<u>On Wind-Driven Currents in Chautauqua Lake</u>

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Introduction

If you ask someone in Chautauqua County about currents in Chautauqua Lake, they will likely say "yes, there is a North to South current". This is primarily because the outfall for the lake is the Chadakoin River at the South end. This current does exist when the water is flowing out into the Chadakoin River. However, when the wind is blowing over the Lake, the dominant current is the wind-driven current. Why is this important? Because towns around the lake have been killing lake weeds using herbicides. The application of these herbicides must be approved by the New York State (NYS) Department of Environmental Conservation (DEC) for certain areas and times. Here's the problem: these herbicides are in liquid water that is not stationary but is in motion due to water currents. If it were only the N - S lake current, it wouldn't be a problem as these are very weak compared with wind driven currents when the wind speed is above 7 mph. In the last 5 years there have been multiple incidents where the wind-driven current has transported the herbicide from an approved application area to a much larger unapproved area. A worst case occurred from near shore application area in Lakewood to halfway across the lake (at the widest part of the lake).

Because of the paucity of water current data in Chautauqua Lake, there is no actual current data for Chautauqua Lake in this paper. Scientific analysis is used in 2 areas:

1) Wind-driven current data from another medium sized lake was used to get <u>typical</u> values for wind-driven currents as a function of wind speed and depth; and
2) North to South "outflow current" was calculated based on a historical average of outflow into the Chadakoin River and cross-sectional areas from lake bottom topography at 3 locations in Chautauqua Lake.

<u>Wind-Driven Currents</u>

Wind-driven currents are caused by shear stress on the water surface due to wind. This stress causes the water to move. We can't usually see the current in the water, but we can easily see the waves caused by the wind. At low wind speed, the waves start with ripples, that gradually get larger with increasing wind. Somewhere between 10 – 15 mph, the waves become unsteady and start to break, and we can see "white caps". These are obviously moving in the general direction of the wind. This is a transport that we can see.

There has been very little water current data collected in Chautauqua Lake. However, that is changing. Entities around the lake have invested in bringing in people and equipment used on Lake George (NY) to collect current, chemistry, temperature, and other important data. Without access to this new data, data on wind-driven water currents from Lake Mendota in Madison, Wisconsin will be used as <u>typical</u> for a medium sized lake. This lake is not the same shape as Chautauqua Lake, but an irregular, more circular shape, with dimensions of 6 mi E to W and 4 mi N to S. A detailed wind-driven current study was done by Shulman and Bryson in 1960 – Ref 1. They took data on wind-driven water currents (direction and speed) at depths from 0 – 3 meters. The wind-driven currents are not in the same direction as the wind, but to the right of the wind due to the Earth's rotation (Coriolis Force). They collected data near the center of the lake to avoid shore effects. Their data is for 3 wind speed ranges: 0 – 4.9 mph, 5 – 9.9 mph, and 10 – 14.9 mph. The average water current and deflection (near the center of the lake) of the water current (to the right of the wind) is shown in Figure 1. The average deflection is 20.6 degrees to the right (of the wind direction). For simplicity's sake, the currents in the plot are average for this entire range of wind speeds. As can be seen, the average water current steadily decreases with depth. The deflection of the current to the right increases sharply just below the surface, then levels off, before decreasing below 1.5 meters.

