

University of Minnesota
Aquaculture

**Design and Construction of
Diversion Ponds for Aquaculture**

by

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Research Assistant

Dave Landkammer
Assistant Extension Specialist

**Department of Fisheries and Wildlife
University of Minnesota**

December 1990



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INTRODUCTION

Many factors influence the design of a fish pond. The physical features of the site, the farmer's finances, expertise and goals, and the species of fish are examples of considerations that affect a pond's layout. Because every farmer has unique needs and resources, no one set of blueprints can be suitable for all, or even most, situations. This booklet, therefore, is not intended to provide exact specifications, but to discuss basic decisions and procedures involved in the design and construction of a pond.

To produce high yields of fish at low cost, a pond must perform some basic but important functions. First, it must hold water with a minimum of seepage. A pond that leaks costs more in pumping, lost nutrients and potential dike blowouts than one that holds water well.

Second, it must completely drain when necessary. Harvesting the crop, maintaining water quality, controlling undesirable fish populations, etc., are extremely difficult and expensive in a non-drainable pond.

Third, it must be serviceable and accessible in order to keep daily management costs low. For example, the ability to drive a vehicle to the water's edge while harvesting and stocking lowers stress on fish, reduces labor and saves time.

Finally, it must be durable and require low maintenance over the long run. A pond's ability to perform these functions can spell the difference between profit and financial disaster. While the construction costs of a well built pond may be greater than those of a poorly built one, the security and return is worth the initial investment for the serious fish farmer.

POND TYPES

Fish may be raised in embankment, groundwater, watershed or diversion ponds. Each has advantages and disadvantages in terms of cost, return, control, etc.

Embankment Pond

In long narrow valleys with streams, a single dike can be constructed that will back water up and form an embankment pond (Fig.1). One advantage of an embankment pond is that a large surface area of water can be obtained with relatively little work. The major disadvantage is that water constantly flows through the pond. This creates problems in control of undesirable fish, contamination from upstream water and loss of nutrients. These ponds are often used in low-intensity fish production.

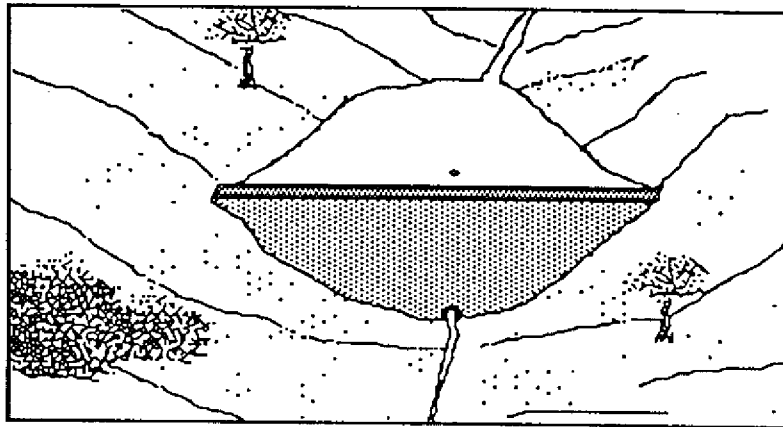


Figure 1

Embankment ponds are very useful as reservoirs (Fig.2). The dike raises the level of the water, which can then be transported to other fish ponds downstream through pipes or canals.

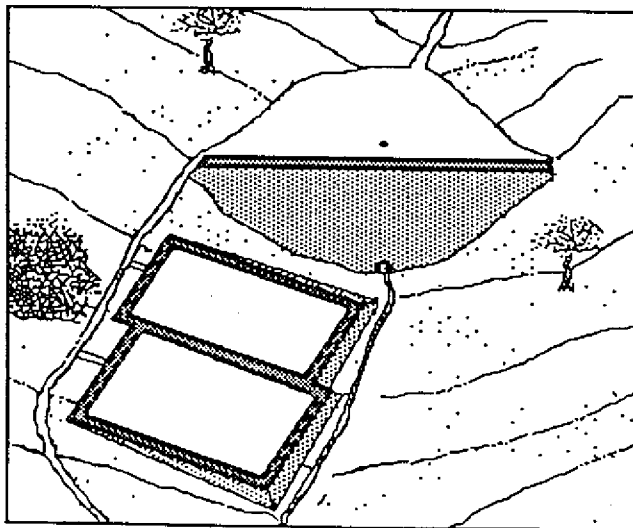


Figure 2

Groundwater Pond

If the water table is very near the ground's surface, a pond that is entirely excavated will fill through seepage (Fig. 3). While groundwater ponds are usually inexpensive and easy to build, they have several important disadvantages. First, they are often seasonal. They generally cannot be drained when the water table is high, and during dry months the water level may fall significantly. Second, flushing the pond is difficult, making it hard to maintain water quality. As a result, the usefulness of groundwater ponds in commercial aquaculture is limited, though they are often used for low-intensity fish culture.

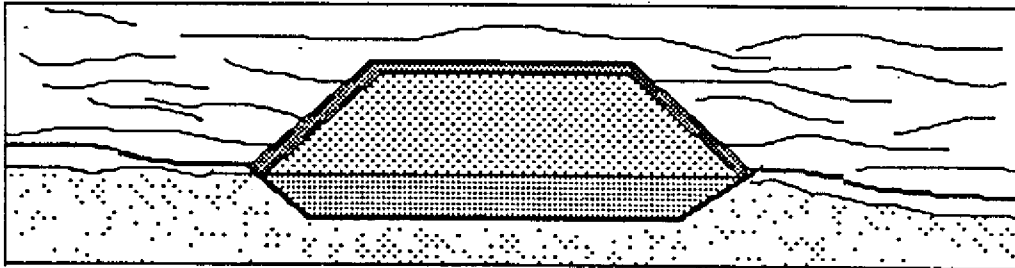


Figure 3

Watershed Pond

When rain falls on a hill, part of the water sinks into the ground, and the run-off goes down the slope (Fig. 4). The watershed of an area consists of all the slopes that contribute run-off to that area. If a dike is built to catch this run-off, water will collect and form a watershed pond.

Watershed ponds are relatively inexpensive to build and can be useful as a supplemental water source for other ponds. One major disadvantage is that the farmer is entirely at the mercy of the rain. If water quality problems arise, there may be no way to flush with fresh water. In times of low precipitation, the pond may go dry. Also, herbicides and pesticides used on land within the watershed may wash into the pond.

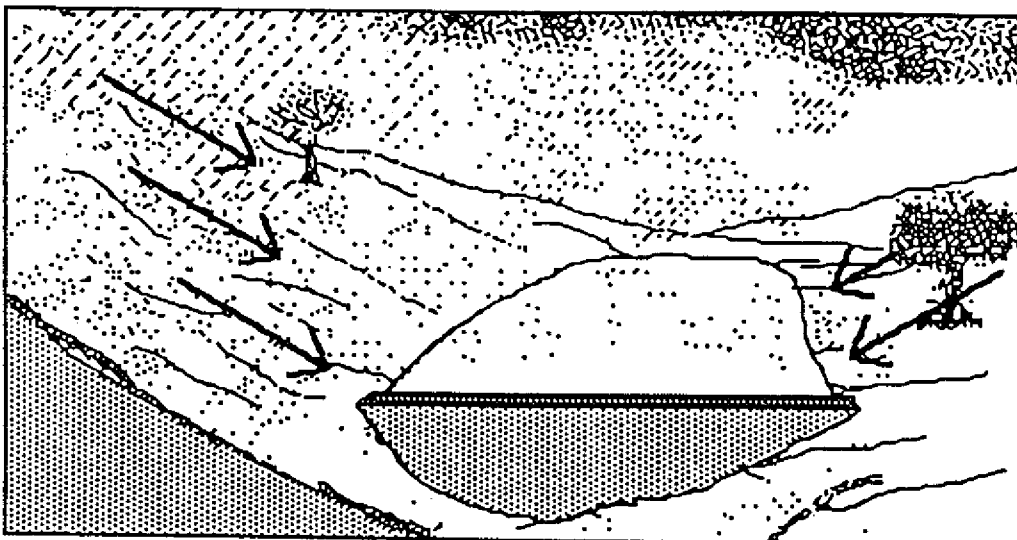


Figure 4

Diversion Pond

Diversion ponds are usually built partially by excavating earth and partially by constructing dikes (Fig. 5). Water is diverted in from an outside source. Diversion ponds are usually the most expensive and difficult to construct. When properly built, however, they provide great control over the water and organisms in the pond, and they are very well suited to intensive fish culture. For this reason, and the relative complexity of their design, diversion ponds are the focus of this booklet.

