

The outlet gate should be installed on the upper, or reservoir end of the pipe so that in case of pipe failure the water can be shut off while repairs are made. If the gate is on the downstream end, the pipe will be under pressure at all times, making repairs for leaks difficult.

A cast iron slide gate of the type com-

The bank of this reservoir was seeded, but note the better growth of covercrop where fertilizer was applied (as pointed out by the man in the background).

This dam uses a siphon instead of an outlet pipe which is proving very satisfactory for the owner. Power from the automobile engine is used to pump air out of the pipe and start the water flowing, but any small, gasoline-driven engine can be used to perform the same function.

monly used in concrete irrigation pipe systems is satisfactory. The slide gate should be fastened securely to the outlet pipe by means of an ample block of concrete. It may be set in a vertical position, in which a catwalk will be needed for operation, or in a sloping position so that it can be operated from the crest of the dam. (See diagram.)

A regular valve that screws onto the pipe is also satisfactory, but such valves are usually quite expensive. The pipe next to the valve should be anchored in a block of concrete for stability.

A siphon may be used in place of an outlet pipe. Siphons are usually made of sheet metal pipe, coated with asphalt—considerably cheaper than regular water pipe. However, when using a siphon, some method of priming must be devised to remove the air to start the water flowing.

There is usually quite a lot of debris, scum, moss, etc., in a reservoir. If the upper end of the outlet pipe is not protected against this material by a screen it is apt to become stopped up. It is usually a good idea to have a rather large screen so that it will catch a lot of trash before it has to be cleaned. In general a satisfactory screen can be built by making a crate shaped as a cube with about 3-foot edges and covering five sides with wire netting with openings of 1-inch or less. If you think the screen may become plugged before the end of the season you may want to provide some means of raising it to the surface for cleaning and restoring it to its former position.

Crown the dam both ways

The crest of the dam should be graded lengthwise so that the center is at least 6 inches higher than the ends. This will serve the double purpose of keeping rainwater from running from the ends toward the center, then down the faces where it will cause erosion. It will also be helpful in case water overtops the dam and causes washouts—the washouts will occur at either end, where they are relatively easy to repair. A hole in the middle of the dam requires a big repair job.

Crown the top of the dam sideways as a road so that it will shed water instead of gullying the road tracks.

When a dam has been filled with water and has gone through one winter it will usually settle—just how much is difficult to predict. It may therefore be desirable to add more soil and regrade the crest of

The crest of this dam has been crowned both ways so that it will shed water. The road across the dam dips through the spillway on the far side.

the dam after it has been through one winter.

Protective covering

The entire downstream face, the top, and the upstream face above the waterline should be protected against erosion by a vegetative cover. This will be especially important during the first winter.

Annual ryegrass will do the job. Fertilize well and use a mulch as described for cuts above the reservoir for rapid growth.

Avoid grain cereal crops as they will attract squirrels and gophers that will burrow into the dam.

Final Check for leaks

After the dam is completed make a final check of the reservoir site for potential leaks in an area at least 100 feet wide, extending upstream from the dam.

Cover all rock outcrops and areas of sandy or gravelly soil with surface soil. Fill all holes left when trees or brush were removed.

It is difficult to prescribe definitely how much of this work will be needed or how it will be done, but the idea is to seal all sources of possible leaks. The importance of this operation cannot be over-emphasized—a leaky dam is a real headache.

The spillway can be very important

The location of the spillway was discussed on page 6. Its size will be determined by the volume of water it must accommodate, which in turn is dependent on the number of acres in the drainage area above the dam.

Size. The depth of the spillway is measured as the difference in elevation between the highest point in the bottom of the spillway to the lowest point on the crest of the dam. A *minimum* spillway should be 3 feet deep and 10 feet wide.

The table below gives the desirable sizes for spillways for different drainage areas.

Shape. It is usually more economical to make your spillway shallow and wide rather than deep and narrow because the latter type of spillway will probably necessitate a higher (bigger) dam.

