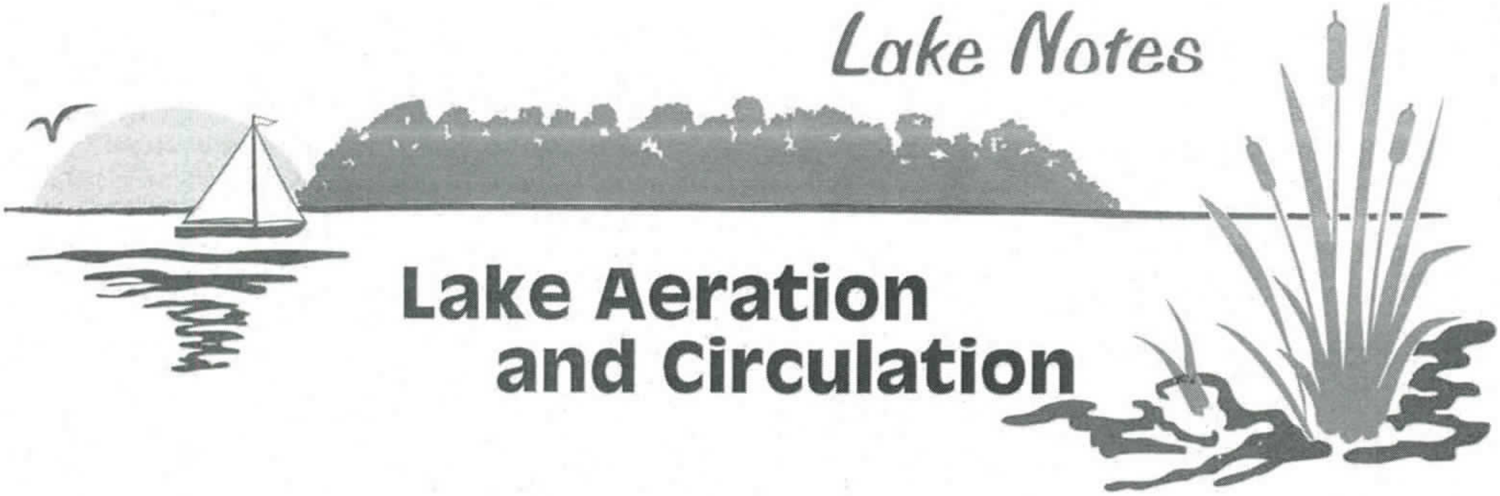


Lake Notes

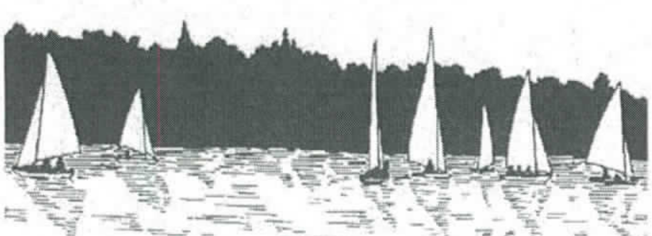
# Lake Aeration and Circulation

The purpose of aeration in lake management is to increase the dissolved oxygen content of the water. Various systems are available to help do this—by either injecting air, mechanically mixing or agitating the water, or even injecting pure oxygen.

Aeration can increase fish and other aquatic animal habitat, prevent fishkills, and improve the quality of domestic and industrial water supplies and decrease treatment costs. In some cases, nuisance algal blooms can be reduced or a shift to less objectionable algae species can occur. However, aeration can be misused. It is not a "cure-all" for a lake's ills. It's important to understand what aeration can and can't do for your lake so you don't end up with unexpected or unwanted results—and possibly a waste of money.

This issue in the *Lake Notes* series focuses on ***artificial circulation*** as a lake aeration technique. We'll explore its applicability, potential consequences, and other factors to be considered before deciding to invest in an artificial circulation system—or in reevaluating the system you already have in place.

**Note to the Reader:**
This *Lake Notes* fact sheet uses some rather complex terms that may be unfamiliar to you. In order to better understand their meaning, you are encouraged to first read another fact sheet in the *Lake Notes* series, "Lake Stratification and Mixing."



