Southern
Regional
Aquaculture
Center

September 2002
Revision

Watershed Fish Production Ponds

Guide to Site Selection and Construction

Gregory N. Whitis*

To be profitable, an aquaculture pond must be sited properly and designed for efficiency. An inaccessible location, leaks in the pond, poor seining conditions, or lack of good quality water will doom an aquaculture enterprise to failure.

Ponds do not have to be built on land as flat as the delta regions of western Mississippi, southeastern Arkansas or northeastern Louisiana. There are more than 20,000 acres of catfish production in slightly hilly areas of Mississippi, Tennessee, Alabama, Georgia and Illinois. On rolling terrain the annual rainfall may be enough to completely fill and periodically recharge production ponds. Such watershed systems are not so dependent on groundwater. They also act as flood control reservoirs and can greatly reduce erosion on land previously scarred with unsightly gullies.

Watershed ponds are constructed by building dams across valleys to form reservoirs that store rainwater (Fig. 1). Some aquaculture facilities have large reservoirs that, in turn, fill smaller ponds with captured runoff. Watershed ponds can be cheaper to build than levee ponds on flat land and they don't require expensive wells.

Figure 1. Watershed pond.

A disadvantage of deep watershed ponds is that they are prone to stratify. However, most aquaculture production ponds are routinely aerated and adequate aeration will break up daily stratification.

Water supplies

Watershed ponds are usually filled by surface runoff from an area above the dam. This area, the watershed, can be estimated by drawing a line on a topographic map that follows the ridge lines forming the perimeter of the watershed (Fig. 2). The watershed area and pond acreage can be roughly estimated using a planimeter. Field engineers with the Natural Resources Conservation Service (NRCS) should be able to help landowners with this calculation.

The entire watershed area of a proposed pond must be investigated to determine whether runoff might be polluted. Large chicken and hog farms, extensive areas of row crops, grazing livestock, industrial sites and other water quality hazards in the watershed could preclude the

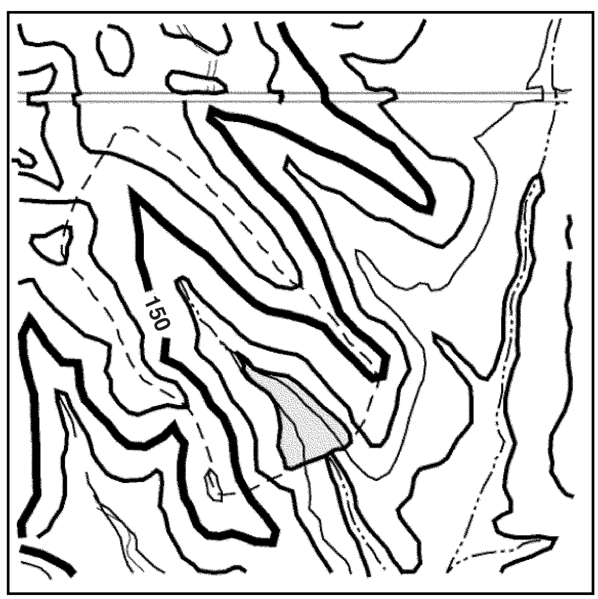

Figure 2. Determining the possibility of a potential pond site and its respective watershed. The dashed lines indicate the boundaries of the watershed. Numbers are elevations in feet.

*Alabama Cooperative Extension System

operation of a watershed pond. Good watersheds contain well-established, undisturbed vegetative cover such as timber or grass. A buffer zone of grass or sod should surround the pond, especially if there are croplands, concentrated feed lots, or large denuded areas in the watershed.

Springs or streams can be used as a water source. Large streams flowing through watersheds may require some kind of diversion device. Streams can be contaminated with wild fish or man-made pollutants, so it's a good idea to get the water tested before construction begins. Also, large inflows of soft water in acid soils may hinder any long-term remedial effects of liming.

