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A Review of Topography in Fish Culture in Nigeria Part 1

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Abstract: A review of topography in fish culture in Nigeria part two is aimed at bridging the technical language gap between the fish culturist and; both land surveyors and civil engineers. The fish culturists need to understand the principles in topography for good site selection in fish culture. The fish farmer can design and build fishponds, reservoirs and small dams and use existing topographical maps. An adequate knowledge of topography by fish culturist bridges the technical language gap between the fish culturist and; both land surveyors and civil engineers. The fish culturist can discuss his plans, projects and understand books on topography, engineering and surveying. Good fish farm construction can only be possible with the right topography. Features of a fish pond, different kinds of pond, advantages and disadvantages of these types of pond, basic pond types, characteristics of shallow and deep ponds, setting out a straight line between two points, prolonging a line, horizontal distance measurement, pace count, chaining, clisimeter, stadia method are some principles in topography for good site selection in fish culture reviewed in this part aimed at enabling the fish culturists know these basic principles to design and build fishponds, reservoirs and small dams and use existing topographical maps.

Key words: Distance meaning, horizontal classification pond, measurement, topography distance, measurement

INTRODUCTION

The fish culturist can discuss his plans, projects and understand books on topography, engineering and surveying. Good fish farm construction can only be possible with the right topography (FAO, 1994). Topography is the science of measuring the earth and its features, and expressing them in charts and plans. These features may be natural (plains, hills, lakes, mountains, streams, rocks or forest) or man made (paths, roads, buildings, villages or fishponds). Topographical maps show slopes of the ground, high, low and steep land between high and low points. Topography is sometimes referred to as surveying. A surveyor measures the earth, makes maps, charts and plans. The fish culturists need to understand the principles in topography for good site selection in fish culture. The fish farmer can design and build fishponds, reservoirs and small dams and use existing topographical maps (FAO, 2006). The highlights of these are:

- Measurement of distances, angles, slopes and height differences
- Setting out straight lines, perpendiculars and parallels in the field
- Determination of horizontal and vertical lines
- Surveying a land area to determine the relief
- Simple surveys for fish farms
- Prepare and use topographical plans and maps
- Calculate areas and volumes

The measurement requirements for a chosen fish farm lands area are:

- Its size
- The slope of its ground surface
- Its elevation (height) in relation to the source of water
- The distance between water source and ponds location
- The best water supply method for the ponds
- The easiest way of draining the ponds

Distances are measured in different ways. Long distances are measured and maintained along a straight line. Slopes are determined through horizontal distances rather than ground distance. The best choice for a dam site

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is a narrowing valley with sleep slope walls and small gradient. In the absence of an existing topographical map to detect such a valley, it can be measured to determine its suitability for a good dam site. If the best site is chosen, topographical methods unveil the level of work on site. Survey the site in the desired plan by measuring the distances, directions, areas, slopes and heights. Draw a detailed topographical plan to make these measurements. The plan shows the position of boundaries, different heights of landforms such as hills and location of existing physical features (FAO, 2002).

The features include paths, roads, streams, spring, forest, rocks and buildings. Such a plan is very important because it provides information on the basic horizontal and vertical elements of the area, facilitating the fish farm design. It provides information on the direction of water flow, position of water supply canal and pond drainage ditches. This forms the basis for estimating the quantity and cost of mud to be excavated.

All physical features of fish farms depend directly on the site topography. These features include the type, number, size, and shape of the fishponds and how they are placed in relation to each other. Water supply and drainage type also depend on the site topography. Topographical methods guide a detailed site survey and fish farm design. Ensure a regular adequate water supply. A Water supply canal with an appropriate size and bottom slope can solve the problem. Stake out water supply canal along its centre line. Maintain a definite width, depth and canal length; and estimate the level of soil to be removed at each point (FAO, 2002).

Stake out the bottom area of each pond for proper disposal of the excavated soil. This allows a natural drainage of all water out from the ponds, for effective fish harvest and pond management. Stake out the dykes of each pond and determine where to add or remove soil. There is need to mark the location, height and width of each dykes as well as the slopes of their walls. Perpendicular (crossing) and parallel (side-by-side) lines can do the job.

The exact plan of the fish farm need be followed. Do this by ensuring the position to build each structure. Check these locations during construction. Height differences between different parts of the farm need be measured to ensure natural water flow in the right direction. Water will have to flow from the water source to the ponds, from pond inlets to the outlets and from the outlets into drainage ditch, which transports water away from the farm site (FAO, 1980).

It is important to learn the use of simple topographic methods for:

- Estimating the surface area and water volume of ponds
- Determining the water flow system of a steam
- Using a weir
- Measuring water head pipes and siphons
- Dam site selection
- Estimating the volume of a reservoir

Soil quality varies and depends on the topography of the area. Shallow soil is found on sloppy land and deep soil is found on flat land, for instance, alluvial soil which is found in sedimentation plains, contains large amounts of clay. The clay in this soil aids in water retainsion and buffers the materials for building of dams.

Topographical method can be used for maps showing the different kinds of soil present in an area of land. The commonly used topographical methods are reconnaissance surveys and detailed soil surveys (FAO, 2006).

Most topographical methods are based on lines. Lines are of two types:

- Lines of measurement
- Lines of sight

Lines of measurement can be horizontal or vertical or follow the ground level (FAO, 1980). These lines are clearly plotted in the field with markers to show the exact path measured. A line of measurement can be:

- A straight line drawn in one direction between two marked end-points
- A broken line drawn in more than one direction between two marked points, with each point in the new direction
- A curved line, marked like a broken line, but with closely spaced marker, that clearly follows the curve

A line of sight is an imaginary line starting from the surveyors' eye to a fixed point; lines of sight are either horizontal or oblique (between horizontal and vertical). Lines of measurement are always plotted on the ground either as one straight-line or as many interconnected straight lines. Pegs, small concrete pillars, simple wooden stakes or ranging poles are used as markers to indicate the direction of the line (FAO, 1980).

Lines of sight are straight lines. The reference point is marked with either a ranging pole or a leveling staff. Vertical lines of measurement can be formed with a plumb line. Straight pieces of wooden pegs with diameter ranging from 3 to 8 cm and length ranging from 0.1 to 1.0 m can be used for pegging the line. Shape the pieces at one end with a knife to make the ground. Pegs carved from hard wood last longer and when coated with engine oil, prevents rotting (FAO, 1994).

Apart from wooden pegs, iron pegs made of cut pieces of iron rod or tube of diameter ranging from 1.3 to 2.0 cm, and long wire nails can be used. Iron pegs last longer than wooden pegs, but are more expensive and less portable for fieldwork. Mark any long-term reference point with a small, upright pillar made of concrete. Such pillars should range from 15 to 30 cm^2 and 10 to 60 cm high. The pillars can be placed on a small concrete base built on the site. The peg or pillar need marked point for accurate measurements because; the marked point determines the measurement position or measurement instrument placement position. A nail can be driven into the flat top of the wooden peg or set a nail into the concrete pillar top (FAO, 2002).

Ranging poles are the most commonly used markers in topographical surveys. Ranging poles are long, thin poles used in marking a point on the ground seen from a distance. A personal ranging pole can easily be prepared from a wooden pole of length ranging from 2 to 3 m and thickness 3 to 4 cm. Shape the lower end into a point for easy penetration into the ground. Cut a slit 5 cm deep into the topside of the other end. Paint from the top in alternating red and white sections to the end of the pole.

A ranging pole can be sighted from a long distance. Fasten two small flags of different colors, one above the other, near the pole top. A 15×25 cm piece of white cardboard in the slit at the pole top can also be used. Ranging poles are driven vertically into the ground. Walk few steps backwards and watch to ensure that the poles are vertical. Walk one-quarter the distance around the pole and check from the side for straightness. Adjust it until both front and side views are vertical (FAO, 2002).

A ranging pole can be centered over a marker and placed in position for a period of time. This can be done using a series of guys. Guys are ropes or wires tied around the poles and fastened to pegs in the soil. Guys can also be used with poles on hard soil, difficult to drive deep in a vertical position. In this part: Features of a fish pond, Different kinds of pond, Advantages and disadvantages of these types of pond, Basic pond types, Characteristics of shallow and deep ponds, Setting out a straight line between two points, Prolonging a line, Horizontal distance measurement, Pace count, Chaining, Clisimeter and Stadia method is reviewed to provide the basic knowledge needed to build good, efficient and reliable pond systems.

FEATURES OF A FISH POND

Although there are many kinds of fish ponds, the following are the main features and structures associated with them in general (Wilcox, 1985) (Fig. 1):

- Pond walls or dikes, which hold in the water
- Pipes or channels, which carry water into or away from the ponds
- Water controls, which control the level of water, the flow of water through the pond, or both
- Tracks and roadways along the pond wall, for access to the pond
- Harvesting facilities and other equipment for the management of water and fish

A fish pond is defined as an artificial structure used for the farming of fish. It is filled with fresh water, is fairly shallow and is usually non-flowing. Tidal ponds, reservoirs, storage tanks, raceways and fish farm tanks are not included.

