TRANSPORT IN LAKES

OVERVIEW: LIMNOLOGY

The study of lakes (Gr.: limnos)

LAKE: Inland basin of water

Most often, but not alway, fresh.

Represent about 2.5 million km^2 of earth's surface

Out of ~ 500 mill km^2 total so

~ 0.5% of surface

LAKE Water Mass ≈ 2.5×10^{16} kg

~ 0.002% of TOTAL WATER

YET STILL LARGE & VITAL

LAKES ARE TRANSITORY ON GEOLOGIC TIME SCALES

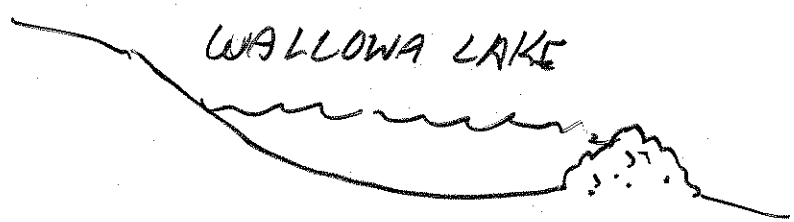
"... usually born of catastrophes, to mature and to die quietly & imperceptibly"

— C. Evelyn Hutchinson
(A Treatise on Limnology)

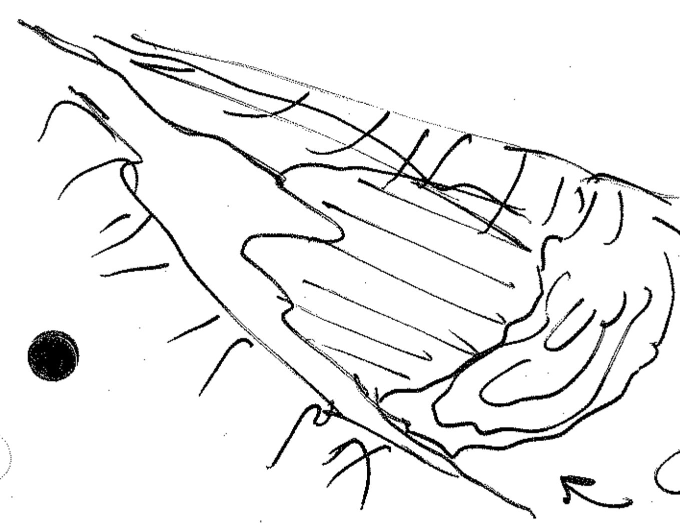
FORM IN MANY WAYS

CRATER LAKE

CALDERA OF VOLCANO

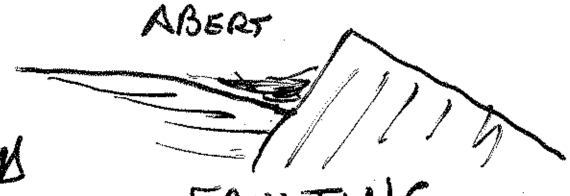