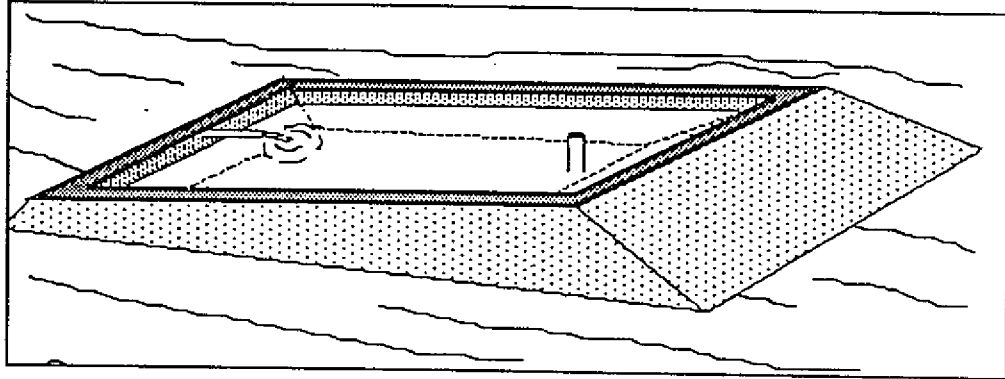


Figure 5

CHARACTERISTICS OF A DIVERSION POND

No one pond design can be used in every situation. However, there are general principles that keep construction and maintenance costs low and returns high.

Dikes

Proper construction of the dikes is critical (Fig. 6). Important features include topwidth, height, side slopes, cores and compaction.

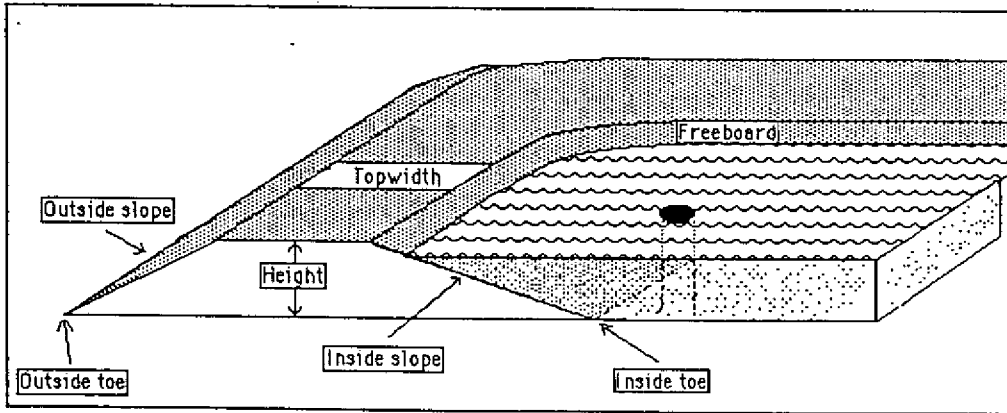


Figure 6

Topwidth

The topwidth is the area between the inside slope and the outside slope. Its size depends on the dike height and the function it serves for the farmer. The United States Department of Agriculture Soil Conservation Service recommends the following for minimum topwidths:

<u>Height of dike (in feet)</u>	<u>Minimum topwidth</u>
Under 10	6
11-14	8
15-19	10

An important function of the dike is to support vehicles used in day-to-day pond management. The topwidth should be great enough to do this, with a good safety margin. When large tractors are to be used regularly, a topwidth of 16 feet may be appropriate even though this is wider than needed for simply holding back water.

Height

The dike height is equal to the desired depth of water plus a safety margin called freeboard. During heavy rains, more water may enter the pond than the emergency overflow can handle. Freeboard allows extra room so that the water does not overflow the dikes. A foot or more of freeboard is typical, but if there is a large watershed around the pond, this should be greater.

Side Slopes

There are several reasons for building dikes with sloping sides. First, water pressure increases rapidly with depth. The dike must be wider at lower depths to compensate for this. Second, gently sloping sides reduce erosion and prevent water from under-cutting the dike. Third, slopes allow access to vehicles and people, which will aid in seining, aerating, harvesting, etc. Finally, some species of fish require sloped sides in order to successfully reproduce.

Steep gradients are expressed as a ratio of horizontal distance to vertical distance. For example (Fig. 7), if a dike's side extends 9 feet out and 3 feet down, the ratio is 3 feet to 1 foot, and the slope may be expressed as 3:1.

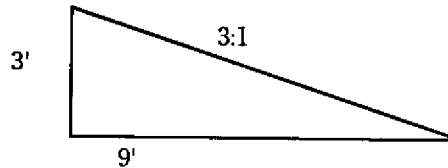


Figure 7

Generally, ponds are built with inside slopes of between 2:1 and 4:1. Outside slopes of 2:1 to 3:1 are common.

Compaction

Dirt that has simply been piled up is structurally unsound and can be washed away by water. It is vital that dikes be firmly compacted in order to prevent seepage or rupture.

Dike Cores

To hold water without seeping, a pond must be built on impermeable soil. However, there are often many soil types at a site. For example, a sandy layer of earth, which would allow some seepage, may overlay impermeable clay. In a case like this, a clay core (Fig. 8) may be built through the permeable soil, into the impermeable layer below. This forms a bowl of impermeable earth which will hold water with minimal seepage.

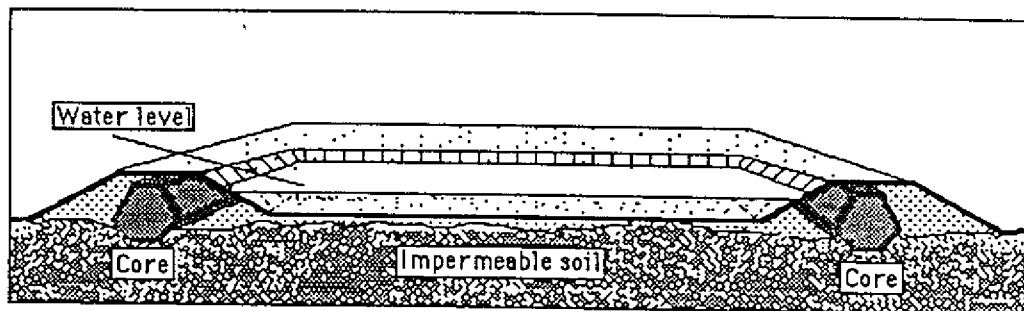


Figure 8

Pond Bottom

The bottom of the pond should slope downward toward the drainage point. This allows the pond to drain quickly during harvest. The slope may be anywhere from 0.5% to 2%, and is limited by the need to have a reasonable depth of water at both the shallow and the deep end.

Percentages are used when discussing pond bottoms, canals, and other structures with a relatively gradual slope. The slope is found by dividing the vertical rise by the horizontal distance and multiplying by 100%. If the earth rises 1 foot over a distance of 100 feet, the slope is found by dividing 1 by 100, and multiplying by 100%. This yields a 1% slope (**Fig. 9**). If the earth rises 3.5 feet over a distance of 50 feet, the slope would be $(3.5/50) \times 100\% = 7\%$.