Proper site selection

When choosing a pond site, consider the soil type, topography, characteristics of the watershed and, of course, safety. A power supply for aeration equipment must also be available.

Soil type

The suitability of a pond site is mostly dependent on whether the soil will hold water when compacted by heavy machinery during the construction process. Soil composition ranges from pure sand to heavy clay. Soil type can vary drastically within a single site. The pond area should contain a relatively impervious layer of clay or silty clay soils. Coarse soils containing large amounts of sand and/or gravel are unsuitable. If the soil can be formed into a tight ball that maintains its shape or is moldable, it is suitable for pond construction. A rule of thumb is that soil must contain at least 20 percent clay.

If there is poor soil over a portion of the pond, large amounts of clay may have to be trucked in to make it impervious, and that could make construction costs too high. Also beware of limestone areas. They may have sinkholes or caverns just beneath the surface. Ponds built in limestone areas have been known to drain completely overnight!

The type of soil in the dam area is especially critical for safety reasons. Dam seepage can lead to dangerous dam failures. The NRCS and some private agricultural and civil engineers have hydraulic probes that can sample soils several feet down. A backhoe swipe also will help in analyzing soil. Cutoff trenches and dam cores must be located where soil has a high clay content so they will remain structurally sound during the life of the pond.

Topography

The objective is to locate a pond where the largest storage volume is obtained with the least amount of earth fill needed for the dam. Locating a dam between two gently sloped ridges in front of a broad section of valley is ideal. The less pond excavation needed, the more feasible the site and the lower the construction costs.

Safety

Do not locate large dams where their failure could cause loss of life, injury to people or livestock, damage to buildings, or the interruption of the use of railways, highways or public utilities. Aquaculture ponds are not as deep as public reservoirs and dam failures are rare. However, if the site involves some degree of risk to the public, a professional engineer with experience in dam construction should be consulted.

Almost every state has a dam safety law. Contact an Extension fisheries specialist or aquaculturist for more information.

The location of buried pipelines, electrical lines or telephone wires should be researched before any construction begins. Breaking a fiber optic communication cable will put most pond construction budgets into the red!

Determining an adequate watershed area

The amount and quality of water entering the pond from the surrounding watershed is dependent on several factors—slope, soil type, vegetative cover and the amount of precipitation. There are no set criteria for determining whether a watershed is sufficient for a given size pond, but there are some general rules. Watersheds containing mostly pasture with heavy clay soils may supply 1 acre of water for every 5 acres of land. At the other extreme, timberland on sandy soil may require a ratio of 30 acres of land to 1 acre of water.

Excessively large watersheds can be just as problematic as limited watersheds. Too much water may dilute water amendments such as lime and salt, allow valuable fish to escape during floods, and make it necessary to install expensive flood or diversion devices. Ponds with excessive watersheds also may fill in faster with sediments, requiring frequent and costly renovations. An undersized watershed may cause pond water to remain shallow, allowing weeds to get a foothold and preventing the use of emergency aeration devices when fish become stressed.

Pond design and layout

Because of the liability involved with dams, most aquaculturists should confer with a person experienced in the design of commercial aquaculture ponds. The Natural Resources and Conservation Service, a federal agency, offers technical assistance in pond design in most states. This agency designs ponds that incorporate exact safety standards, well-established design criteria, and the latest conservation practices. They are almost always approved by a professional engineer or the NRCS approval authorities. However, the NRCS can't always respond to requests quickly because of its small staff. Private engineers or consultants may be available for a fee. Be sure to get referrals and check any state codes for pond construction before paying for the services of a consultant.

