WATER WISE

Pond Construction for Residential and Commercial Properties

Best Management Practices for

Water Conservation and Pond Management

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Water-Wise Approaches for Creating a Pond

In Colorado's dry climate, adding a pond to your landscape—whether for aesthetic or practical purposes—is a welcome departure from our mostly dry, desert-like environment. Homeowners and businesses typically choose to build a pond strictly to enhance the beauty of their environment. Ranchers and farmers use ponds for other reasons, such as storing water for livestock and crops. Golf courses rely on ponds to hold irrigation water for the hundreds of acres of turf they must keep from drying up and dying.

Regardless of why you want or need a pond, it's important to recognize that building one is not as simple as planting a garden. For your pond to be legal, cost effective and properly constructed, a great deal of consideration must go into:

- Safety - If the pond is accessible to children, it could be a liability. Also, if a dam is built to create the pond, use a certified professional for design and construction.
- Obtaining the legal right to or ownership of the water source.
- A sufficient quantity of water.
- Specific site - Is the topography of your land suited for a pond? Will it both increase the value of your land and be functional? Will there be enough holding capacity?
- Soil type - sandy (porous) versus clay (less porous).
- Pond type - perched above ground water level or intercepts groundwater.
- Environmental impacts - wildlife can benefit from the pond. Fish must be native, or there must be screens or other devices installed to prevent mixing native and non-native species downstream, thus causing more competition for native species.
- Seepage - water that leaks from unlined ponds and greatly contributes to groundwater that transports salts and selenium downstream.
- Maintenance - Cleaning, draining, and landscaping takes time and effort.

Safety, Liability and Regulation

Ponds, like any body of water, attract both animals and people. Is it safe for wildlife drinking from or swimming in your pond? What is the likelihood that a small child, who doesn't know how to swim, could fall into your pond? How tempting will it be for older kids who want to jump in on a hot day, or take a moonlit dip? How will you prevent injury or drowning? Is the pond easily accessible to the public?

Consider these points carefully as you may be liable in the case of injury or death resulting from use of your pond whether you authorized such use or not.

- Human *safety* isn't the only safety consideration. Environmental hazards also pose dangers. Do not locate your pond where failure of a dam could cause: loss of life; injury to persons or livestock; damage to residences, buildings, or highways; or interrupted use of public utilities. Always consult an engineer experienced in pond design to reduce the possibility of failure from improper design or construction.
- Be sure that no buried *pipelines or cables* cross the proposed pond site. They could be broken or punctured by the excavating equipment, which can result not only in damage to the utility, but also in injury to the operator of the equipment. Colorado law requires that the Utility Notification Center of Colorado be contacted prior to any excavation over 18 inches deep, and it is best to notify them of any excavation. Their services are free. You can reach them at: 1-800-922-1987.
- *Permits:* Creating a safe, clean and functional pond depends both on common sense and following regulations. Prior to construction, Coloradoans are required to complete a 'Notice of intent to construct a non-jurisdictional water impoundment.' This is a simple form that must be filed with the Colorado Division of Water Resources (CDWR) and allows them to track ponds and their associated water rights (http://water.state.co.us/). They can also help clarify what kinds of permits you need.

Photo: Leigh Fortson

You must obtain all required permits including a depletion permit from the United States Fish and Wildlife Service (USFWS, http://www.fws.gov/). This is for water loss due to evapotranspiration from the pond. The water loss is considered a loss from the Colorado River, and a negative effect on the endangered Colorado River fish. Contact the USFWS prior to hiring a contractor. If wetlands are involved, a permit may be required from the Corps of Engineers. Pond sites that involve a total of one or more acres of land disturbance during construction require a Colorado Discharge Permit System (CDPS) permit issued from the Colorado Department of Public Health and Environment. This permit requires that a Stormwater Management Plan (SWMP) be developed and implemented to control erosion and other stormwater pollution sources during construction, and also requires that the management practices be monitored to ensure they are working properly.

All ponds require some form of water rights permit, unless stated by the CDWR. The State of Colorado classifies dams as follows:

- Class I – a dam for which loss of human life is expected in the event of failure of the dam.
- Class II – a dam for which significant damage is expected to occur, but no loss of human life is expected in the event of failure of the dam. Significant damage is defined as damage to structures

where people generally live, work, or recreate, or public or private facilities exclusive of paved roads and picnic areas. Damage means rendering the structures as uninhabitable or inoperable.