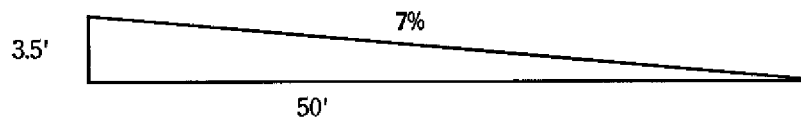


Figure 9

SITE SELECTION

Choosing an appropriate pond site is extremely important. There are three vital factors to consider in site selection: water, soil and topography.

Water Quality

Poor water quality may inhibit production and hurt profits. Some problems can be solved simply and inexpensively. Others cannot, and may be determining factors in selecting a water source. Examples of important parameters to consider are:

Pollutants (insecticides, herbicides, etc)

These are extremely difficult to remove from water, and a source with measurable levels should probably not be considered.

PH

This should be in the range physiologically suited to fish culture: 6.5 to 8.5. If the pH is slightly outside this range, liming may help.

Iron and Other Metals

Many metals are toxic to fish at low concentrations. Some, such as iron, are readily removed. Others, such as lead, present a much greater problem.

Other Dissolved Gases

Many, such as hydrogen sulfide and carbon dioxide, can be removed simply by splashing the water as it enters the pond.

Suspended Solids

These may limit photosynthesis and be harmful to fish. A basin can be built to allow solids to settle before the water is put into the pond.

Water Sources

Water may be supplied to a pond from a variety of sources. Each has advantages and disadvantages.

Springs

Permeable layers of earth that are above or between impermeable layers can hold water. These are called aquifers. When an aquifer intersects the surface of the ground, water flows out freely, forming a spring.

Advantages

- No pumping costs
- Temperature relatively constant
- Usually pollutant free

Disadvantages

- Flow can vary with the seasons
- Often low in O₂, high in CO₂.

Artesian Well

This is a well that is dug into the aquifer (**Fig 10**). The pressure of water in the aquifer above forces the water up and out of the well.

Advantages

- No pumping costs
- Temperature relatively constant
- Usually pollutant free

Disadvantages

- Rarely found in areas with topography suited for aquaculture
- Often low O₂, high CO₂

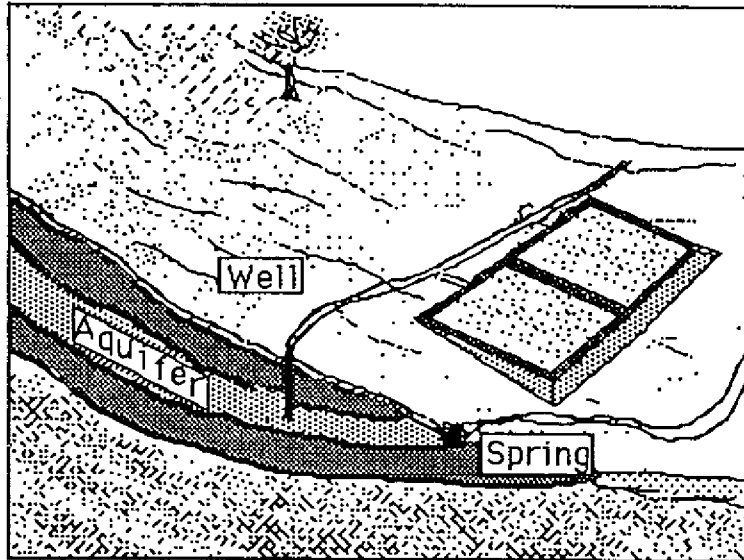


Figure 10

Water Table

Water can be held in the permeable layers of earth below the ground's surface. If the water table is high, the pond may extend into it.

Advantages

- Usually pollutant free
- No pumping costs

Disadvantages

- Low O₂, high CO₂
- No control over water supply
- Cannot be drained

Water Table Well.

Often, the water table is relatively deep. In order to reach it, a well must be dug and the water pumped out.

Advantages

- Usually pollutant free
- If the well is deep enough, supply will not vary throughout the year

Temperature is usually constant

Disadvantages

Low O₂, high CO₂
May be high in other dissolved gases
May be expensive to dig
Pumping required

Rivers and Streams

Advantages

High in O₂
Depending on topography, pumping may not be necessary

Disadvantages

May be subject to pollutants
Temperature and supply may vary with season
Other organisms may be present
May affect water downstream
Often heavily regulated

Lakes

Advantages

Usually high in O₂

Disadvantages

Pumping generally required
Other organisms may be present
Temperature may vary

Recirculated Waste Water From Ponds

Depending on circumstances, pumping or siphoning water from one pond to another may be cost-effective. A fresh water supply must also be used to maintain water quality and quantity.

Advantages

Makes efficient use of water

Disadvantages

Filtering necessary
Pumping usually necessary

Watershed

Advantages

No pumping costs

Disadvantages

Dependent on rainfall
Susceptible to pollutants

Water Quantity

There must be sufficient water all year to maintain normal pond levels, to flush with fresh water when necessary and to fill ponds when necessary. A reasonable estimate of the quantity needed to maintain a constant water level can be calculated by considering evaporation and seepage.

Evaporation is influenced by temperature, wind, humidity, water surface area and other factors. It is difficult to obtain an exact measure of evaporation as these factors vary greatly from year to year and place to place. However, the map below (**Fig. 11**) can be used to approximate annual evaporation across Minnesota. This shows pan evaporation rates measured in inches. Evaporation from ponds can be reasonably estimated by multiplying these pan rates by 0.75.

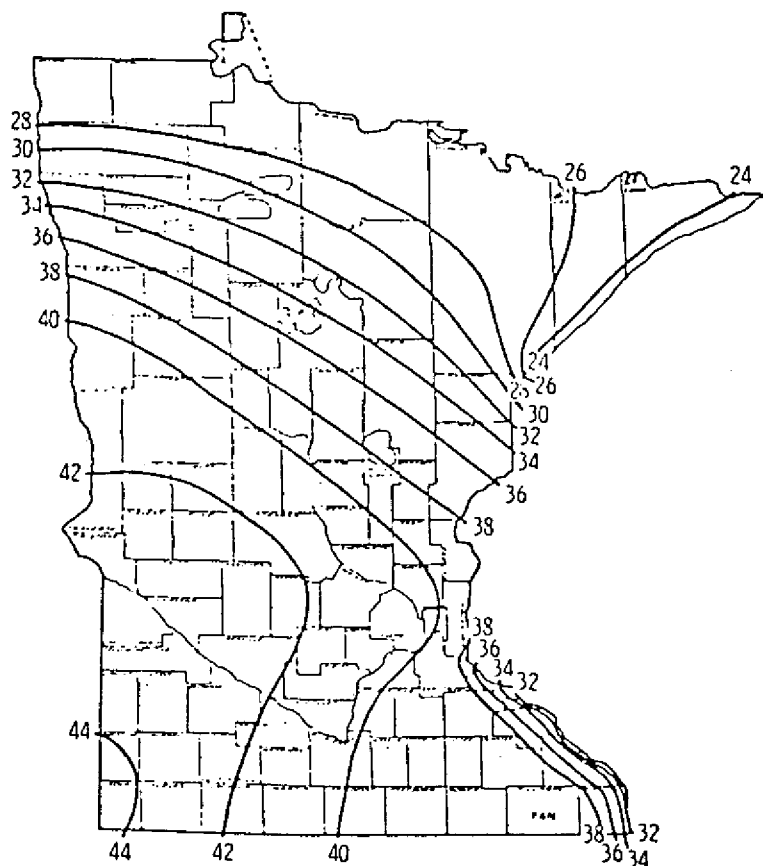


Figure 11

Water can be lost vertically through the bottom of the pond or horizontally through the dikes and drainage system. The amount of water in contact with the bottom is much greater than that in contact with the sides, so horizontal losses will be comparatively small if the dikes and drainage system are well built and maintained. The table below gives vertical seepage rates for various types of soils. This assumes there is no source of water counteracting the seepage, such as a high water table.

