

# Lake Leelanau Monitoring

Update to Dam Authority

June 21, 2023

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# Existing and **New** Sensors

## Little Traverse Lake Association

- Little Traverse Lake
- Lime Lake
- Shalda Creek
- **Shalda Culvert**

## Glen Lake

- Dam
- Narrows
- Culvert → **Crystal River**
- Hatlem Creek

## Crystal Lake

- Dam

## Leelanau County

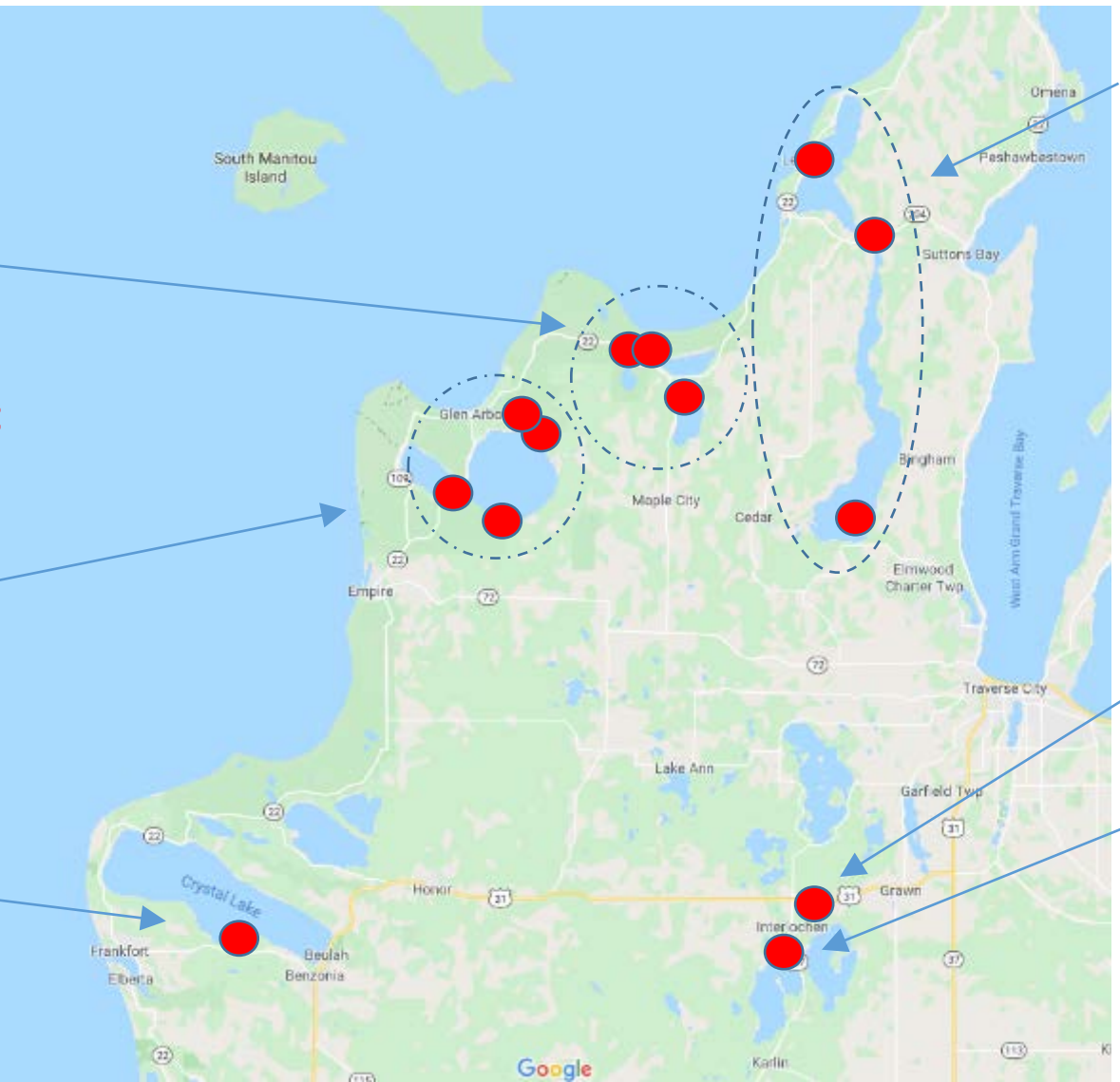
- Dam
- Narrows
- South Lake

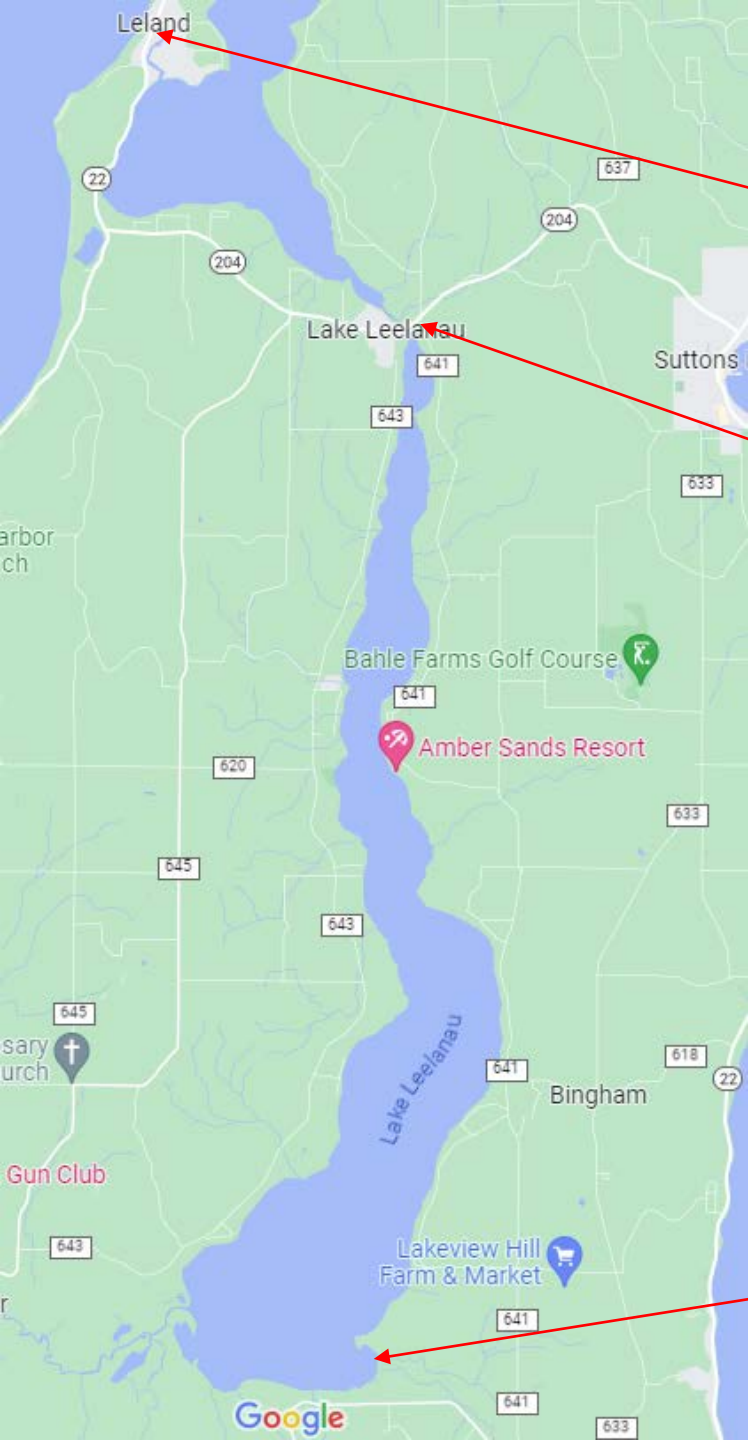
## Grand Traverse County

- Duck Lake

## Green Lake and Duck Lake Association

- Green Lake





# Lake Leelanau Sensors

Dam

Narrows



South Lake



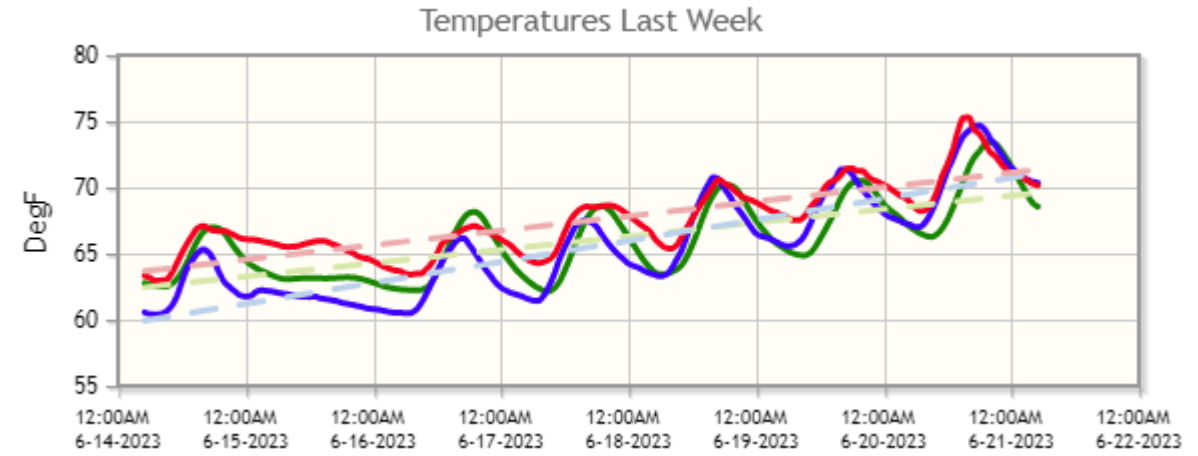


<https://lakeleelanau.org/lake-levels/>

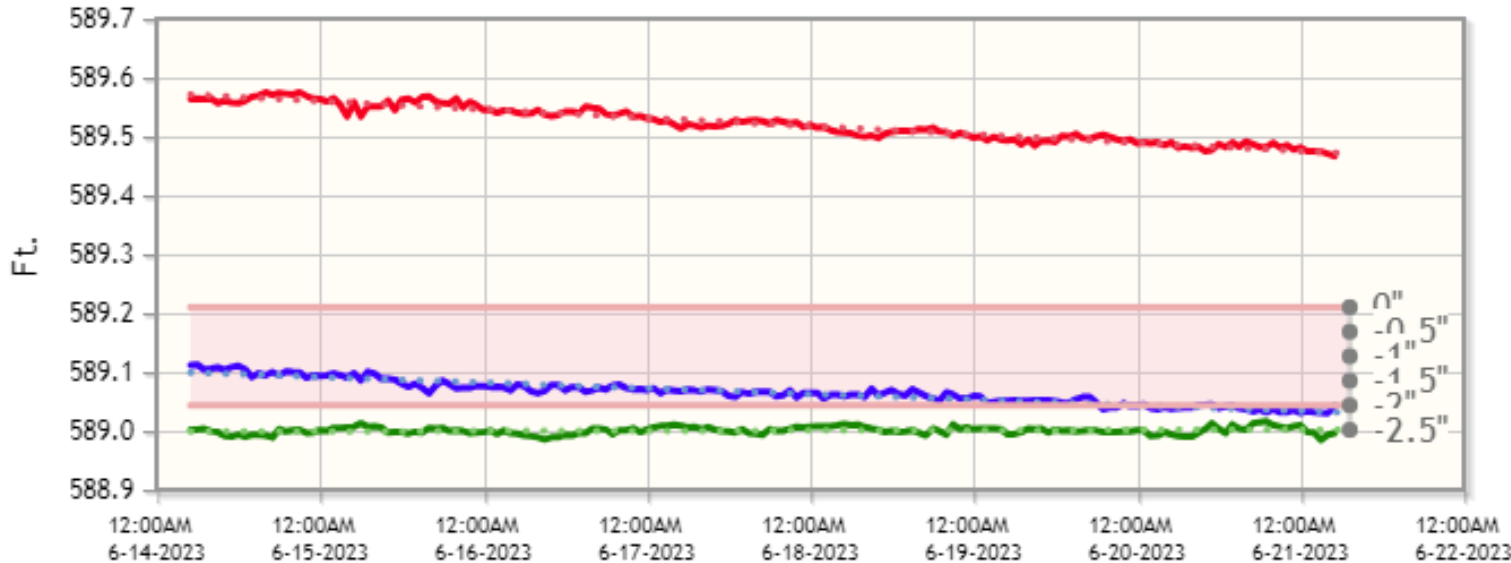