GLACIAL VALLEY W/ TERMINAL MORAINE

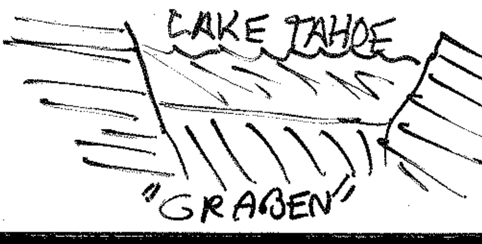


VALLEY BLOCKED BY SLIDE, LAVA, GLACIAL ACTION

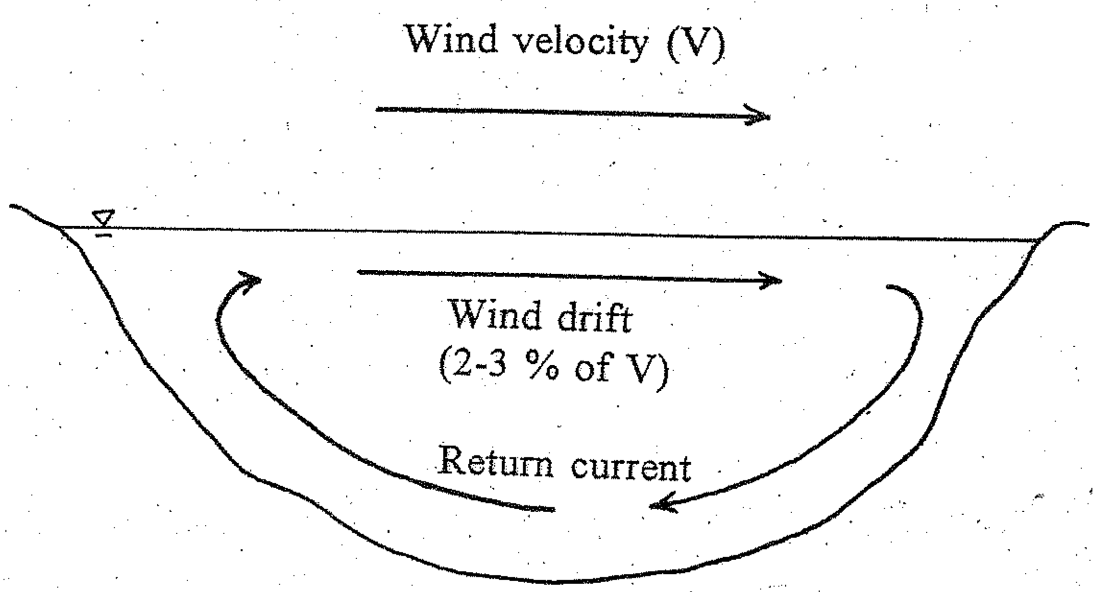
LAKE ABERT



FAULTING

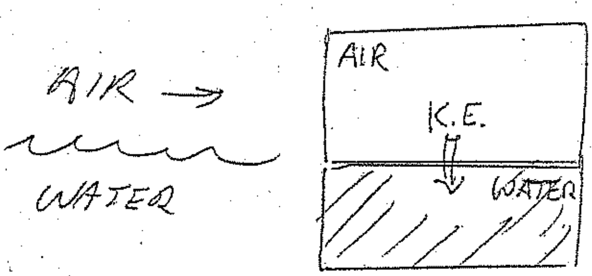


"GRABEN"



Wind-driven currents in a lake. (a) Circulation in a small lake of simple geometry. water current, or *wind drift*, averages 2 to 3% of wind velocity. Deeper in the lake, a *t* is established, returning water to the upwind end of the lake. (b) In a large lake : Michigan, variability of winds, complex lake geometry, and other forces (such as effect) lead to complex patterns of water movement [Ayers *et al.* (1958)] *(Figure*