## Artificial Circulation Systems

Lakes get much of their oxygen from the atmosphere through a process called diffusion. Artificial circulation increases a lake's oxygen by forcefully circulating the water to expose more of it to the atmosphere. Proper choice and design of an artificial circulation system depends on your lake management goals and the lake's physical characteristics.

### Destratifiers

Destratification is a type of artificial circulation that completely mixes a stratified lake's waters from top to bottom and thereby eliminates or prevents summer stratification (the division of a lake into water layers of different temperatures). Two techniques are most common: air injection and mechanical mixing.

- **Air Injection (Diffuser) Systems** are the most common destratification method. A compressor on shore delivers air through lines connected to a perforated pipe(s) or other simple diffuser(s) placed near the bottom, typically in the deep area of the lake. The rising air bubbles cause water in the hypolimnion (the cold, bottom water layer) to also rise, pulling this water into the epilimnion (warm, surface water layer). When the colder, hypolimnetic water reaches the lake surface, it flows across the surface and eventually sinks, mixing with the warmer epilimnetic water. If the system is adequately powered and enough air is injected, this process continues and the metalimnion (transition zone between the epilimnion and hypolimnion) is broken down. Eventually, the entire lake becomes of nearly equal temperature with oxygen distributed throughout. Many people are surprised to learn that the majority of oxygenation occurs through the water's contact with the atmosphere; relatively little oxygen increase occurs through direct diffusion from the bubbles. This aeration technique is

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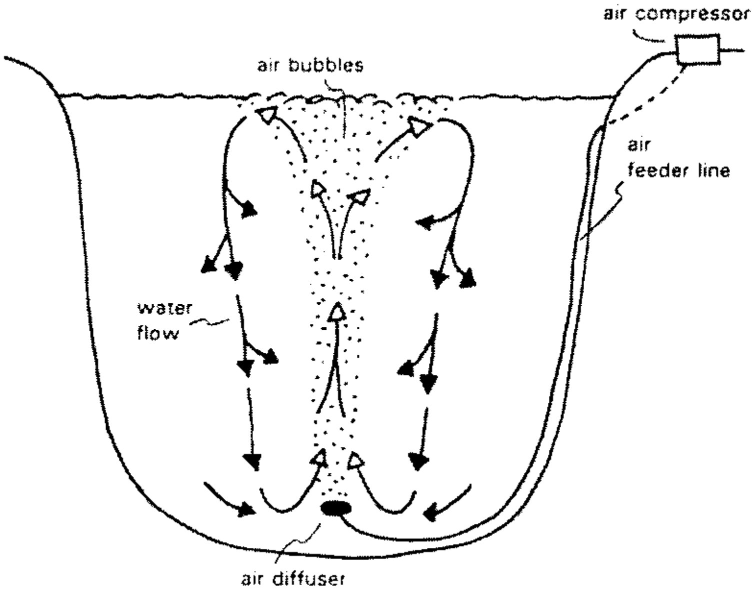
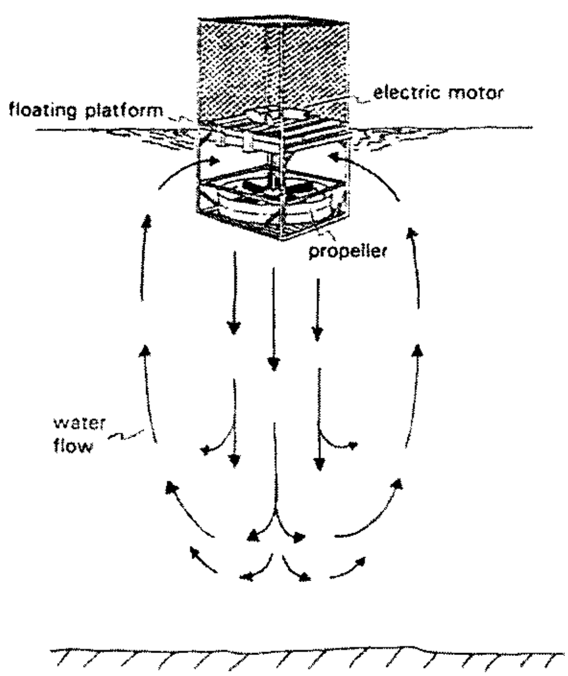
sometimes referred to as the *air-lift* method of circulation, since bottom waters are "lifted" to the lake surface through the action of the injected air.