## Lake Levels

This page shows live data from three sensors monitoring the level of North and South Lake Leelanau - one at the dam in Leland, one at the narrows, and another at the south end of the lake. Long-term lake level and temperature data can be found here.

A few notes on the graphs:



All 3 Sensor Levels - 1 Week



**Dam Trend:**  
 0.000 ft./day  
 589.00 ft. ave

**Narrows Trend:**  
 -14.1 cfs  
 -0.010 ft./day  
 589.07 ft. ave

**South Lake Trend:**  
 -40.5 cfs  
 -0.014 ft./day  
 589.52 ft. ave



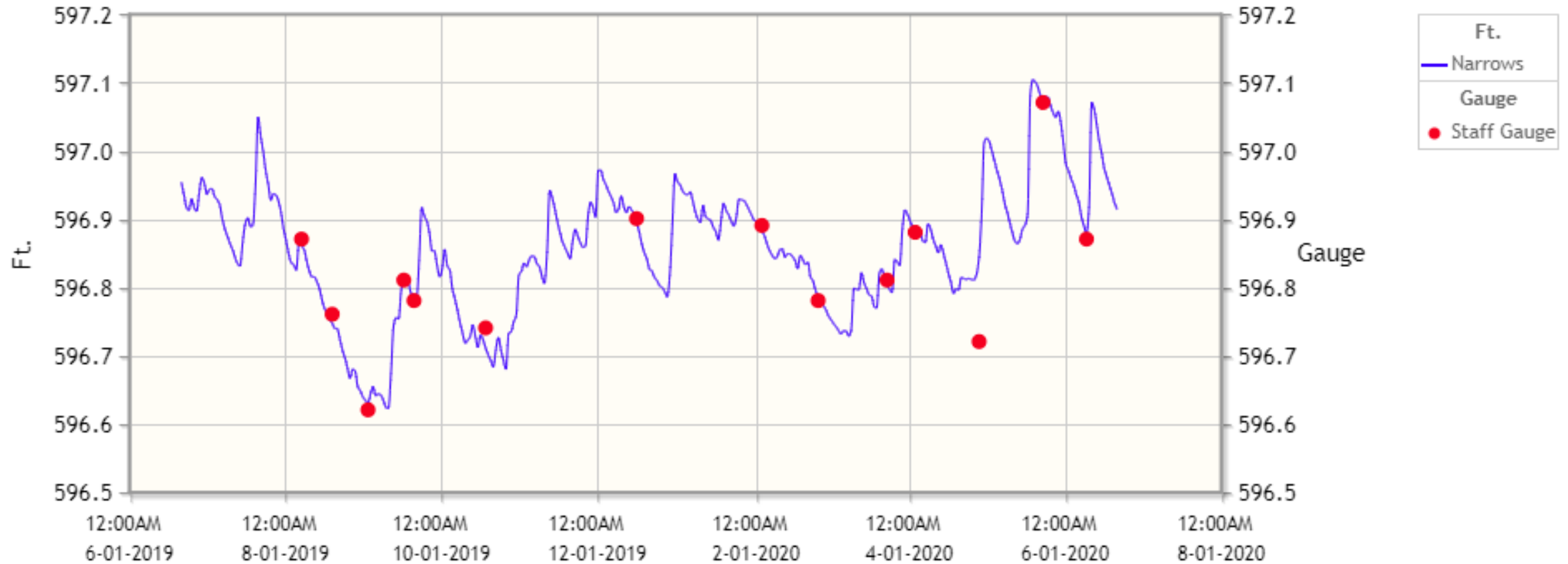
How do we know if the sensor is giving us the right information?

How should it be checked and calibrated?

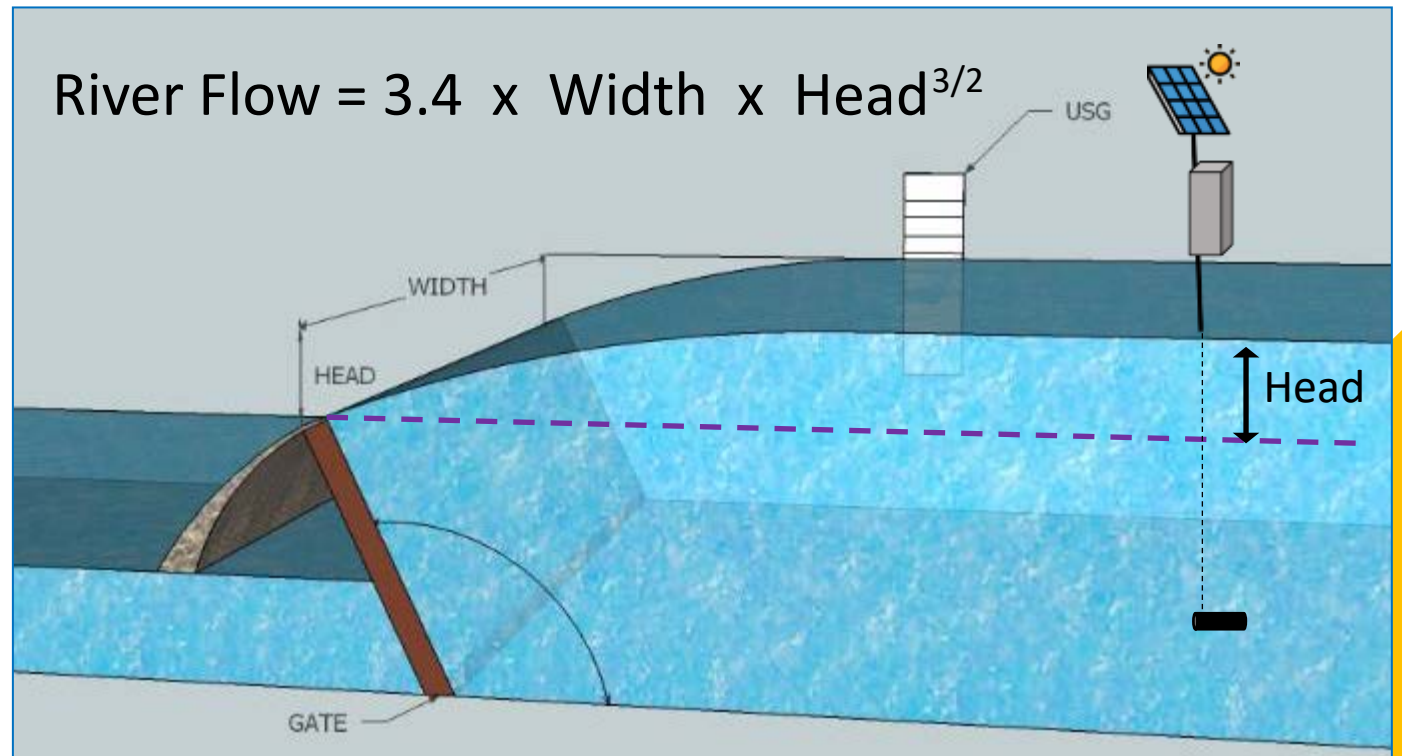
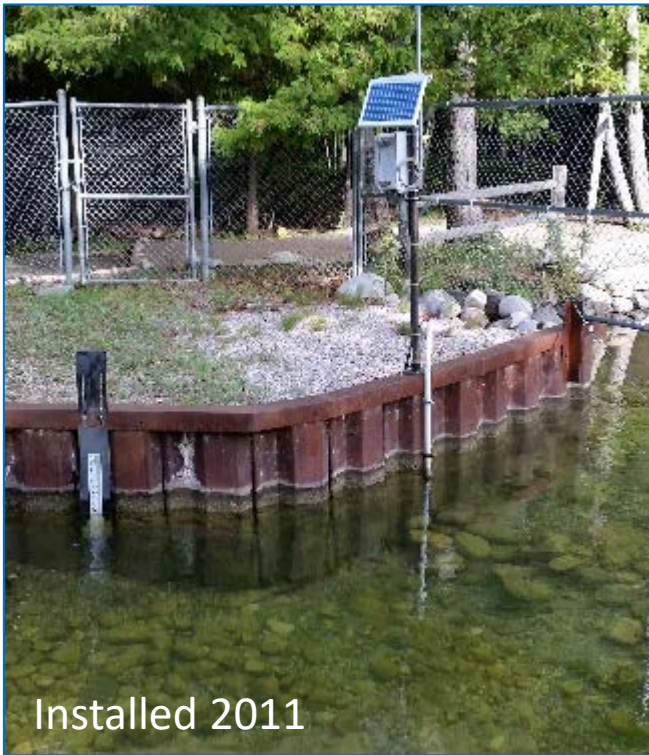
# Continuous Calibration Manual Measurements