Why is current only 2-3% of wind velocity



Do a kinetic energy balance

At EQUILIBRIUM

$K.E._{AIR} \approx KE_{water}$

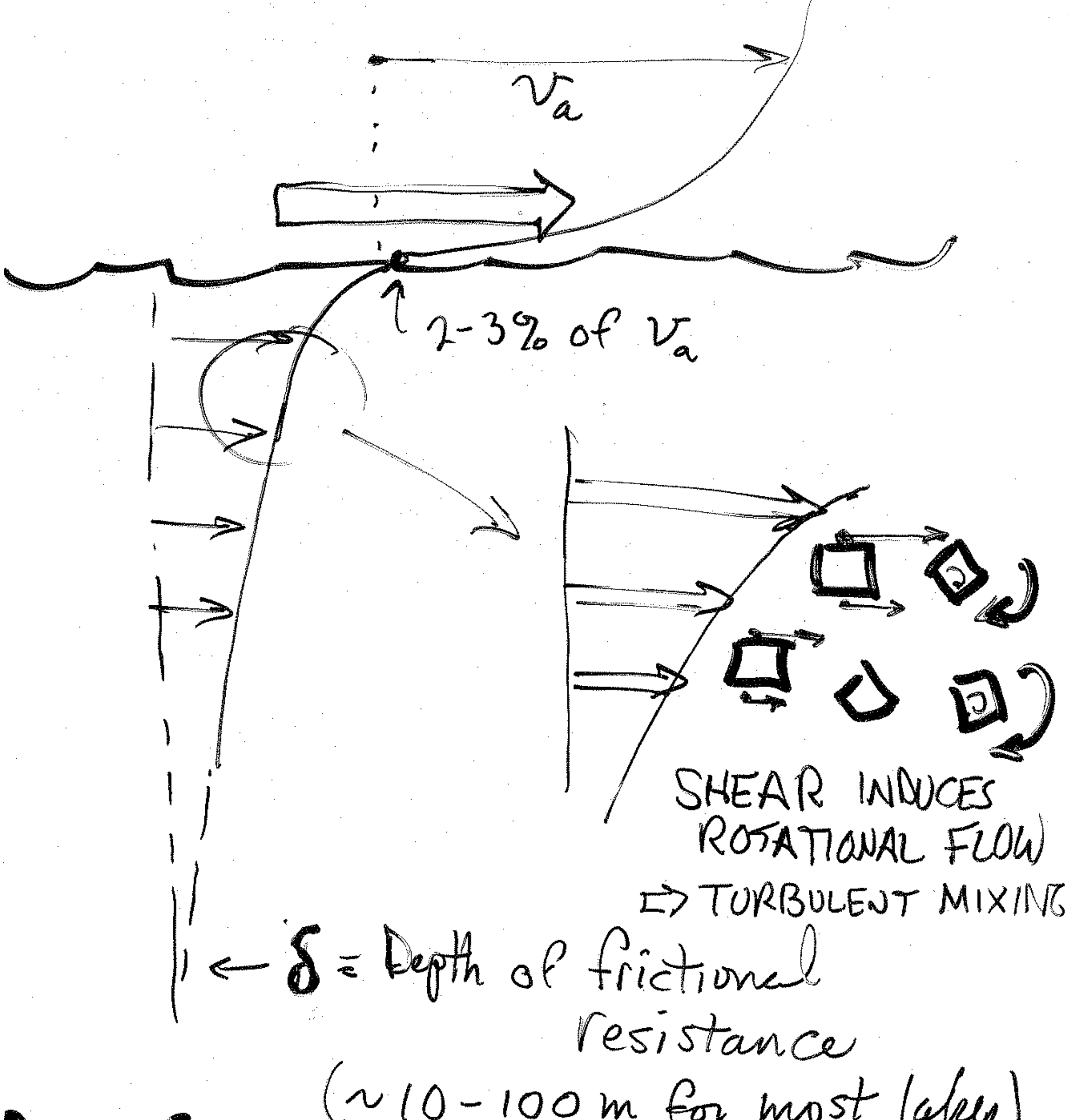
$KE = \frac{1}{2} m V^2$ so... $m_a V_a^2 = m_w V_w^2$

$$\frac{m_a}{m_w} = \frac{V_w^2}{V_a^2} = \left(\frac{V_w}{V_a}\right)^2 \qquad \frac{V_w}{V_a} = \sqrt{\frac{\rho_A}{\rho_w}}$$

$$\frac{m_a}{m_w} = \left(\frac{Vol_A}{Vol_A}\right)\frac{\rho_A}{\rho_w} = \left(\frac{V_w}{V_a}\right)^2$$

