Eagle Spring Lake Flow Analysis 4/09/2026 By David Voves Chairman ESLMD

Project Overview:

Eagle Springs Lake Management District is looking to fund a 5-year study to measure water flow through our two water control structures or dams. One dam named Wambold, empties into Jericho Creek which in turn empties into the Mukwonago River and another dam named Kroll which empties into the Mukwonago River. See figure 1.

The goal of this project is to determine if the current design of our two spillways is of sufficient capacity to accommodate the flow of a 1000-year rain event without overtopping our embankments which could lead to a breach and subsequent property damage downstream. To accomplish this, we want to monitor both rainfall in our sub-basin and the resulting flows through our dams to be able to extrapolate how differing rain events effect flow through our sub-basin and then into our spillways.

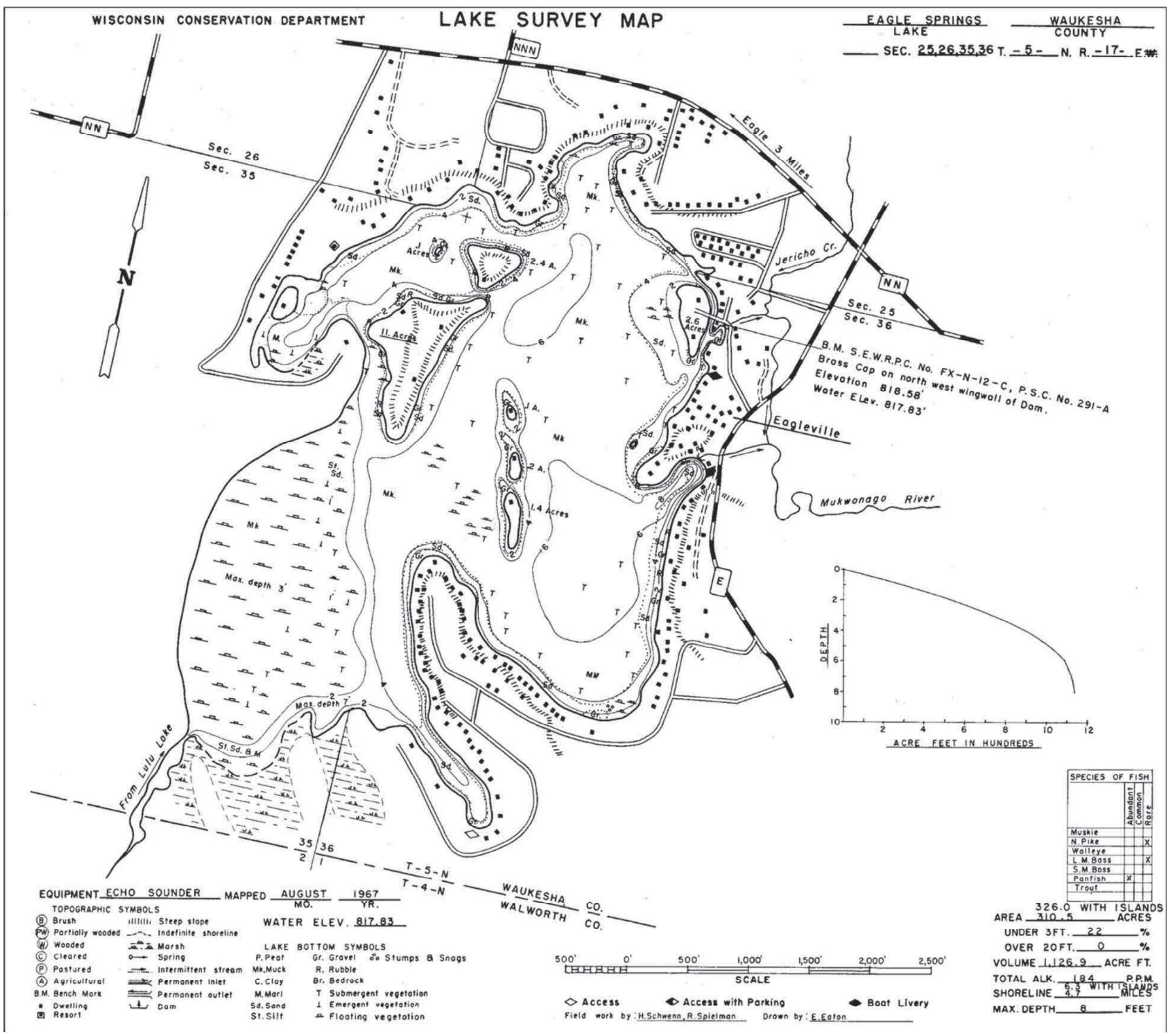


Figure 1

Table 1

COMPARISON OF HISTORIC AND CURRENT HYDROLOGY AND MORPHOMETRY OF EAGLE SPRING AND LULU LAKES: 1969-2005

Parameter	Eagle Spring Lake		Lulu Lake	
	1969	2005	1969	2005
Surface Area (acres)	310.5	279.2	84.26	95.5
Percent of Area Less than 3.0 Feet Deep	22	28 (78.3 acres)	10.1	10.8 (10.4 acres)
Percent of Area Greater than 6.0 Feet Deep	No data	13.3 (37.2 acres)	No data	78.6 (75.1 acres)
Percent of area Greater than 20.0 Feet Deep	0	0	63.1	52.5 (50.2 acres)
Total Watershed Area (acres)	22,713.6	16,076.1	6,387.2	- -[a]
Total Watershed Area Excluding Internally Drained Areas (acres)	- -	13,127.7	- -	- -
Ratio of Watershed Area to Lake Area	73.2	57.6	75.8	- -
Volume (acre-feet)	1,126.9	1,005.1	2,008.9	- -
Residence Time (years)	0.086	0.07	0.086	- -
Maximum Length of Lake (miles)	1.18	1.18	0.55	0.55
Maximum Width of Lake (miles)	0.65	0.65	0.42	0.42
Length of Shoreline (including islands) (miles)	6.30	7.44	2.40	2.07
Shoreline Development Factor[b]	- -	3.2[c]	- -	1.5
General Lake Orientation	- -	N-S	- -	N-S
Mean Depth (feet)	3.6	3.6	24	24
Maximum Depth (feet)	8.0	8.0	40	40
Ratio of Mean Depth to Maximum Depth	0.45	0.45	0.6	0.600

[a] *Watershed area was not calculated specific to Lulu Lake.*

[b] *Shoreline development factor is the ratio of the shoreline length to the circumference of a circular lake of the same area.*

[c] *This value was originally presented as 2.5 in the initial SEWRPC plan of 1992; the current measurement is based on elevation refinements made possible through Commission digital terrain modeling analysis.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 2

We would also like to measure the inflow into our lake which comes from lake Lulu via a channel from the south. The inflow is mostly from springs but a component of it can also be from storm run-off. Figure 2 shows the stage storage area of our lake.