Different kinds of pond: Freshwater fish ponds differ according to their source of water, the way in which water can be drained from the pond, the material and method used for construction and the method of use for fish farming. Their characteristics are usually defined by the features of the landscape in which they are built. Ponds can be described as follows (Wilcox, 1985).

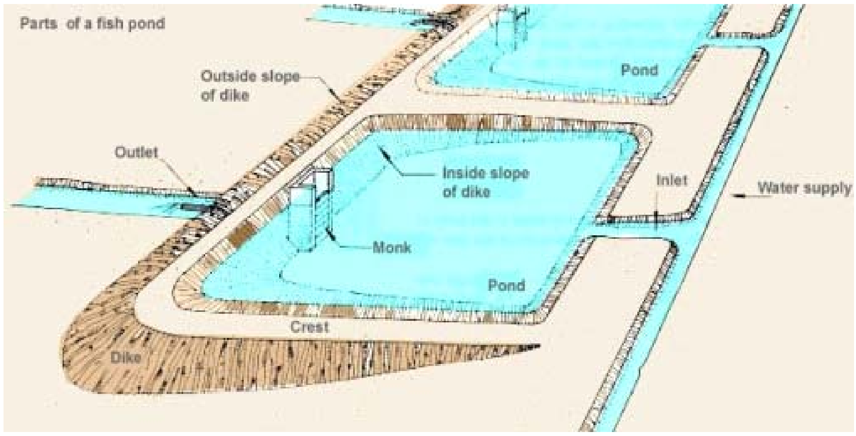
According to the water source: Ponds can be fed by groundwater (Fig. 2): (a) Spring-water ponds are supplied from a spring either in the pond or very close to it. The water supply may vary throughout the year but the quality of the water is usually constant. (b) Seepage ponds are supplied from the water-table by seepage into the pond. The water level in the pond will vary with the level of the water-table.

Ponds can be fed from a water body such as a stream, a lake, a reservoir or an irrigation canal (Fig. 3). These may be fed directly (e.g., barrage ponds (a)), by water running straight out from the water body to the ponds, or indirectly (e.g., diversion ponds (b)), by water entering a channel fom which controlled amounts can be fed to the ponds. Pump-fed ponds (c) are normally higher than the water level and can be supplied from a well, spring, lake, reservoir or irrigation canal, by pumping.

According to the means of drainage: Undrainable ponds (Fig. 4) cannot be drained by gravity. They are generally fed by groundwater and/or surface runoff, and their water level may vary seasonally. Such ponds have two main origins. (a) They may be dug in swampy areas where there is no source of water other than groundwater. (b) They may result from the extraction of soil materials such as gravel, sand or clay.

Drainable ponds (Fig. 5) are set higher than the level to which the water is drained and can easily be drained by gravity. They are generally fed by surface water such as runoff, a spring or stream, or are pump-fed.

Pump-drained ponds may be drainable by gravity to a certain level, and then the water has to be pumped out. Other ponds, similar to undrainable ponds, must be pumped out completely. These ponds are only used where groundwater does not seep back in to any extent.



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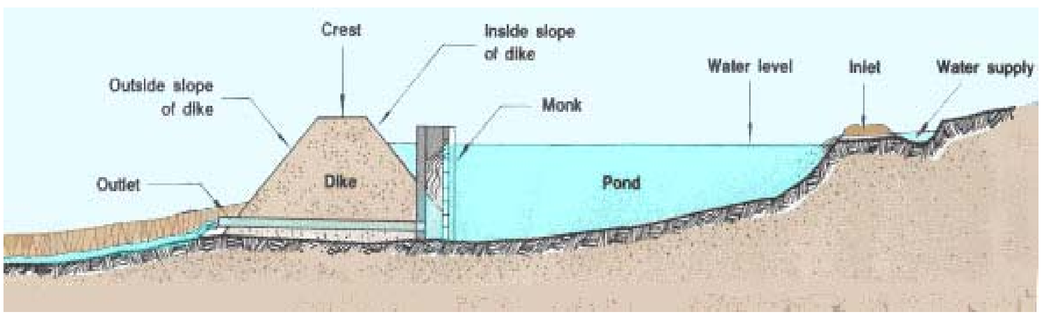
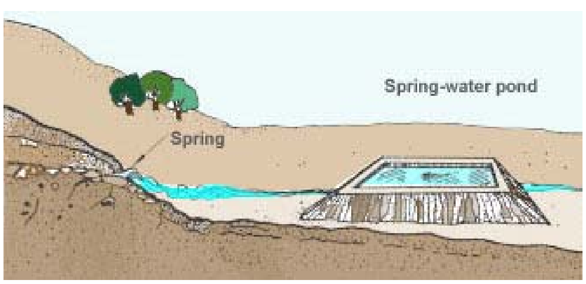
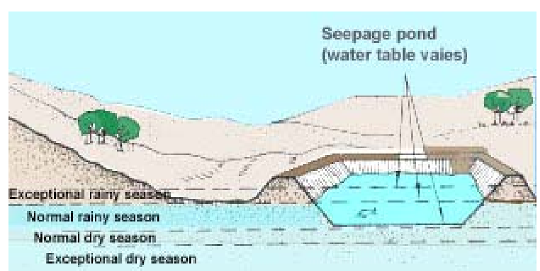


(b)

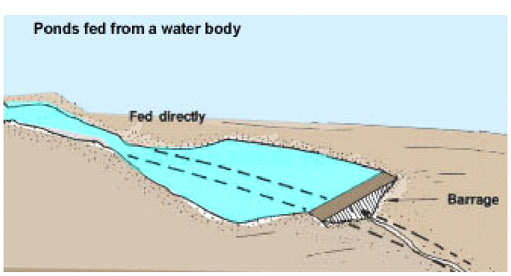
Fig. 1: Main features and structures associated with fish ponds

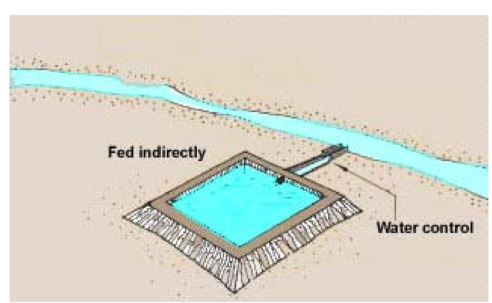




(a) (b)

Fig. 2: Ponds fed by ground water





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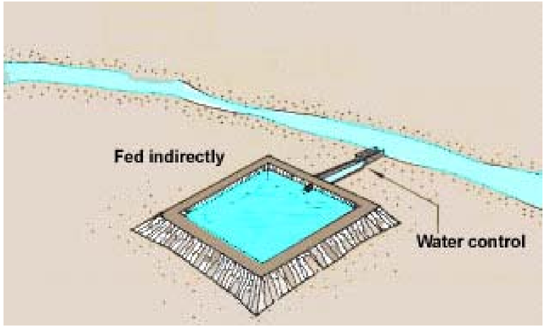

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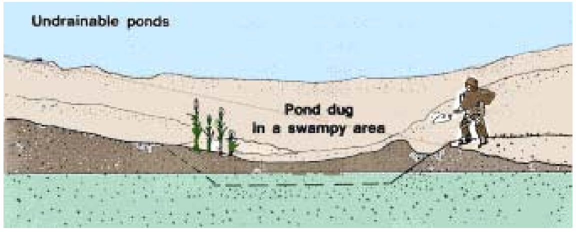
Fig. 3: Ponds can be fed from a water body



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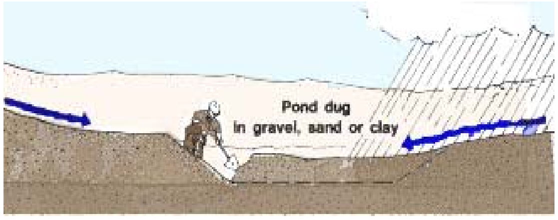

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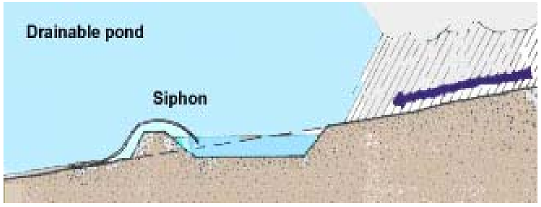
Fig. 4: Undrainable ponds



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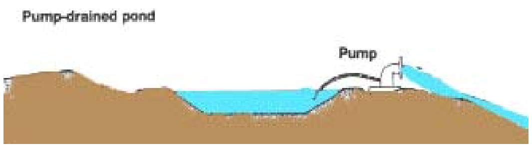
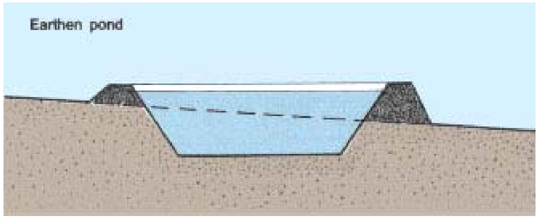


(b)