Glen Lake Narrows + Staff Gauge

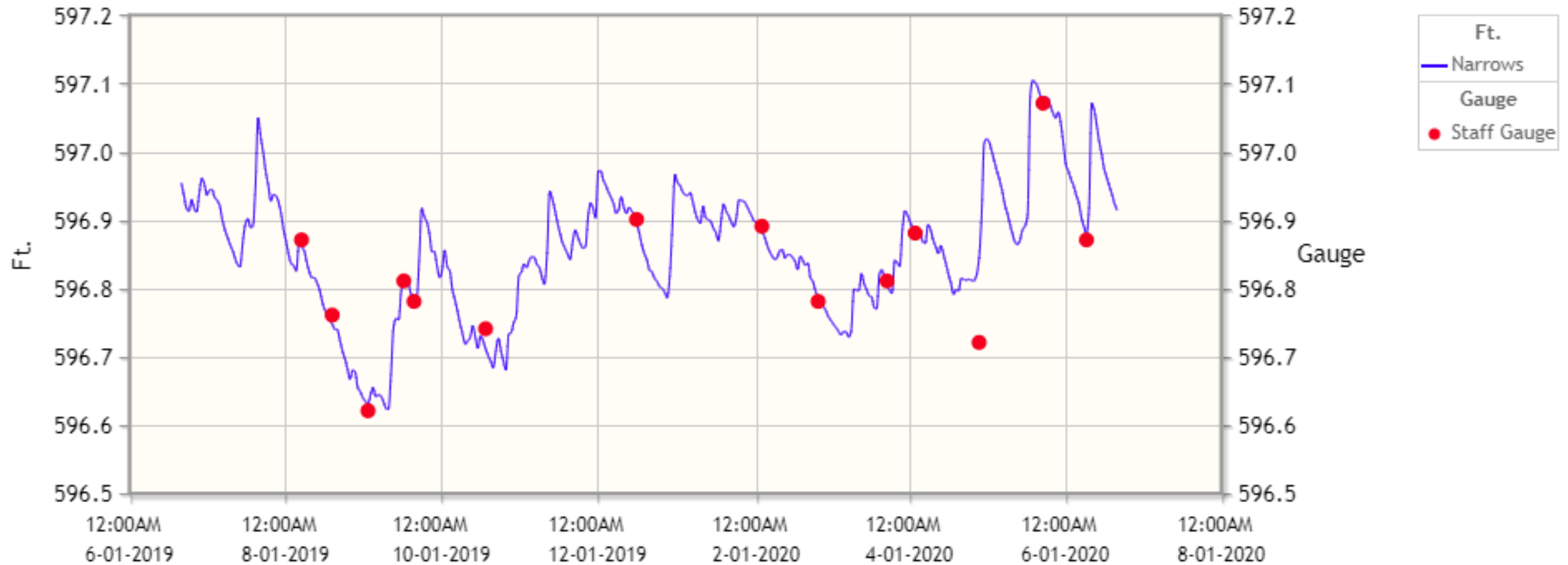


# Glen Lake Dam



# Continuous Calibration

Glen Lake Narrows + Staff Gauge





# Hydrology 401

Manning Formula: 
$$V = \frac{u_m}{n} \cdot R_h^{2/3} \cdot S^{1/2}$$

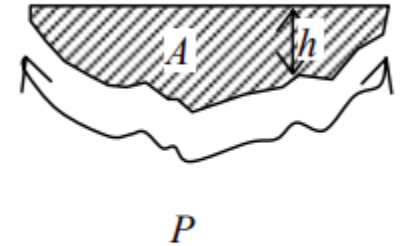
Velocity is proportional to the square root of the slope of a stream/river/channel. How much depends on the size, shape and roughness of the channel.

# Hydrology 101

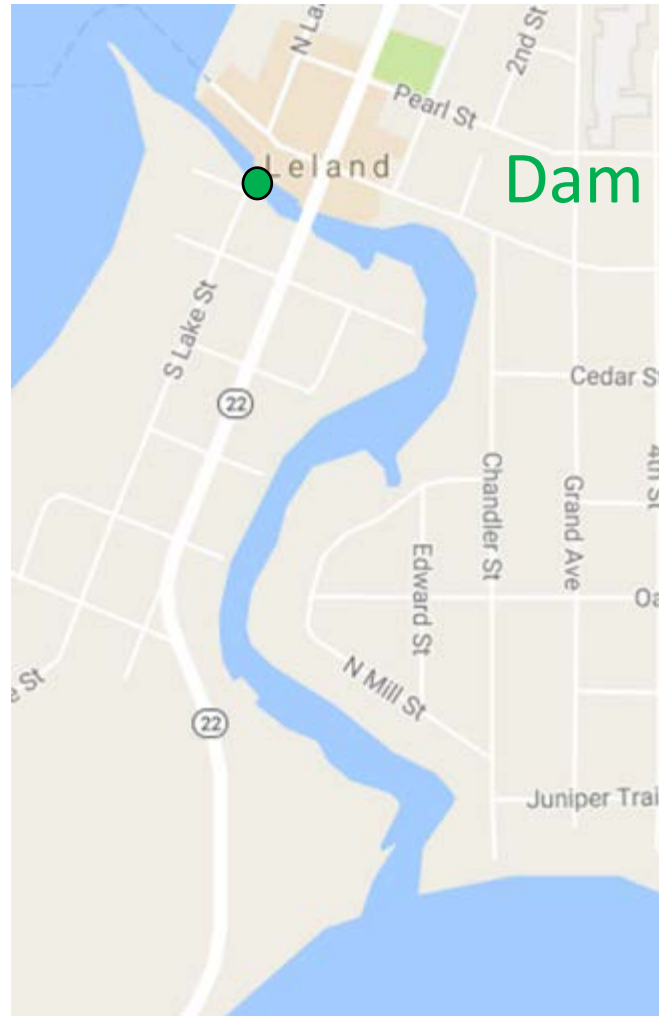
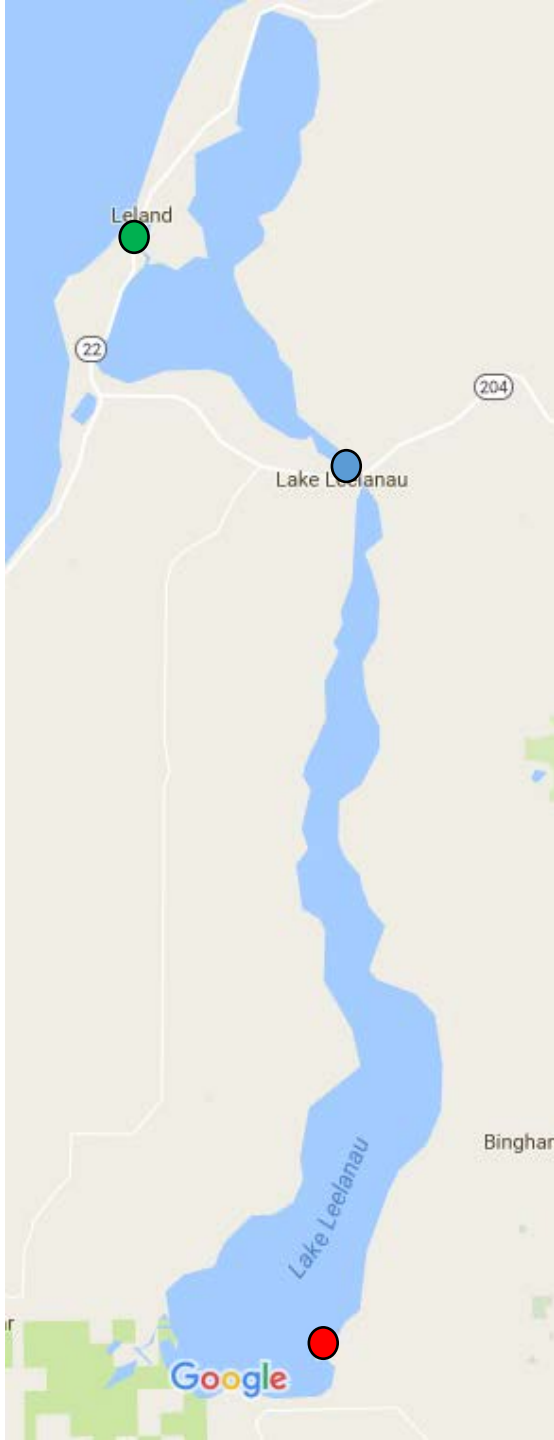
1. Water runs downhill
2. The faster water is running, the steeper the slope of the stream/river/channel
3. The longer the channel the bigger the drop (head loss) from end-to-end
4. Conversely – no movement indicates ~flat water (but over long distance...)