- Class III – a dam for which loss of human life is not expected and damage to structures and public facilities is not expected.
- Class IV - a dam for which no loss of human life is expected, and which damage will occur only to the dam owner's property in the event of the failure of the dam.

Choosing a Site

Photo: Leigh Fortson

Before breaking ground, you'll need to get advice from a consulting engineer about whether the conditions on your property are well-suited for a pond. The Natural Resources Conservation Service (NRCS) representatives work primarily with landowners who have several agricultural acres, and generally do not provide technical or financial services for residential and commercial properties.

First, explore the legal rights of using the water for a pond. What is the source of the water? Irrigation delivery system? A natural stream? Do you have the legal right (diversion right) to use the water for these purposes? Have you secured a storage permit so you are legally storing it? Has the water been appropriately filed or documented with the Colorado Division of Water Resources?

Choosing your site is every bit as important as the actual construction process. A well-selected site and proper construction can ultimately save you tens-of-thousands of dollars in repairs, reconstruction and legal fees.

To minimize leakage, it's also critical that the pond be lined if it is perched above the groundwater table. Unlined perched ponds that are built on or above soils derived from Mancos shale are responsible for some of the seepage that transports salts and selenium into the rivers, harming fish and wildlife. Leaky ponds can negatively impact downstream homeowners, structures and utility infrastructure. If the source of trouble is tracked to leakage from your pond, you could be liable for damages.

Engineers can design a leak-free pond with either an impermeable lining of a synthetic material, or a slightly permeable compacted clay liner such as commercially available bentonite clay. There's more information about preventing leakage and lining the pond later in this booklet.

The location of your pond will be determined, in part, by capacity. Since it's so dry here, adequate capacity matters because if you don't start with enough water, you'll lose it quickly. The evaporation rate from an open water surface in the Tri-County area of Western Colorado is about 3-4 feet per year. This means that if your pond is eight feet or 96 inches deep, the top 36-48 inches will evaporate in the course of a year if there is zero inflow and zero outflow. An acre-size pond will lose 3-4 acre feet (or 1.3 million gallons) of water throughout the year to evaporation. Start your plans with an estimate on how large your pond needs to be. Seek assistance from NRCS or an engineer.

Even though your pond's depth-to-surface ratio is impacted by evaporation, it isn't the only factor to consider. Capacity should be determined by the amount, duration and dependability of the water source.

The other key factors in pond sizing are:

- Physical location
- Drainage area feeding the pond
- Purpose of the pond
- Budget

A hefty budget can almost always remedy whatever might go wrong, but you may want to limit the amount of money you invest in your pond. Ultimately, budgets should be determined by the purpose of the pond.

The legal requirements of embankment ponds often determine the size of them. However, an increase in size can cause the legal requirements to change, which can alter the budget. Again, get the help you need to make the right decisions for your pond.

Other factors that will determine the placement of your pond are as follows:

Soils

With an idea of how big the pond needs to be, it's time to determine if your soils are appropriate.

The composition of soils in the lower Gunnison Basin and Grand Valley range from:

- Fine textured (clay) soil with good water-holding capacities
- Coarser textured (sandy) soils, with lower water-holding capacities
- Silt soils with an intermediate texture that falls between the clay and sandy soils

Photo: Jeff Vanuga, USDA-NRCS

Take note that permeability and water-holding capacity are very different. The suitability of a pond site depends on the ability of the soils to hold water. Permeability is most important for ponds; water-holding capacity is most important for agronomic purposes and irrigation water management.

Even though you will likely be lining your pond, the best soil should contain a layer that is impervious and thick enough (usually a two-foot minimum) to prevent excessive seepage in case of a lining leak. Synthetic pond liners need properly conditioned soils with a good foundation to prevent soil movement that causes liners to yield and break. Also, protect liners from course material such as rock to prevent punctures. In general, soils with more than 40% clay content and less than 15% rock and gravel should be suitable for pond construction; sandy clays are unsatisfactory. Coarse-textured sands and sand-gravel mixtures do not hold water well.

If the site you have selected has poor soils, it's possible to make it impervious by importing and compacting a good-quality clay soil incorporating bentonite clay into the pond bottom. Keep in mind, however, that sealing pond bottoms that way can be very expensive. If soils are questionable, choose a secondary pond site with better soils.

