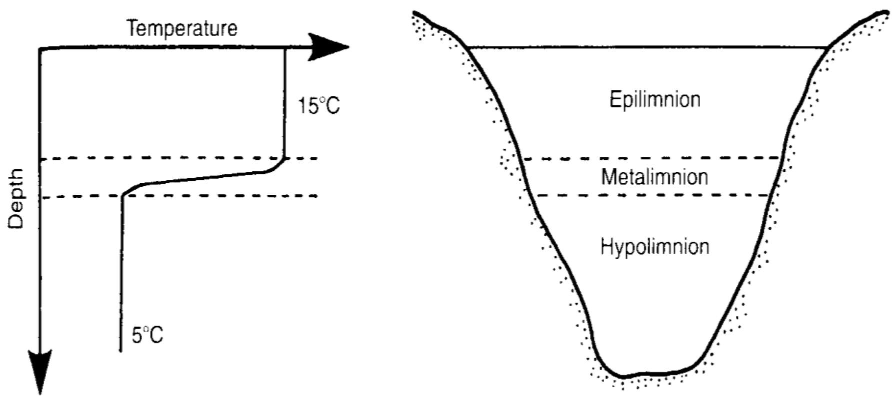
Lakes and Reservoirs:

Most lakes have an input and an output, and so in some ways they can be considered as very slowly flowing rivers. The very long period of time that water remains in the lake or reservoir ensures that the water becomes cleaner due to bacterial activity removing any organic matter present and physical settlement processes, which remove small particulate material. Storage of water, therefore, improves the quality which then minimizes the treatment required before supply.

Natural processes :

1- Thermal stratification is caused by variations in the density of the water in both lakes and reservoirs, although it is mainly a phenomenon of deep lakes. Water is densest at 4°C, when it weighs exactly 1000kg per cubic-meter (kg/m^3). During the summer, the sun heats the surface of the water reducing its density, so that the colder, denser water remains at the bottom of the lake. As the water continues to heat up then two distinct layers develop. The top layer or ***epilimnion*** is much warmer than the lower layer, the ***hypolimnion***. Owing to the differences in density the two layers, separated by a static boundary layer known as the ***metalimnion*** or ***thermocline***, do not mix but remain separate (Figure1).

FIGURE 2.2 Thermal stratification in deep lakes and reservoirs. (Reproduced from Gray (1994) with permission of John Wiley and Sons Ltd. Chichester.)



The epilimnion of lakes and reservoirs is constantly being mixed by the wind and so the whole layer is a uniform temperature. As this water is both warm and exposed to sunlight it provides a very favorable environment for algae. Normally the various nutrients required by the algae for growth, in particular phosphorus and nitrogen, are not present in

large quantities (limiting concentrations). When excess nutrients are present, for example due to agricultural run-off, then massive algal growth may occur. These so-called ***algal blooms*** result in vast increases in the quantity of algae in the water, a phenomenon known as ***eutrophication***. The algae are completely mixed throughout the depth of the epilimnion and in severe cases the water can become highly colored. Normally this top layer of water is clear and full of oxygen, but if eutrophication occurs, then the algae must be removed by treatment. The algae can result in unpleasant tastes in the water even after conventional water treatment, as well as toxins. Like all plants, algae release oxygen during the day by photosynthesis, but at night they remove oxygen from the water during respiration. When eutrophication occurs then the high numbers of algae will severely deplete the oxygen concentration in the water during the hours of darkness, possibly resulting in fish kills. In contrast, there is little mixing or movement in the hypolimnion which rapidly becomes deoxygenated and stagnant, and devoid of the normal aerobic biota. Dead algae and organic matter settling from the upper layers are degraded in this lower layer of the lake. As the hypolimnion has no source of oxygen to replace that already used, its water may become completely devoid of oxygen. Under anaerobic conditions iron, manganese, ammonia, Sulphides, phosphates and silica are all released from sediments in the lake or reservoir into the water while nitrate is reduced to nitrogen gas. This makes the water unfit for supply purposes. For example, iron and manganese will result in discoloured water complaints as well as taste complaints. Ammonia interferes with chlorination, depletes the oxygen faster and acts as a nutrient to encourage eutrophication (as does the phosphorus and silica). Sulphides also deplete the oxygen and interfere with chlorination, have an awful smell and impart noxious taste to the water.