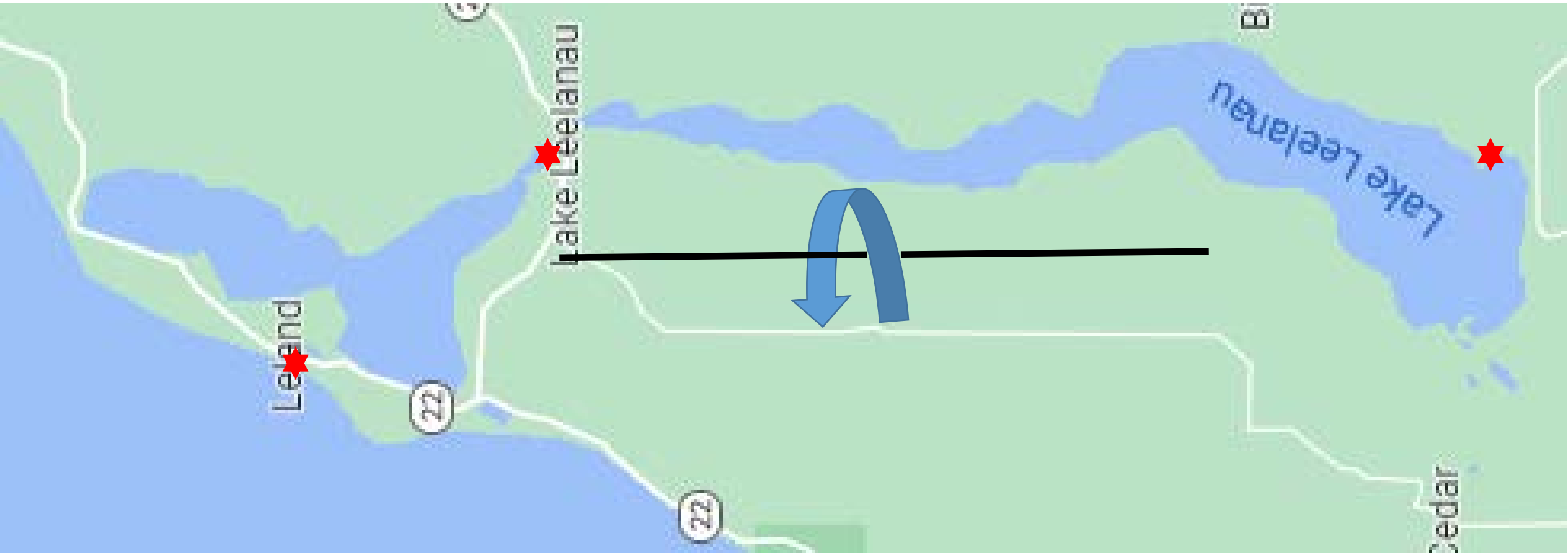
## **Box 2: Hydraulic Radius**

The hydraulic radius ( $R_h$ ) is sort of like an “equivalent radius” that represents a combined effect of cross-sectional area ( $A$ ) of bottom/bank shape (wetted perimeter,  $P$ ):  $R_h = A/P$ . For wide, shallow streams (depth  $< 0.05$  width), the hydraulic radius is essentially the average depth,  $R_h \approx h$ .



# Sensor Placement



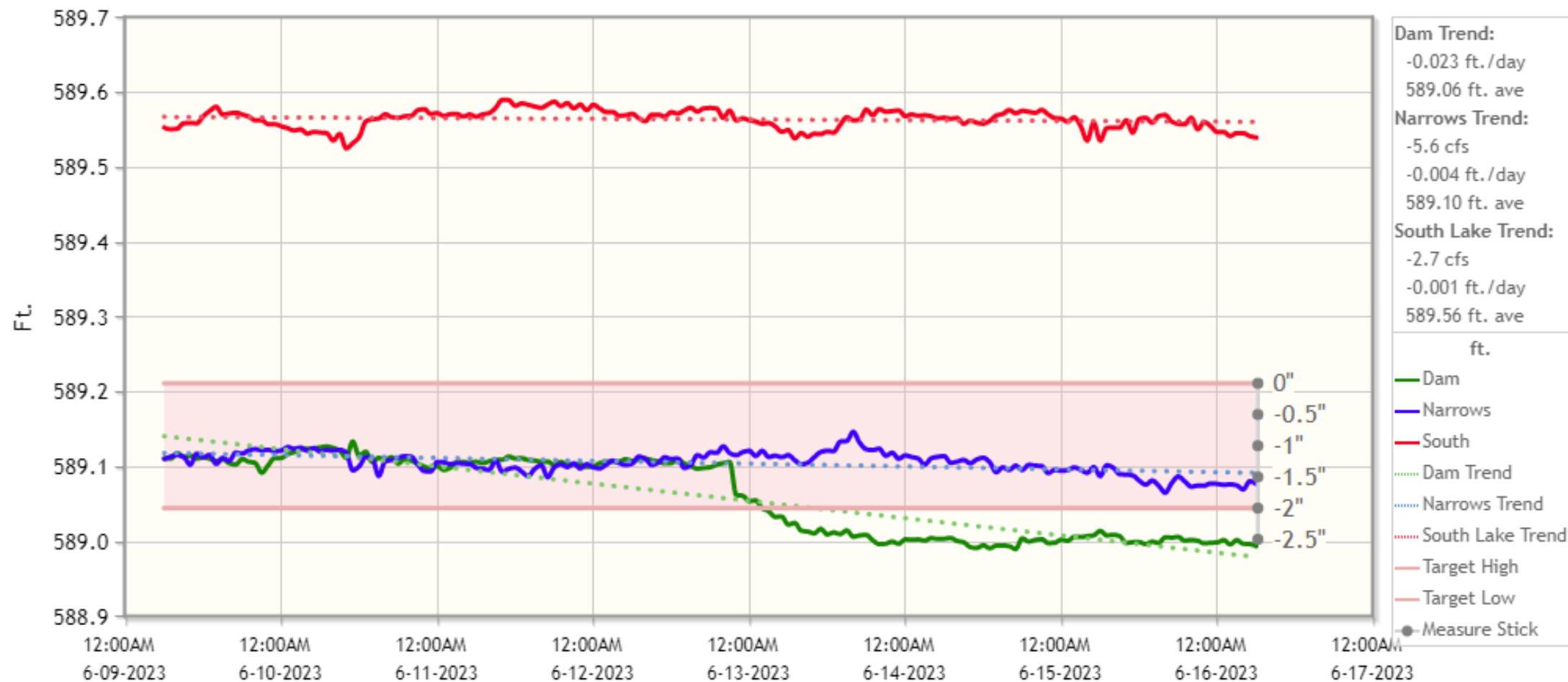




## Court Ordered Leelanau Lake Level - October 16, 1978

.... IT IS ORDERED AND ADJUDGED and this Court by virtue of the authority therein vested and in pursuance of the statute in such case made and provided, does ORDER AND ADJUDGE that a level of 589.21 feet "Mean Sea Level Datum", with a maximum fluctuation of plus 0 inches and minus 2 inches, shall be maintained from April 15 of each year or at ice break-up on said lake, whichever occurs later, until November 15 of each year; on November 15 of each year said lake level shall be reduced to 588.21 feet "Mean Sea Level Datum" until the following April 15 or ice break-up, whichever occurs later at which time it shall be increased to the previous above stated level until further Order of this Court. These levels shall be maintained at the site of the dam located in the Village of Leland, County of Leelanau, and State of Michigan. ....