Fig. 5: Drainable ponds



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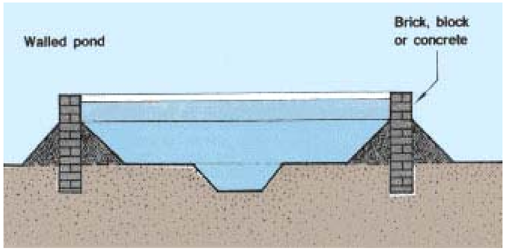

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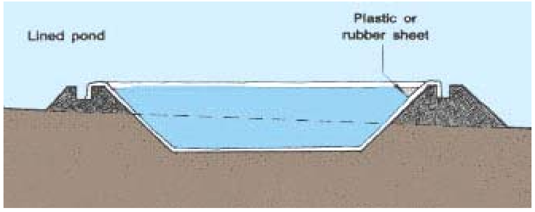

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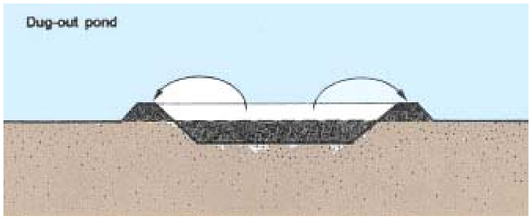
Fig. 6: Earthen ponds



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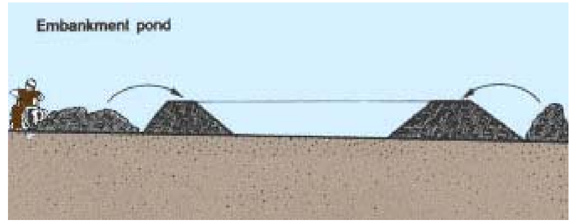

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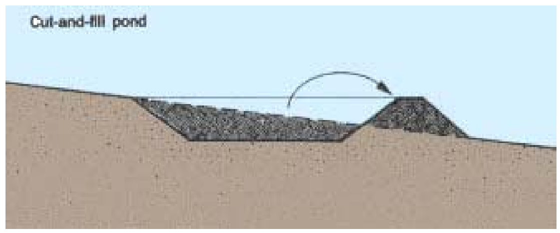


(c)

Fig. 7: Dug out ponds

Fig. 8: A fish farm

According to the construction materials: (a) Earthen ponds (Fig. 6) are entirely constructed from soil materials.They are the most common, and you will learn primarily about these ponds in this manual. Walled ponds are usually surrounded by blocks, brick or concrete walls, (b) Sometimes wooden planking or corrugated metal is used, (c) Lined ponds are earthen ponds lined with an impervious material such as a plastic or rubber sheet.

According to the construction method: Dug-out ponds (Fig. 7) are constructed by excavating soil from an area to form a hole which is then filled with water (a). They are usually undrainable and fed by rainfall, surface runoff* or groundwater. Embankment ponds (b) are formed without excavation by building one or more dikes above ground level to impound water. They are usually drainable and fed by gravity flow of water or by pumping. Cut-and-fill ponds (c) are built by a mix of excavation and embankment on sloping ground. They are usually drainable, and water, which is impounded within the dikes, is fed by gravity or by pumping.

According to the use of the pond: There may be different types of pond on a fish farm (Fig. 8), each used for a specific purpose:

- Spawning ponds for the production of eggs and small fry
- Nursery ponds for the production of larger juveniles
- Brood ponds for brood stock rearing
- Storage ponds for holding fish temporarily, often prior to marketing

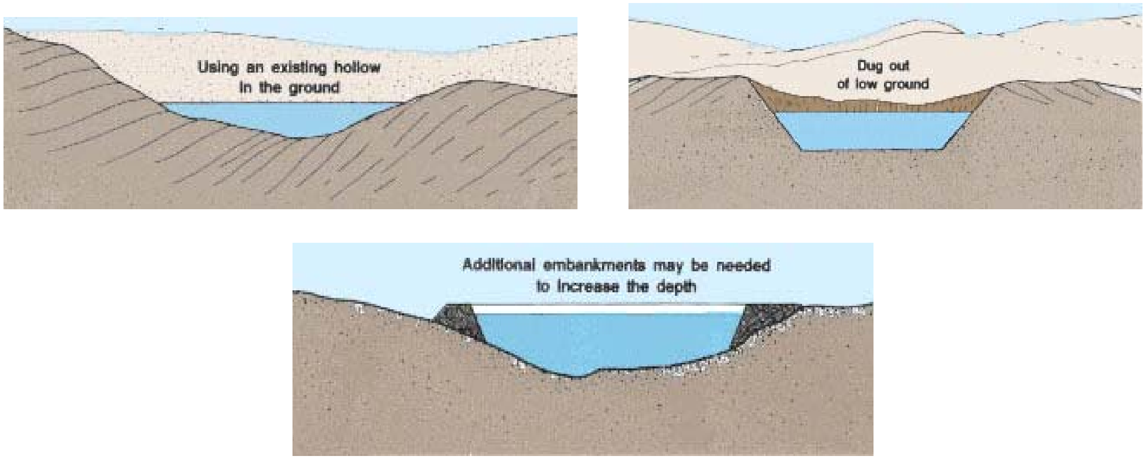


Fig. 9: Examples of Sunken ponds

Table 1: Basic types of fresh water fish ponds

	Main water supply						Draining			Construction method		
	Groundwater		Surface water	Water body		Pumped						
Basic type of POND (subtypes)	Seepage	Spring	Rain full and Suface run-off	Direct	Indirect	Various sources	Undrai able	Drain-able	Pumped	Dug-out	Embankment	Cut-end fill
SUNKEN POND Single water supply Any combinaion of supply	●	●	●		●		●		○	●	○	○ Sloping ground
BARRAGE POND Without diversion canal With diversion canal in series		○	●	●	●		○	●	○		● Dam	
DIVERSION POND In series In parallel			○		●	●		●	○		● Flat ground	● Sloping ground

● Most common; ○ Less common

- Fattening ponds, for the production of food fish
- Integrated ponds which have crops, animals or other fish ponds around them to supply waste materials to the pond as feed or fertilizer
- Wintering ponds for holding fish during the cold season

Basic pond types: There are many types of pond (Table 1). They can be conveniently grouped into three basic types depending on the way the pond fits in with the features of the local landscape (Hem, 1989).

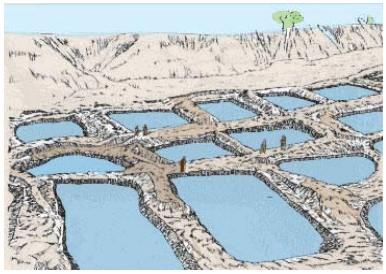
Sunken ponds (Fig. 9-10):

- The pond floor is generally below the level of the surrounding land
- The pond is directly fed by groundwater, rainfall and/or surface runoff. It can be but is not normally supplemented by pumping
- The sunken pond cannot be drained or only partially drainable, having been built either as a dug-out pond or to make use of an existing hollow or depression in the ground, sometimes with additional embankment

Barrage pond (Fig. 11):

- They are created in the bottom of a valley by building a dam across the lower end of the valley. They may be built in a series down the valley
- The barrage pond is drainable through the old river bed
- If large floods are present, the excess water is normally diverted around one side of the pond to keep the level in the pond constant. A diversion canal is built for this purpose; the pond water supply is then controlled through a structure called the water intake
- Directly fed from a nearby spring, stream or reservoir, the water enters the pond at a point called the inlet and it flows out at a point called the outlet
- To protect the dike from floods, a spillway should be built

Diversion pond (Fig. 12): The diversion pond is fed indirectly by gravity or by pumping through a diversion canal (which becomes the main feeder canal), from a spring, stream, lake or reservoir. The water flow is



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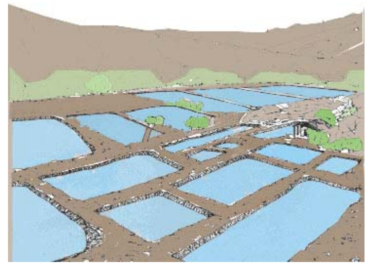
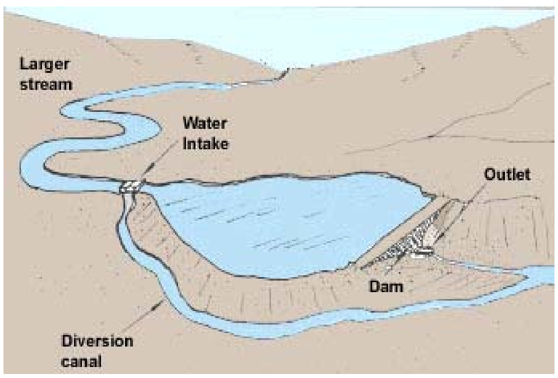
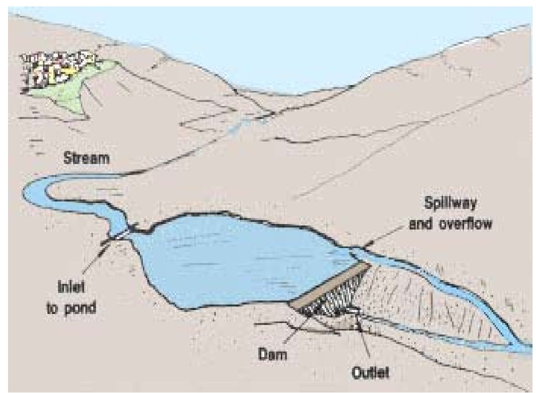