$$\frac{V_w}{V_a} \approx \sqrt{1/1000} \approx 1/30 \approx 0.0$$

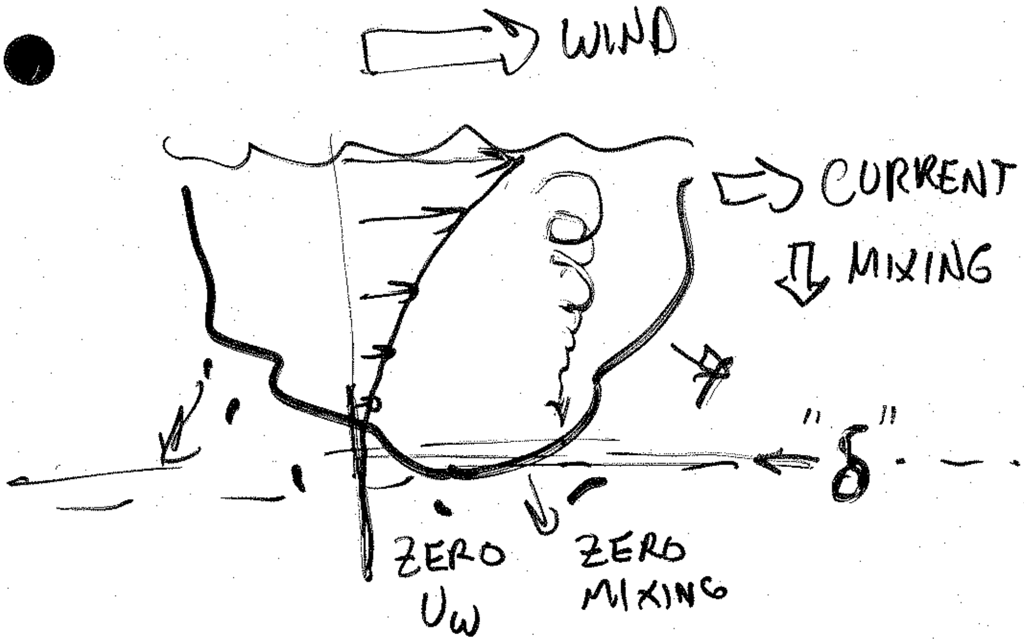
Vertical Structure of Wind-Driven Flow



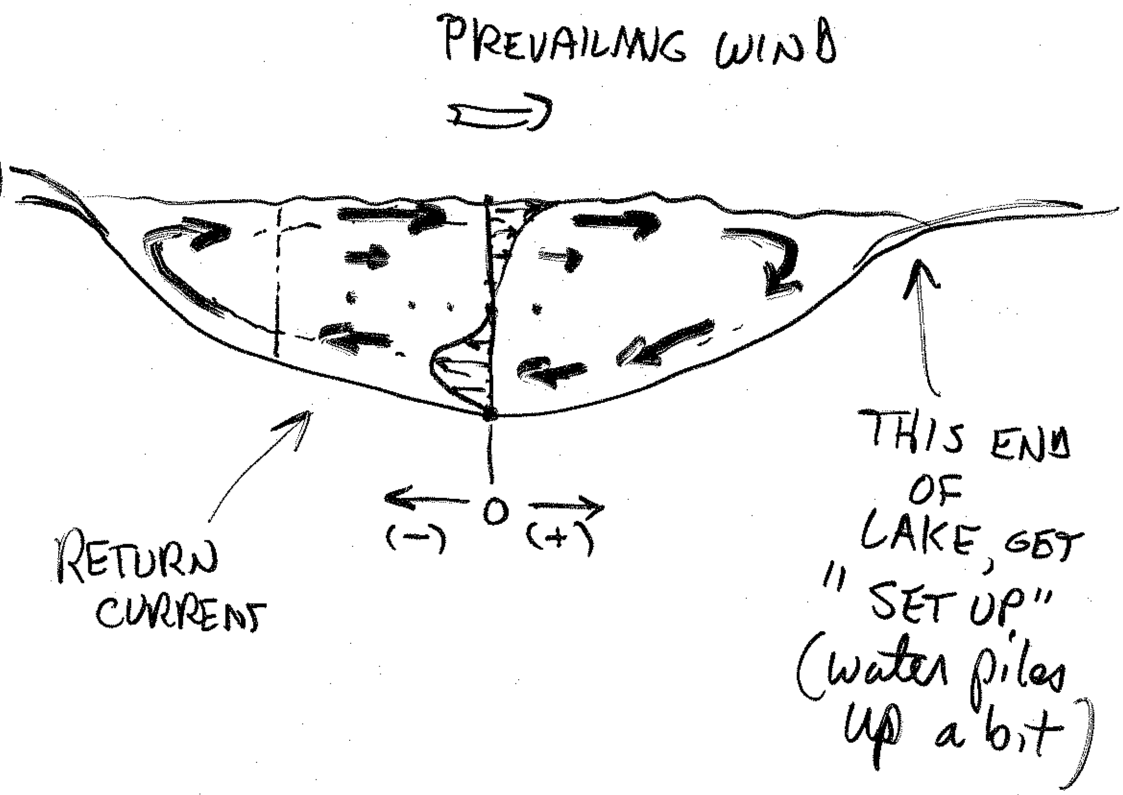
SO WIND CURRENTS LEAD TO:

- Horizontal ADVECTION
- Vertical DISPERSION (MIXING)

"INFINITE LAKE"



FINITE LAKE (Real)

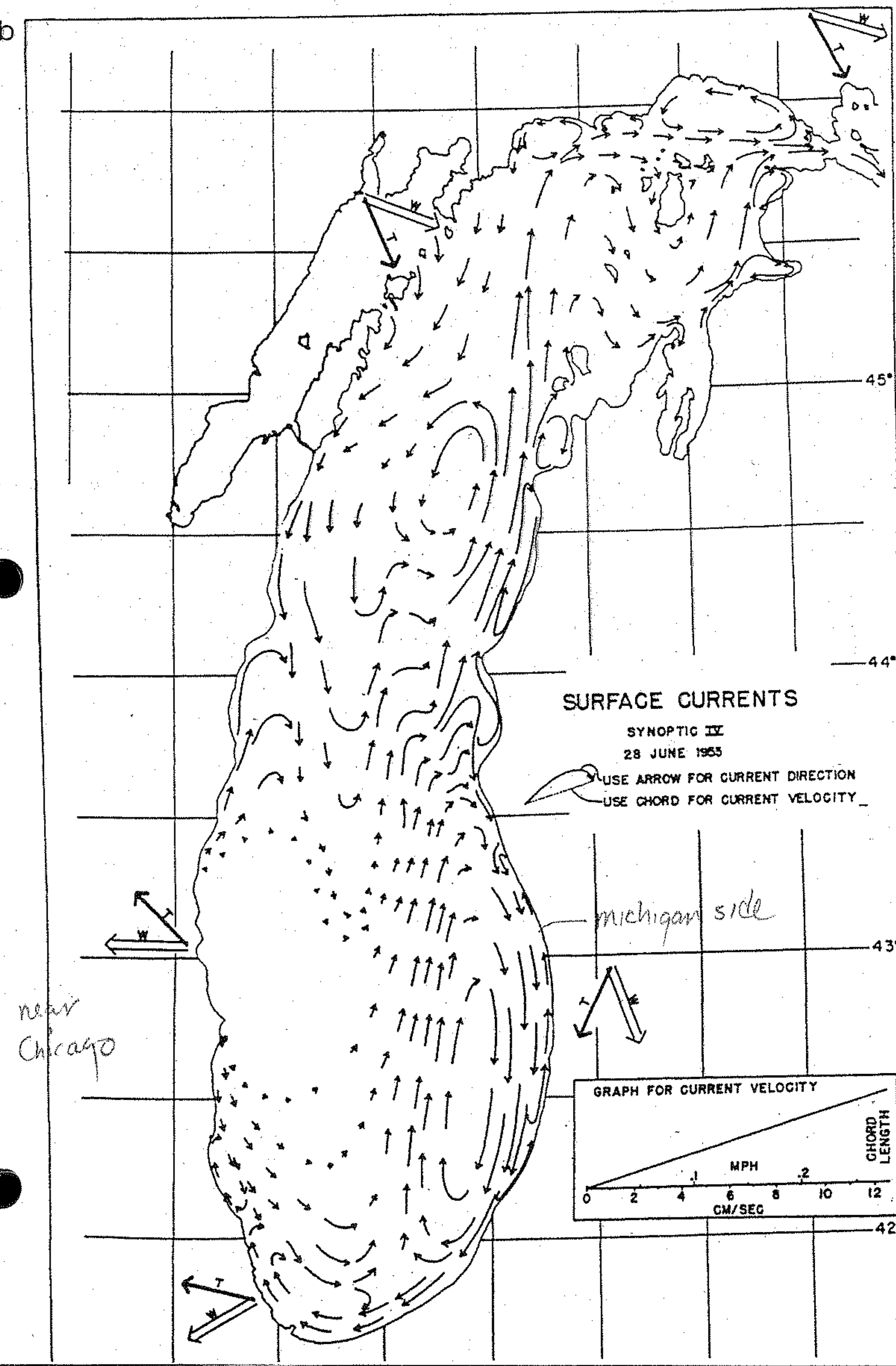


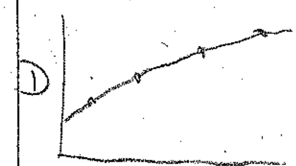