Natural Soil Type	Seepage Losses (mm/day)
Sand	25.00 - 250
Sandy loam	13.00 - 76
Loam	8.00 - 20
Clayey loam	2.50 - 15
Loamy clay	1.25 - 10
Clay	0.25 - 5

Soil

Different soils hold water differently. To a great extent, this is a function of particle size. Small particles can be closely packed, leaving small spaces and making it difficult for water to pass through. Particle sizes for various soil types are given below.

Soil Type	Particle Size (mm)
Gravel, pebbles, etc.	> 2.000
Coarse sand	2.00 - 0.500
Medium to very fine sand	0.50 - 0.050
Silt	0.05 - 0.020
Clay	< 0.002

The pond's ability to hold water and the stability of the dikes are a function of the soil's clay content. Ideally, the soil should be 30% to 70% clay, mixed with sand and/or silt (never organic material). Pure clay has two major disadvantages. First, when it gets wet, it swells. When it dries, it contracts. If a pure clay pond has been holding water and is then dried, deep cracks may form. This may expose underlying permeable soils and allow seepage. Second, pure clay is very sticky when wet and very hard when dry, making it difficult to work with.

Testing

Before any serious work is done on a site, the soil should be tested by the Soil Conservation Service or another reputable agency. However, there are simple field tests that will indicate the soil's suitability.

The ball test: take a handful of the soil and dampen it. Compress it into a ball, throw it a couple of feet into the air, then let it land on the open palm. If the ball does not fall apart, the soil may be suitable. If it does fall apart, there is probably too much sand or silt, and it is not suitable.

The manipulative test (from Simple Methods in Aquaculture, FAO): The steps of this test must be performed in the order below.

1. Take a handful of soil and wet it until it begins to stick together, but does not stick to your hands.
2. Roll the soil sample into a ball about 3 cm in diameter.
3. Put the ball down. If it falls apart, it is sand.
4. If it sticks together, roll it into a sausage shape, 6-7 cm (about 2.5 inches) long. If it does not remain in this form, it is loamy sand.
5. If it remains in this shape, continue to roll it until it is 15-16 cm (about 6 inches) long. If it does not remain in this shape, it is sandy loam.
6. If it remains in this shape, try to bend it into a half circle. If you cannot, it is loam.
7. If you can, bend it into a full circle. If you cannot, it is heavy loam. If you can, with slight cracks, then it is light clay. If you can without any cracks, it is clay.

The local Soil Conservation Service office or a qualified professional consultant can test soil and provide more precise information.

Topography

The land's topography will determine if a pond can be entirely drained without pumping. Topography will also influence pond construction.

Minimum Slope

Ponds are most efficiently built by digging out earth while simultaneously building dikes. This puts the pond bottom below the original ground surface. If the entire site is flat, there will not be a nearby area where the natural ground level is lower in elevation than the pond bottom. Therefore, the pond will not be able to drain entirely. If the land is sloped, a drainage canal or pipe can carry water to an area of lower elevation. In planning a site, it is important to find the drainage area and determine its elevation to be sure the ponds can drain.

Maximum Slope

At the other extreme, the land's slope cannot be so great that a lower dike must be built for a relatively small surface area of water. Take, for example, a site with a 10% slope. A farmer wishes to build a one acre pond (43,500 square feet), and would like the width, from side dike to side dike, to be 220 feet. This means that the length, from the uphill dike to the downhill dike, would have to be approximately 200 feet ($43,500 \text{ ft}^2 / 220 \text{ ft}$). The farmer wants the tops of all the dikes to be at the same elevation (**Fig. 12**), which, with a 10% slope, means the downhill dike would have to be built 20 feet high (200 feet x 0.10). This would be very expensive.

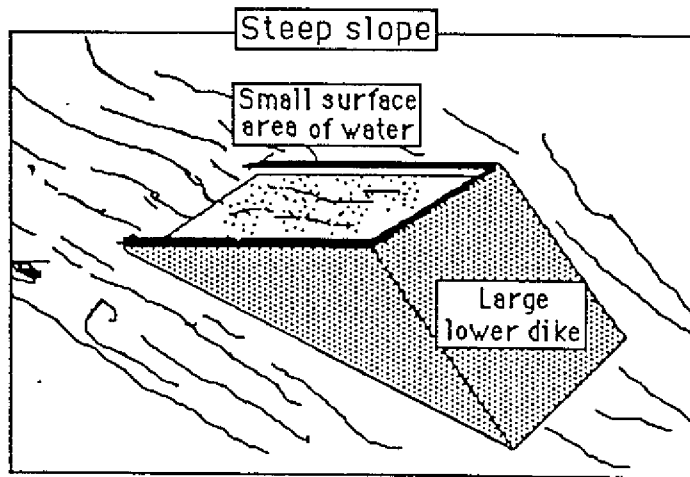


Figure 12

On land with a 3% slope (Fig. 13), the dike would need to be 6 feet high (200 feet x .03), which is more reasonable for a diversion pond.

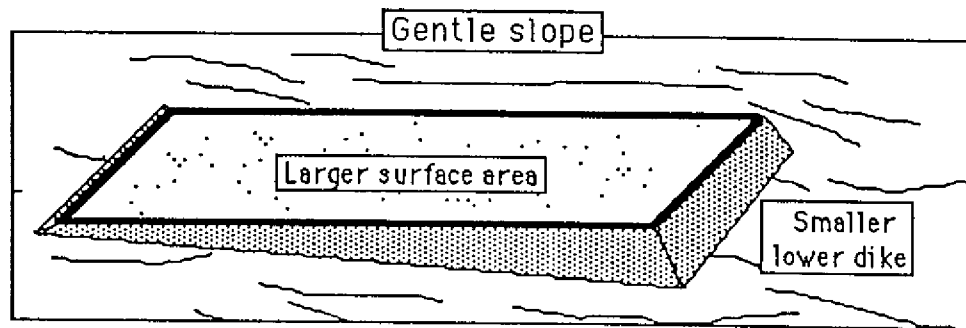


Figure 13

The acceptable limits of the land's slope are determined by the planned size of the pond. If a very small holding pond is to be built, a 10% slope may be acceptable, though for a fifty acre pond, this would be too steep. For the 50 acre pond, a slope of 0.25% may be acceptable, though for a smaller pond this would mean a very long drainage canal would have to be built.

WATER CONTROL

The basis of effective water control is flexibility. A well designed system will allow the farmer to manage each of his ponds independently, and enable him to easily drain and fill them as he sees fit.

Water Supply

Though all the water in a system may come from one source, each pond should be controlled separately from the others (Fig. 14). Generally, this involves a separate inlet pipe and valve for each pond.

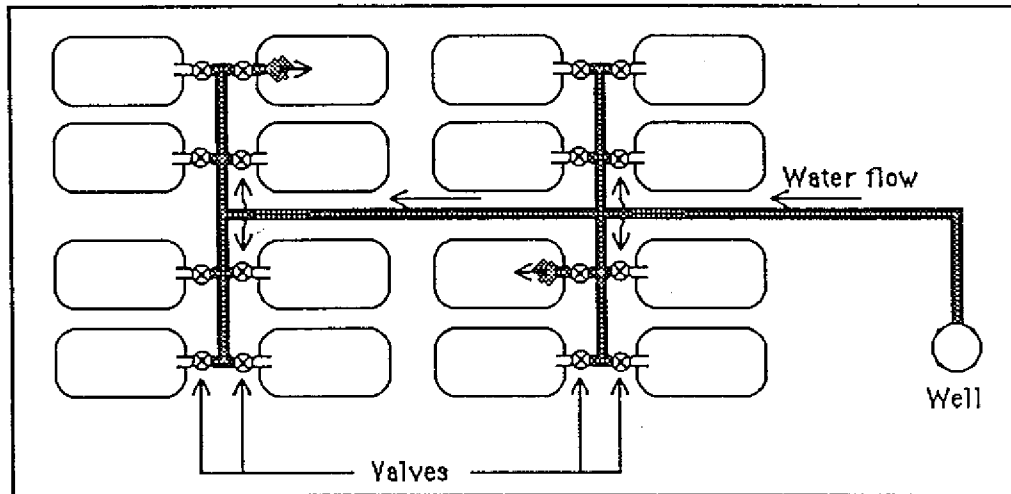


Figure 14

When pipes run along dikes, it is usually best to bury them. This prevents PVC (polyvinyl chloride, a commonly used plastic) from degrading through exposure to sunlight, and protects pipes from damage due to vehicles. Valves should be covered with valve boxes at or just below ground level.

