

Watershed Wisdom – The Belgrade Chain of Leaky Buckets

This week we will try to give you more insight into why and how things happen in lakes and especially why it takes so long to improve water quality in a lake compared to a river or stream. Rivers and streams flow continuously down hill and are constantly mixed, with the water at any particular location being continually replaced with new water from upstream. If a river or stream becomes contaminated, the basic remediation technique is to stop the source of the contamination and then wait a few days and you have new fresh water from upstream. Once the water quality returns, the plants, aquatic insects and fish will return in reasonably short order.

Lakes take a lot longer to cure, especially large lakes. Most lakes have water flowing into them on a continuous basis from streams or groundwater and also have water flowing out via some type of outlet stream or river. There are some lakes, particularly in arid regions, where the water only leaves when it is evaporated. These lakes either become very salty (e.g., Great Salt Lake, Utah) or disappear completely if it hasn't rained for a while. Luckily our Maine lakes aren't like this. The water in our lakes gets replaced eventually.

The Belgrade Lakes all have flowing water entering them on average and a discharge stream, typically flowing over some type of dam that regulates flow. These lakes act like leaky buckets that have a notch cut in the side. As water is added to the bucket, it will fill to the level of the bottom of the notch. If you continue to add water to the bucket, the water will rise a bit (it will rise more if the notch is narrow, less if it is wide) but then fall to the level of the bottom of the notch if you add water at a rate slower than it can leak out. The actual level of water within the bucket is determined by the rate the water flows in and the size and shape of the notch in the side of the bucket.

Suppose someone dumps green food coloring into our bucket. How long will it take to flush the bucket clean by simply adding clean water and letting the green water flow out through the notch? Obviously it's going to take a lot longer if you have a big bucket and don't have much water flowing through it than if your bucket is small and has a lot of water flowing into it. This is the basic concept of what hydrologists call "flushing rate," which is directly related to "residence time."

Residence time is defined as the average amount of time that water entering the lake stays in the lake before it flows out of the lake. It is calculated by dividing the average volume of the lake by the annual flow going through the lake. If our lake holds 150 million cubic meters (M^3) of water like Messalonskee Lake does, and the average annual flow is 240 million M^3 per year, the average residence time is .625 years or roughly 7-1/2 months. The flushing rate is simply the inverse of the residence time which represents the average number of lake volumes that flow through the lake in a year. For Messalonskee, the flushing rate is about 1.6 flushes/yr.

Studies done by Colby College have estimated the following flushing rates for the Belgrade Lakes:

Lake	Flushes/yr	Residence Time (yrs)
Messalonskee	1.59	0.63
Great Pond	0.53	1.89
Long Pond South Basin	3.55	0.28
Long Pond North Basin	2.80	0.36

Salmon-Mcgrath	0.59	1.69
East Pond	0.25	4.00
North Pond	1.36	0.74

Of course natural lakes are much more complex than our simple bucket analogy and these rates assume the lakes are perfectly mixed, which is rarely the case. These flushing rates do give a rough idea of how fast the lakes flush and are more accurate for a long, regularly shaped lake like Messalonskee that only has one deep area than for a large, irregularly shaped lake like Great Pond that has several deep basins and streams of various sizes coming into different coves. And these rates assume average precipitation rates- years like this one with above average precipitation will result in greater flushing rates and dry years will result in less flushing. It also shows how long it takes to flush a chain of lakes- water that washes into East Pond will take almost seven years to pass through East Pond to North Pond to Great Pond to Long Pond to Messalonskee and out to the Messalonskee Stream.

In lakes like Great Pond that stratify, the surface waters flush more rapidly than the calculated flushing rate, while the deeper waters flush much more slowly because they are only really well mixed about twice a year (during spring and fall turnover). This means that if you are trying to remediate the high phosphorous levels in the deep holes, which are the biggest problem as we have previously discussed, it takes a long time to flush these areas. Where the average residence time for water in Great Pond is slightly less than 2 years, the residence time in some of the deep holes is probably more on the order of 20 years or more. This means that fixing lakes takes a lot longer than fixing a stream or river.

If you interested in finding out more about some of the topics I have written about, I invite you to visit our web site at www.belgradelakes.org. We have a lot of good information on watersheds posted there.