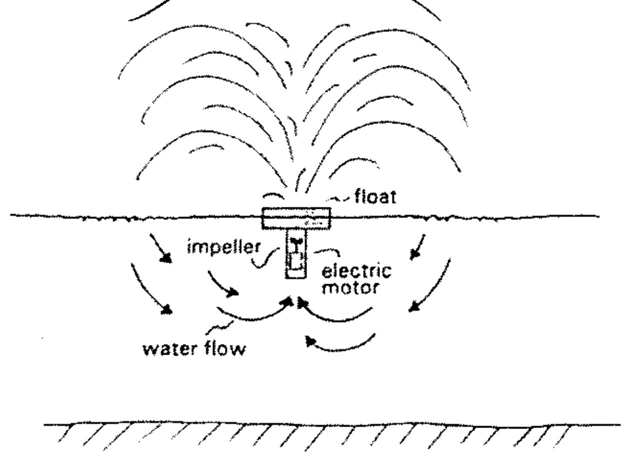

■ **Mechanical Axial Flow Pumps** use a "top-down" approach to set up a circulation pattern. A floatation platform and frame support an electric motor, gearbox, drive shaft, and large propeller (6–15 foot diameter). The propeller is suspended just a few feet below the water surface. Its rotation "pushes" water from the lake surface downward, setting up a circulation pattern that prevents thermal stratification. Oxygen-poor water from the lake bottom is circulated to the lake surface, where oxygenation from the atmosphere can then occur. These systems are being utilized in several Illinois water supply reservoirs.



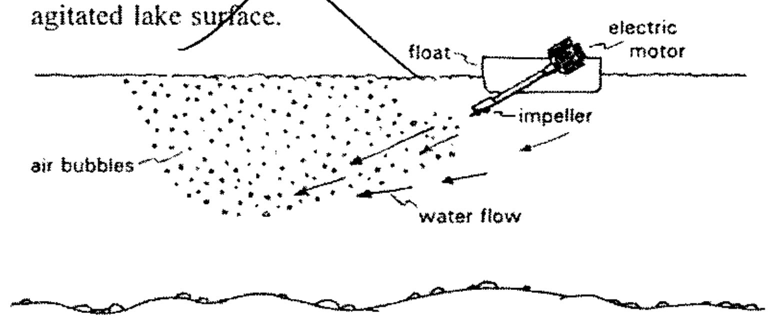

## Other Systems

Other mechanical circulation systems include surface spray units, impeller-aspirators, and pump-and-cascade systems. While they do set up a circulation pattern in the water, they typically are not designed to destratify a lake. Hence, they probably have more applicability in non-stratified (shallow) lakes and ponds to enhance the water's oxygen content.

■ **Surface Spray** units consist of a float supporting an electric motor-driven impeller. The rapidly-turning impeller pulls water up a vertical tube and throws it out in an umbrella- or fountain-shaped spray a few to many feet above the lake surface. Atmospheric reaeration occurs in the sprayed water and at the agitated lake surface.




■ **Impeller-Aspirator** systems consist of an electric motor-driven impeller at the bottom of a hollow shaft extending at an angle down into the water. The assembly floats on the lake surface. The rapidly-turning impeller draws air down the shaft and propels water and air bubbles into the lake. Aeration takes place through air bubble/water contact and at the agitated lake surface.

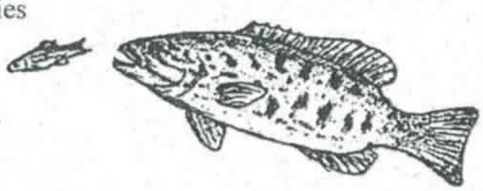



■ **Pump-and-Cascade** systems consist of a large pump that moves lake water to the top of a ramp-like chute containing numerous baffles. The water cascades down the ramp and falls back into the lake at a point located as far as possible from the water inlet (to prevent recycling of just-pumped water). Aeration occurs in the cascade chute and in the plunge pool as the water flows away from the ramp.