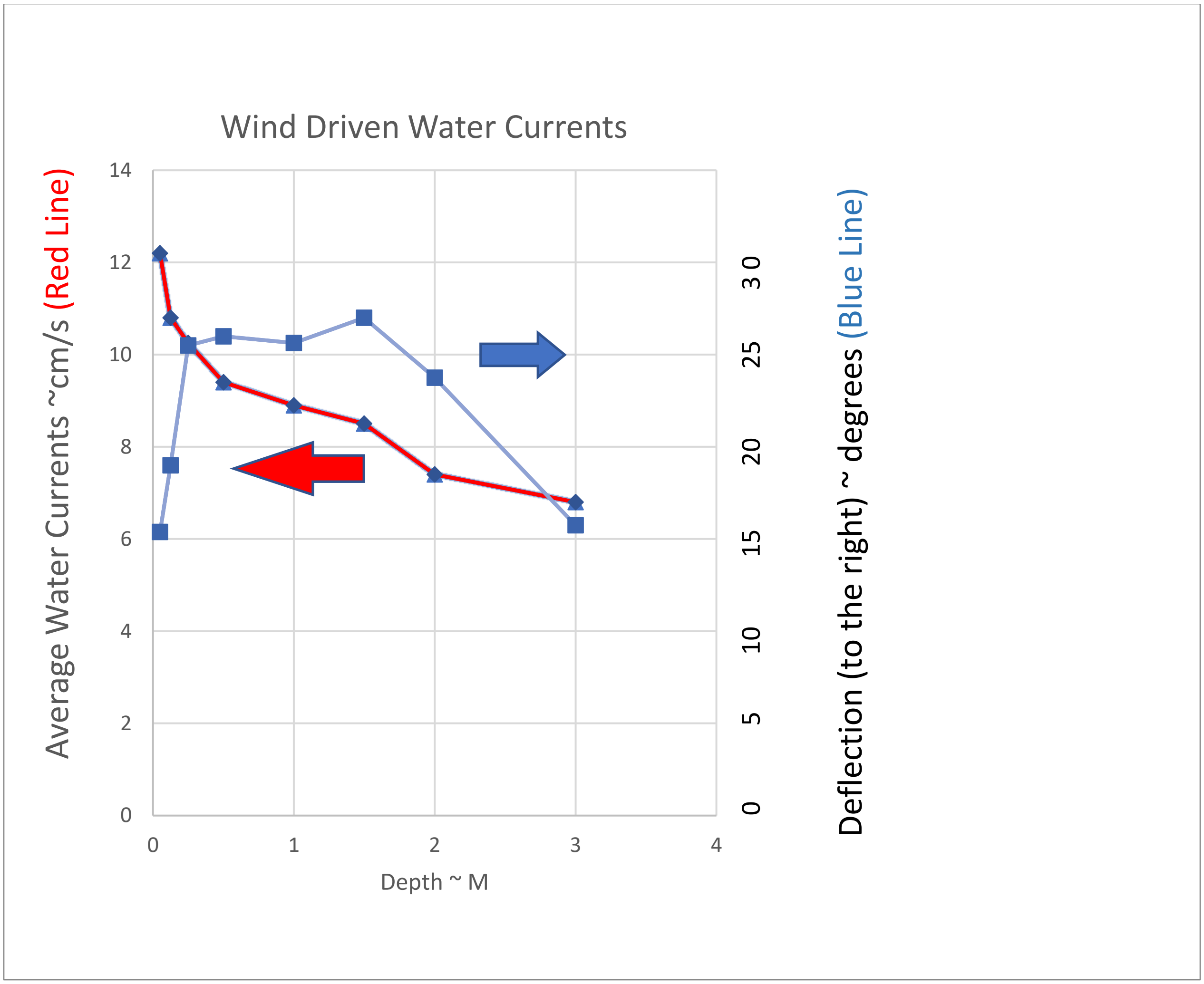

Figure 1 – Wind-driven water current: speed and direction vs depth – data from Ref 1 (Lake Mendota)

Comparison of N - S current in Chautauqua Lake and the wind-driven currents

The N – S current can be calculated using the continuity equation. The continuity equation, which states that the flow rate is equal to the cross-sectional area times the velocity. There is no major, singular water input into Chautauqua Lake. It is fed by springs, streams, and rain. Using a historic average (for the last 20 years) outflow rate of 432 cubic ft/sec (Ref 2) into the Chadakoin River at Falconer, NY and input flow rate (due to streams, springs and rain) that is constant (analysis assumption) along the length from N to S. The cross-sectional areas at the below locations are used to compute the currents, shown in Table 1. The cross-sectional areas are from several sources of bathymetry data: 1) NYS Dept of Environmental Conservation (DEC) – Ref 3; and 2) Fishermap – Ref 4.

Table 1 - North – South currents in Chautauqua Lake

- CI Bell Tower (wide and deep)	0.00028 mph	or	0.013 cm/s
- Stow (narrowest point)	0.012 mph	or	0.52 cm/s
- Ashville (widest, shallowest)	0.0019 mph	or	0.084 cm/s

The highest current in the Lake is at the Chadakoin outlet (don't have the outlet cross-sectional area to calculate current speed).

Next, let's compare these current values with wind-driven currents. The wind-driven current data collected by Shulman and Bryson for Lake Mendota in Wisconsin in 1960 is plotted in Fig 1. The average water current over a range of wind speeds of 0 – 15 mph is plotted for 0 – 3 M depth. The average deflection (degrees to the right of wind) is also plotted as a function of depth. The water current decreases exponentially with depth from 12 cm/sec down to 6 cm/sec at 3M depth. The deflection increases steeply, then levels off, before a linear decrease. The average deflection to the right is 20.6 degrees. When we average the N – S current values, we get 0.21 cm/sec. The range of the wind-driven currents in Fig 1 is 12 cm/sec down to 6 cm/sec, with a rough average of 9 cm/sec. Taking the ratio of these 2 averages, the N – S current is 2% of the average wind-driven currents. Bottom line is that when the wind blows, the N-S current is negligible.

Maximum wind speed for herbicide application

The NYS DEC – Region 9 has a wind cut-off of 10 mph for applying herbicide into the water. So, if the wind is higher than 10 mph, the herbicide should not be applied. There needs to be a rationale for wind cut-off as the herbicide labels specify "quiescent or slow moving water" – see herbicide product information in Table 2. So, the burning question is "how slow does the current have to be to be quiescent?" and what is the wind speed that generated that current? For enlightenment on this question, surface currents (0 - 60 cm depth) were plotted to see where the "knee" of the curve is - Figure 2. The figure shows a break point between 5 and 10 mph – let's call it 7 mph, which is 30% lower than the current DEC limit. The bottom line here is that the DEC should require a current measurement and put a current limitation on the application for a go/no-go decision for application. This is recommended as the winds can be variable and changing fast, while the water currents have much more inertia, due to water having a much higher density than air. This inertia causes the currents to continue flowing for a period of time after the wind drops.