For example—your drainage area takes in 600 acres; from the table consider 2 of the 6 alternatives. You find that your spillway can be 5 feet deep and 20 feet wide, or it can be 8 feet deep and only 10 feet wide.

If you can use the 5 × 20 foot spillway you can make your dam 3 feet lower than would be the case with the 8 × 10 foot spillway. The sketch on page 15 gives an idea of the savings you can effect in the movement of fill.

Remember also—if you intend to use a barrier in your spillway to store water from the late spring runoff, the spillway will have to be of such a size that it will accommodate any permanent structures supporting the removable part of the barrier and still fulfill minimum requirements of outlet dimensions (see below—Barriers).

Another consideration is that a higher barrier can be built in a deep spillway than in a shallow spillway, thus permitting more water storage. Hence this whole question of dam height, spillway size, and water storage can involve quite a lot of figuring to get the most economical setup. When doing this figuring be sure to take into account the limitations on barriers in the spillway as discussed below.

Slope of spillway bottom. The spillway bottom downstream from the crest should have a slope of at least 6 inches per 100 feet so that the water can get away rapidly.

Where necessary, line the bottoms of spillways with concrete or other material that will prevent erosion.

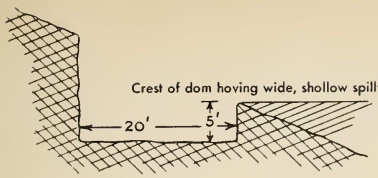
Occasionally a spillway is built through earth, on a relatively flat grade similar to an irrigation ditch. If needed this type of spillway can be protected from erosion by vegetation.

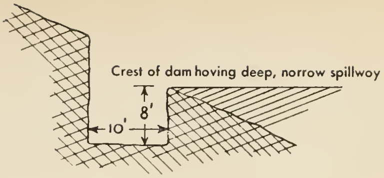
In any event—the water in a spillway located at one end of the dam **must** be

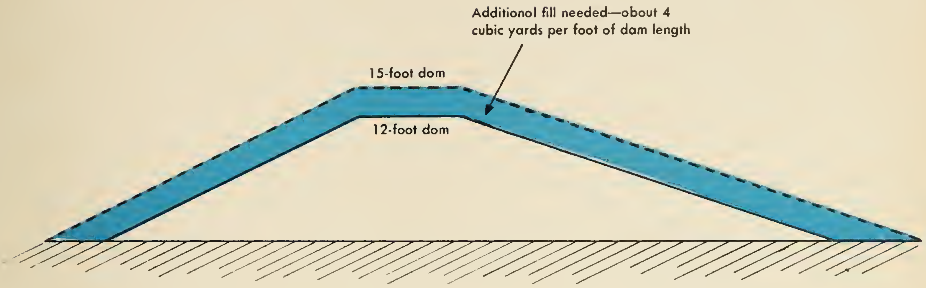
Specifications for Spillways

Drainage area in acres	Depth of spillway in feet: 3	4	5	6	7	8	9
	Width of spillway in feet						
0– 129	10						
129– 190	22	13	10				
191– 320	34	20	11	10			
321– 480	47	27	16	12	10		
481– 640	58	34	20	15	11	10	
641– 800		40	25	19	13	11	10
801– 960		44	27	20	15	12	10
961–1280		55	35	26	19	15	12
1281–1600			42	31	23	19	15
1601–1920			48	35	26	21	17
1921–2240			55	40	30	24	19
2241–2560			60	42	32	26	21

These figures taken from ASCS–SCS specifications for construction of earth dams, revised November 1, 1954.


Crest of dom hoving wide, shollow spillway
20′
5′


Crest of dam hoving deep, norrow spillwoy
8′
10′


Additionol fill needed—obout 4
cubic yards per foot of dam length
15-foot dom
12-foot dom

delivered to the stream below the dam so that it will not erode the dam itself.