If canals are used, they should be built on undisturbed ground. The sides should have slopes of 1:1 or 2:1 to prevent undercutting by water, and the bottom should be slightly sloped to facilitate flow. It is often desirable to run canals along the land's contours, keeping the water as elevated as possible. This leaves the maximum amount of room for ponds below the canal.

Filters

Streams, rivers and lakes often contain unwanted organisms, such as predator fish and eggs, which must be filtered from the inflowing water. Filters may be made from a variety of materials. Saran is a strong, fine mesh cloth which can be sewn into a long sock and attached to the outflow of a pump. This is fairly inexpensive and easy to make, but must be checked and cleaned frequently. Another common method (Fig. 15) uses gravity to draw water through a fine particulate such as sand and/or gravel. The water flows into the top of a box that contains the particulate, soaks through, and comes out the bottom of the other side.

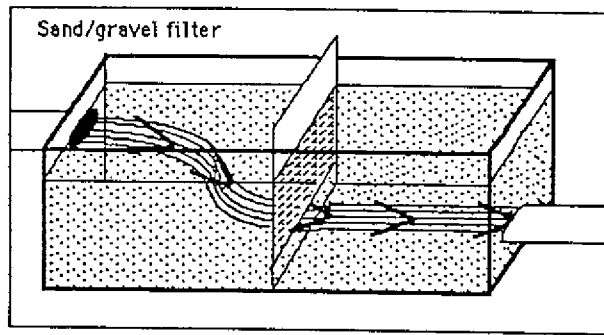


Figure 15

The Drainage System

The drainage system must accommodate three needs. First, it must allow water to be released when necessary while preventing release under normal operating conditions. Second, it must act as an overflow. Third, when water quality deteriorates and the pond is flushed, it must allow the farmer the option of drawing from the bottom, where the water quality is the worst.

The drainage system consists of a device that controls the water level, and a pipe or canal that carries the water to an outside drainage area. Some common devices are monks, sluice gates and canfield (also called turndown) drains.

Monk

This is reminiscent of a monk's cloister (Fig. 16). It is a three-sided box, often made of concrete or wood. At the bottom of the back side is a drainage hole fitted with a pipe. The open side is fitted with wooden boards that are slid into grooves to prevent water from escaping. The top edge of the top board determines the water level. If water rises above this, it flows over and out the drain pipe.

If there are two sets of slots, the monk can be set up as a bottom water draw. In the front slot, a screen is placed at the bottom to prevent the escape of fish. Boards are then set above the screen, and extend above the water's surface. The back boards are set at the bottom of the pond, and extend to the desired water level. If the pond is flushed, water will flow under the front boards then up and over the back controlling boards.

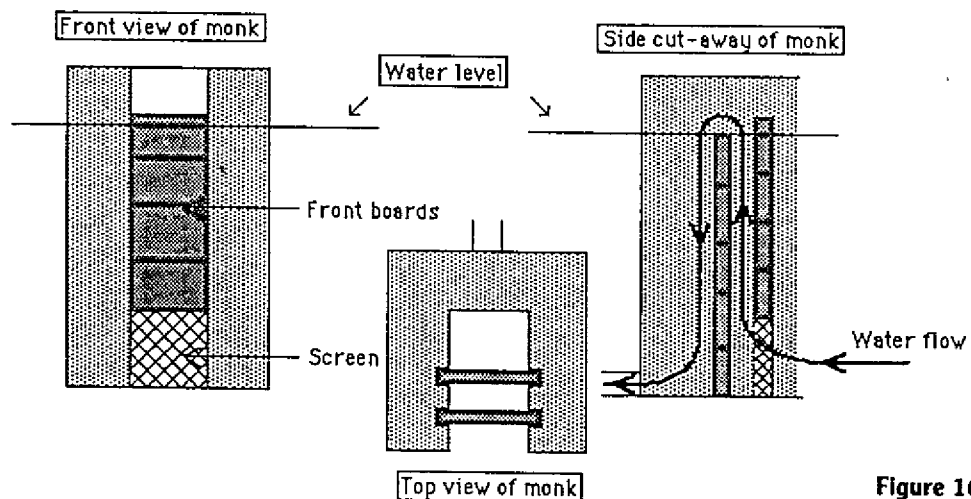


Figure 16

Sluice Gate

This is a monk built into the dike (**Fig. 17**). Water flows over the top board and directly out of the pond.

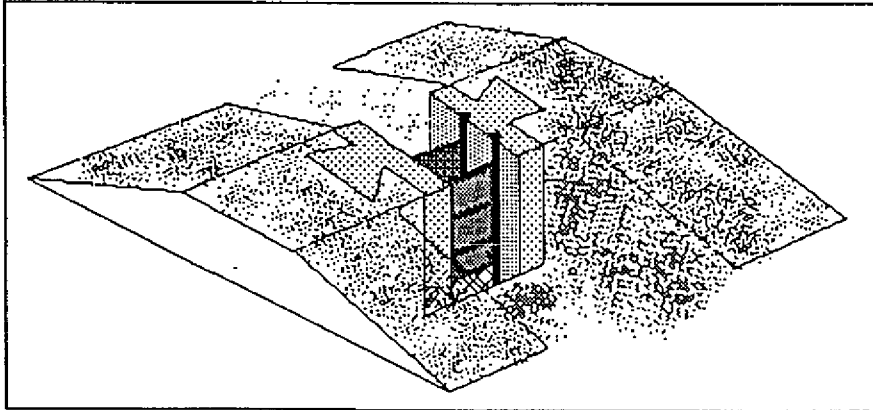


Figure 17

Canfield Drain

This is inexpensive and simple to construct. It consists of a riser pipe, often made of PVC, which extends from the water's surface to the pond bottom. This is connected by a 90 degree elbow to a horizontal pipe that goes through the dike to a main drainage pipe or canal (**Fig. 18**). The pipes are not glued to the elbow. The riser pipe can be turned down to control the water level or drain the pond. For drawing water off the bottom, a larger diameter pipe is suspended over the riser, extending from above the surface of the water to just off the pond floor. When flushing, water enters from the bottom, flows up and into the riser, and out of the pond. A screen should be placed on the inside pipe to prevent loss of fish.

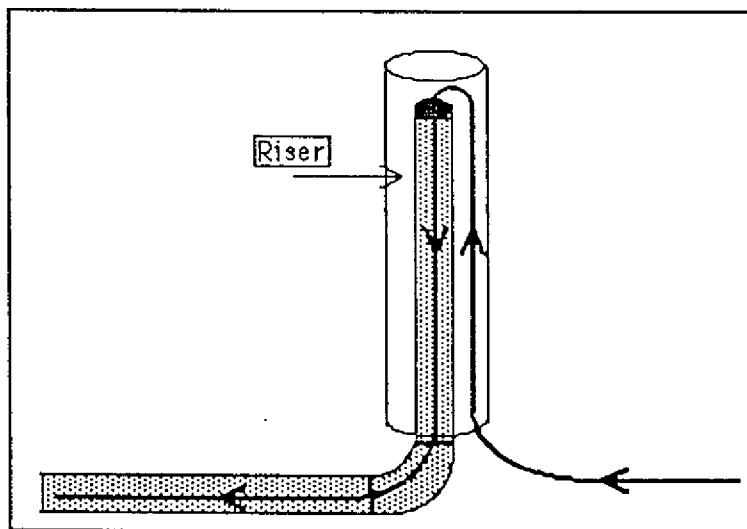


Figure 18: Canfield drain.