### All 3 Sensor Levels - 1 Week

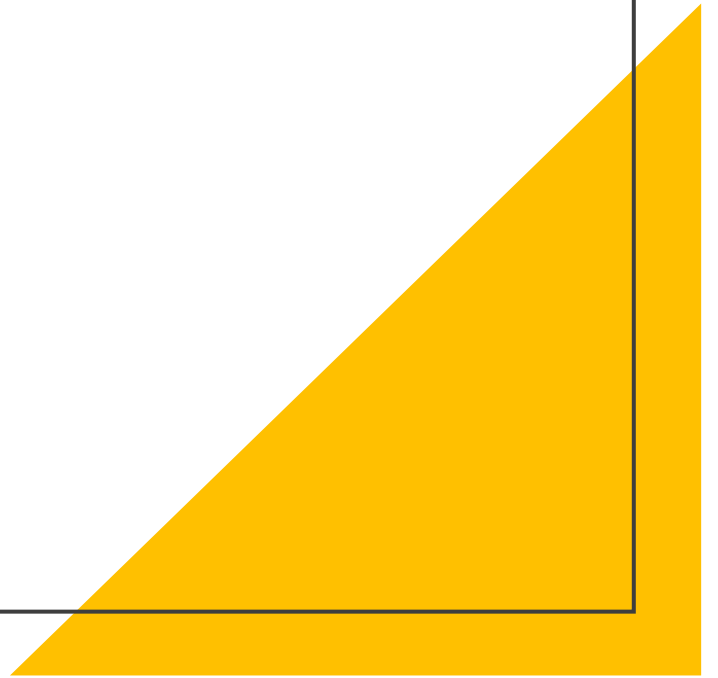


# Conclusions

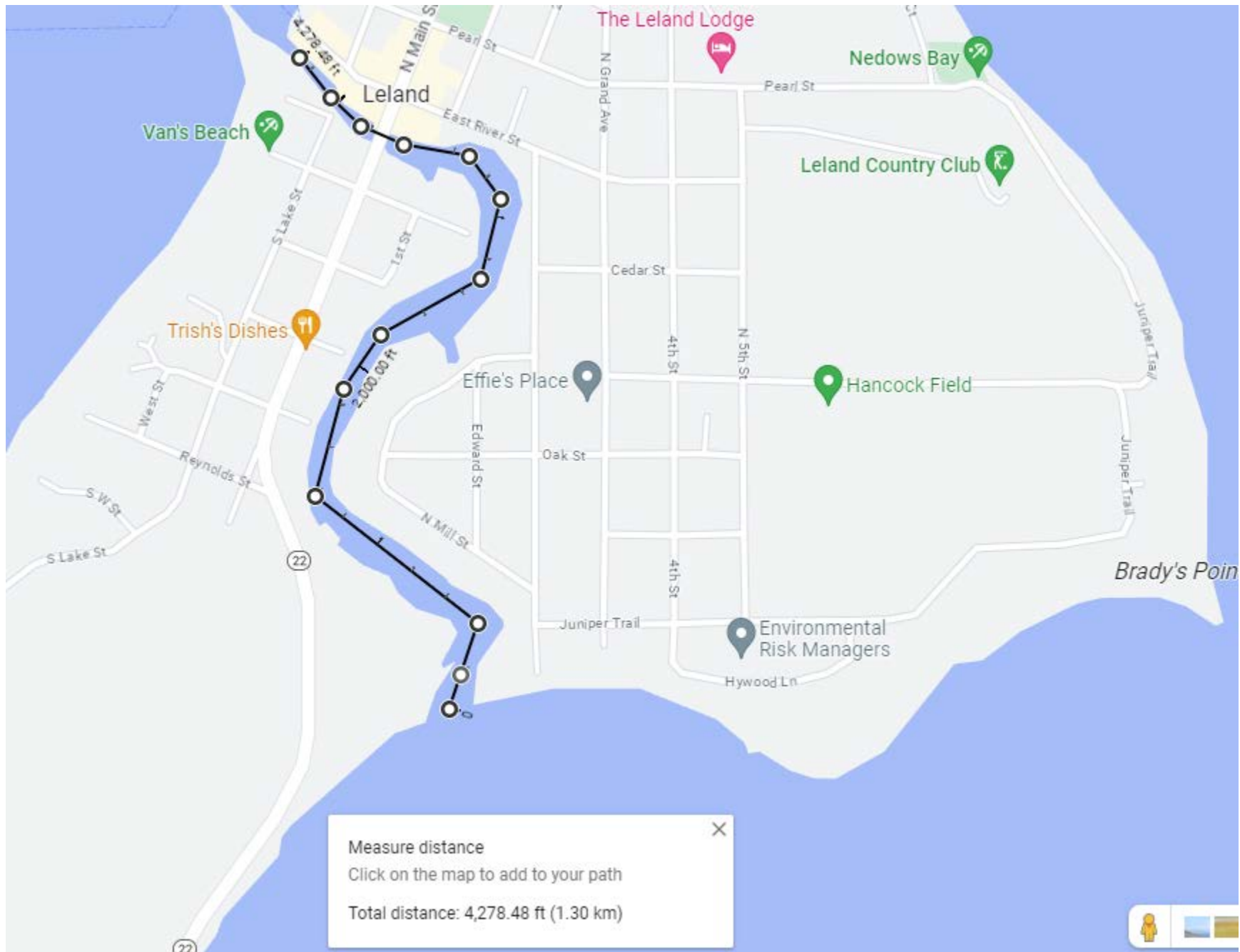
- Calibrations should be ongoing with staff gauges very close to sensors and periodic readings
- North Lake level  $\neq$  Narrows sensor
- Bridge marker  $\neq$  Narrows sensor
- In graphs, you should always\* see water levels : South > Narrows > Dam
- When the dam is running high:
  - Narrows >> Dam (immediately)
  - South >> Narrows (eventually)
  - The dam staff gauge & sensor will be reporting very low levels
- Closing the dam will start to bring up the water level there.
  - It will asymptotically approach the level of North Lake after Carp River (.8 mile) has filled ( > 1.1 hr @ 1fps).
  - It will approach the level of South Lake when North = South and there is no movement of water in the Narrows (never).