Barriers in the spillway

Spillway sizes as shown in the table on page 15 are calculated to leave a freeboard of about 1.5 feet for any flood that might occur once in 25 years. Thus dams built to the specifications given in this circular are designed to hold water to within 1.5 feet of their crest at least for short periods.

It would therefore be practical to store water from late spring runoffs in these dams to a height somewhat lower—perhaps 2 or 2.5 feet from the crest—by means of barriers in the spillways.

But before you build barriers, consider these facts and possibilities:

The Department of Water Resources defines the height of a dam as the difference in elevation between the downstream toe and the crest of any barriers in the spillway. Hence it would be illegal to place barriers in the spillway that would violate the height regulation of a dam that is exempt from state supervision and inspection.

On dams built with ACP assistance, that agency does not allow any structure in the spillway that reduces the area of the spillway below the minimum requirements.

Remember also that barriers in the spillway have . . .

Advantages—you can store additional water from late spring runoff to be used in irrigating or making stock-watering ponds last longer into the summer and fall.

And disadvantages—the dam must be watched more closely. Barriers must be removed immediately if late spring rains cause excessive runoff. They must always be removed before fall rains start. Piers in the spillway, to support flashboards, may cause floating debris to clog the spillway.

If, after considering all of the good and bad features, you decide you want barriers, here are some construction tips:

Earth-filled sacks make practical and inexpensive barriers.

Piered drop structures, similar to those used in irrigation canals can also be built in the spillway. While it is beyond the scope of this circular to give detailed specifications for such structures, a few generalities may be useful (see photo, page 17).

Space all piers an equal distance apart so that drop boards will all be the same length and can be used interchangeably. They should not be more than 6 feet long. Drop boards can be of $2'' \times 6''$ lumber, but $3'' \times 6''$ are better because they will

This dam was not properly crowned lengthwise and the flashboards were not removed in time. That break (on the left) will be expensive to repair.

Here earth-filled sacks are used in the spillway to store additional water from late spring runoffs. Such barriers are inexpensive and easy to remove.

give less distortion when the water rises behind them.

The channels into which the ends of the boards fit are best made of channel iron—slots in the concrete piers are usable but will probably result in more leakage.

The face of the barrier should slope from 30 to 45 degrees downstream.

It is usually desirable to pour a slab of concrete for the water to fall on, in order to prevent erosion.

When drop boards are put in place there may be considerable leakage around them. This leakage can be stopped by putting a blanket of trashy soil or manure on the upstream side of the boards.

A good spillway—cut down to solid rock. Some of the softer part of the rock has been washed away, but has reached stability.

Flashboards supported by concrete piers can be removed easily if late spring rains cause excessive runoff from the watershed.

Maintenance will pay off in good service

Keep the spillway clear of floating debris. Even though you have thoroughly cleared off the reservoir site, a certain amount of material may find its way into the spillway from time to time and cause clogging, if not removed promptly.

A log boom floating about 50 feet from the spillway will keep most floating material away.

A wire mesh fence—such as that used for hogs—will also serve to intercept logs and brush but would have to be rather high.

Pine cones and small pieces of wood that will clear the spillway need not be intercepted, but all material that is caught by boom or fence should be removed in the fall before the rains start. Such material should be burned or hauled out of the reservoir.

Wave action may cause problems on dams in areas where the surface of the reservoir is exposed to high winds. A log boom floating close to the dam is usually effective in preventing wave damage. Sometimes it is necessary to put a blanket of coarse gravel on the threatened part of the dam.

Trees and brush should not be allowed to grow on the dam—they have large roots and if they should die, the root channels might cause leaks.

Guard against rodents building burrows in the dam. If rodents get started, see your local University of California Farm Advisor for information on rodent control by poisoned baits, traps, etc.