Piping and Canals

All pipes and canals in the drainage system should be slightly sloped. As with inlet canals, drainage canals should have side slopes to prevent undercutting from the moving water.

Water can seep a considerable distance along the length of a pipe, even if dirt is well packed around it. Anti-seep collars (**Fig. 19**) are large thin surfaces attached perpendicular to the pipe. They form a barrier to the seeping water. The diameter of the collar should be about five times the diameter of the pipe. The collar can be made of any material that does not degrade and does not let water pass through. Cement, plastic and metal are commonly used. One or two collars should be installed, and both should lie within the dike core.

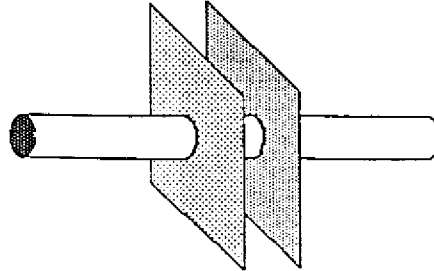


Figure 19: Anti-seep collars.

PLANNING THE SITE

Deciding on the locations of the ponds, inlet and drainage canals, water source, and drainage area should be done before the first pond is built. Costly errors, such as inefficient land use or blockage of drainage areas, may result from lack of proper planning. Before considering the details of planning a pond site, the concept of cut and fill must be addressed.

Determining the Cut and Fill

Cut is dirt excavated from inside the pond area. Fill is the dirt used to build up the dikes (Fig. 20).

If a farmer decided he wanted a 6 foot deep pond, he could:

1. Dig 6 feet down, and throw away the dirt,
2. Build the dikes 6 feet up by importing dirt, or
3. Dig down 2 feet, and use the excavated earth to build the sides up 4 feet.

In example number 3, dirt is neither imported nor wasted. To be most efficient, the cut should equal the needed fill. The ratio of cut to fill can be adjusted by raising or lowering the elevation of the whole pond.

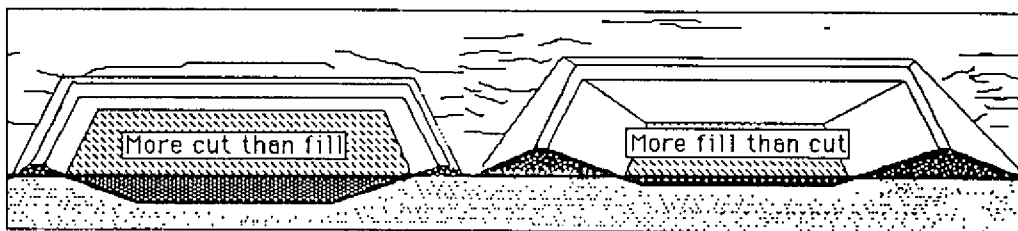


Figure 20: Cut and fill.

The following steps help calculate how deep to dig the bottom and how high to build the dikes from the natural ground surface to equalize the cut and fill:

1. Decide on the total dike height from the pond bottom to the dike top.
2. Roughly estimate how deep the bottom should be dug and how high the dikes built. For example, if the total dike height is to be 7 feet from pond bottom to dike top, then a first estimate may be to dig down 3 feet and build up 4 feet.
3. Calculate the cut and fill.
4. Compare the two. If the cut is greater than the fill, raise the elevation of the pond bottom and dike top. Perhaps dig down 2 feet and build up 5 feet. If the fill is greater than the cut, lower the elevation of the pond bottom and dike top. Perhaps dig down 3.5 feet and build up 3.5 feet.
5. Repeat steps 3 and 4 until the cut is roughly equal to the fill.

To Calculate Fill

Each of the pond's dikes may require a different amount of fill (Fig. 21). If the land is sloped, the downhill (lower) dike will be larger than the uphill (upper) one, and the side dikes will be smaller uphill and larger downhill. There may be times when all

the dikes are larger in some places than in others. Doing these calculations to an exact degree is time consuming and tedious. The following method is less exact but comparatively easy, and is accurate enough for most situations.

1. The corners of the pond are geometrically complex, making their volumes difficult to calculate. If the dikes are sub-divided as follows, the calculations will be reasonably accurate:
 - a. The side dikes go from point "a" to point "b"
 - b. The downhill dike goes from point "c" to point "d"
 - c. The uphill dike goes from point "e" to point "f"

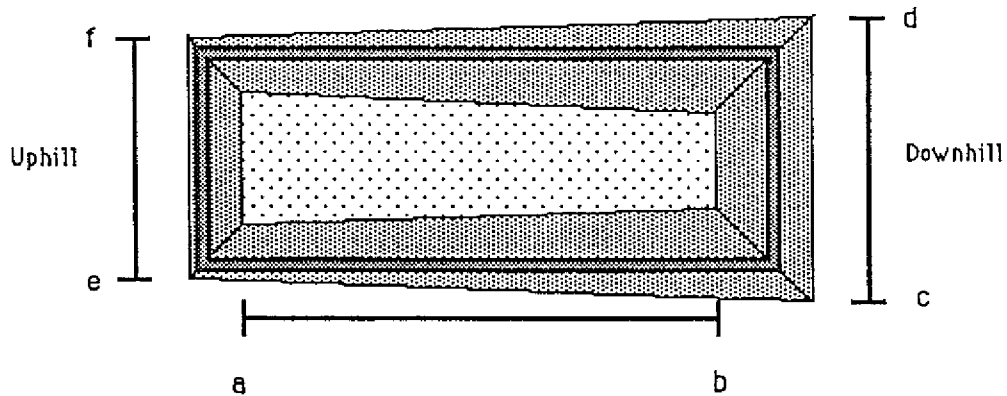


Figure 21: Calculating fill.

2. Take cross-sections of the proposed dikes at equal intervals (Fig. 22). For each, find the area of the dirt that is above the natural land. The more irregular the natural topography, the more cross-sections are needed.

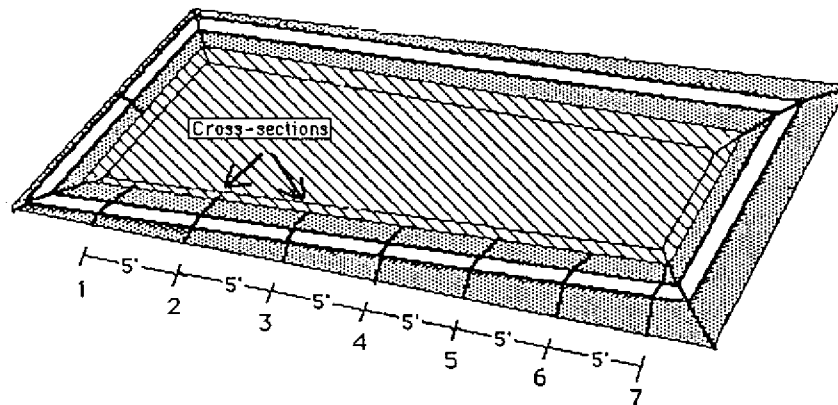


Figure 22: Cross-sections, dikes.

To find the area, divide the cross-section into a square and two triangles (Fig. 23). The area of a square is its length times its height. The total area is the sum of the 3 areas.

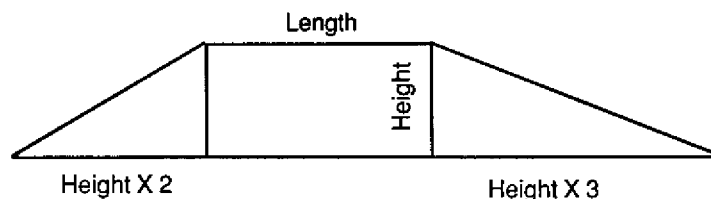


Figure 23

3. Average the areas of all the cross-sections and multiply by the total dike length. This will give the volume of the dike.
4. Add the volumes of the individual dikes. This will give the total volume of fill.