(b)

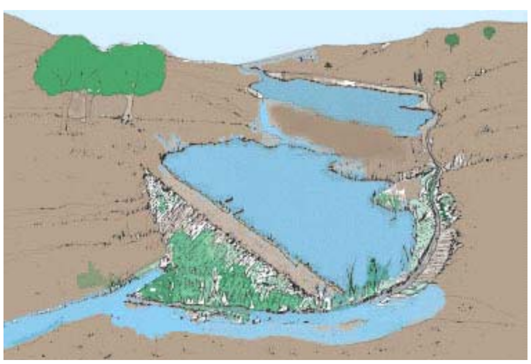
Fig. 10: Examples of sunken ponds built on the bottom of a valley



(a) Barrage ponds in series with diversion canal



(b) Barrage ponds in a V-shaped valley, with no diversion canal



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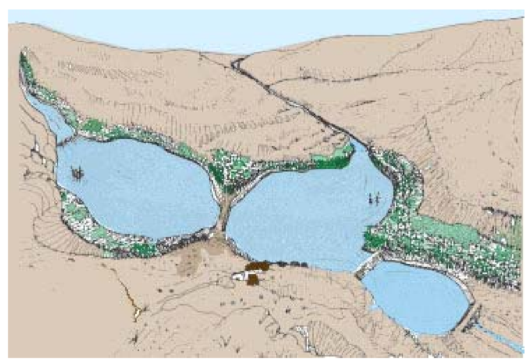
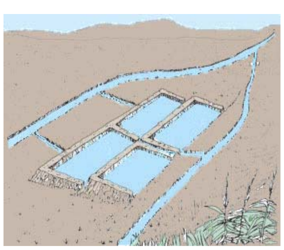
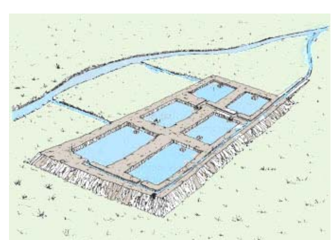


(d)

Fig. 11: Examples of barrage ponds



(a) Cut and fill diversion ponds built on slope ground



(b) Diversion or paddy pond built on flat ground (Four-dike embankment)

Fig. 12: Diversion ponds

controlled through a water intake. There is an inlet and an outlet for each pond. The diversion pond can be constructed:

- Either on sloping ground as a cut-and-fill pond
- Or on flat ground as a four-dike embankment pond sometimes called a paddy pond

It is usually drainable through a drainage canal.

Advantages and disadvantages of these types of pond: The advantages and disadvantages of the three basic types of pond that have just been defined are summarized in Table 2. It is important to remember the following points. Better control of the water supply means easier management of the pond, e.g. when fertilizing the water and feeding the fish. Better drainage also means easier management of the pond, e.g. when completely harvesting the farmed fish and when preparing and drying the pond bottom. A regular shape and the correct size makes a pond easier to manage and more adaptable for particular purposes. The choice of a particular type of pond will largely depend on the kind of water supply available and on the existing topography of the site selected. When you have a choice of several types of pond, you should give:

- Highest priority to diversion ponds fed by gravity
- Lowest priority to barrage ponds in flooding areas requiring large diversion canals

A barrage pond without a diversion canal should preferably be constructed only:

- To be supplied by local surface runoff and/or springs
- Across a stream with a small and regular water flow
- Below a reservoir where it will be supplied by a controlled water flow.

Unless pumping is very cheap, you should not rely on it for filling or draining ponds. Do not use it where there is excessive seepage into or out of a pond

Shape of fish ponds: A fish pond may have any shape, as shown by barrage ponds whose shape depends exclusively on the topography of the valleys (Fig. 13) in which they are built (Glover, 1996). Generally, however, sunken ponds (Fig. 14) and diversion ponds are designed with a regular shape, either square or rectangular. For the same pond size, the total dike length regularly increases as the pond shape gradually deviates from square and becomes more elongated. At the same time the construction costs increase. There are some cases where it may be simpler and cheaper to match the shape of the pond with the existing topography. Rectangular ponds are not so much more expensive if you can build a group of them, with shared walls (Amarnighe, 1987).

Note: When designing a fish farm with several fattening ponds (Fig. 15), consider also that the construction costs decrease as pond size increases, and that the flexibility of management improves as the number of ponds increases (Amarnighe, 1987).

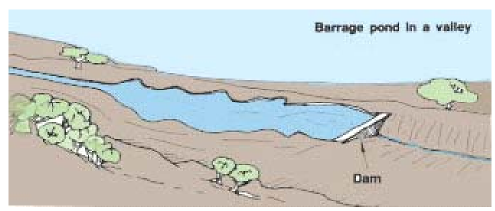


Fig. 13: Barrage ponds in a valley

Table 2: Advantages and disadvantages of the three basic types of pond

Types	Advantages	Disadvantages
Sunken pond	No need for dikes except for flood protection No water body to supply water Little skill required for construction	Water level can greatly vary seasonally Requires more work to excavate Undrainable; uncontrolled water supply ,unless pumped; may be expensive Low natural productivity of groundwater Pond management difficult
Barrage pond*	Simple to design for small streams Construction costs relatively low unless there are flood defence problems Natural productivity can be high, according to quality of water supply	Dike need to be carefully anchored Need for a spillway and its drainage canal No control of incoming water supply (quantity,quality,wild fish) Cannot be completely drained except when incoming water supply dries out Pond management difficult (fertilization,feeding)as water supply is variable Irregular shape and size.
Diversion pond	Easy control of water supply Good pond management possible Construction costs higher on flat ground Can be completely drained Regular pond shape and size possible	Construction costs higher than barrage ponds Natural productivity lower ,especially if built in infertile soil Construction requires good topographical surveys and detailed staking out

*: if the barrage pond is built with a diversion canal,some of the disadvantages may be eliminated (controlled water supply ,no spillway ,complete drainage ,easier pond management), but construction coats can greatly increase if the diversion of a large water flow has to be planned
**: Relative advantages will vary according to the arrangement of the ponds, either in series (pond management is more difficult) or in parallel (both water supply and drainage are independent, which simplifies management)

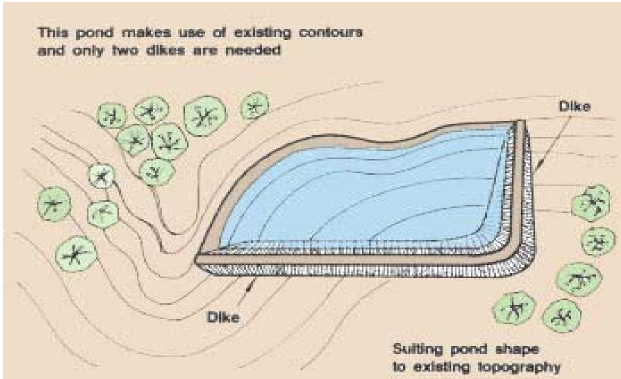


Fig. 14: Pond making use of existing contour

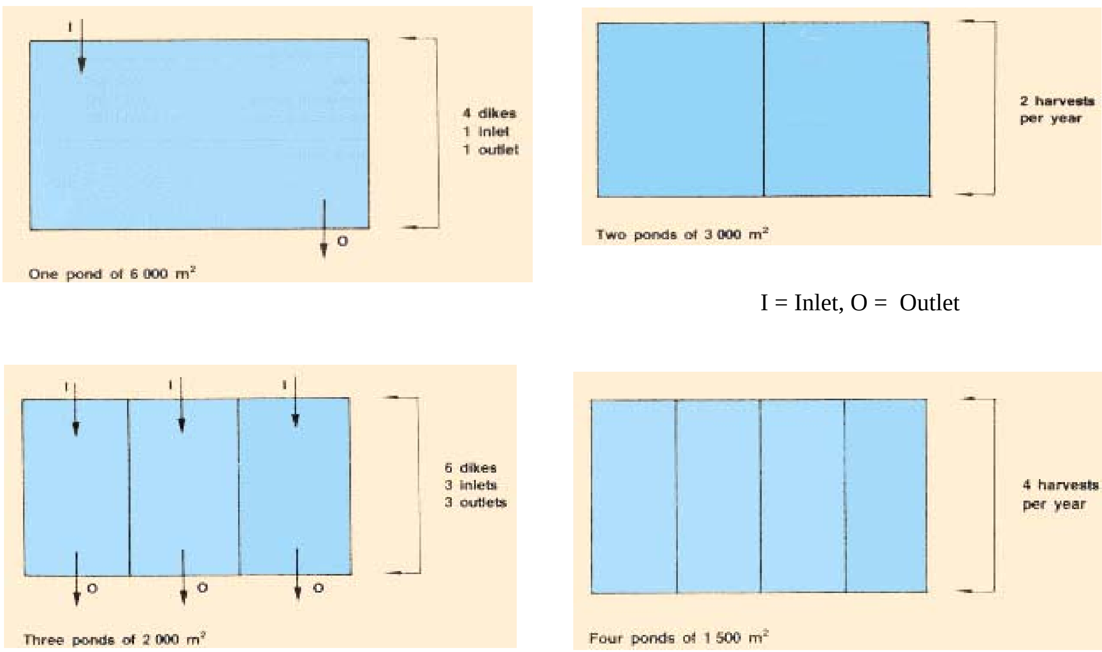


Fig. 15: Fish farm with several flattering ponds

When square ponds are preferable: Because they are cheaper to build, square ponds (Fig. 16) are particularly useful as smaller ponds (up to 400 m^2), which you plan to harvest by draining (Amarnighe, 1987).