## Effects of Destratification/ Circulation

■ **Dissolved Oxygen:** The most common result of destratification is an improvement in dissolved oxygen levels—and consequent benefits on warmwater fish and water supply quality.

■ **Fish:** Destratification is generally considered beneficial for warmwater fish. Fish require adequate dissolved oxygen levels and cannot survive in an oxygen-deficient hypolimnion. Warmwater fish (e.g., bass, bluegill) require a minimum dissolved oxygen concentration of 5 mg/L, and coldwater fish (e.g., trout) need 6-7 mg/L. Destratification allows warm-water fish to inhabit the entire lake, and enhances conditions for fish food organisms as well. However, because destratification warms the deep waters, some coldwater fish species may be eliminated or prevented from inhabiting that lake.



■ **Water Supply Quality:** A common result of destratification is an improvement in industrial and drinking water supply quality (in fact, the first artificial circulation system was used in 1919 in a small water supply reservoir). Under anoxic (without oxygen, anaerobic) conditions, lake bottom sediments release metals (iron, manganese) and gases (hydrogen sulfide)—which can cause taste and odor problems in drinking water. When the anoxic hypolimnion is eliminated, these problems are eliminated or greatly reduced as well. Water treatment costs also decrease.

■ **Phytoplankton:** The effects on phytoplankton (algae) are less predictable. Destratification *may* reduce algae through one or more processes: 1) algal cells will be mixed to deeper, darker lake areas, decreasing the cells' time in sunlight and thereby reducing their growth rate, 2) some algae species that tend to sink quickly and need mixing currents to remain suspended (e.g., diatoms) may be favored over more buoyant species such as the more noxious blue-greens, 3) changes in the lake's water chemistry (pH, carbon dioxide, alkalinity) brought about by higher dissolved oxygen levels can lead to a shift from blue-green to less noxious green algae or diatoms, and 4) mixing of algae-eating zooplankton into deeper, darker waters reduces their chances of being eaten by sight-feeding fish; hence, if more zooplankton survive, their consumption of algal cells also may increase.

While algal blooms have been reduced in some lake destratification/circulation projects, in other lakes phytoplankton populations have not changed or have actually increased. For shallow lakes, it's even less likely that complete circulation would result in any of the above-mentioned benefits. This is because algae are less likely to become light-limited in shallow lakes, nor would water chemistry changes be as pronounced.

■ **Phosphorus:** Destratification has the potential to reduce phosphorus (P) concentrations in some lakes. During summer stratification when the hypolimnion is oxygen-poor, P becomes more soluble (dissolvable) and is released from the bottom sediments into the hypolimnion. Because stratified lakes can sometimes partially mix, this allows greater amounts of P to "escape" into the epilimnion. These increased P levels in the lake's surface waters can potentially stimulate an algal bloom. For similar reasons, algal blooms often are seen at fall turnover. Because destratification increases the bottom water's oxygen content, it follows that P release from the sediments should be reduced, which in turn can lead to decreased algae abundance. However, the most suitable candidates for P reduction are deep, stratified lakes where a majority of the lake's P comes from anoxic, hypolimnetic sediments (i.e., internal sources). In lakes where the majority of P comes from external sources (such as watershed runoff, the atmosphere, waterfowl, septic systems), a reduction in sediment P release may not be enough to notice a change in algae abundance.

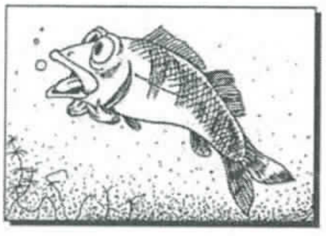
## Winter Operation

Artificial circulation systems also can help prevent winter fishkills in ice-covered lakes. Low dissolved oxygen levels during winter occur because ice covering the lake prevents diffusion of atmospheric oxygen into the water. Even though photosynthesis by some algae and rooted aquatic plants occurs in the winter months under the ice, bacterial decomposition of organic matter on the lake bottom can consume

more oxygen than photosynthesis can replace. Furthermore, if enough snow covers the ice or if the ice is opaque, sunlight will be unable to penetrate and photosynthesis will stop. If under-ice oxygen levels become too low before ice-out, a partial or total fishkill will occur. Shallow lakes are most susceptible to dissolved oxygen depletion since they have a smaller amount of water as compared to deeper lakes.