To Calculate Cut

1. At regular intervals take cross-sections of the ground that will be dug (Fig. 24 and 25), and find the areas of each.
 - a. Again, the cross-sections can be divided into a square and two triangles.
 - b. Find the area of the square by averaging the depths of the cut (the vertical distance from the natural ground to the planned pond bottom) and multiplying by the width of the pond.
 - c. Apply the formula for the area of a triangle. The height of the triangles will be the depth of the cut.

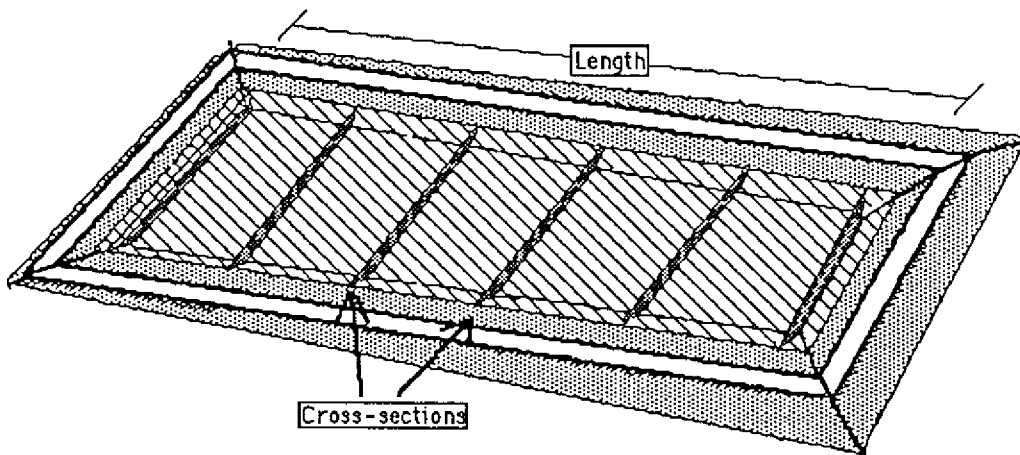


Figure 24

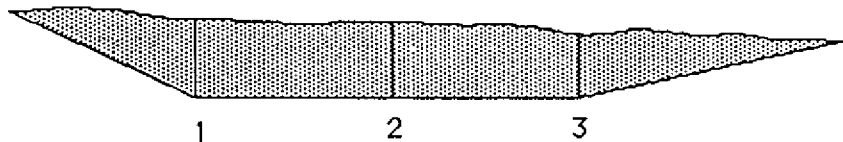


Figure 25

2. Average the areas of all the cross-sections and multiply by the total pond length. This will give the volume of the cut.

Site Layout

Designing the pond site can be complicated and requires weighing benefits against costs. Here are some general guidelines:

1. Determine size limitations imposed by the site. There may be restrictions to pond size that are outside the farmer's control. They may include slope, land ownership, water supply, government regulations, areas with poor soil and heavily forested areas.

2. Within the above limitations, determine the desired size of the pond. This will depend on the farmer's goals, management skills, resources, etc.
3. Determine the dike dimensions, including topwidth, height (water depth plus freeboard) and side slopes.
4. Find the drainage area and determine its elevation.
5. Determine where the lower dike will lie. If it is clear that the bottom of the pond will be well above the drainage area, then this is fairly straightforward. If it is less than certain, the placement of the bottom dike may have to be changed, depending on the cut and fill calculations.
6. Stake the perimeter of the pond. This corresponds to the outer toes.
7. Survey the pond area in detail (**Fig. 26**). To simplify the cut and fill calculations, surveying should be done on a grid. Set a base line and find elevations along it at equal distances. Set transects perpendicular to the baseline, and find elevations along them at equal distances. These elevations can then be used directly to calculate cut and fill as explained above. The more complex the topography, the closer the stations should be to one another. Depending on the place and situation, there may be a government agency that can help with the survey.

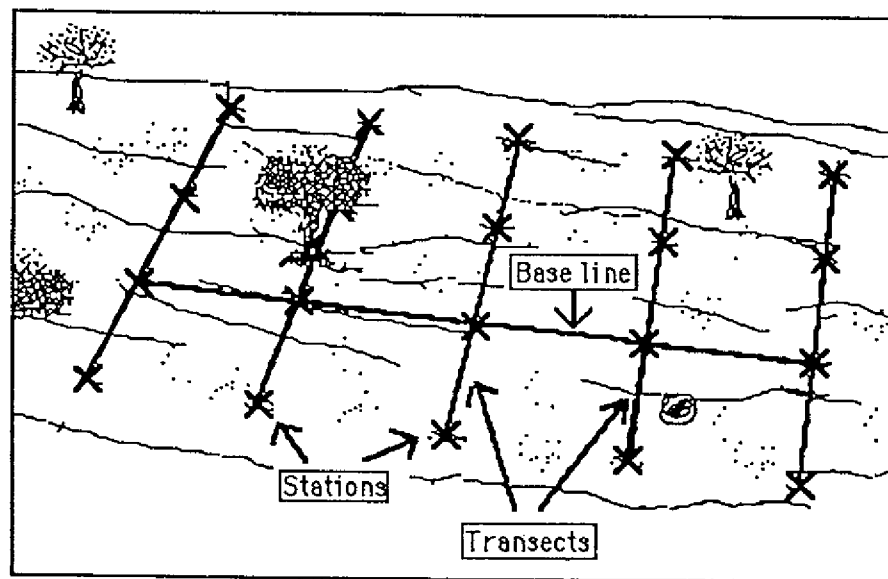


Figure 26

8. Equalize the cut and fill. If you find the pond bottom is below the drainage area, the pond will have to be moved uphill and the cut and fill recalculated.
9. Design the water supply and drainage systems.

CONSTRUCTING THE POND

Construction methods will be influenced enormously by the pond shape and size, topography of the land, and other factors. The following method describes some of the essential steps.

The organic layer of dirt should not be used in the construction of dikes. Over time, the material in this layer will decompose, rendering it structurally unsound.

The first step is to strip the organic layer from the pond area (**Fig. 27**). Stake the outer toes of the pond, so the bulldozer operator will know from where to remove dirt. If there are trees, rocks or other large objects, they will need to be removed along with the soil. All of this should be pushed to the outside of the pond perimeter.

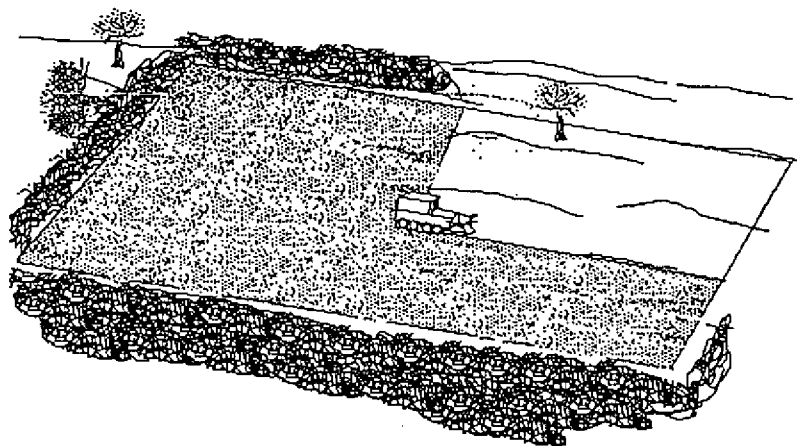


Figure 27: Building the pond.

Setting the Core

If the impermeable earth is covered by a more permeable layer, a core should be constructed (**Fig. 28**). This is done by digging a trench under the center line of the future dike. The trench should extend well into the impermeable layer. The best quality soil from the pond site should then be back-filled into the trench and compacted. This core trench will form the base of the core.