\* Wind can have a temporary affect

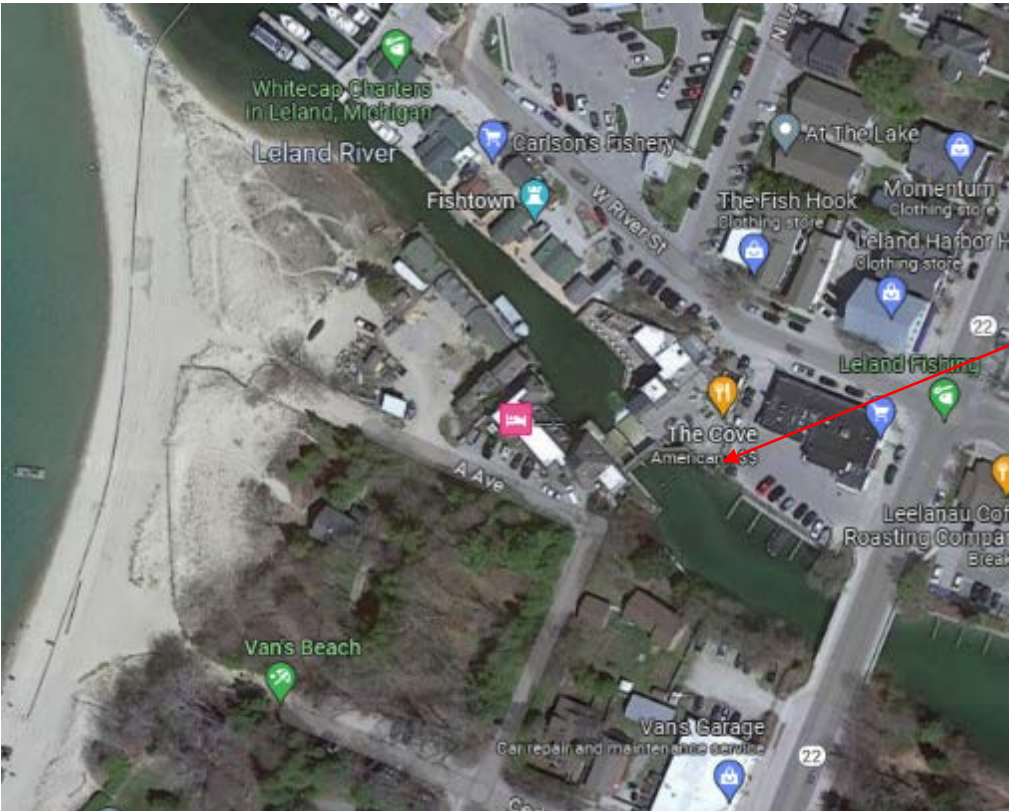
Backup



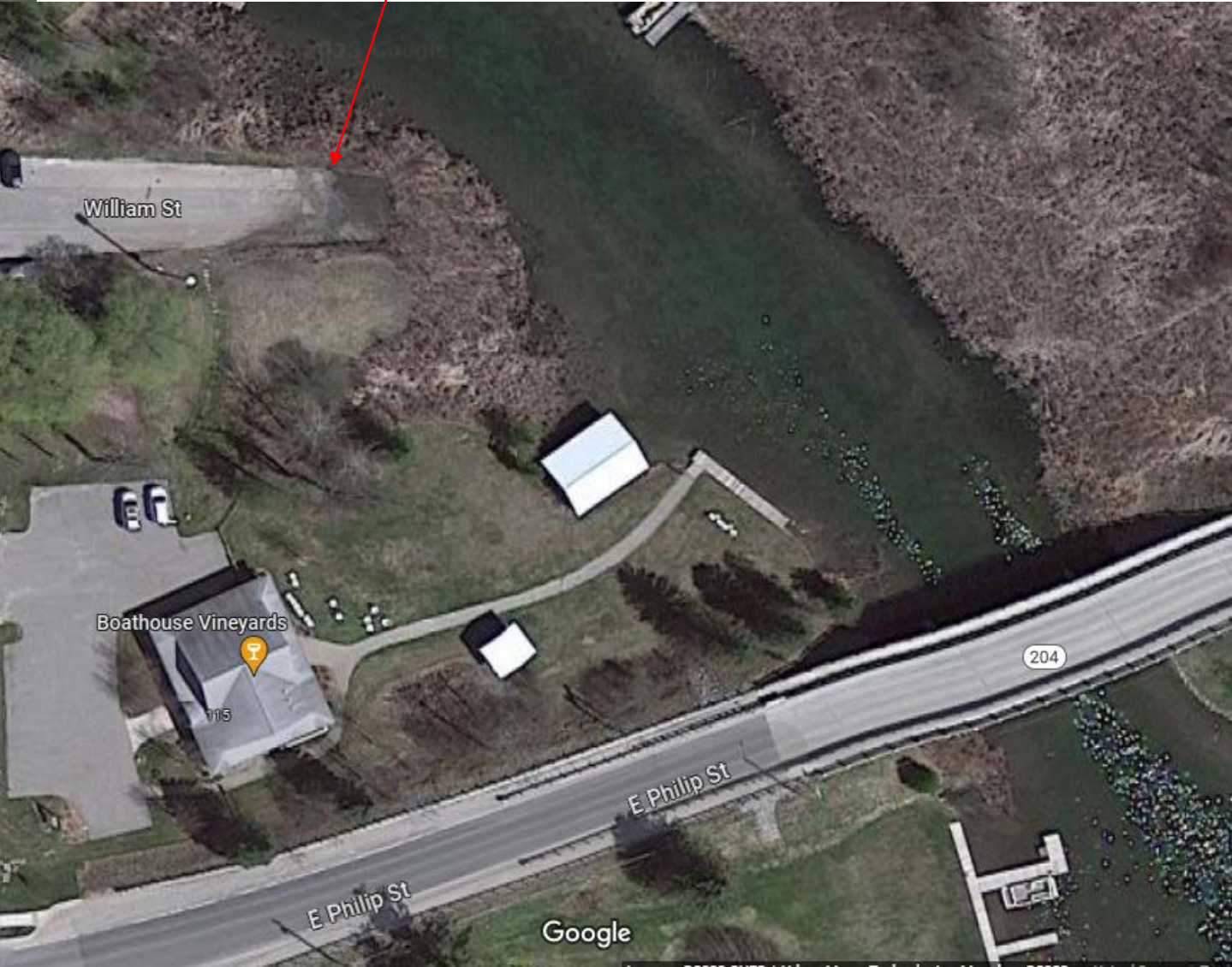
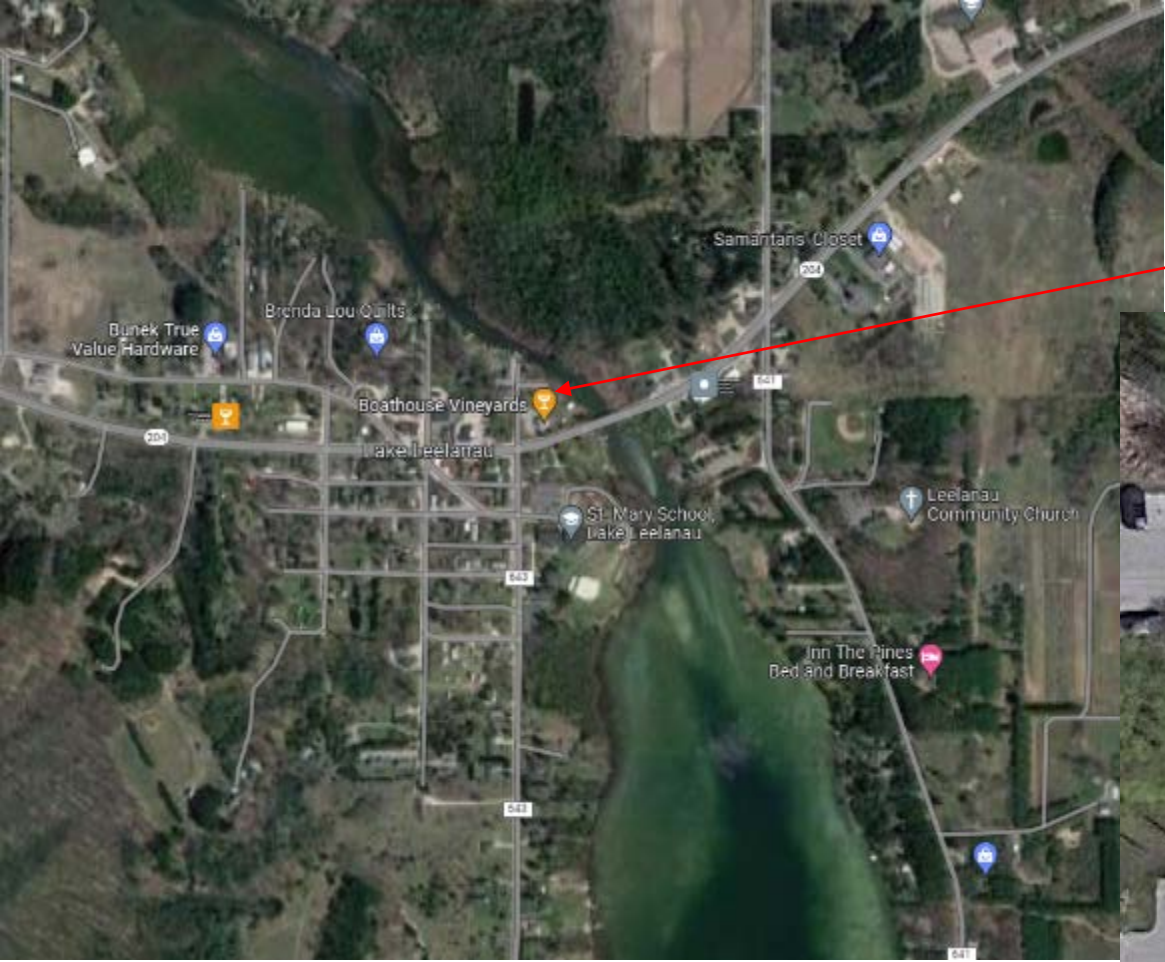