In addition, the wetland south of Eagle Spring Lake which includes Lulu Lake acts as one large area providing significant additional stage storage during storm events which acts to dampen peak flows during storm events. We want to monitor the inlet at Nature Road for both rain and water level to see how precipitation enters our lake from nature road.

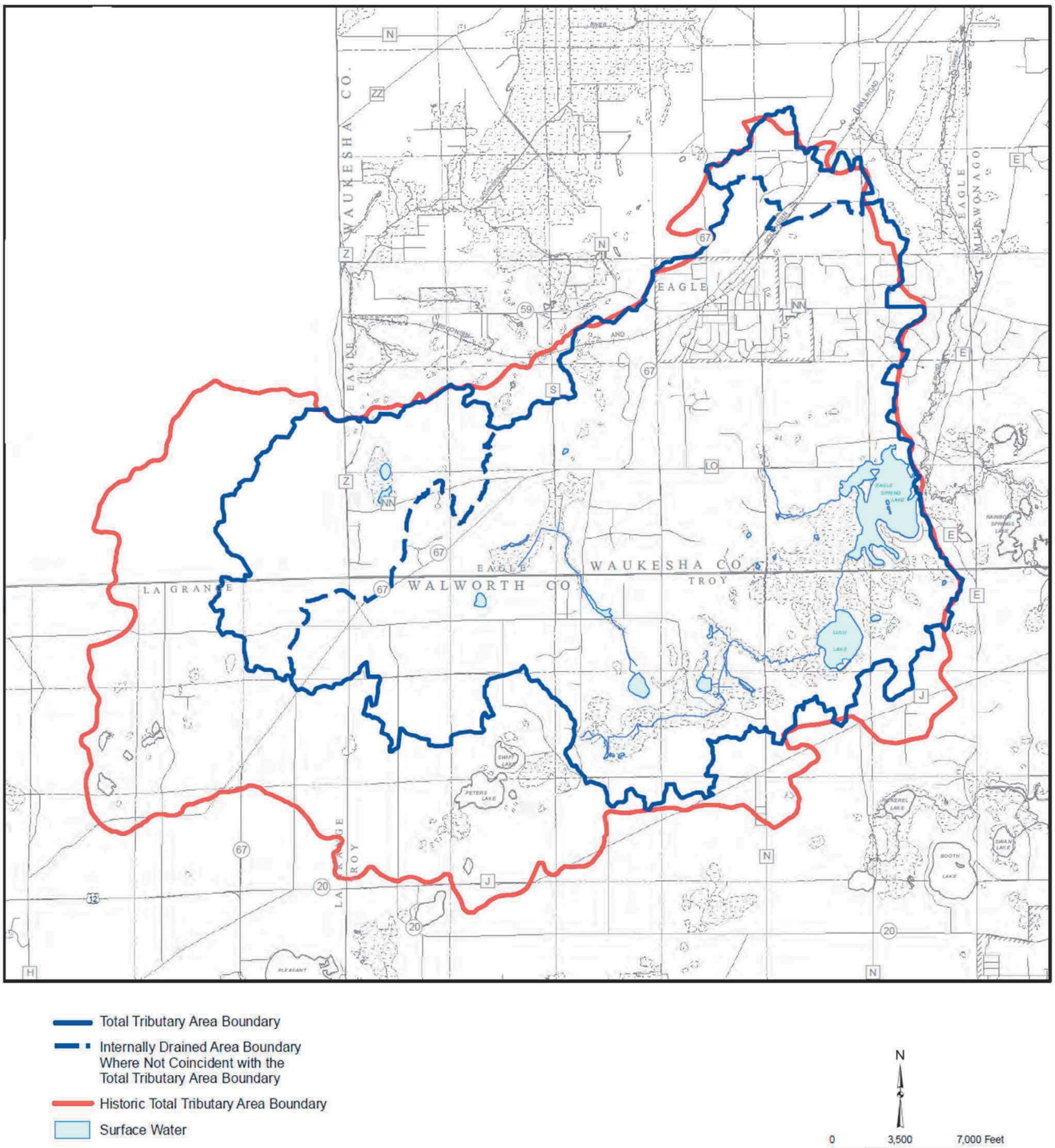
The Eagle Spring Lake sub-basin shown in figure 3, is one of 5 sub-basins (Shown in figures 4-6) which empty into the Fox River. (Jericho, Eagle Spring Lake, Lake Beulah, Phantom and Mukwonago sub-basins all empty into the Fox River. Currently the USGS monitors flow at the Dam in Mukwonago which then empties into the Fox river. This total area is about 74 square miles of drainage area which empties through the dam in Mukwonago.

We are looking to establish an understanding of how precipitation runoff affects peak flows through our two spillways during extreme storm events. The flow through our spillways could also be affected by flow from Jericho Creek which can introduce flooding downstream of our dams and affect flow through the spillways if it backs up our spillways.

Once we can establish accurate peak flow estimates for 10, 25, 50, 100, 500, and 1000 year flood events, we can better understand if our spillways are appropriately sized to accommodate extreme flood events without over-topping our water control structures.

Map 1

HISTORIC AND CURRENT WATERSHED BOUNDARY TRIBUTARY TO EAGLE SPRING LAKE: 2008



Source: SEWRPC.