Unfortunately, some of the soils in the lower Gunnison River Basin and Grand Valley are just not suitable for pond construction and are doomed for failure no matter how well the pond is constructed. Don't get tempted to cut corners or try it anyway; it will cost you in the end.

When you investigate how best to line your pond, be aware that parent material such as rock and ground water, can all become construction and design hurdles that could increase your budget.

Pond Types

There are several types of ponds.

- Embankment Ponds

Also called a watershed pond or hill pond. A watershed is the drainage area around the pond within which rainfall runoff drains toward the pond. A dam or embankment is constructed in a depression between two hills and serves to impound water in a basin area on the upstream side of the dam. This type of pond is best suited in areas with slightly to moderately rolling topography.

Embankment ponds usually depend on rainfall runoff or irrigation water to fill and then maintain water levels. This type of pond works well in the high country where there is more seasonal moisture and snow pack runoff, as it all goes back into the water supply. Pond size, shape, and depth are limited by the topography of the site and the size of the watershed draining to the pond. Generally, the steeper the slope of the pond site, the smaller the pond that can be constructed. Well-sited embankment ponds generally require the least amount of earthmoving per acre of water impounded compared to other types of ponds. Because construction costs are based largely on the amount of earthmoving, an embankment pond is generally the least expensive type of pond per surface acre of water to construct.

Building a dam across a large, permanent stream is not recommended when constructing a pond. Following heavy rainfall, streams often carry large amounts of suspended sediments that will settle out in the pond and severely shorten its useful life. Ponds fed by large streams can be difficult to manage for fishing due to competition from non-native fish, the introduction of fish diseases, and the inability to effectively fertilize the pond due to excessive outflow. Hence, it's best to construct ponds away from perennial streams and/or channels.

Furthermore, most perennial streams that contain non-native fish in the Grand Valley are used for spawning areas. Native fish, such as the flannel mouth sucker, migrate up these streams from the Colorado River, so an embankment-type pond in the stream will act as a barrier to this spawning migration.

Most streams in the high country contain non-native rainbow, brook, or brown trout, but there are isolated populations of native Colorado River cutthroat trout. Consult with the Colorado Division of Wildlife (CDOW) before any embankment pond is constructed. They can help determine if there are native Colorado cutthroat present.

The majority of ponds around the Grand Valley have an abundance of algae. Ask your NRCS representative or the CDOW for ideas on control methods.

Embankment ponds can also create costly engineering expenses so as to prevent breeching as a result of severe storms. Damaging weather is inevitable, so engineers must determine the economic and legal requirements for potential hazards that could cause the dam to fail.

Photo: Jeff Vanuga, Courtesy USDA-NRCS

- Excavated Ponds

Excavated, or "dug," ponds are constructed almost entirely below original ground level. This construction method is usually used only for construction of small ponds (generally less than 1/2 acre) because of the large amount of earthmoving required in relation to the size of the pond. Excavated ponds require an external water source to fill and maintain the pond where springs, groundwater, or runoff are not sufficient. An excavated pond is usually the most expensive type of pond to construct on a per-acre basis.

- Levee Ponds

Suitable for flat or nearly flat land, levee ponds are only partially excavated. Earth from what is to be the basin area of the pond is removed and used to construct the sides, or levees, of the pond that impound the water. The water level in a levee pond is higher than the original ground level. Water depth is usually similar throughout the pond and is regulated by the height of the outlet pipes and constructed levees. An externally pumped water source, such as a creek, will be necessary to fill and maintain this type of pond due to the absence of a watershed. Per-acre construction costs of levee ponds generally fall between those of watershed and excavated ponds.

- Combination Watershed-Levee Ponds

An example of a combination watershed-levee pond would be a two- or three-sided levee pond that connects to an existing hill to form its other side. Depending on the site, the hill side of the pond can provide a significant amount of watershed runoff to the pond, thus reducing and, in some cases, eliminating the need for pumping water to fill and maintain the pond.

Don't expect yourself to know with certainty which type of pond is best for you. Consult a professional for help.

Source of Water

The three sources of water for filling ponds are: rainfall runoff, groundwater, and surface water. Each has advantages and disadvantages.

- Rainfall Runoff

Rainfall runoff is the primary source of water for embankment ponds. It comes from the drainage or watershed area surrounding the pond. The best runoff water source for ponds is a watershed containing undisturbed, well-vegetated cover such as timberland or grassland. In the Delta, Montrose, and Mesa counties where most development is slated to occur, we have relatively unvegetated watersheds with excess muddiness.