A good site survey and layout design will contain the following information:

1. Location, top width, slopes, earth fill requirements, and elevation of the dam

2. Emergency spillway location and size
3. Shoreline dimensions
4. Soils investigation report
5. Dimensions of the cutoff trench and core
6. Location, dimensions and elevations of the riser and barrel pipes
7. Estimate of the total cut and fill in cubic yards (This figure will account for most of the expense in pond construction.)
8. Watershed area and characteristics
9. A bill of materials needed, including valves, concrete and lumber for the pipe ballast, pipes, vegetative materials (seed, fertilizer, lime), and any diversion pipes or valves

Pond sizing and depth

The size of a watershed pond should be based on the availability of water from the watershed. The water should be deep enough to compensate for evaporation and seepage. Even during summer drought the water should be at least 3 to 4 feet deep. Ideally, the average water depth in a commercial watershed pond should be 4 to 5 feet. The maximum depth should be 8 to 10 feet because of the limited size of commercial seines. Ponds that can be seined without releasing water are called "seine-through" ponds. Catfish ponds in the southeastern United States are seldom drained for harvest.

Other design features

Since catfish and most other finfish ponds are always seined for harvesting, pond bottoms should be smooth and almost flat. Stumps and other natural obstructions should be removed.

Watershed ponds need not be rectangular or square in shape. Curvilinear shorelines will work as long as the maximum width of the pond doesn't exceed the length of the seines used for harvesting. Most seines used by custom seiners and processing plants are 1,000 to 1,500 feet long. Ideally the seine will have some slack or curvature, so maximum pond widths should be about 700 to 1,000 feet.

The dam should have a minimum inside slope of 3:1, 4:l if economically feasible. A 4:1 slope makes it easier and safer to position emergency aerators and load and unload boats. It also reduces wave erosion and makes for better seine contact with the bottom at the inside toe of the levee. However, 4:1 slopes are more expensive because there must be more earth fill. The outside slope can be 3:1. This slope will allow for maintenance duties such as bush hogging and driving around emergency aeration equipment with pickup trucks.

Occasionally it is necessary to drain a pond to capture large, seine-wary fish, repair drains or renovate banks. Pond bottoms should be graded toward the drain at a 0.1 to 0.3 percent fall to ensure complete drainage and allow fish to concentrate in the deeper end.

Pond construction

Contractors

Pond contractors run the gamut from "fly-by-night operators" to companies that have their own engineers and use laser devices for leveling. It is always a good idea to get references for work already completed. If possible, get competitive bids from several contractors, check out their references, and then decide. Be sure to establish specifics about what is to be done by whom, the quality of material and workmanship required and payment details. Some companies prefer to do turn-key jobs, from building the pond to planting the dam with grass. Contractors are usually paid by the number of cubic yards of dirt moved so a good estimate of earth fill is needed. A welder will be needed to fabricate the drainage structures so be sure to negotiate who will be responsible for this phase of construction.

Figure 3. Farm tractor with pan.

Construction costs

Pond construction costs can be highly variable. On a per-acre basis, large ponds are much cheaper to build than small ones. Data at the Alabama Fish Farming Center in Greensboro indicate that watershed ponds larger than 15 acres cost less than $1,000 per acre to build in ideal locations. This includes clearing, earth fill, excavation, pipe and valve, concrete, seeding and dam gravel. Ponds smaller than 10 acres may cost as much as $1,800 per acre. Ponds on poor sites, i.e., on sites that are steep and require large dams to impound relatively small acreages, may cost $10,000 or more per acre.

The largest cost of building a pond is earthmoving. All other costs are relatively minor. Contractors in commercial catfish areas currently charge $.70 to $1.25 per cubic yard of dirt moved. Costs will no doubt continue to rise as machinery, fuel and labor costs increase.

Equipment needed

Pond construction equipment may include the following: large and small bulldozers for clearing and final dressing of levees; self-loading scrapers or tractor-pulled pans; laser leveling and welding equipment; backhoes and hydraulic excavators; farm tractors with soil implements such as cultivators or discs; and a sheepsfoot roller (Fig. 3).