Figure 3

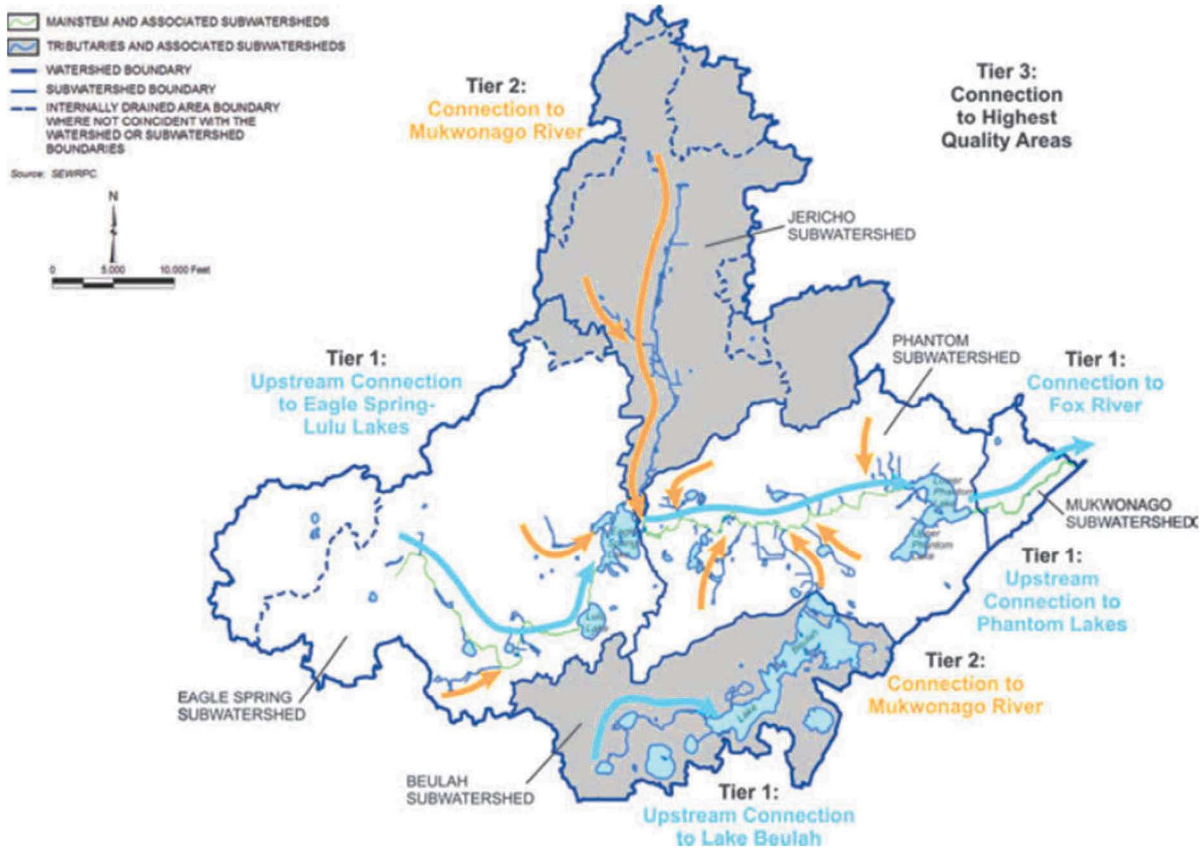


Figure 4

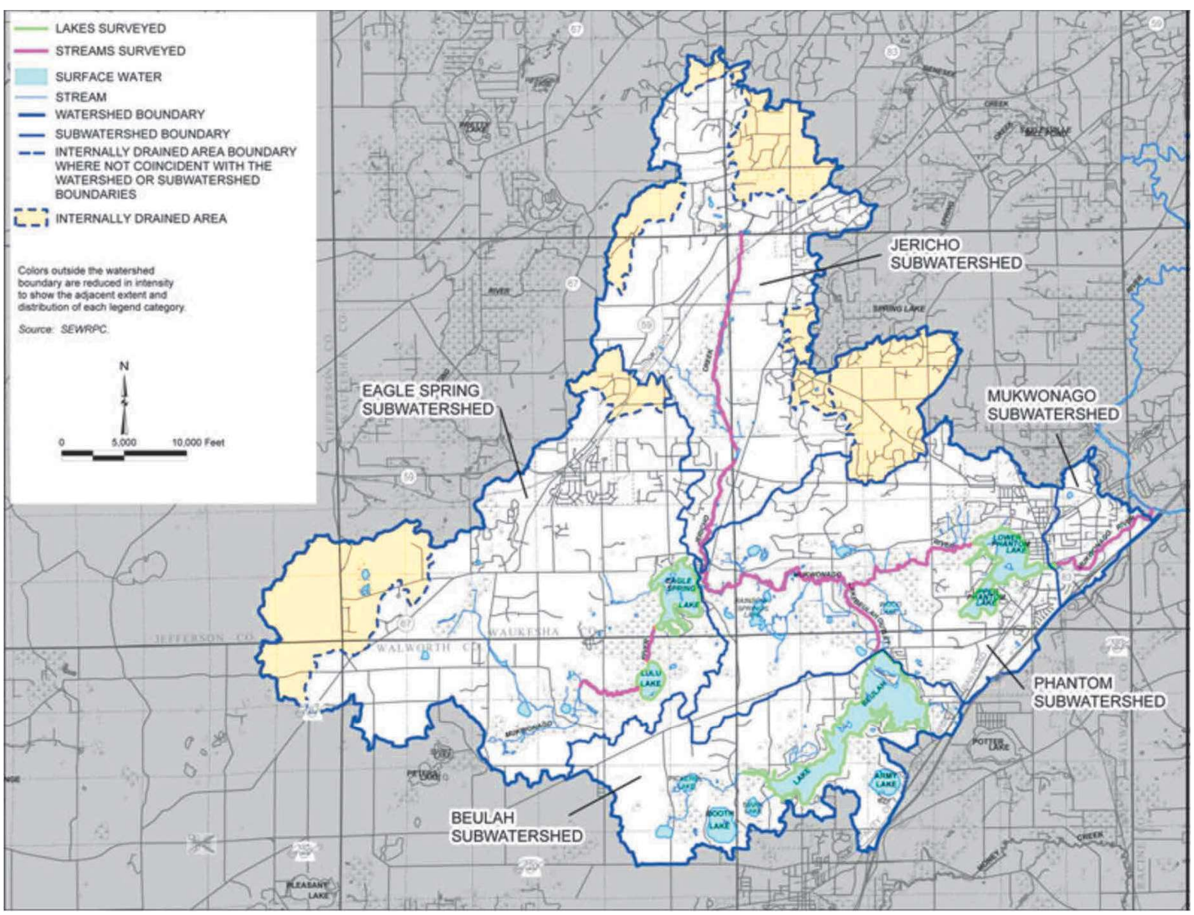


Figure 5

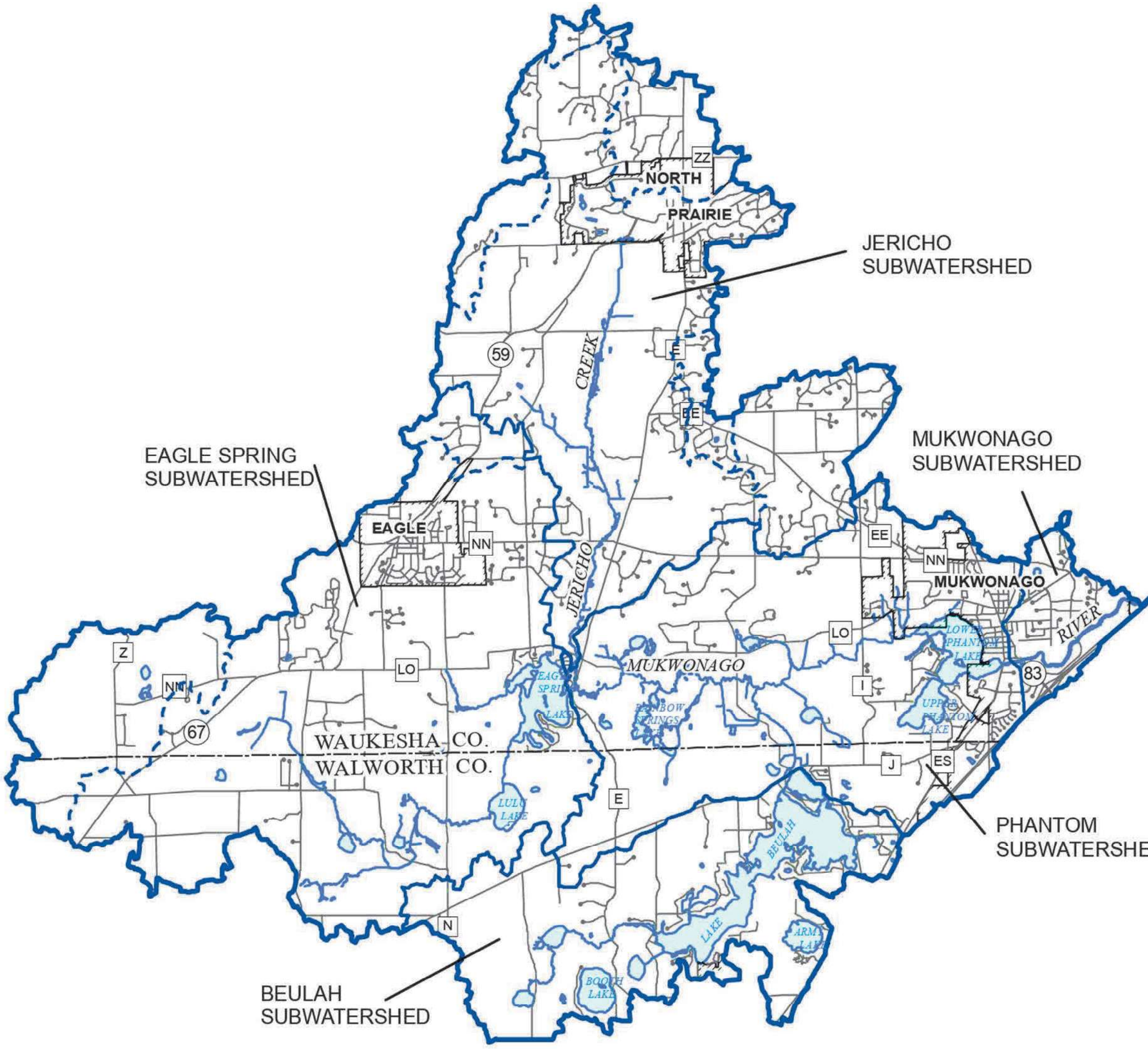


Figure 6

If the study determines the current structures are inadequate, the information gathered will be used as the design parameters to improve the spillway design to meet the required spillway capacity based on the assigned dam hazard rating per Wisconsin law.

The goal of these measurements is to accurately characterize how rain events affect spillway flows, lake level rise, and the time latency between these items.

We are proposing that we measure lake and stream-bed water levels and calculate flows from water levels based on sluice gate position and standard weir-flow and orifice formula. Flow will not be measured directly but rather inferred from water level measurements.

Figure 7

Project Concept Discussion:

To accomplish our measurement goals, we are proposing the following sensors to measure the following items:

1.) Water Level measurements every 15 minutes, like USGS in Mukwonago

(5) Sensor Locations Required

- Lake level at the Kroll inlet.
- Water level after the Kroll Dam at the steam bed just across Highway E.
- Lake level at the Wambold inlet for redundancy.
- Water level after the Wambold Dam at the stilling pool just across the Wambold bridge.
- Water level at the intersection of Nature Road and the stream that feeds Lulu Lake.