When rectangular ponds are preferable: You should prefer rectangular ponds (Fig. 17) whenever: Build ponds larger than 400 m^2 on land with a slope greater than 1.5% and ponds larger than 100 m^3 with plan to harvest your fish by seining (Ajana, 2003)

Selecting a rectangular shape: In general, rectangular ponds (Fig. 18) are about twice as long (L) as they are wide (W); but if you build your ponds with a bulldozer, it is cheaper to select a pond width which is a multiple blade width of the bulldozer (Fig. 19).

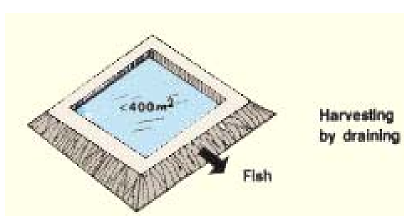


Fig. 16: Square ponds

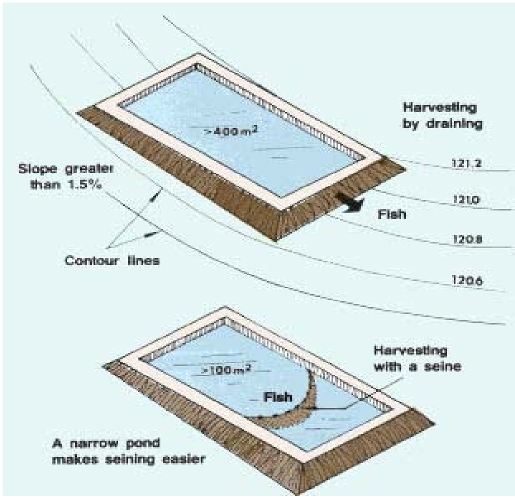
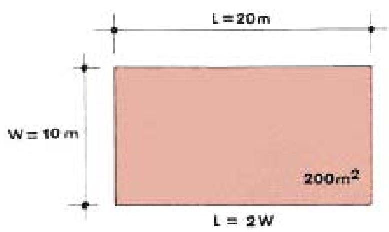
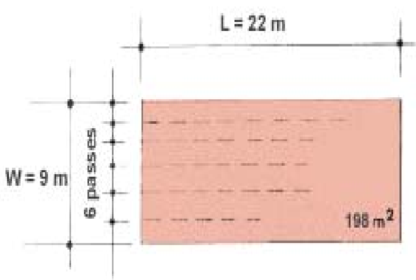


Fig. 17: Rectangular ponds

Normal rectangular pond



Rectangular pond excavated by bulldozer



if the bulldozer blade = 1.50 m then the pound width should = 1.50 m × 6 (passes) = 9 m

Fig. 18: Rectangular ponds

Note: It is best to use a standard width for ponds that are meant for the same use. This will enable you to use standardized seine nets when harvesting them.

Where the ground slope is greater than 1.5% (Fig. 20a), the ponds are best built with the longer sides running across the slope, with the width of the ponds limited accordingly, so that the downhill dike does not need to be too high, and so that the earth built up as walls

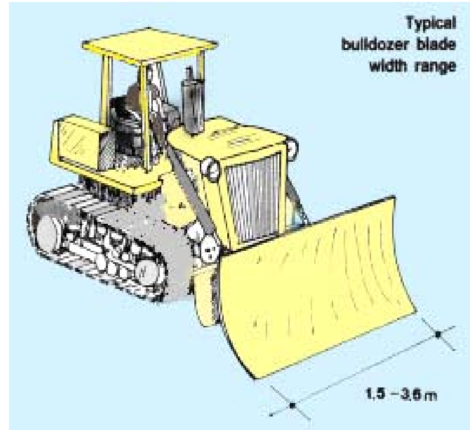


Fig. 19: A bulldozer

balances the earth dug out. As the slope increases, the ponds should become narrower (Fig. 20b). Avoid building dikes higher than 3 m (Ajana, 2003).

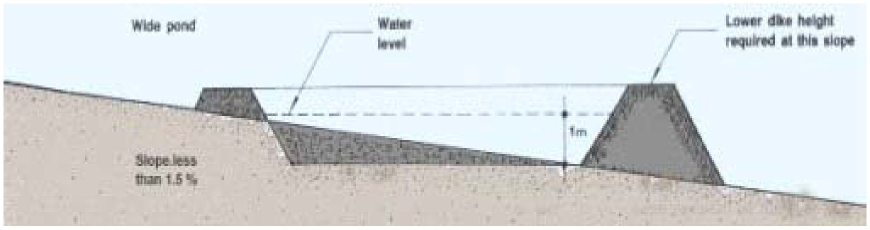
Selecting ponds shaped to the topography: Select ponds shaped to fit the local topography whenever:

- Every part of the available area is to be used
- Shaping the pond this way entails good cost savings, for example by using existing earth banks or slopes
- A regular pond shape is not too important

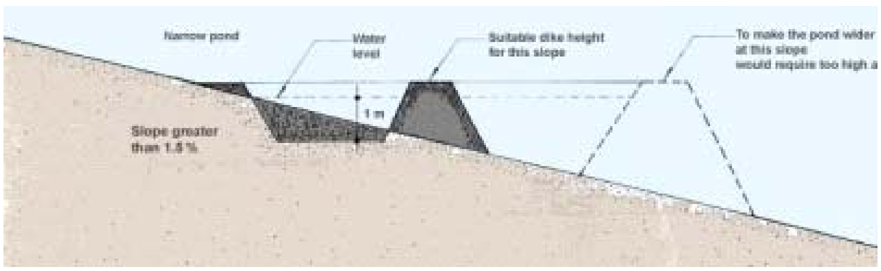
Water depth in fish ponds: Except in some barrage ponds built on streams with steep longitudinal (downhill) profiles, fish ponds are generally shallow (Fig. 21). Their maximum water depth does not normally exceed 1.50 m. Their shallowest area should be at least 0.50 m deep to limit the growth of aquatic plants (Ajana, 2003). The water depth in small rural ponds normally varies from 0.50 m (shallow area) to 1 m at the most (deep area). Deeper ponds are much more expensive to build, because the volume of the dikes increases rapidly as you make ponds deeper (Fig. 22).
Sometimes it is necessary, however, to use deeper ponds:

- In dry regions where you need to store water through the dry season to make sure there is enough for the fish
- In cold regions where it may be necessary to provide the fish with a refuge in deeper, warmer waters during cold weather

Note: During the cold season, it is sometimes better to keep the main ponds dry and to hold the fish in smaller, deeper wintering ponds. In such cases, the main ponds can be designed more cheaply. They will also warm up more quickly than deep ponds in spring (Table 3).



(a)



(b)

Fig. 20: Ponds built across the slope

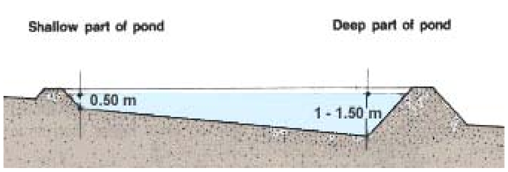


Fig. 21: Shallow fish ponds

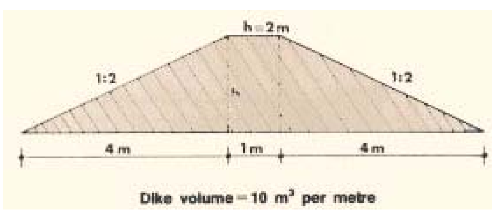


Fig. 22: Volume of dikes

Table 3: Characteristics of shallow and deep ponds

Shallow ponds	Deep ponds
Water warms up rapidly	Deep water warmer in cold season
Great fluctuations of temperature	Water temperature more stable
Greater danger from predatory birds	Less natural food available
Greater growth of water plants	Difficult to seine in deep water
Smaller dikes needed	Strong, high dikes needed

FAO (2002)

MATERIALS AND METHODS

Setting out a straight line between two points: It is important to set out straight lines between two given points, not more than 50 m, when carrying out a simple survey. This can be done by, "ranging" and plotting intermediate points along the line at regular intervals less than 30 m. The likely problems encountered in ranging a line are:

- Both points can be seen from each end
- Both points cannot be seen from each end when obstacles such as forest, rivers and lakes are present

In setting out a straight line between two points visible from each other (line AB); mark the beginning with a ranging pole and mark the end with another ranging pole. An assistant is inevitable in placing the ranging poles. Stand behind ranging pole A and look at ranging pole B (the position of the assistant). Let the assistant walk 40 paces from pole B towards A with another ranging pole. He walks sideways with the ranging pole held vertically in one hand between the thumb and forefinger. When the ranging pole hides ranging pole B, drive it vertically into the ground. This is intermediate point C (FAO, 1980).