lake michigan

D is not constant with respect to time

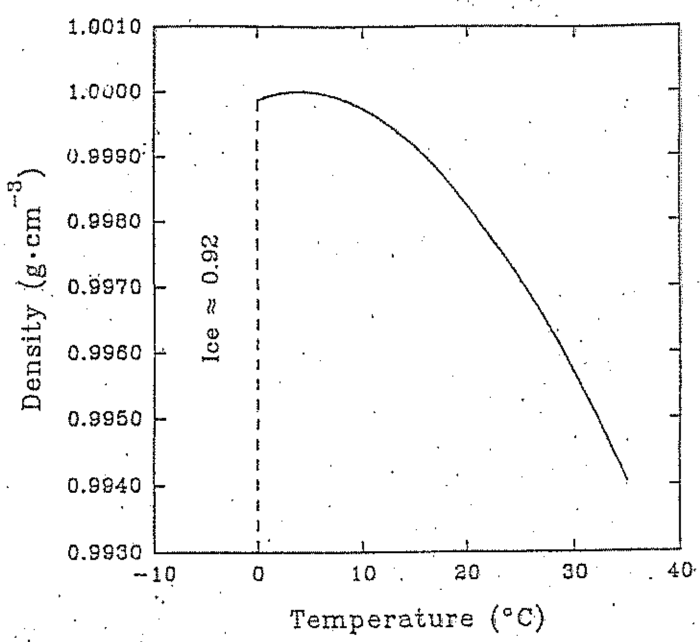
$D_{t_2} = D_{t_1} (\Delta t)^{4/3}$ approximately