Seeps through the dam. In some instances the water, even in a well-designed dam, may cause seepage on the downstream face of the dam. Again, if water is held too high in the dam, it may cause similar seepage. In either case this condition may cause the downstream toe of the dam to slough off. The reason for this is that a large part of the soil in the dam becomes saturated—the upper limit of the zone of saturation extending from the waterline of the reservoir toward the downstream toe.

When the above condition is noted the

This dam shows the results of little or no maintenance. Large trees have been allowed to grow on the dam. If these trees should die or blow over the dam might be seriously weakened, due to rotting roots or large holes.

water level in the reservoir should be lowered immediately to a point where the saturated area on the downstream face disappears. Then you can build a downstream addition to the dam, bringing the additional fill to a point a few feet above the top of the seep area.

Watch those barriers. If you have barriers in the spillway it is extremely important—for the safety of the dam—that they be removed when the dam is full and runoff from a late spring rain occurs. This has to be done in a matter of minutes—not hours—so it is absolutely essential that someone be on the job when such unusual conditions arise.

Also be sure that barriers are removed before the rains begin in the fall.

For the spillway

Keep the spillway from becoming clogged by removing debris promptly.

Each fall burn or remove all material collected by a log boom or wire fence.

Sometimes water flowing in a spillway may cause a gully that heads back toward the crest of the spillway. This is usually due to the fact that the underlying rock, such as decomposed granite, was softer than anticipated. When such conditions arise it may be necessary to line part of the channel with concrete, put in a drop structure or use other means to prevent heading back.

For the watershed

Check the watershed periodically for erosion of soil that will eventually wash down into, and fill your reservoir. Take whatever steps may be needed to check erosion. This is very important if you are to get good service from your reservoir.

For the reservoir

If you have followed the suggestions and specifications in this circular for selecting and clearing the site for your reservoir it is unlikely that severe leaks will develop. However, leaks in reservoirs may develop in spite of all the precautionary measures you have taken.

Leaks are usually caused by previously undetected cracks in underlying rocks, or by channels of pervious material. They are also usually very difficult to locate.

Most leaks originate in the reservoir bottom, relatively close to the upstream face of the dam.

Badly tended dam. Spillway on opposite side was not lined and has eroded to the point where the entire dam is threatened. To repair it would be very expensive.

Here are some suggestions for locating and repairing leaks.

Watch for stoppage of leaks as the water in the reservoir is lowered in steps. If the leak stops as the water recedes over a definite area, it is fairly certain that the leak occurred in that area. Stakes around the water's edge will help keep track of recession if the natural shore line is not apparent.

When the area is located, look for outcroppings of rocks, gravel, or sandy soil—any or all of these may be the source of the leak.

Cover leak-producing areas with a blanket of clay, 3 or 4 inches thick. If the leak is found to occur below the low-water stage of the reservoir a similar blanket of clay will have to be spread over the entire bottom close to the dam.

Clay for this work can be found on most farms. The clay should be worked up to very small clods—the finer the better—before it is applied to the reservoir bottom.

Since a 4-inch layer of clay on one acre would weigh about 650 tons, it is easy to see how important it is to locate small areas for treatment. This also adds importance to the final inspection and treatment of the reservoir for possible leaks before it is filled the first time.

Bank, shoreline and water-loving weeds

About a dozen plants, including willows and cottonwoods, may prove to be pests. Under some conditions it may be practical to control this vegetation by hand or by cultivation.

Control measures for cattails, tules, floating and submerged weeds, and algae are described in the booklet mentioned in the box on this page.

Controlling marginal vegetation by sprays is difficult because any given product may not be uniformly effective in different areas—the variations possibly being due to varying chemical constituents of the water.

> No recommendations are given here for specific sprays or chemicals to control weeds because new products are being developed continually. Your University of California Farm Advisor office can provide you with weed control information in the form of a booklet that is revised each year.

Management of the reservoir

Trout ponds

These can be established in reservoirs where the temperature of the water does not rise above 70° F for any length of time. If the owner permits the public to fish in his trout pond, the Fish and Game Department will provide fish for stocking the pond (trout will not spawn in reservoirs so have to be replaced continually).