- Groundwater

Groundwater can serve as a source of water to excavated ponds, or as a supplementary source to ponds with inadequate watersheds or excessive seepage. Well water in the Gunnison Basin and Grand Valley is generally not suitable as a water source for ponds, due to the high salt content.

- Surface Water

Surface water from nearby irrigation ditches, springs, streams, rivers, or reservoirs with good water quality can be used as a pond water source. For properties in the lower Gunnison Basin and Grand Valley, potential sources of surface water include tributaries (i.e. water from streams, rivers, washes, or drains) and the numerous canal systems throughout our areas. Remember: the soils in the lower Gunnison River Basin and Grand Valley are typically characterized by Mancos shale—soils high in salt and selenium. That can also be true for tributary waters. If you are relying on water from a tributary source, test it to see if it's high in salts. If so, don't use this water for irrigating. Saline or salty water can burn turf and stress landscape plants.

Photo: Gary Kramer, USDA NRCS

If using surface water, you must file for your rights to divert the water and use it for the purpose intended. Diversion and storage permits are available from the CDWR.

Environmental Impacts and Pond Lining

It's typical for an unlined pond to leak several feet of water in a year. That wasted water then leaches tons of salts, which include calcium, magnesium, and selenium compounds from the soil and dumps it into the river. Generally speaking, "perched" ponds (those constructed above groundwater level) tend to leak more than "unperched" ponds (those built in existing wet areas). Pond leakage is one reason to line your pond. But there are other reasons that affect the pond owner more directly.

Leakage not only elevates selenium that threatens fish and wildlife, it also weakens the structure of the pond itself, can cause problems with adjacent septic systems and building foundations, and can cause slope failure of the dam. Recently, irrigation storage ponds were not lined nor were delivery systems piped for a newly built golf course in Delta. This resulted in considerable seepage that created environmental hazards for people located nearby. Consequently, the ponds were lined and delivery systems improved after the original construction. The time and cost were significant. Lining your pond, or creating an effective barrier, is as important as filling the pond with water. It simply needs to happen.

Surface seep resulting from pond seepage and irrigation at the Devil's Thumb Golf Course near Delta. (Photo: Delta County)

There are several different approaches for keeping water in the pond, thus ensuring a healthy environment and safe, strong pond structure:

Installing a liner at the Devil's Thumb Golf Course pond (Photo: Delta County)

- Waterproof linings: This is a good method to reduce excessive leakage in both coarse-grained and fine-grained soils. Polyethylene, vinyl, butyl-rubber membranes, and asphalt-sealed fabric liners are gaining acceptance as linings for ponds because, if properly installed, they virtually eliminate leakage. Care must be taken to avoid breaking or puncturing the liner. All liners should have a cover of six inches of earth, or earth and gravel, to protect against punctures, and for UV protection.

- Compaction: Soil moisture and an effective compacting effort can create a good, protective barrier around the pond. Moisture content of the soil must be monitored. Soil that is too dry or too wet will not properly compact. Compaction of the soils is the least expensive method and the effectiveness is entirely dependent on soil properties.

- Clay blankets: Ponds that contain high percentages of course grained soils, but lack enough clay to prevent leakage, can be sealed by blanketing. The blanket should include material containing at least 20 percent clay. Clay blankets must be protected against cracking that results from drying and against rupture caused by freezing and thawing.

- Bentonite: This is a fine-textured colloidal clay. Adding bentonite can reduce excessive leakage in soils made of coarse-grained particles, and low in clay content. Upon wetting, bentonite absorbs water and swells eight to 20 times its original volume. Mixed in the right proportions with well-graded coarse-grained material, thoroughly compacted, then saturated, the bentonite particles swell to the point that the mixture is nearly impervious to water. On drying, however, bentonite returns to its original volume leaving cracks that can lead to significant leakage. For this reason, it is not recommended for ponds in which water levels are expected to fluctuate widely.

Keep in mind, however, that improper installation can cause excess suspension of clay particles and often cause depleted oxygen to fish and aquatic species. This can be rectified by using a flocculent, but is best managed by competent, quality construction and testing.

Note that clay blankets and bentonite are similar. Usually clay blankets are made up of bentonite that's situated between two pieces of geotextile. These blankets, or mats, have equivalent installation prices to synthetic liners, but don't have near the reliability.