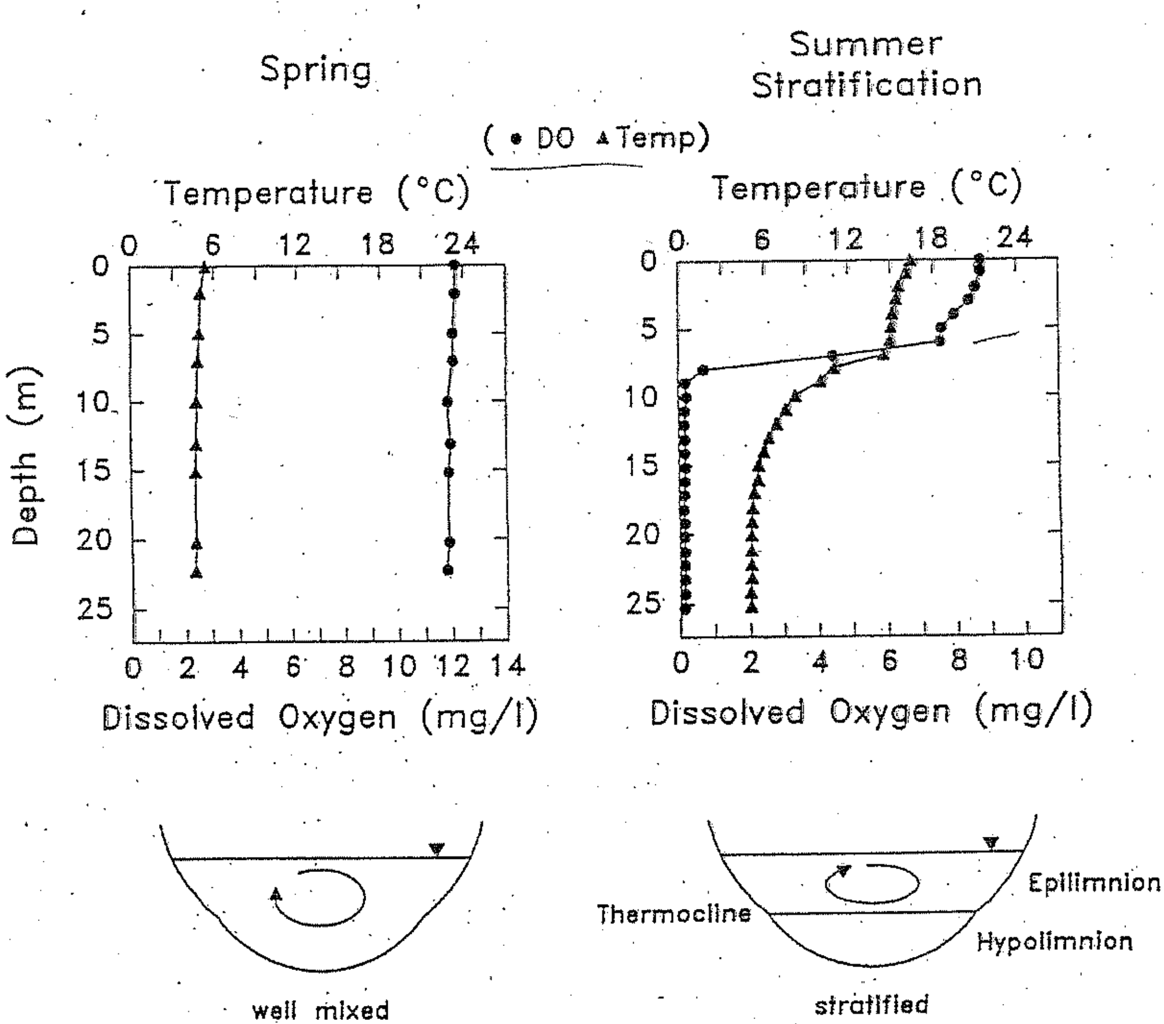
b





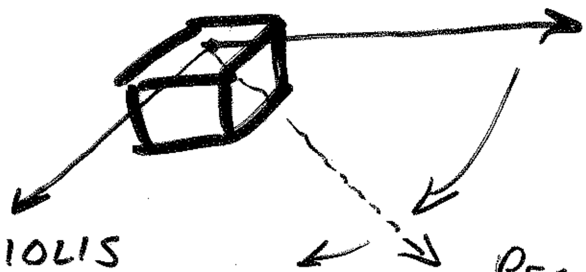
near Chicago

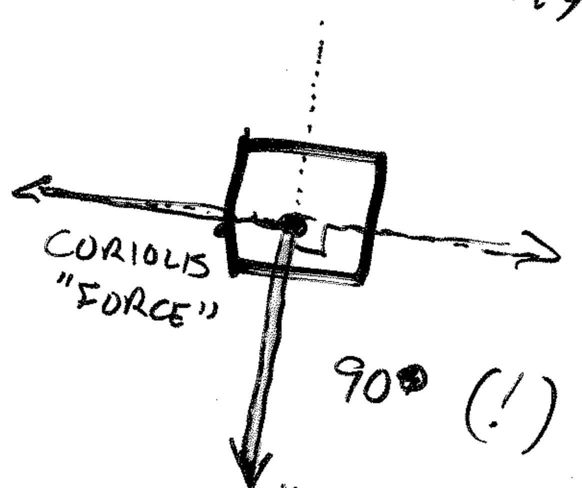




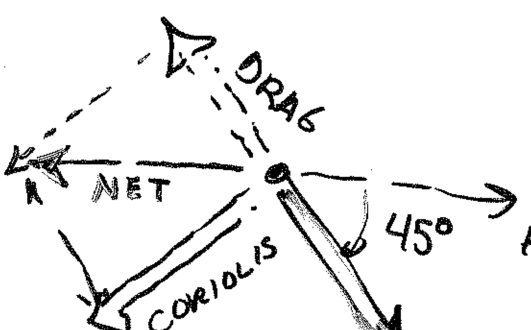
F GURE 2-7 Measured temperature and oxygen profiles from the Upper Mystic Lake in e Massachusetts, on April 1, 1991 and September 30, 1991. (Left) the lake is unstratified an mixed during turnover, which occurs in spring and fall. (Right) during summer, this eut

LARGE LAKES:
"Ekman Phenomena"

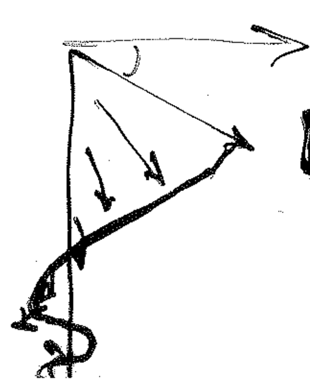




BUT
ADD IN DRAG FROM
BELOW:



(TRUE FOR
LARGE AIR
MOTIONS
(HURRICANES))



EKMAN SPIRAL

WHEN DO WE WORRY ABOUT THE CORIOLIS EFFECT?

Coriolis UNIMPORTANT when

$$\left[\frac{\Omega_o L}{U}\right] \ll 1$$

For a given LATITUDE ($\rightarrow \Omega_o$) the relative importance depends on the ratio $\left[\frac{L}{U}\right]$

Rewrite an as:

$$\left[\frac{\Omega_o}{[U/L]}\right] \quad \left[\frac{\text{CHAR. VELOCITY}}{\text{CHAR. LENGTH}}\right] = 1 \Big/ \left[\begin{array}{c}\text{CHAR. TIME SCALE}\\ \text{OF THE FLOW}\end{array}\right] \rightarrow \left[\frac{T_{flow}}{T_\Omega}\right] = \left[\frac{T_{FLOW}}{10^4 s}\right]$$

AT 45°

$\Omega_o^{@45°} \; \frac{2\pi}{86{,}000\,s} \sin 45° \approx 10^{-4} s^{-1} \Rightarrow T_\Omega \approx 10^4 s$

Water Body	L (m)	U (m/s)	$[\Omega_o L/U]$
Toilet	0.1	1	10^{-5}
Stream	10	1	10^{-3}
River	100	0.1	0.1 ↑
Lake/Coastal Zone	10,000	0.1	10 ↓
Estuary	10,000	1	1
Ocean Current	1,000,000	00.1	10^4