Dam



# Narrows





South Lake

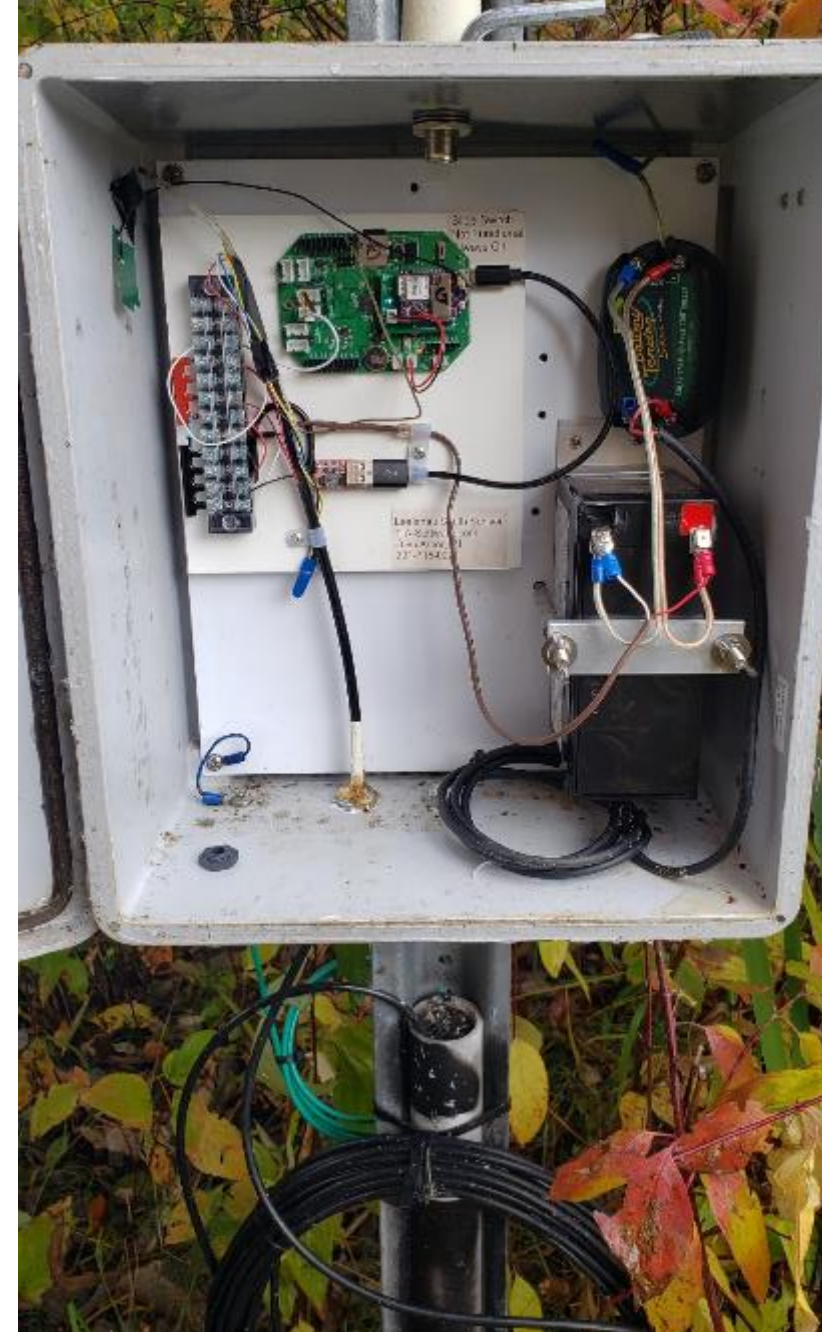




11/2016 – 11/2019

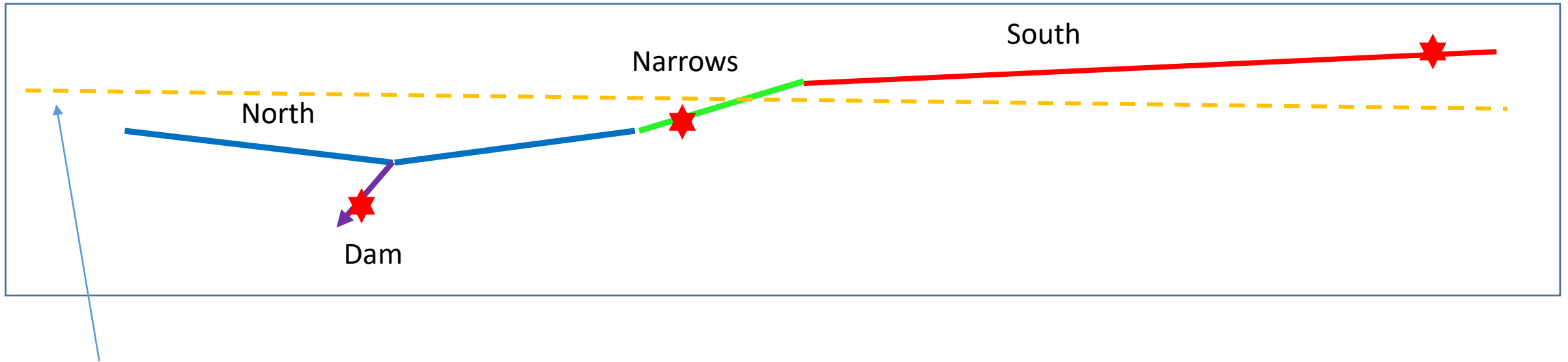


11/2019 – 11/2020



11/2020 -

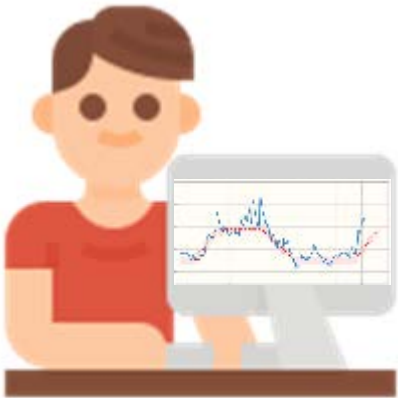
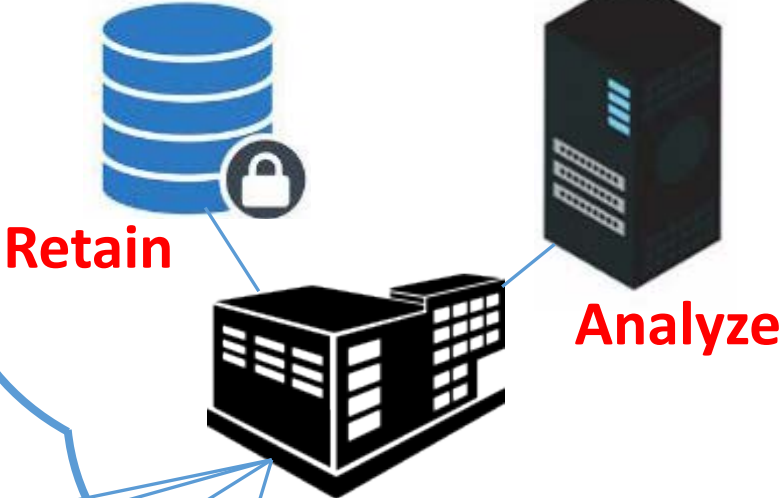
## Lake Level View with Average



### Theoretical average of Lake Level:

- Can be mathematically computed
- Simulates closing the dam long enough (without inflow/outflow) to average out the levels
- Equates to “measuring lake level at the dam” – complies with court order
- Can be easily understood and communicated to public
- Requires knowing/computing the North Lake Level