Optional Depending on Cost

- *At the confluence of Jerico Creek and the Mukwonago River*
- *At the Rainbow spring golf resort crossing*

2.) Measure sluice gate positions every 15 minutes in sync with water level. There are three manually operated sluice gates which utilize a worm screw and hand operated gearbox to lift and lower the gates. Two gates are part of the Kroll Dam and one gate is part of the Wambold Dam. We are proposing to monitor the position of the top of the worm screw with an optical laser sensor and record it at the same time as water level.

Measure and record gate position:

- North Kroll Sluice Gate Position (76 inches of gate travel)
- South Kroll Sluice Gate Position (76 inches of gate travel)
- Wambold Sluice Gate Position (48 inches of gate travel)

3.) In addition to three gates, Wambold has 6 manually removable weir boards which can be removed to increase spillway capacity. These boards would only be removed under flooding conditions. Typically, lake level can be easily managed utilizing the sluice gates. If we must remove a weir board, we would digitally account for this in the flow calculations with two position potentiometers. One (3 position) potentiometer will indicate the number of boards present restricting the north weir channel and one (3 position) potentiometer will indicate the number of boards present on the south channel. Both potentiometers would only be adjusted by the operator if they remove boards. These position settings will be recorded electronically every 15 minutes along with water level readings and will affect the flow calculations derived from water level measurements.

Monitor Wier Boards in Place:

- 6-inch-high board top north side
- 6-inch-high board mid north side
- 6-inch-high board bot north side
- 6-inch-high board top south side
- 6-inch-high board mid south side
- 6-inch-high board bot south side

4.) To measure rainfall, which is representative of just the Eagle Spring Lake sub basin we would only need two rain gauges at most. One could be located at Kroll Dam and the other could be located further west at the Nature Road creek crossing. This will provide some redundancy and can be averaged together.

- 1 Rain Guage at the Kroll Site
- 1 Rain Guage at Nature Road creek crossing

By combining lake water level measurements, with gate, weir board positions, and the known gate and wier geometry, we can calculate flow through the spillways for each 15 minute interval 24 hours a day seven days a week.

Wambold Dam

Wambold Dam is constructed with 3 channels which pass under a bridge. (3) removable weir boards on outer 2 channels, (1) sluice gate in center channel controlled by ball screw mechanism. Weir board needs to be physically removed one at a time by lifting out of concrete slots. The two outer channels only have half the opening size of the center channel. A concrete half wall sits directly below the weir boards. Subsequently removing the any of the 6-inch-high weir boards does not significantly increase flow.