Studies in Wisconsin and Minnesota have found that air diffuser systems seem most effective in providing efficient, reliable winter aeration. To save energy costs, the system can be run only on an as-needed basis. Careful monitoring of dissolved oxygen levels throughout the winter can be used to determine when, or even if, aeration in a particular year is necessary. Oftentimes, dangerously low oxygen levels do not appear in Illinois lakes until late winter. In most cases, if a lake's average dissolved oxygen level was found to be between 4 and 5 mg/L, start-up would be warranted. After you become more familiar with your lake's situation, start-up can be fine-tuned.

Turbulence from the rising air bubbles and uplifting of the slightly warmer bottom waters will begin opening the ice within a few hours after system start-up. Be aware that if the system is turned on when oxygen concentrations already have fallen too low, mixing of anaerobic bottom water with low-oxygen water just under the ice may cause the entire lake to have oxygen levels too low for fish survival.



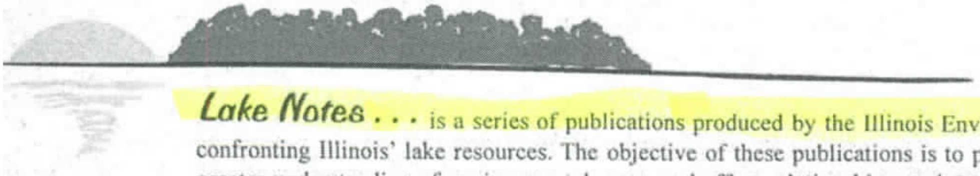
Surface spray units, impeller-aspirators, and pump-and-cascade systems also can be used in the winter to keep an area ice-free. Of the three, pump-and-cascade systems appear to be the most reliable in averting winter fishkills. They also can be moved from lake to lake. On small lakes, their wintertime performance has compared favorably with air diffuser systems.

## Design Considerations

There are several technical issues to consider when designing and installing an artificial circulation system. For example, if the air diffuser is positioned too far above the lake bottom, an anaerobic zone will remain below it. However, if the diffuser is placed on or too near the lake bottom—or if the system is oversized (mixing is too vigorous)—sediments may be stirred up and resuspended in the lake. If the system is undersized, mixing will be incomplete. In very large lakes, mixing will be limited unless more than one device is used.

## To Aerate—or Not to Aerate?

It's a good idea to seek experienced professional help when considering the installation of and in designing a properly-sized aeration system. The first question to consider is whether your lake can really benefit from a destratification/circulation (or other) aeration system. Would summer and/or winter operation be most effective? Answering these questions requires background knowledge of your lake's physical and water quality characteristics. You also should have established lake use goals (e.g., what you'd like to use the lake for, how you'd like the lake to look). Seek out the advice of unbiased water quality professionals—don't limit your advice to just the individual or company proposing to sell you a system! By examining your lake's characteristics together with your goals, you can then better determine whether aeration, and what type of system, might meet your objectives.



*Lake Notes . . .* is a series of publications produced by the Illinois Environmental Protection Agency about issues confronting Illinois' lake resources. The objective of these publications is to provide lake and watershed residents with a greater understanding of environmental cause-and-effect relationships, and actions we all can take to protect our lakes.

This *Lake Notes* publication was prepared by Holly Hudson and Bob Kirschner of the Northeastern Illinois Planning Commission, Chicago, Illinois. Illustrations by Holly Hudson, University of Wisconsin-Extension, Wisconsin Department of Natural Resources, and Illinois State Water Survey.

For more information about other publications in this series and to request copies, please contact: Illinois Environmental Protection Agency, DWPC-Lake and Watershed Unit, P.O. Box 19276, Springfield, Illinois, 62794-9276; 217/782-3362.