# Data → Information



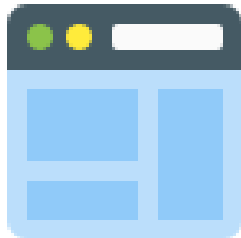
**Graphs**



**Alerts**



**Email**



**Assoc. Web Page**

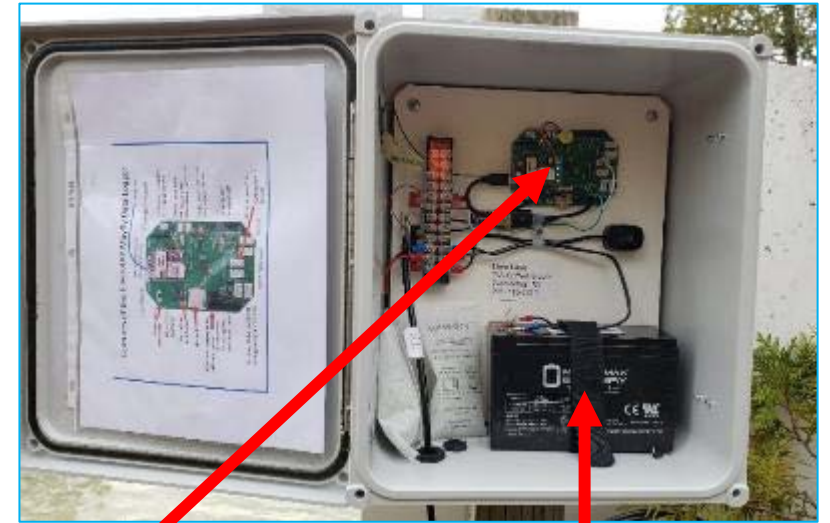
Lake-Man.com

<https://lakeleelanau.org/lake-levels/>

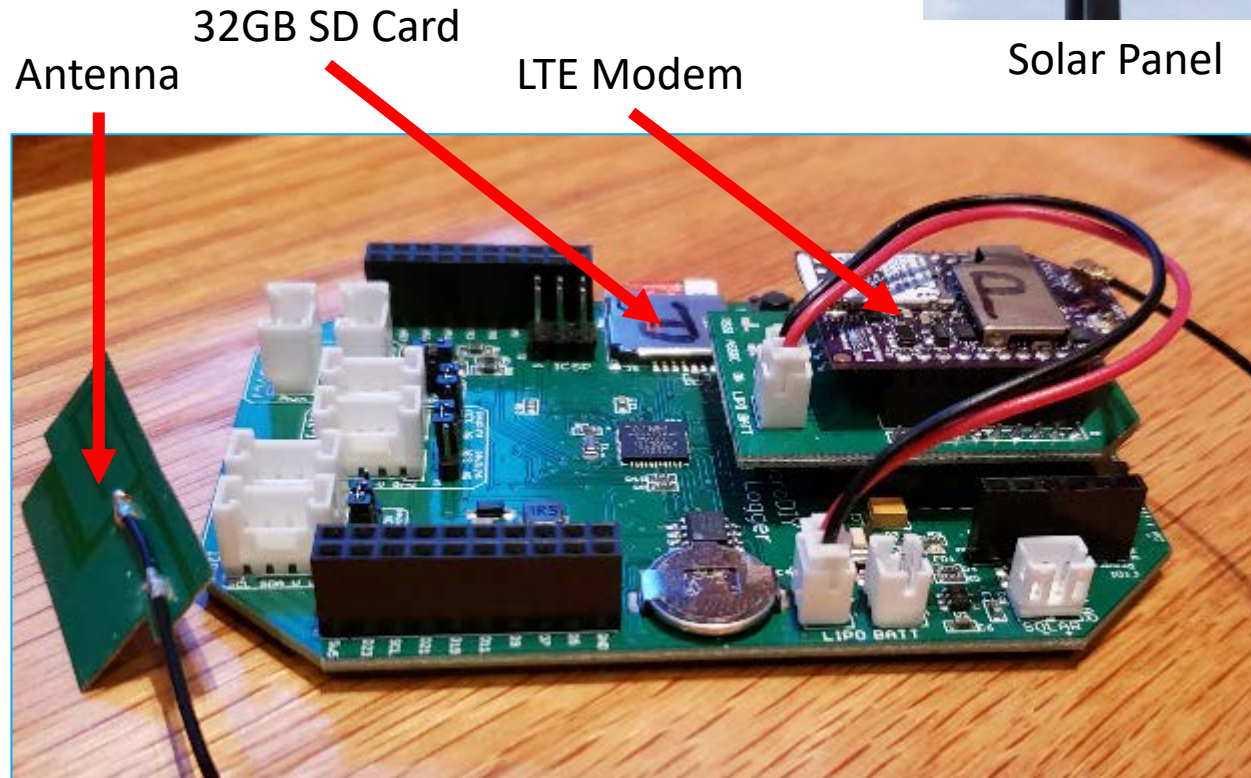
# Current Datalogger



Solar Panel



12v Battery



Antenna

32GB SD Card

LTE Modem

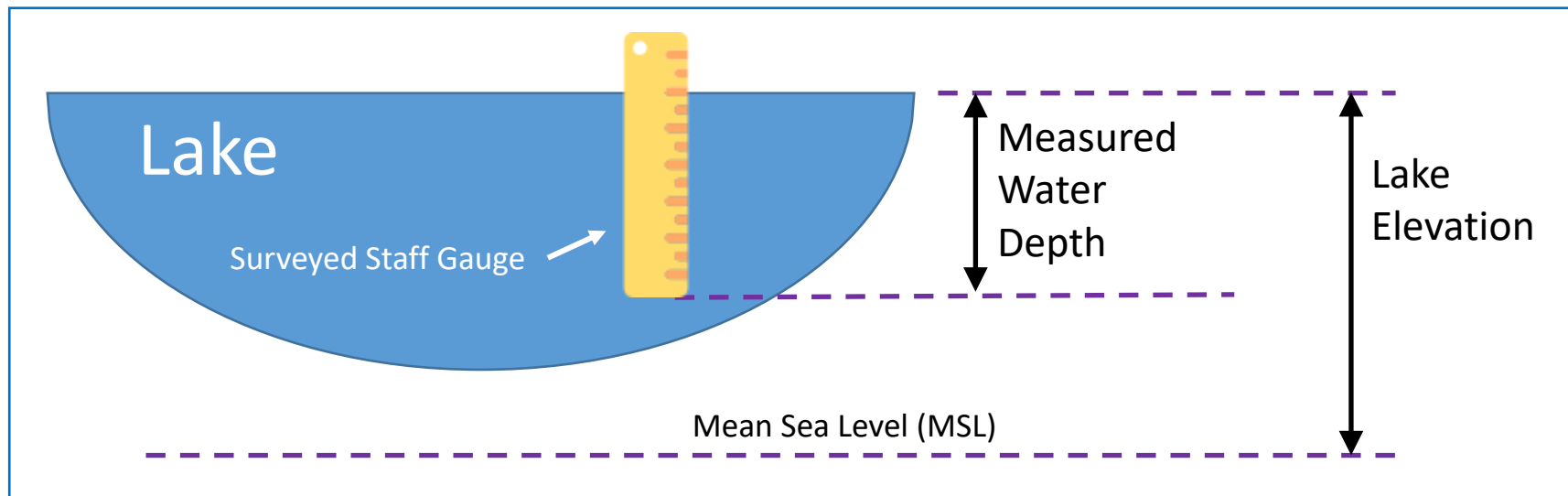


Sensor with cable and capillary tube

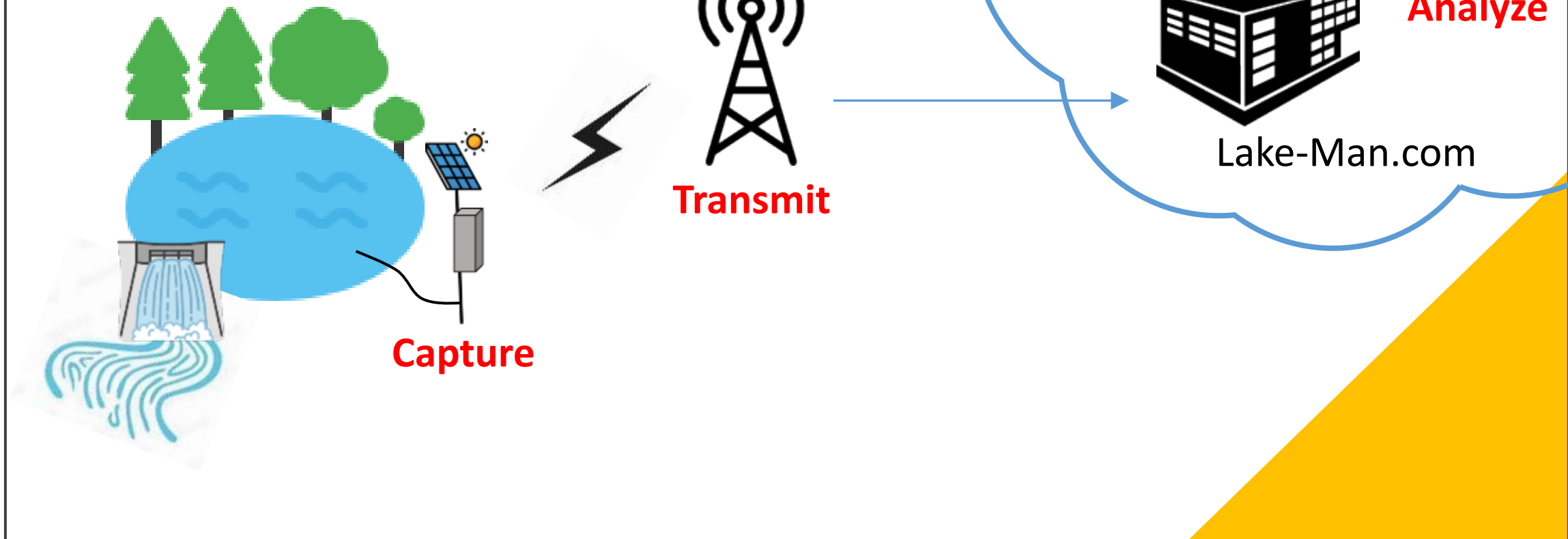


# Depth $\rightarrow$ Elevation

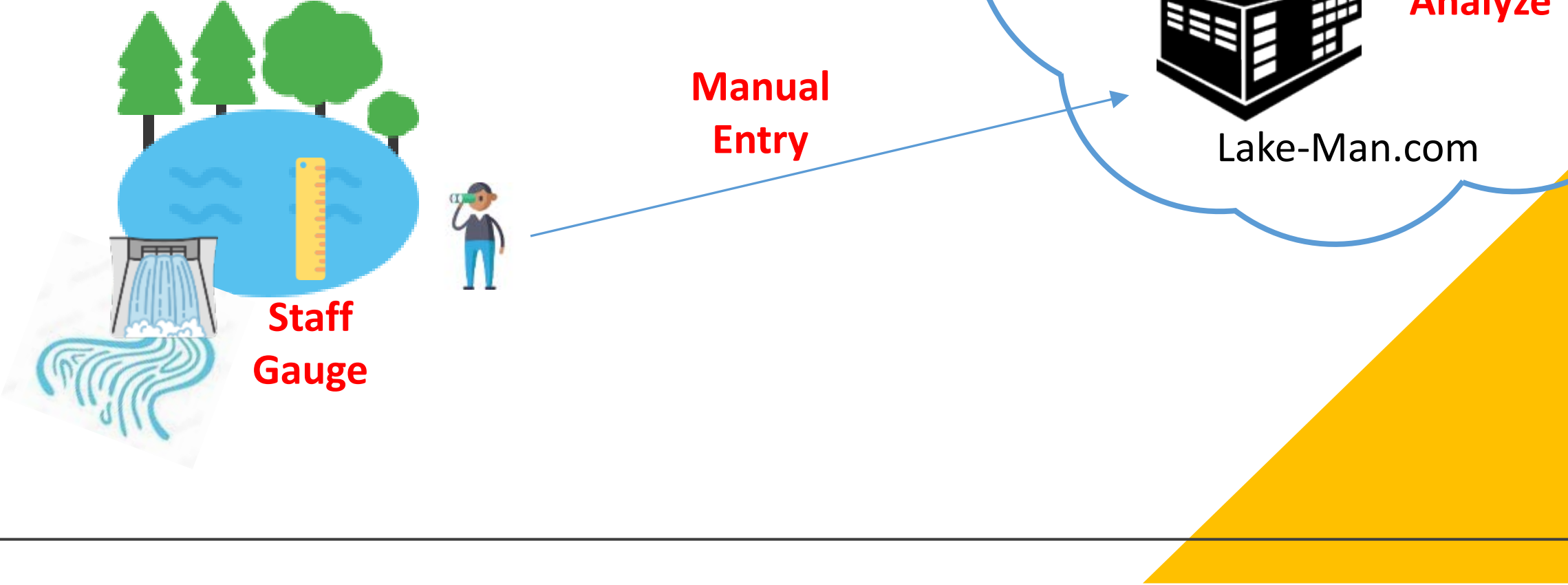
- Measure the **Depth**, then calculate the **Elevation**



# Data Input – Automated



# Data Input – Manual Entry



# Dam Sensor Replacement Plan

- **BACKGROUND:**

In the Fall of 2022, Bill noticed that the Dam Sensor was not tracking with the USG readings.

Further analysis proved that the sensor at the dam (OTT PLS c. **Nov 24, 2011**) had been “drifting” for the past 5 years.

To correct historical and future measurements, adjustments were made from an original depth of 593.73 to:

- 593.62 (down 0.05 ft.) on **January 2017**
- 593.57 (down another 0.05 ft.) on **May 2021**.

Blue Dots = Sensor – USG

Red Line = Calibration Adjustment