If the owner of a trout pond does not open it to public fishing, the state will not provide fish but will furnish a list of trout dealers and a transportation permit at no charge.

In any case, fishing is allowed only during trout season.

Warm water ponds

Theoretically, the most productive planting of warm-water fish is a mixture of bass and bluegills—both species reproduce rapidly and both make good eating. One of the main sources of bass food is young bluegills; carp and catfish tend to eliminate other species and take over the reservoir.

After an initial stocking, allow warm-water fish to spawn once before doing any fishing—spawning will be evidenced

Water for sprinkler irrigation of otherwise poor pastureland can often be taken from a dam but pumping is usually required.

by the presence of small fish. Most reservoirs are underfished—when large numbers of fish are present they do not attain the size they would if fewer were left in the pond.

Food for fish is quite often produced in abundance by plankton-like material in the reservoir. It is evidenced by brownish coloring in the water.

While opinions differ on whether reservoirs need fertilizer to help produce fish food, local experience indicates that it is seldom necessary. It should be avoided, if possible, because addition of fertilizer to the reservoir will encourage undesirable marginal growth which will have to be destroyed.

Muddy water in the reservoir may be due to the presence of a large number of carp or catfish which feed on the bottom and stir up the mud. This can only be avoided by eliminating the carp or catfish.

If the muddy condition is not due to carp or catfish, but winter runoff, it can be alleviated by adding finely ground, agricultural gypsum to the water—a rather expensive process. The gypsum costs about $15 per ton and it may take as much as half a ton per acre-foot of water to clear up muddiness. However, much smaller amounts may do the job so it is suggested that the gypsum be applied at the rate of about 200 pounds per acre-foot, allowing a few days to observe results before adding more.

Spread the gypsum uniformly over the surface by shoveling from a boat.

Owners of this lake not only enjoy fishing but have set up a picnic area on a pleasant part of the shore.

Here a small pump takes water out of a dam through the spillway. This saves lifting the water over the crest of the dam and is practical in some instances.

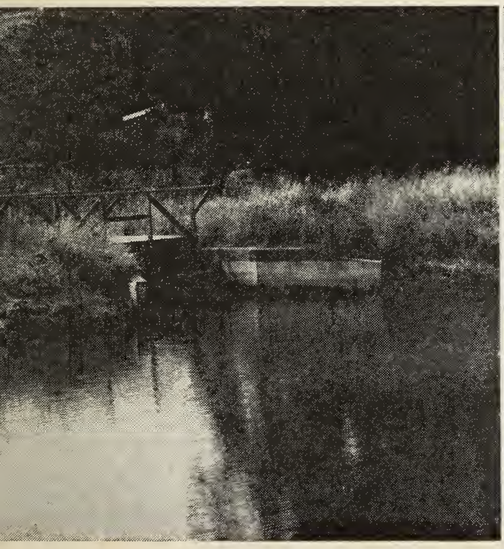
Some do's and don'ts in dam construction

Here are random photos of farm dams in two California counties—some good, some with problems. Since it is obviously impossible to warn against all hazards or cover all good points of dam construction in a booklet this size it is hoped that these photos will bring to mind a few ideas that may prove valuable.

This pond occupies land formerly made useless by a winding creekbed. The photo was taken from end of dam, looking upstream.

Here the dam itself held but the soil on the bottom of the pond was too porous and the water all seeped out. Small pool in the background is all that is left of a good-sized pond.

Front and back views of the concrete-lined spillway for the dam pictured at the left. Spillway is in the center of the dam and empties into the old creekbed.



20m–12,'65(F5524)

141

Co-operative Extension work in Agriculture and Home Economics, College of Agriculture, University of California, and United States Department of Agriculture co-operating. Distributed in furtherance of the Acts of Congress of May 8, and June 30, 1914. George B. Alcorn, Director, California Agricultural Extension Service.