Building a watershed pond

Following the pond design, begin by flagging the dam, emergency spillway, contours for the top of the riser, top of the dam, and the emergency spillway elevation. (Fig. 4) The contour for the top of the riser will become the actual shoreline. The dam will be built at the same elevation as the top of dam contour around the pond.

The first step in actual earthmoving will be site preparation. This involves clearing trees, removing stumps and roots, and stockpiling the topsoil which can be used to dress the dam later. Trees, stumps and roots should never be buried that would prevent bonding of the earth fill and dam foundation must be removed.

Before filling the cutoff trench with the best available clay soil, the trench may have to be pumped out and lightly scarified. The clay fill should be compacted tightly as each layer is added to the trench. If properly compacted, the clay will strengthen the dam. Eventually the trench will be filled and then the remaining dam core will be constructed above ground. The core of the dam must be as high as the permanent water elevation. Allow 5 to 10 percent for settlement.

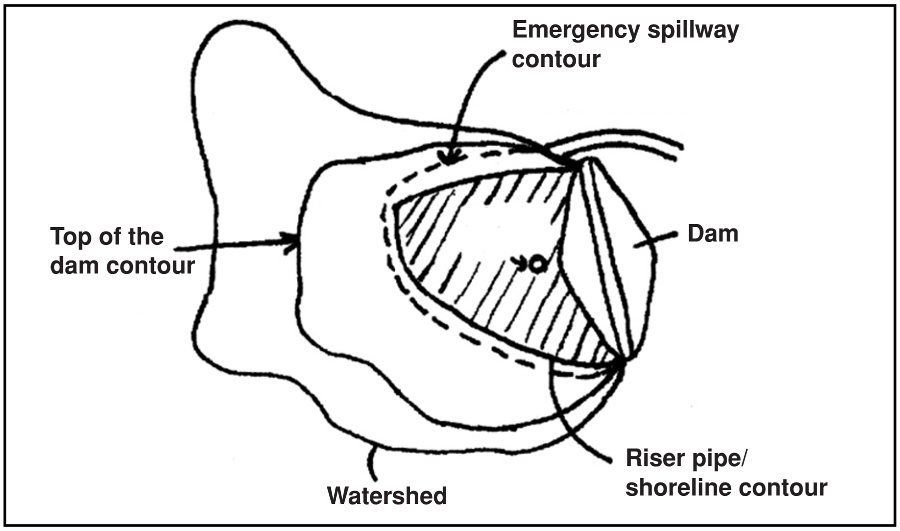

Figure 4. Pond contour examples.

inside the pond or near the dam. Some landowners have used portable saw mills to recoup some of the costs of removing valuable timber. Check with a local power saw shop for names.

The next step is dam construction. A cutoff trench is excavated along the centerline of the dam; it extends up each abutment as far as there is any pervious material that might allow seepage (Fig. 5). Any potential seepage must be prevented to avoid water loss and failure of the dam. The bottom of the trench should be at least 8 feet wide with sides no steeper than 1:1. Old stream channels running through the dam should be cleaned out. All stones, gravel, sand, sediment or anything else