Table 2 - Product information from herbicide labels

Herbicide	Product Information/water conditions
Aquathol	"For aquatic plant control in quiescent or slow moving water,.."
ProcellaCOR EC	"a selective systematic herbicide for management of freshwater aquatic vegetation in slow-moving/quiescent waters with little or no continuous outflow: ponds, lakes, reservoirs, freshwater marshes, wetlands,……."

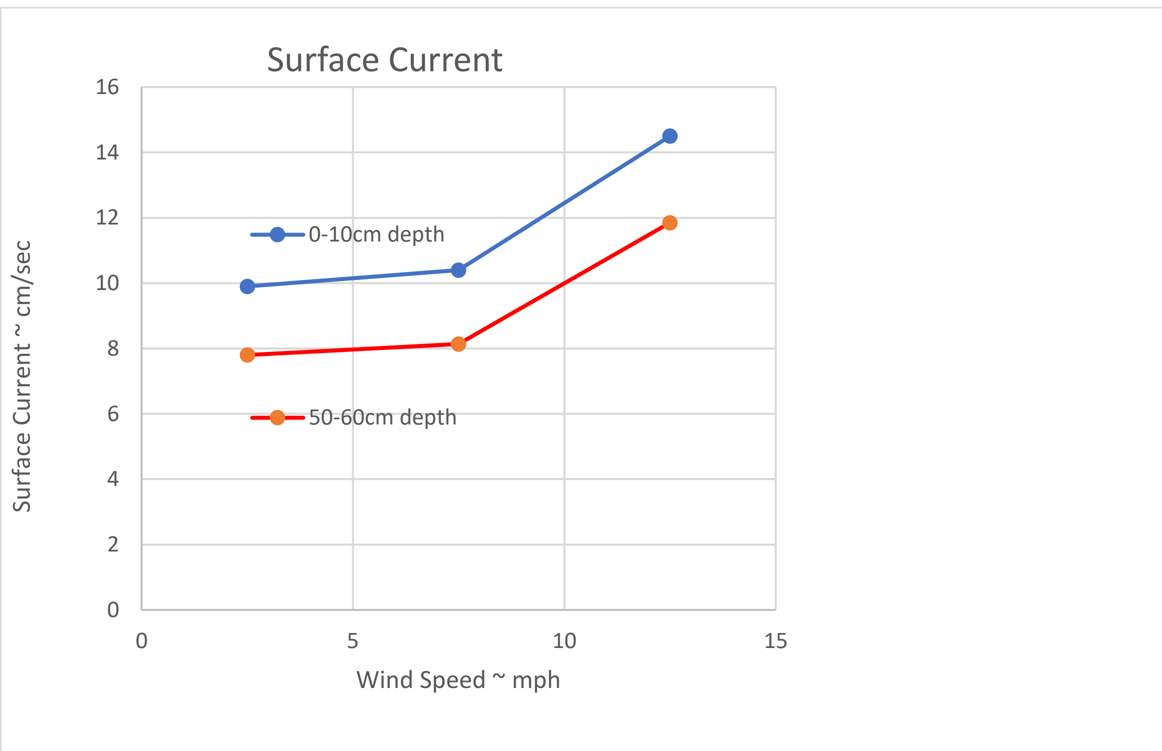

Figure 2 – Surface currents (0 – 60 cm depth) vs wind speed (0 – 15 mph) – from Ref 1

Summary

Summing up, this data from Ref 1 shows that the wind-driven currents in the middle of the lake are the dominant currents if the wind is blowing more than 7 mph. We need current data in Chautauqua Lake for shallow water (as currents could be higher near the shore) to help NYS DEC set the criteria for "slow moving/quiescent waters" to avoid collateral damage due to wind-driven current transport. This shallow water data is very important as that is where the herbicides are applied and transported by primarily wind-driven currents.

Reference 1 – Shulman, M. D. and R. A. Bryson. 1960. "The Vertical Variation of Wind-Driven Currents in Lake Mendota", No. 20 in the series of Reports to the Univ. of Wisconsin Lakes Investigation Committee.

Reference 2 – USGS Surface-Water Annual Statistics

https://waterdata.usgs.gov/nwis/annual?

Reference 3 - https://www.dec.ny.gov/outdoor/9230.html

There are specific links for Chautauqua Lake's North and South Basin bathymetry maps:

3a) North Basin https://www.dec.ny.gov/docs/fish_marine_pdf/chautnlkmap.pdf

3b) South Basin https://www.dec.ny.gov/docs/fish_marine_pdf/chautslkmap.pdf

Reference 4 - https://usa.fishermap.org/depth-map/chautauqua-lake-ny/