Figure 8 Wambold Location

Figure 9 Wambold Storage Shed and inlet view

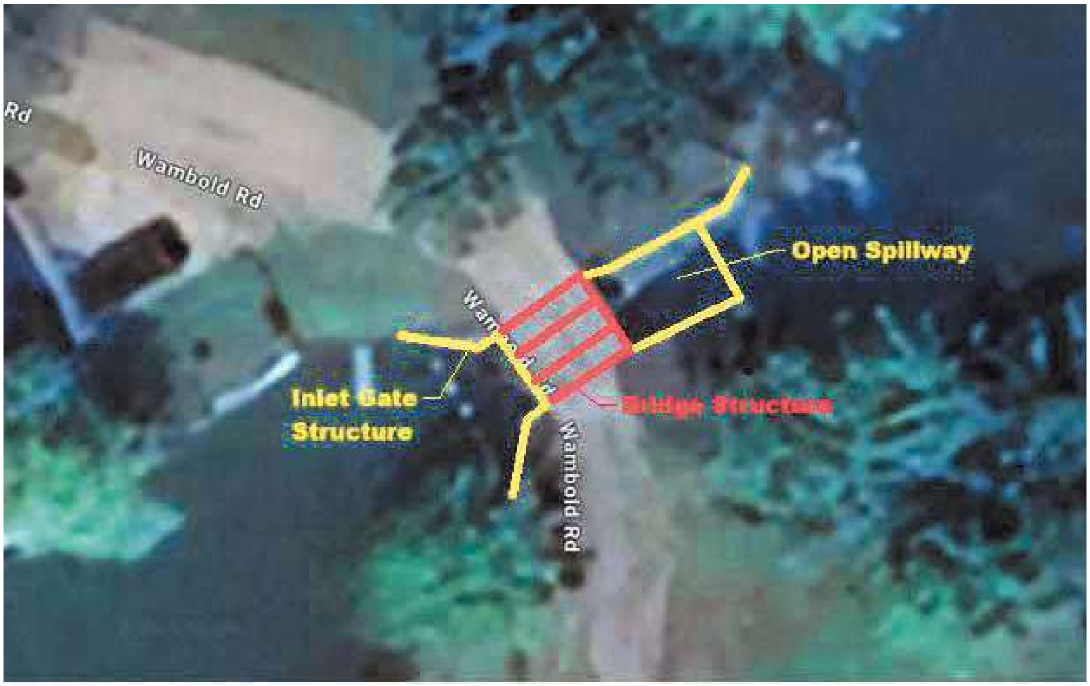


Figure 9

Figure 10 Notice the three spillway channels

Figure 11 Notice the worm screw with crank handle for adjusting gate opening

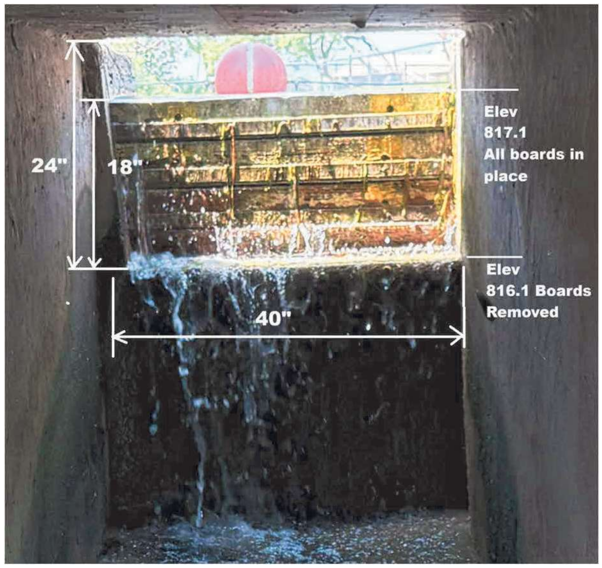


Figure 12 South Channel with (3) Weir Boards

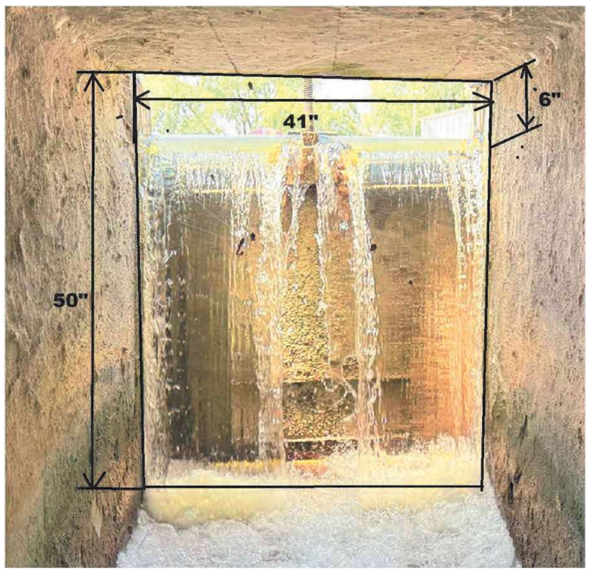


Figure 13 Center Channel with Sluce Gate

Figure 14 North Channel with (3) Weir Boards

Kroll Dam

The Kroll Dam consists of a large intake channel obstructed by two sluice gates which are roughly 74 inches by 38 inches per gate flow area. Each gate has a small wicket gate (a gate within a gate) which is primarily used to control flow during periods without rain. Each wicket gate is 24 inches by 12 inches when fully open. If a storm surge happens, two full 84 x 44 inch gates can be opened dramatically increasing spillway flow capacity.

Figure 15 Kroll Dam

When the ball screw is fully lowered, both the primary and wicket gate is shut. When you start to open the gate, the ball screw first opens the wicket gate. Once it is fulling open, continuing to rotate the ball screw opens the larger sluice gate until it is fully open. This allows for both fine tuning low flow and accommodating very large flows.

The gates are housed in a building, and the mill race runs under the building floor through the gates and out the back of the building where the water drops down into a concrete chamber and is funneled into two culvert pipes which take it under highway E where it empties into the streamed of the Mukwonago River.