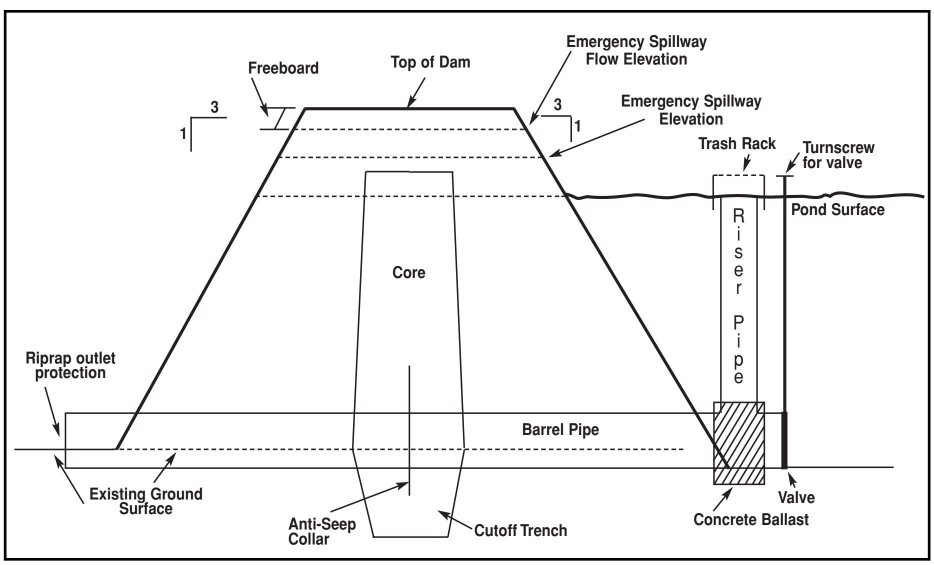

Figure 5. Typical cross-section of dam at the pipe.

Soil moisture and compaction

Good compaction requires suitable moisture and compactive effort. The dam must be built gradually in layers of 6 to 8 inches and each layer packed with heavy equipment or sheepsfoot rollers. The soil used in the dam must be free of all vegetation, roots and large rocks. Soil moisture is critical. Soil too wet or too dry will not adequately compact no matter how many times it's run over. If the soil is so dry it can't be hand molded, stop construction or add water with large tank sprayers. If the soil is so wet that it adheres to construction equipment, stop or, if possible, find drier material. Most dam seepage problems occur because dams were built during drought conditions.

Constructing the pond area

Water depth at the shoreline should be at least 3 feet, with a minimum 3:1 slope. This will eliminate most aquatic weed problems and allow for emergency aeration anywhere in the pond. The bottom should be level and graded to the lowest point in front of the dam where the barrel pipe will be located. The bottom should also be pulverized with a disc harrow and then leveled. If agricultural lime is required, spread it before filling the pond with water.

Installing the drainage pipe

Typically, the barrel pipe with anti-seep collars attached is installed after the dam core has been partially constructed above ground (Fig. 5). The dam core is trenched down to the bottom of the pond and a barrel pipe with anti-seep collars is laid in the trench. Anti-seep collars are required because water will seek the path of least resistance. This is most likely to be alongside a straight barrel pipe. Anti-seep collars are simply steel plates welded vertically and completely around the barrel pipe to provide the necessary resistance to laminar flow. The connection must be watertight. If the dam is taller than fourteen feet, more than one collar will be needed. And be sure the barrel pipe has a slight fall to the outside of the dam so the pond completely drains.

Compaction around the barrel pipe is extremely important. This is the weakest area of the dam and the cause of most dam failures. The fill should be compacted with power tampers to ensure good compaction against the pipe and the collars. Manual compaction should continue until there is at least 2 feet of material over the pipe.

Riser pipes can be located inside or outside of the pond area. Locating pipes inside the pond area reduces the chance of vandals tampering with drains. One disadvantage of locating them inside the pond, however, is that it will interfere with seining. A disadvantage of locating the riser outside the pond is that the riser and barrel pipe are hydraulically charged or pressurized at all times so all the welds must be good or leaks will develop and cause the dam to fail. Risers placed outside of the pond area will have to be larger because of the reduced head pressure on the pipe opening. The dam's freeboard may have to be increased also, adding to the expense. Large watersheds may preclude the outside placement of the riser for safety reasons. In colder, northern climates outside risers may freeze. Riser placement should be a carefully engineered consideration.

A canal gate or alfalfa valve is installed to regulate discharge.

Concrete ballasts

If an inside riser is installed, there must be a concrete ballast to counteract buoyancy forces of the water on the riser pipe. Steel pipes, like battleships, have a tendency to float. Buoyant forces are created when any object is submerged in water, whether or not the object is heavier than water. When an object is submerged in water, a force equal to the weight of the water displaced acts upward on the object. A 24-inch riser 10 feet tall will have a buoyant force of 1,372 pounds. In order to counteract this force, 0.6 cubic yards of concrete must be poured around the base of the riser. This amount of concrete weighs 2,430 pounds in the air but only 1,419 pounds under water (again because of the buoyant force on the concrete).