- Chemical additives: Applying small amounts of certain chemicals, like polyacrylimide, or PAM to porous aggregates may result in the rearrangement of clay particles, reducing permeability. A laboratory analysis of the soil in the pond area is needed to determine which dispersing agent will be most effective. Flocculants and dispersants can be used. Flocculants rely mostly on clay particles in suspension in the pond water or incoming water.

Maintenance

Ponds require periodic maintenance.

Cleaning: If the inflow water contains trash, such as weeds and other organic materials, the inflow will need to be screened. Most irrigation ditches that supply water will carry a considerable amount of silt at specific times of the irrigation season. Consequently, you may need to clean your pond every year or so to maintain the desired capacity. Great care must be taken during the cleaning process to avoid damage to the pond liner. Many ponds are designed with two chambers, the first which is used as a stilling basin to allow the silt load to settle out before it enters the main storage area.

Vegetation Management: In addition to removing debris from the filter when necessary, pond bank vegetation should not be allowed to grow uncontrolled. Common phragmites should be avoided, if possible. Cattails, willows, reeds, and sedges are acceptable in some areas, but excessive shoreline vegetation will limit access to pond banks. Thick vegetation on banks also provides habitat for muskrats and beavers, which can cause severe damage to ponds.

Noxious weeds must also be controlled. They can find their way into ponds from inflow water, animals, and humans carrying seeds to the site.

Don't let trees grow on a new pond dam, and remove any smaller trees (less than six inches in diameter) found on older pond dams. Tree roots can eventually penetrate the core of the dam and cause excessive pond leakage. Cutting down larger, existing trees (over six inches in diameter) will result in deteriorating roots leaving large voids in the dam.

Photo: Bob Nichols, USDA-NRCS

Spillways also need to be maintained. The original design crest of spillways should be maintained to the design height, and never increased without sound engineering evaluation. Never construct objects in auxiliary spillways, nor plant trees in them.

Cattle and other livestock can be detrimental to ponds and should not have uncontrolled access. The damage they cause to the banks can shorten the life of a pond. They do this by trampling edges, exposing soil of pond banks through overgrazing, and muddying the pond through wading. This causes premature siltation and shallowing of the edges. Shallowing of pond edges promotes aquatic weed growth. Cattle wading in the pond may introduce nutrients that will increase the productivity of the pond, thus increasing the oxygen producing algae and aquatic plants. The dissolved oxygen level can decrease to lethal levels when these algae or aquatic plants are in a non-productive state, such as during the night or on cloudy days. The decreased amount of oxygen being produced along with the normal consumption of oxygen from fish, insects, bacteria, etc., can decrease the oxygen significantly.

Ponds can serve the purpose of stock watering without allowing direct animal access to the pond. A watering line can be installed through the dam during construction to provide water to a trough below the dam. Gravity-flow waterlines can also be installed over the dam of existing ponds. For information about installing livestock watering devices, contact your local NRCS office.

Stocking permits or lake licenses may need to be obtained from the CDOW before you can stock fish in your pond. If you do have fish in your pond, keep in mind that aquatic vegetation may not be necessary nor desirable for maintaining a healthy fish population. In fact, aquatic vegetation can interfere with fishing, decrease the quality and quantity of the fish, and make ponds unattractive. The vegetation can grow to the point where it is a nuisance and be considered a weed. For more information on maintaining fish in your pond, go to: http://wildlife.state.co.us/ .

Photo: Lynn Betts, USDA-NRCS

Other Considerations

We've covered the basics required to build and maintain a useful and cost-effective pond. But there are other considerations, including mosquito control.

West Nile virus has found its way into Western Colorado communities. It's likely to stay, and since it's transmitted to humans and animals (both wild and domestic) through mosquito bites, you may want to investigate various ways to control the mosquitoes. Placing bird houses near your pond and encouraging bird populations may help. Bat houses are also effective; a brown myotis bat can consume up to 600 insects in a single night. Larvicides can also do a good job. For more information, go to: http://www.ext.colostate.edu/PUBS/INSECT/05526.html.

Also note that ponds in the Colorado River Basin, including the Gunnison basin below 6500 feet in elevation, require fish screens to prevent non-native fish species from entering the rivers. Screens may be necessary even if owners have no intention of stocking the pond with non-native species. The requirements are set by the USFWS and can be obtained there, or through the CDOW.