Figure 16 Notice Inlet channel

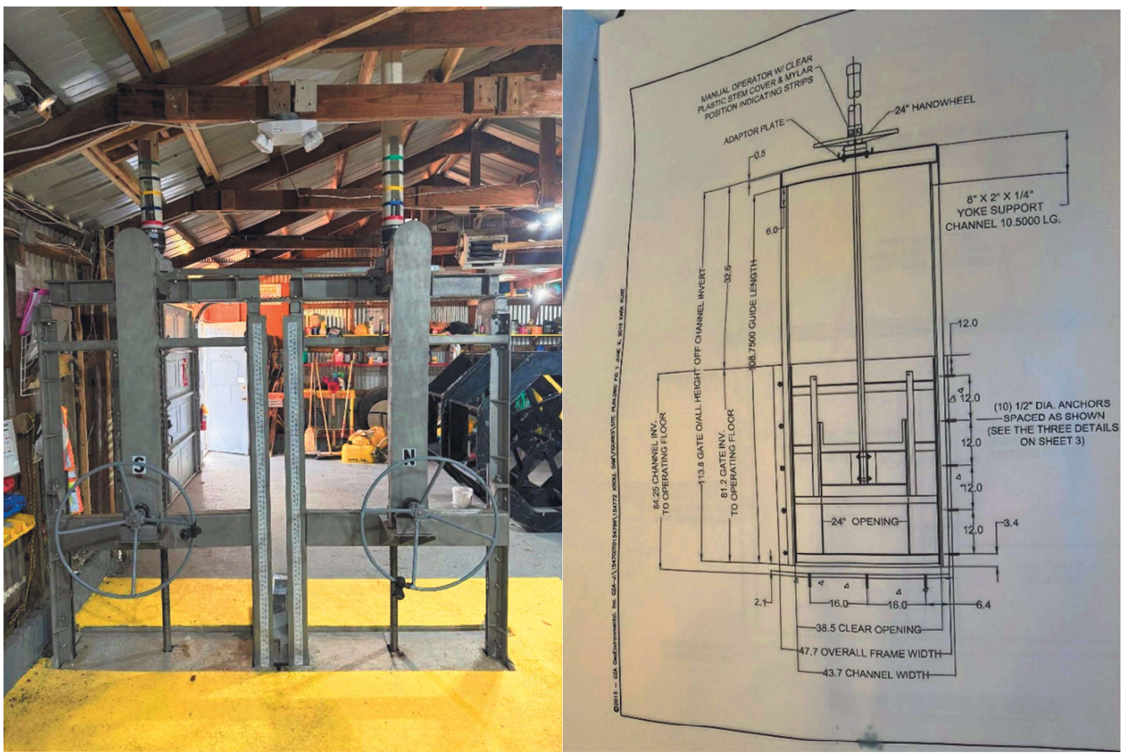


Figure 17 Notice (2) Sluice Gate Crank Wheels

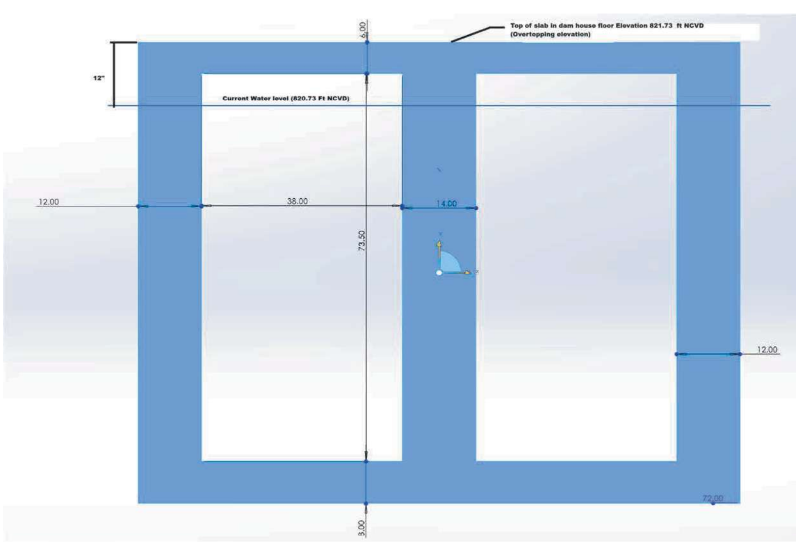


Figure 18 Notice Gate Dimensions

One culvert pipe has a 48 inches inside diameter and one has a 30 inches in inside diameter. Here we want to measure lake level at the inlet and water level at the streambed. We also want to measure the two gate worm screw postions so we can determine the open area of each sliuce gate. Each worm screw proturded up through a tube which protudes through the roof. Lasre sensors will monitor the top of the worm screw positions. The total drop in elevation from the lake level to the streambed level is about 9 feet.

Figure 19 Kroll Outlet Culverts

Water Level Measurement Methodology

We plan to use a solid-state pressure sensor to monitor water levels in 5 locations. Each sensor measurement will be placed in a vertical pipe (stilling well) and dropped down in the water a known distance inside the pipe below the frost line. A electronic module called a mote will wirelessly transmit measurement data every 15 minutes to a Data Logger located by the inlet of the Kroll Dam.

PART NUMBERS

MX2001-04-SS-S • MX2001-01-SS-S • MX2001-02-SS-S • MX2001-03-SS-S • MX2001-04-TI-S • MX2001-01-TI-S

Water Level Sensor

From **$449.00**

For use with HOBO MX2001 loggers, MicroRX Water Level Stations, RX3000 stations, and the HOBOnet Remote Water Level Monitoring System, for water pressure, temperature, and water level measurements.

SELECT OPTION | REQUEST A QUOTE

PART NUMBER - CABLE-DR

MX2001 Direct Read Cable

From **$102.00**

This direct read cable provides the connection between the MX2001 logger's top-end unit and water level sensor.

IMPORTANT INFORMATION

For custom cable lengths, please call our sales team at 508-759-9500 for assistance.

SELECT OPTION | REQUEST A QUOTE

https://www.youtube.com/watch?v=IPh_hCZGFV8&t=3684s

Figure 20 Wireless Mote

Figure 21 Stilling Well Cap

We will need (5) water sensors, wireless interfaces, and cables. We need to supply a post to mount these items and bury a pipe to hang the sensor in water.

Data Communication to Internet

Figure 22 All Sensor Data is Collected to a Data Logger Module

PART NUMBERS
RX2101 • RX2102 • RX2103 • RX2104 • RX2105-900 • RX2105-868 • RX2105-922 • RX2105-921 • RX2106-900 • RX2106-868 • RX2106-922 • RX2106-921

MicroRX Station

From **$735.00**

A rugged, easy-to-deploy, low-cost cellular solution for long-term, reliable field monitoring. Inputs for up to five plug-and-play sensors. Data access through LI-COR Cloud platform.

IMPORTANT INFORMATION

External sensors must be purchased separately. Requires an RX data plan, which must be renewed annually. Learn more about LI-COR Cloud.

Figure 23 Data Logger Module with Cellular Interface

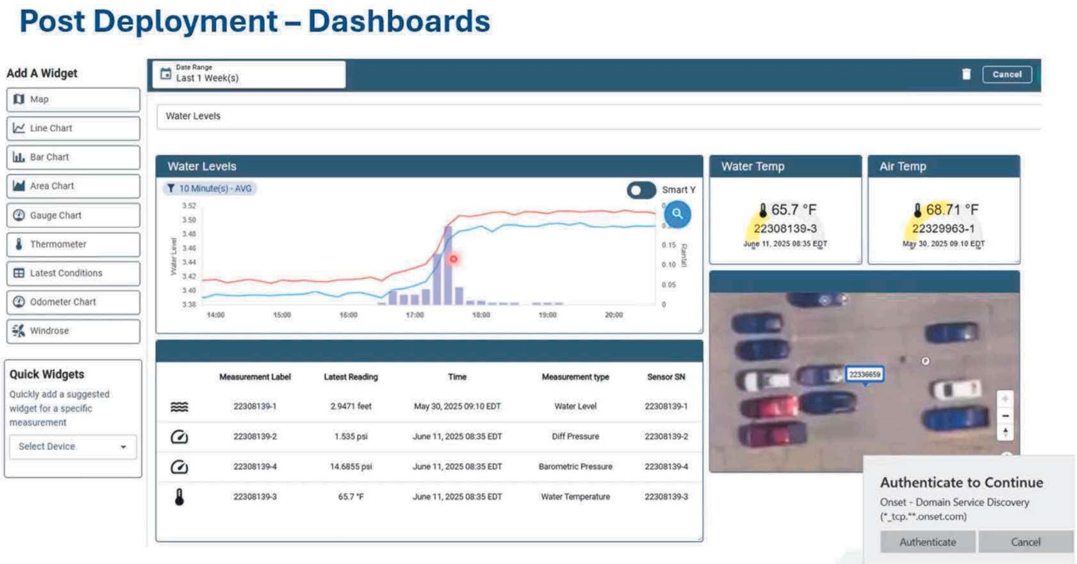
We will need (2) Micro RX Data logger with a cellular plan to transmit measurements to the cloud/ internet. One at Krolls and One at Nature Road. These units are battery powered.