Without a ballast, constant upward forces on the riser pipe will weaken any joints over time and may crack welded seams. Also, water flowing through the pipe causes vibrations and movement. The ballast acts as a damper, adding longevity to the pipe system.

Sizing riser and barrel pipes

The characteristics of the watershed and the typical rainfall in the area are used to size riser and barrel pipes. Riser pipes are larger in diameter than barrel pipes. They are welded together in a "tee." Riser pipes are usually designed for 5-year storms, or rainfalls that occur normally once every 5 years for a 24-hour period. For the west central area of Alabama, this is about 5 to 6 inches of rain. Of course, the larger the pond and watershed, the larger the riser must be. Barrel pipes are similarily sized. It is obviously better to oversize pipes than to undersize them.

Emergency spillways and dam freeboards

Emergency spillways are required, particularly if ponds are located on large watersheds. Spillways can discharge large volumes of water around the dam. If properly designed, they will prevent water from overtopping the dam. Spillways are designed large enough to handle a 25-year storm. This size storm also establishes the top-of-the-dam elevation that includes adequate freeboard—the distance between the designed flow of the emergency spillway and the top of the dam. This critical dimension is a minimum of 1 foot (Fig. 5). There should be a vertical drop where the spillway discharges into a natural watercourse to discourage wild fish from entering the production pond. The spillway should be transversely flat, shallow, and grassed to minimize any channeling of water by erosion. The proper sizing of emergency spillways should be determined by qualified persons, especially if dams are located in potentially hazardous areas.

Establishing vegetation

Some new pond owners pay a lot for pond construction and then neglect to finish the project. Unless the soil is protected it may wash into the bottom of the pond. Gullies and rills can develop with the first rainfall, making maintenance difficult and even jeopardizing the integrity of the dam.

To prevent this, vegetation should be established as quickly as possible. If surface soil was stockpiled before construction, use it to top dress banks and dams. This will promote quick and stable vegetative cover. Soil on slopes should be roughed up with a disc or spike harrow. This encourages rainfall to soak in instead of running off and reduces erosion. Distribute lime, fertilizer, seed and mulch at recommended rates. Depending on the season, plant warm or cool season grasses. Check with your county Extension office for recommendations.

All-weather gravel roads to and on the dam are necessary for checking water quality, operating and maintaining aerators, and carrying out stocking and harvesting operations. If banks have good sod cover, it shouldn't be necessary to have gravel completely around the pond.

A trash rack should be installed on top of the riser if it is located inside the pond. This keeps debris from entering the pipe and clogging it.

For more information on watershed pond construction please contact the NRCS office and the Extension aquaculture specialist in your area.

Material for this publication was partially derived from NRCS information, the publication "Pond Building: A guide to planning, constructing, and maintaining recreational ponds" (ANR-114, Alabama Cooperative Extension System, by Chris Hyde and Perry Oakes), and "Channel Catfish Culture," edited by C. S. Tucker.

The author thanks Bill Kyser of Kyser Catfish Farms, Wilmer Penner of Penner Pond Construction and Bill Hemstreet for critically reviewing the manuscript, and Mickey Barton, Gayle Barnette and Bruce Dupree for their assistance with the drawings.

SRAC fact sheets are reviewed annually by the Publications, Videos and Computer Software Steering Committee. Fact sheets are revised as new knowledge becomes available. Fact sheets that have not been revised are considered to reflect the current state of knowledge.

The work reported in this publication was supported in part by the Southern Regional Aquaculture Center through Grant No. 00-38500-8992 from the United States Department of Agriculture, Cooperative State Research, Education, and Extension Service.