The assistant walks 40 paces towards point A from point C. Repeat the same procedure with a fourth ranging pole and mark the new intermediate point D. Repeat the same procedure for the next intermediate points E, F, G, when the distance from point D to point A is more than 50 cm. Make sure that the ranging poles are vertical.

In setting out a straight line between two points invisible from each other (in a forest), mark point A and B with ranging poles. Choose a point x, which is beyond point B. Mark point X with a ranging pole or a marking peg. Set out a line as above from point A to point X, avoiding the forest. Drop perpendicular BC onto line AX from B. The lines will cross out at point C.

Choose a point D on line AX, close to the forest, and set out perpendicular DY. Point Y must be on the other side on line AB. Measure the horizontal distance AD, AC and CB. The point of intersection of line DY with line AB is the intermediate point E. Calculate the horizontal distance DE using the formula.

$$DE = AD \times CB / AC$$

To mark point E, measure this distance DE horizontally. Starting from D, pace off the distance DE along line DY. Mark intermediate point E with a ranging pole. Walk along line AX to the other side of the forest. Set out a perpendicular FZ close to the forest such that point F is on line AX and point Z is beyond line AB. Measure horizontal distance AF. Point G intersects lines AB and FZ. Calculate the horizontal distance FG as:

$$DE = AD \times CB / AC$$

Measure this distance FG horizontally. Measure along line FZ from F to determine point G in the intersection of lines FZ and AB. Mark intermediate point; G with a ranging pole. Line AB is clearly laid out and marked in the field as line AGEB (FAO, 2002).

Prolonging a line: To prolong a line marked in the field, the marked straight line is often extended. Two different circumstances are considered.

- Prolonging a line without an obstacle
- Prolonging a line with an obstacle

In prolonging a line without an obstacle:

- Make a straight line AB in the field with a ranging pole and walk away from point B following the direction of line AB as closely as possible. Stop and turn to face ranging poles B and A after walking 40 paces
- Hold the ranging pole vertically in front between the thumb and forefinger. Move slightly sideways until the pole seems to hide ranging poles B and A from view. Drive the pole into the ground in a vertical position
- Walk backward 1 to 2 m along the line and observe that ranging poles B and A are hidden behind each other. If not move the pole a little to the left or right, and walk backwards and observe again. Repeat this procedure until the pole is in the right position. The point C prolongs line AB
- Stand 1 to 2 m behind ranging pole A to determine a line of sight AB while the assistant stands by ranging pole B
- The assistant walks, carrying a ranging pole, 40 paces from ranging pole B in the opposite direction. He stops and turns round to face you
- The assistant holds his ranging pole vertically, while he moves to the left or right until ranging poles A and B hides his ranging pole. At that point, he drives his ranging pole vertically into the ground. This marks point C, which prolongs line AB

In prolonging a line with an obstacle:

- Set out perpendicular AX and BY from points A and B respectively to prolong line AB
- On these two perpendiculars, measure equal horizontal distance AA′ = BB′. Make sure that it is distant enough along the perpendiculars; so that, the line joining point A′ and B′, when prolonged clears the obstacle
- Prolong line A′B′ through C′ and D
- At point C′ and D′ set out perpendicular lines C′Z and D′W
- On these two perpendiculars, measure horizontal distance equal to AA’ and determine C and D. Mark these points with ranging poles. The line is prolonged with line CD

Horizontal distance measurement: In topographical surveys, distance is measured along straight lines. These lines either join two fixed points plotted in the field with pegs, pillars or ranging poles. Distances are often measured as horizontal distances (Fig. 23). Horizontal distances are often measured in terrains with more than 5% slope. Grounds with less than are qual to 5% slope may not need horizontal distance measurement. Another method of measurement confirms horizontality of the terrain or correct all measurements made on the terrain.

It is ideal to reach all points of the straight line measured; but can be hindered by an obstacle such as lake, river or cultivated field. Indirect measurements are required in such cases. The horizontal distance along the original line can be calculated.

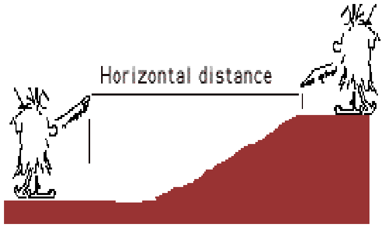


Fig. 23: Horizontal distance measurement

Table 4: Distance measurement methods

Method	Distance	Error per 100 m^2	Remark	Equipment
Face count	Medium to long	1 to 2 m or more	For quick rough estimates	None
Pacing with a pass meter or pedometer	Long	1 to 2 m or more	For quick rough estimates	Pass meter or pedometers
Ruler	Short	0.05 to 0.10 m	Especially useful for sloppy ground	Ruler (Masons level, plumb line)
Chaining using a band or tape	Medium to long	Less than 0.05 m	Best results with steel lines	Steel band, measuring tape
Chaining using a rope	Medium to long	0.5 to 1.0m	Cheap	Liana or rope, string marking line
Chaining a chain	Medium to long	0.02 to 0.10 m	Strong quality	Surveying chain
Clisimeter	Medium	1 to 2 m	For quick and rough estimates	Clisimeter (Lyre) 2 m media staff
Stadia	Medium to long	0.1 to 0.4 m	For quick and accurate measurement	Telescopes with stadia, hairs leveling staff

FAO (2006)

(a) the step (b) the half foot (C) thefoot

Fig. 24: Pace count methods

Fig. 25: The chain

Several distance measurement methods exist (Table 4). The measurement method used depends on several factors:

- The accuracy of results needed
- The equipment available
- The type of terrain measured

Pace count: Distance can be estimated by pacing (Fig.24). This means counting the number of normal steps in the distance between two points along a straight line. Pacing is particularly useful in reconnaissance surveys, grid method, contouring and chaining (FAO, 2006). The normal pace (average step length (a)) should be known for accuracy. Always measure pace from the toes behind the foot (b and c) to the toes of frost in front (pace factor). To measure the average normal pace length:

- Walk 100 normal steps on horizontal ground, starting with the back foot toe from a marked point, A and walk along a straight line
- Mark the end of last step with peg B, at the front foot toe
- Measure the distance AB (in meters) with a tape and calculate the pace factor (in meters) as follows:

Pace Factor (Pf)AB / 100

Example: If for 100 paces, a distance of 76 m was measured, the pace factor can be calculated thus:

$$Pf \quad = 76 \text{ m} / 100 = 0.76 \text{ m}$$

To determine a more accurate pace factor:

- Walk over a longer distance (at least 250 paces)
- Repeat the measurements at least three times and calculate the average pace factor

Example: If the successive measurements for 250 paces were: 185, 190 and 188 m. The average pace factor can be calculated thus:

Total paces = 3 x 250 = 750
Total length = (185 + 190 + 188) m = 563 m
∴Average Pf = 563 m / 750 = 0.75 m

Pace factor varies, depending on the type of terrain measured. Remember that:

- Pace is shorter in tall vegetation than in short vegetation
- Pace is shorter walking uphill than walking down hill
- Pace is shorter walking on sloppy ground than on flat ground
- Pace is shorter walking on soft ground than on land ground

To obtain best results, paces should be of the same length. To do this, walk known distances on level and sloppy ground. Let the pace be regular. In measuring horizontal distances by pacing, clearly plot straight lines measured, using pegs or ranging poles. If necessary, remove all high vegetations present. Walk along the straight lines and carefully count the steps. Multiply the number of steps (N) by the pace factor (Pf) for a rough estimate of the distance in meters, as follows:

$$\text{Distance (m)} = N \times Pf$$

Example: To measure ABCD, pace distance AB = 127 steps BC = 214 steps; and CD = 83 steps. ABCD = 127 + 214 + 83 = 424 steps. If Pf = 0.75 m, ABCD = 424 × 0.75 m = 318 m

To avoid errors when counting the steps:

- Count only double steps or strides, and multiply the total count by 2
- Take count of the hundreds with fingers (using one finger for each hundred steps)
- Take account of the thousands by ticking them off on paper
- When crossing obstacles such as fences and small streams, estimate the number of steps, strides or half steps it would take to cross them

When pacing with a pass meter or a pedometer, simple device (a pass meter). The pass meter is almost the size of a wristwatch. Attach it to a belt or waistband. At each pace taken, the jolt of each step makes a pointer as the pass meter turns. This pointer shows the number of paces.