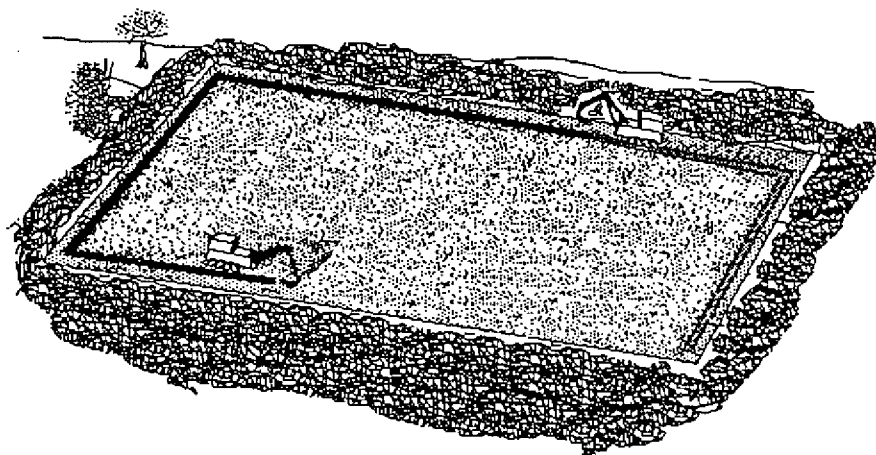


Figure 28

Staking the Site

There are several lines that the bulldozer operator may find useful to have staked, depending on his experience and preference (Fig. 29). These include:

- 1) where the cut meets fill. This will tell him where to quit digging and to start piling dirt, as determined from the cut and fill calculations;
- 2) The back and front of the topwidth;
- 3) Where the inside toe meets the pond bottom.

Stakes may be placed at each of the corners and at intermediate intervals if the dike is particularly long. When flagging the pond bottom, the depth of cut should be clearly written on the stake.

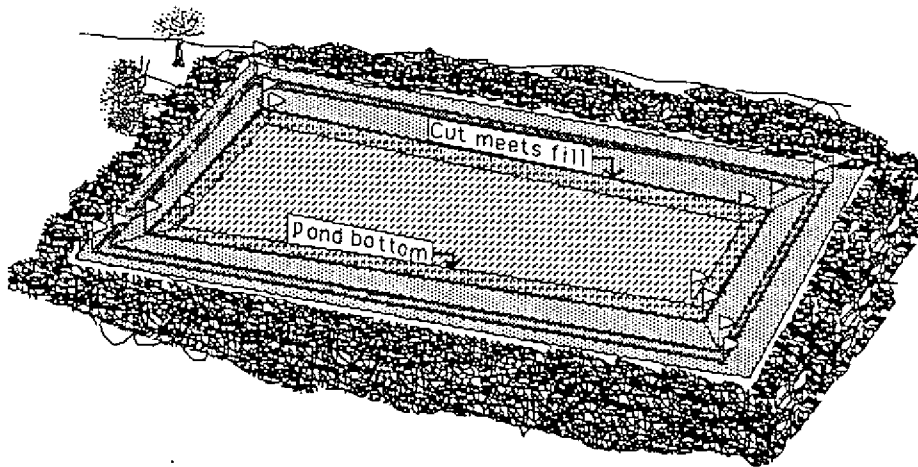


Figure 29

Laying the Drain

The drainage pipe is often laid before the dikes are constructed. A trench is dug (Fig 30) so the top of the pipe can be set at or just below the planned pond bottom (calculated from the cut and fill ratios). Once the pipe has been set in place and the anti-seep collars attached, the pipe can be covered and the soil carefully packed.

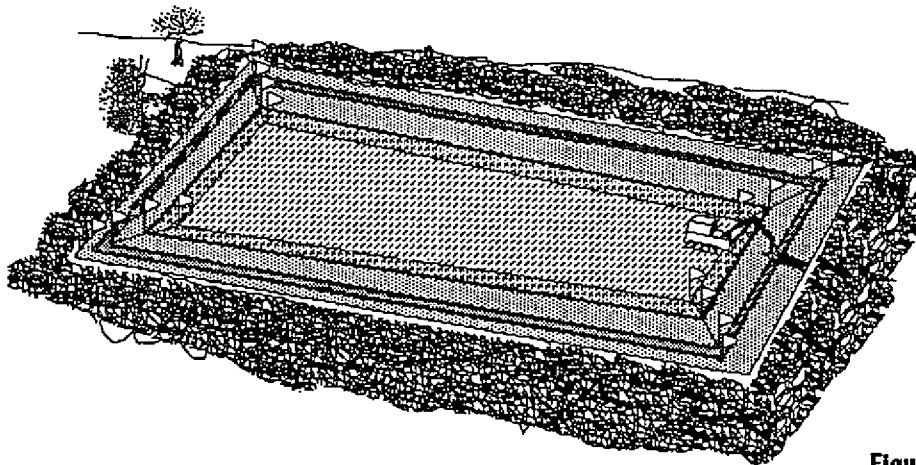


Figure 30

Quality Core

If the soil is not uniform, the best quality earth available should be used for the dike core (Fig. 31). The front slope can be made with the next best soil, and the poorest soil can be used for the back slope.

The dirt should be added in layers 6 to 10 inches thick, each containing the central core of good quality earth, and each well compacted.

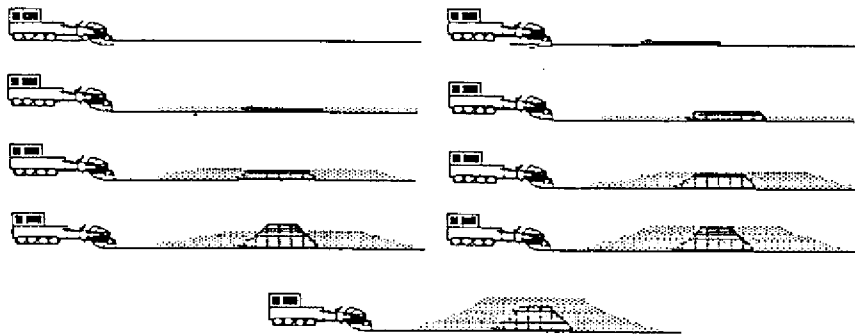


Figure 31:
A cross-section shows how the dike core is incorporated during construction.

Compaction

The greatest compaction is achieved by heavy objects that have a small surface area in contact with the ground. There are a number of devices built specifically for this purpose. A sheep's foot roller is useful in large jobs, such as building production ponds. Gas or diesel powered rammers are useful for smaller jobs. Bulldozers, while very heavy, have a wide tread, and are generally not adequate for proper compaction.

Plant Grass

Once the dikes are complete, topsoil should be pushed back and grass planted to prevent erosion (Fig. 32). The type of grass should be one with a well developed root system to hold the dirt. A thin layer of hay can be spread over the topsoil immediately after seeding to prevent rains from washing away the seed.

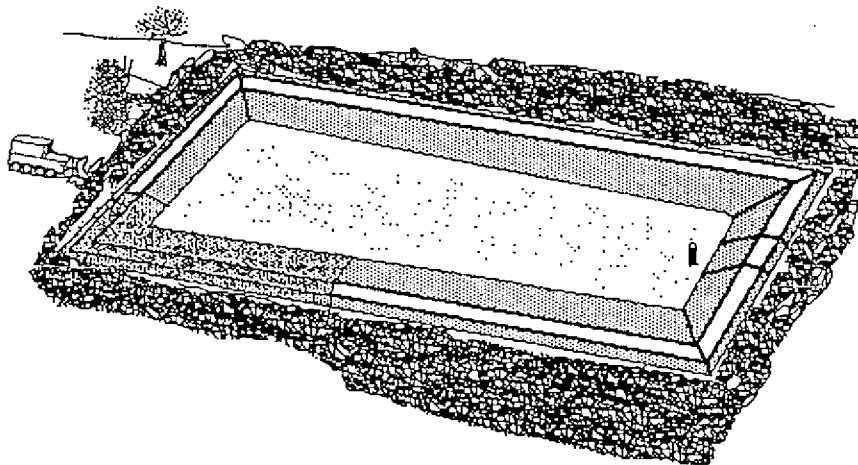


Figure 32:
Grass should be planted to prevent erosion.