The metalimnion, the zone separating the two layers, has a tendency to move slowly to lower depths as the summer progresses due to heat transfer to the lower hypolimnion. This summer stratification is usually broken up in autumn or early winter as the air temperature falls and the temperature of the epilimnion declines. This increases the density of the water making up the epilimnion to a comparable density with the hypolimnion, making stratification rather unstable. Subsequently, high winds will eventually cause the whole water body to turn over so that the

layers become mixed. Throughout the rest of the year the whole lake remains completely mixed resulting in a significant improvement in water quality. Limited stratification can also develop during the winter as surface water temperatures approach 0°C while the lower water temperature remains at 4°C. This winter stratification is broken up in the spring as the temperature increases and the high winds return as shown in (fig. 2).

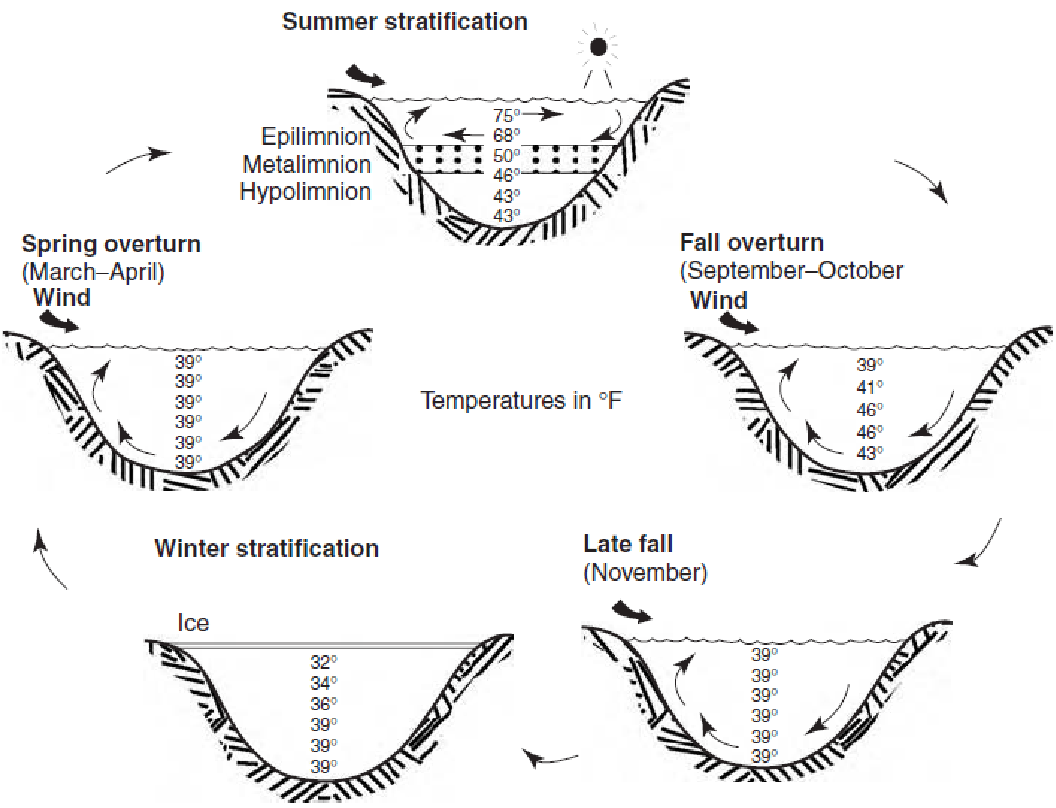


FIGURE 5.9 Lake stratification cycle. (From State of Wisconsin, 2005.)

Table 2.1 Classification of rivers based on discharge characteristics, drainage area and river width

River size	*Average discharge* $(m^3 s^{-1})$	*Drainage area* (km^2)	*River width (m)*	*Stream order*[a]
Very large rivers	>10 000	$>10^6$	>1500	>10
Large rivers	1000–10 000	$100\,000–10^6$	800–1500	7–11
Rivers	100–1000	10 000–100 000	200–800	6–9
Small rivers	10–100	1000–10 000	40–200	4–7
Streams	1–10	100–1000	8–40	3–6
Small streams	0.1–1.0	10–100	1–8	2–5
Brooks	<0.1	<10	<1	1–3

[a]Depending on local conditions.
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