The pedometer is a simpler device, but it registers distances. This is usually expressed in kilometers and its fractions. These two devices can be compared for accuracy before use. To read a pass meter, walk a few hundred paces, counting them carefully. Compare the total count of paces with the number of registered paces, and adjust the device. To read a pedometer, walk at a normal pace along a straight line over a known distance. Compare this distance with the registered distance, and adjust the device.

Chaining (Fig. 25): For more accuracy in measurement, particularly in difficult terrain, a measuring line made from rope can be used. Depending on the distance measured, a measuring rope of 10, 20 m or 30 m can be prepared. Obtain a rope ranging from 1 to 1.5 cm thick, made of natural fibers. Ropes of man-made fibers such as nylon can change over time. Natural material such as jute will shrink or stretch very little. A piece of used sisal rope is more appropriate than a new one. A piece of supple liana easily found in the forest can also be used (FAO, 1983).

Mark the zero point, 20 cm from one end of the rope. Accurately measure the acquired length, a meter at a time. Leave 20 cm at the other end of the rope. Mark each meter point with durable waterproof paint, dye, ink or colored wax. Keep these meter marks close to each other to avoid inaccurate measurements. Thin strings can be used for the marks instead, threading the string through the rope to avoid shift in position. Reinforce the two ends of the measuring rope. To do this, tightly wind light strings around the last 10 cm of each end of the rope.

In measuring horizontal distances with a rope, clearly plot the straight line measured with wooden pegs. On either side of each of these lines, clear a narrow strip of ground completely, removing vegetation and large stones. If the distances are shorter than or equal to the rope, the measurements can be taken directly. To do this, carefully stretch the rope from one peg to the next. If the distance falls between the meter marks on the rope, measure this shorter length with a ruler or a tape graduated in centimeters.

If the distances are longer than the rope, use one of the chaining methods. Bands and tapes can be bought from the stores. A measuring band is made of a strip of steel, usually 6 mm wide and 30 or 60 m long. Meters, decimeters and centimeters are clearly marked on the band. Bands are wound into an open frame, with a spindle and handle for rewinding.

Measuring tapes are made of steep, metallic cloth or fiberglass material. The lengths of measuring tapes range from 10 to 30 m or more marked at 1m intervals, with the first and last meters graduated in decimeters and centimeters. These tapes are wound into a case with a rewinding handle. Tapes can present problems. Steel tapes can easily become twisted. Cloth tapes are less precise than others, due to slight variation in length.

Horizontal distances can also be measured with steel or tape. Plot the straight lines measured. If the lines are shorter or equal to the measuring band or tape, the distance can be measured directly. To do this, stretch the band or tape from one peg to the next. If the lines are longer than the band or tape, use any other method (FAO, 1980).

Pull bands and tapes tight, so that they do not sag, especially when measuring long distances. However, avoid over-stretching them (especially fiber glass tapes) because this can lead to errors.

Surveyor's chains are also sold in stores. These are made of a series of steel links, each 20 cm long. The links are, attached to each other by steel rings. One link length contains straight portion, two round ends and two half-rings that connect the links on either side. Each chain meter is usually marked by a brass ring. At each end, there is a metal handle for measurement. The total length of the chain, range from 10 to 20 m. Chains are stronger but less accurate than bands and tapes.

When using a surveyor's chain, consider the following:

- Make sure that the rounded end of one length does not remain on top of the next. This can make the chain shorter. At the start of each survey, check for this by sliding the entire length of the chain through the hand and straightening all the links
- Avoid leaving the chain in the sun because heat can expand the chain
- Pull chain tight enough for accurate measurement

When using a chain for the first time, carefully measure the length of each link using a ruler. Remember that this length is made up of the straight part, two rounded ends, as well as two connecting half rings. At each end of the chain, the handle, one shorter link, and half the connecting right make up the length of a link. When the length of the link is measured, be sure that 1 m of chain equals the expected number of links.

Example: If each link is 0.20 m long, there should be five links per meter of chain. The surveyor's chain is always folded as follows:

- Take the two handles together in the left hand doubling the chain
- Collect two links at a time with the right hand, putting them slantwise

To unfold a surveyor's chain, hold the two handles in the left hand and throw the chain in the measurement direction. The chain is used for measuring the lengths of straight lines, marked at each end with a ranging pole. An assistant is very necessary. The method of chaining used depends on the type of terrain measured.

When long distances are measured, use of measuring line depends on the slope of the terrain. When the terrain is flat or nearly flat (that is with a slope of less than or equal to 5 percent), the horizontal distance can be measured, following the ground surface. This method is used in measuring fish culture sites, where sleeper slopes are avoided. When the slope of the terrain is steeper than 5%, be careful in measuring horizontal distances because the surface measurements are always greater than the horizontal measurement FAO, 1980).

Mark each straight line measured with a ranging pole at each end. Place intermediate markers at regular intervals On lines longer than 50 m. To measure long distances accurately, marking pins are needed. Thin wooden stakes of 25 cm long easily carried in a small basket can be used. These marking pins are driven vertically into the ground as chaining proceeds.

Chaining is done by a rear and a head chainman. The rear chainman is responsible for the measurements. He notes the results and guides the head chain-man to ensure that consecutive measurements are made along straight lines between the marked ground points. Start measurements from one end of the straight line. Remove the chaining pole and drive the first marking pin into the ground at the exact point.

The rear chainman places his end of the measuring line against the marking pin. The head chainman walks away along the straight line with the other end of the measuring line. The head chainman stops when the measuring line is stretched out tightly to its full length on the ground. He looks towards the rear chainman. If the measuring line is not placed exactly along the chain-line, the rear chainman then tells the head chainman how to correct the position of the measuring line.

When the measuring line is correctly placed, the rear chainman signals the head chainman to place a second marking pin at the end of the measuring line. The rear chainman immediately notes down the measurement and removes the first in marking pin, putting it in his basket, and replaces the ranging pole at the starting point. Still holding the ends of the measuring line, both chainmen move forward along the straight line, always keeping the measuring line well stretched. This is particularly important when using a surveyor's chain (FAO, 1983).

The rear chainman stops at the second marking pin and places his end of the measuring line against it. The head chainman tightens the measuring line along the ground, corrects its position following any direction from the rear chainman, and places a third marking pin at the end of the measuring line when signaled to do so. The rear chainman books this measurement and puts the second marking pin in his basket before moving on. These processes should be repeated along each section of the straight line until the end is reached.

When the end of the line is reached, the number of marking pins in the basket of the rear chainman shows the number of complete measuring-line lengths measured. The measurements noted can be checked using a set of eleven marking pins to keep tract of the number of measurements completed. When the rear chainman has ten pins in his basket, ten complete measuring-line lengths have been measured. He books it and returns the ten pins to the head chainman, leaving the eleventh pin in the ground. This marks the starting point of a new series of measurements (FAO, 1980).

Using a chain 10 m long, the rear chainman marked 4×10 pins in his notebook. He has 6 marking pins in his basket. With the marking pin in the ground, he measured a distance of (4×10) + 6 = 46 chain lengths or 46×10 m = 460 m.

When measuring on ground with a slope greater than 5%, the measuring line is needed to find the horizontal distances. Proceed as described previously. Mark the straight lines with ranging poles of each end and intermediate pegs. Remember to work down hill for greater accuracy. In this case, the head chainman holds the measuring line horizontally above the ground.

When the measuring line is fully stretched in the right position, the head chainman finds the exact point on which to place the marking pin, using a plumb line (FAO, 2002). Keep proceeding along the slope as follows: on steep slopes, use a shorter measuring line of 5 m.

During measuring on sloping ground, consider the:

- Horizontal measuring line
- Well-stretched measuring line
- Exact placement of the marking pins

The ground on a slope can also be measured. However, ground measurements can be corrected using mathematical formula. Distances can also be measured on irregular grounds containing ridges, mounds, rocks, trenches or streams. In such cases, the measuring line can be lifted above the obstacle. Ensure that the following principles are followed:

- Keep the measuring line well stretched. The head chainman shortens it by looping it in his hand
- Keep the line horizontal, using a mansions level
- Lift the back end of the measuring line exactly above the marking pin using a plumb line

Instead of using a plumb line, longer marking pins such as ranging poles set vertically into the ground can be used. Marking pins are inadequate in hand or rocky soils. In such cases, mark the points with objects such as painted rocks that can be easily seen. Be sure that the markers do not blow or roll away. Alternatively, mark the ground with a stick or mark a rock with chalk (FAO, 2006).

To make chaining more accurate, the measurements should be repeated. Start measuring from the end point and continue along the line. This second measurement should not differ too much from the first. If the two measurements agree, calculate the average value. The average value is considered as the true measured distance. The maximum permissible differences between two consecutive distances measured per 100 m are:

- Steel band or tape 0.1 m
- Other tapes 0.2 m
- Surveyor's chain 0.2 m
- Home-made rope 1.0 m

Example: Using a surveyor's chain, the following measurements were obtained:

∴First measurement = 312.6 m
Second measurement = 313.2 m
Real difference = (313.2 – 312.6) m = 0.6 m
\The acceptable difference 0.2 m × 312.6 m/100 m
= 0.2 m × 3.126 m = 0.62 m

This value is greater than the real value and therefore agrees.