Artwork by Scott Patton, Courtesy USDA-NRCS

Conclusion

Ponds are a beautiful addition to any landscape. Even so, if they are not required for your business or environment, it's best not to construct them. The amount of water lost to evapotranspiration and to seepage, takes an enormous toll on our rivers, wildlife and fish.

Clearly, if building a pond is integral to your agricultural operation or for other essential reasons, please follow the guidelines in this booklet and work closely with your engineer or NRCS representative.

Being good stewards of water by constructing ponds with water-wise principles promises a better return on your investment, time savings, cleaner rivers, and a brighter world for future generations in Western Colorado.

Resources for More Information

Much of the information in this booklet was obtained from "*Pond Building: A Guide to Planning, Constructing, and Maintaining Recreational Ponds*." Chris Hyde, Extension Aquaculturist, Alabama Cooperative Extension System, and Perry Oaks, State Conservations Engineer, USDA-NRCS, Alabama. http://www.aces.edu/pubs/docs/A/ANR-1114/

To download more copies of this booklet and to obtain more information on wise water use inside and outside of your residential home, and for wise water use at golf courses and large-acre properties, go to: http://www.thedripwebsite.com, or http://www.seleniumtaskforce.org

Here is a list of resources that can help you navigate your way through the world of wise water use:

Colorado State University Cooperative Extension Offices:

http://www.coopext.colostate.edu/TRA/PLANTS/index.html#main.html

http://www.coopext.colostate.edu/WR/

Delta County 970-874-2195 Montrose County 970-249-3935

Mesa County (Grand Junction) 970-244-1834

Gunnison County 970-641-1260

Natural Resources Conservation Service (NRCS) Offices:

Delta	970-874-5735
Montrose	970-249-8407
Grand Junction	970-242-4511

To learn more about the following topics, go to the related web link:

Pond Construction and Maintenance:

http://www.aces.edu/pubs/docs/A/ANR-1114/

Colorado Division of Water Resource:

http://water.state.co.us/

Colorado Department of Wildlife:

http://wildlife.state.co.us/

Colorado/Gunnison Basin Army Corps of Engineers:

http://wildlife.state.co.us/LandWater/WetlandsProgram/IsItAWetland/

Drought:

http://cwrri.colostate.edu/droughtpubs.html

http://ccc.atmos.colostate.edu/drought.php

http://www.thedripwebsite.com

Evapotranspiration:

http://ccc.atmos.colostate.edu/~coagmet/extended_etr_about.php/

http://www.irrigationprovidersgv.org/soil.html

Irrigation Systems and Guidance:

http://www.ext.colostate.edu/pubs/Garden/07239.html

http://www.irrigationtutorials.com

http://www.ext.colostate.edu/PUBS/Garden/04702.html

Mesa County Water Audit:

http://www.coopext.colostate.edu/TRA/PLANTS/2005_irrigation_audit_final_report.pdf

Mosquito Control:

http://www.ext.colostate.edu/PUBS/INSECT/05526.html

http://wsprod.colostate.edu/cwis79/mosq/entire.cfm

Selenium:

http://www.seleniumtaskforce.org

http://www.ext.colostate.edu/PUBS/natres/06109.html

Soil Amendments:

http://www.ext.colostate.edu/ptlk/ptlk1600.html

Soils in Western Colorado:

http://www.coopext.colostate.edu/TRA/PLANTS/index.html#

http:// www.coopext.colostate.edu/TRA/PLANTS/soil.html

http://www.co.nrcs.usda.gov/technical/soil/soil-index.htm

West Nile Virus:

http://www.ext.colostate.edu/westnile/reslist.html

Books:

Matson, Tim. 1997. *Earth Ponds Sourcebook: The pond owner's manual and resource guide*. The Countryman Press, Woodstock, VT.

Matson, Tim. 1991. *Earth Ponds: The country pond maker's guide to building, maintenance and restoration*. Second Edition. Countryman Press, Woodstock, VT.

Porter, Valerie. 1988. *The Pond Book*. Christopher Helm Publishers, London, England.

"Ponds - Planning, Design, Construction." The USDA Natural Resources Conservation Service (NRCS)- Agriculture Handbook 590. Contains detailed information on design surveys, site selection, drainage area, pond layouts, soil analysis and spillway construction. Contact your county NRCS office or download a copy from the UDSA NRCS website to obtain this publication.