Average distance = 312. 6 m × 313.2 m/2 = 312.9 m

If the two measurements differ much from each other, a third measurement should be taken. Compare this with the first two most similar values.

Example: Chaining with a steel tape, the following measurements were obtained

First measurement = 754.4 m
Second measurement = 753.2 m
Real difference = 754.4 m - 753.2 m = 1.2 m
∴The acceptable difference = 0.1 m × 7.54 m

This value is smaller than the real difference and did not agree.

The third measurement = 753.9 m
The Acceptable difference = 754.4 - 753.9 m = 0.5 m
This value is smaller than 0.7 5 m
Average distance = 754.4 m + 753.9 m/2 = 754.15 m

If there are different measurements of the same line, the measurement might not be along the true straight line. To reduce such errors, put more ranging poles on the same line between the points. If white or brightly colored pieces of cloths are tied to the poles, visibility increases. The head chainman should be carefully guided. The measurements can further be improved by:

- Inspecting the full length of the measuring line before using it to measure a series of straight lines

- Keeping a uniform tension on the measuring line during each measurement
- Accurately marking each point of measurement.
- Keeping an accurate account of these products
- Using the right device, such as a ruler, to measure distances less than the measuring line length, and be able to read the graduation lines

It is better if the head chainman holds the zero end of the measuring line. The rear chainman directly marks and records any intermediate readings.

Clisimeter: The lyre clisimeter is a simple instrument used for distance and ground slope measurement. It is less accurate than measuring line. However, quick estimates of distance can be obtained from a fixed position on the line. The error is directly proportional to the distance measured. Therefore, for accurate results, the lyre clisimeter should not be used for distance exceeding 30 m. However, for rough estimates, a distance of 150 m can be acceptable (FAO, 2002).

The lyre clisimeter consists of a sighting device, a handling ring and a bottom weight to keep the instrument portable and in a stable vertical position. Three vertical scales can be seen through the sighting device. A scale is a series of marks along a line at regular intervals. The central scale, stadimetric scale is used for horizontal distance measurement. The central scale consists of the:

- Top part, marked 150, 100 …………… 7 m
- Bottom part, marked 150, 100 ……… 10 m

To measure a distance with the Clisimeter, an assistant and a reference line (the BASE) are needed. The method used with the clisimeter depends on the BASE chosen.

Stadia staff can be prepared from a straight piece of wood 2.50 m long. A rectangular stake with a cross-section of 8×4 cm is best, but a round pole with a cross-section of 6 to 8 cm can be used. Produce two wooden boards measuring 30×40 cm each. Nail these boards along the centre lines, 10 cm from each end of the stake. Draw a horizontal line across the middle of one of these boards. This is called the median line.

From this line, measure exactly 2 m along the stake to a point near the middle of the second board. At this point draw a horizontal line across the board. Using a pencil and ruler, divide the length of the stake between the two boards, each 1.70 m into 10 cm sections. Paint each board section lying outside the 2 m lengths in bright red. The first 10 cm next to each board should be painted red and each alternate section in between.

Paint all other board sections and stake in white including the 10 cm end section of stake. The stadia staff is now ready for use in distance measurement. A simpler staff can be used for short distances. Produce a pole or staff exactly 2 m long and paint in red and white as described above. Let the assistant carry the stadia staff to the first point along the line measured. He places the staff as vertical as possible with the painted side facing you.

Holding the clisimeter in one hand, look through its sighting device at the stadia staff. Align the zero line of the central scale with the median line of the bottom board. Look at the top part of the central scale (BASE 2.00M) of the clisimeter and read the distance in meters at the graduation, lining up with the median line of the top board, carefully record the reading in a field notebook. Signal the assistant to remove the stadia staff, replacing it with a marking pin. He walks to the marking pin left by the assistant and repeat the procedure until the end of the line is reached. For accurate measurements, each distance measured along the straight line should not exceed 30 m (FAO, 2006).

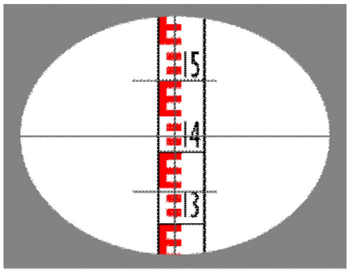
In the absence of a stadia staff, the height of the assistant can be used as a reference. The height needed for this method is 1.70 m. Measure the assistant's height.
If this differs much from 1.70 m, do one of the following:

- If the assistant is taller than 1.70 m, measure the height from his eyes or mouth to the ground and choose the height nearest to 1.70 m
- If the assistant is shorter than 1.70 m, ask him to place an object on his head (such as a can, a bottle or a block of wood), which elevates his height to 1.70 m

Send the assistant out along the line measured and at the selected point, ask him to stand straight, facing you. Holding the Clisimeter in one hand, look through the sighting device at the assistant. Align the zero line of the central scale with the 1.70 m marks chosen. Carefully record the reading in a field notebook. Signal the assistant to drive a marking pin into the ground at the point he stood and proceed to the next point of measurement. Walk to the marking pin and repeat the procedure several times. For more accuracy, each distance measured along the line should not exceed 30 m. When taking a measurement on a slope greater than 5%, correct the clisimeter reading to obtain the true horizontal distance. A mathematical formula can do this.

Stadia method: The stadia method (Fig. 26) is rapid and accurate for long distance measurement. The surveying equipment used is expensive and needs technical knowledge for its usage (FAO, 1994). The basic principles involved in using the equipment are:

- The equipment used in this method is a highly technical device called a telescope. To use it, it must be sighted through two cross hairs and two extra horizontal hairs called stadia hairs. Most surveyors'



(a)

(b)

Fig. 26: Stadia (http//upload.wikimedia.org/wiki/file: levellingrod.jpg), (a) Surveyor's view of the levelling rod with the crosshair, (b) Two sides of a modern surveyor's leveling rod, Note: If it is on sloppy ground, correct this figure to estimate the true horizontal distance

levels have these stadia hairs at an equal distance above and below the horizontal cross hair

- To measure a distance, a leveling staff clearly graduated in centimeters is required
- Set up the surveyor’s level at the point from which the distance is measured. Signal the assistant to place the leveling staff vertically at the next point on the line. The distance from you to the staff may be several hundred meters
- Look through the telescope and read the graduations (in meters) on the leveling staff that line up the upper stadia hair and the lower stadia hair. Record these measurements in a field-book
- Subtract the smaller reading from the larger reading. This represents the stadia interval (interval between the two hairs)
- To find the distance (in meters), multiply the stadia interval by a fixed value (the stadia factor). It is given for each telescope. This factor equals 100 in most instruments

To use the proceeding methods in measuring distances that run through obstacles, it is required to walk along the whole length of each straight line and take direct measurements. There may be an obstacle on the ground that makes indirect distance measurement impossible. The obstacle can be across a water body such as a lake, lagoon, or river; or across agricultural fields with standing crops. In such cases, take indirect measurements of a segment of the line and some previously discussed methods can be used (FAO, 1983).

In measuring a distance across a lake or an agricultural field, from point A on a line XY running through the obstacle set out another straight line AZ, avoiding the obstacle. On this new line, layout a perpendicular line CB joining the original line at point B behind the obstacle. Measure the two new line section AC and CB and Calculate the unknown distance AB using the mathematical formula (FAO, 1980):

$$AB = (AC^2 + BC^2)^{½}$$

In case of a river, the obstacle cannot be avoided. However, the points of measurement from both sides of the river can be seen. There are several methods used, based on geometry. Two such methods are:

- Measuring the distance GH across a river. Using ranging poles prolong line GH back to point C. At G and C, layout perpendicular GZ and CX. On each of these lines, set out a point E and F so that they lie on a straight line FY passing through H, on the opposite river bank. Measuring accessible distance GE, GC and CF. Calculate the inaccessible distance GH as:

$$G = GE \text{ x } GC / CF\text{-}GE$$

Example: To measure GH, across a river:

- Prolong line GH to C
- Lay out perpendicular GZ and CX
- Select points F and E on line FEH
- Measure distances GE = 34; GC = 36 m, CF = 54 m
- Calculate GM = (34 m × 36 m) / (54 m -34 m = 122.4 m / 20 m 61.2
- Measure distance AB across a river. Layout line BX perpendicular to AB on the riverbank. Determine the point C of this perpendicular from which point A can be sighted across the ruler with a 45º.

Example: To measure distance AB:

- From B, lay out perpendicular BX
- Determine C, so that angle BCA = 45º
- Measure BC = 67 m
- Distance AB = BC = 67 m

CONCLUSION

The Features of a fish pond, different kinds of pond, advantages and disadvantages of these types of pond, Basic pond types, characteristics of shallow and deep ponds, Setting out a straight line between two points, Prolonging a line, horizontal distance measurement, pace count, chaining, clisimeter and stadia method are some principles in topography for good site selection in fish culture. The fish culturists need to know these basic principles to design and build fishponds, reservoirs and small dams and use existing topographical maps.

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