Data Plans

RX Plans | MX Plans | Global Cellular Coverage Areas | Renewal Information

LI-COR Cloud® Plan:	RX Basic	RX Standard	RX Premium
Description	Value plan for up to 10 measurements with longer logging intervals	Advanced monitoring capability with standard sensor support	Advanced monitoring capability with best sensor support
Max # of Measurements	10	25	Supports max sensors for each device added
Fastest Logging Interval	Every hour	Every 5 minutes	Supports each device's max logging rate
Remote access and monitoring via HOBOlink	Included	Included	Included
Pricing	$8.29/Month or $99/Annually	$16.49/Month or $199/Annually	$32.99/Month or $399/Annually
US only/Global Product Code	RX-Basic	RX-Standard	RX-Premium

Figure 24 We need a data plan for each data logger



We only need two data plans for the whole system.

After the data is collected and transmitted to the cloud, it can be graphed and interpreted utilizing a web browser interface online. This interface is included as part of the data plans. We will be able to adjust and graph data history to suit our needs and explain rain events graphically. Anyone with a pass word can log into the system a view the data

Calculating Discharge Flow from Water Level

Discharge flow would be calculated using the known geometry of the dam openings, lake water level and the position of the sluice gates utilizing weir and orifice calculations.

Figure 25 Example of water level gage set up with wireles mote.

Gate Position

We would use a noncontact laser dot sensor which would be mounted to measure the distance from a fixed point above the worm screw to the top of the worm screw. Either digital or analog sensor will measure gate position every 15 minutes. This measurement can be transmitted to a data logger and then to the internet. The position of the gate affects the flow calculation.

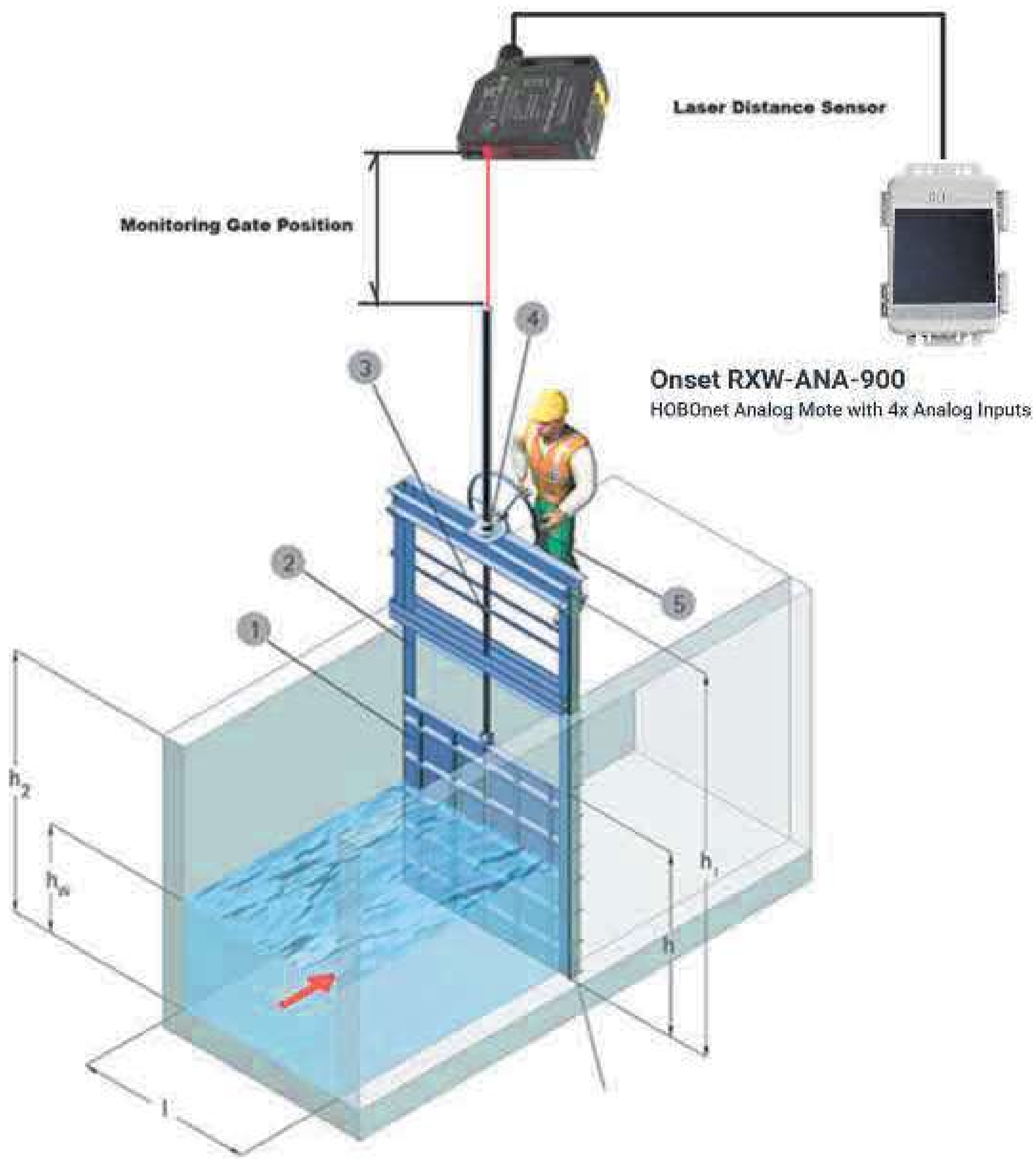


Figure 26

Q5XKILAF3000-Q8

ITEM DETAIL Q5X SERIES HIGH POWER, MULTI-PURPOSE PHOTOELECTRIC SENSOR

CAD FILE STP

CAD FILE PDF

PRODUCT MANUAL PDF

Q5X Series: Laser Adjustable Field
Range: 3000 mm; Input 12-30 V dc
Analog: 4-20 mA Discrete: PNP/NPN with IO-Link
5-pin M12 Integral QD
Part Number: 809366

5 YEARS Warranty on ifm products

Laser distance sensor

O1D105 O1DLF3KG/IO-LINK

- Reliable optical distance measurement with long ranges up to 10 m
- Two switching outputs, one of them programmable as analog output
- Scalable measuring range and window function
- Use in applications with background suppression
- Excellent price/performance ratio

IO-Link

- User-friendly communication and parameterization via IO-Link

Learn more

View other products in this family of sensors

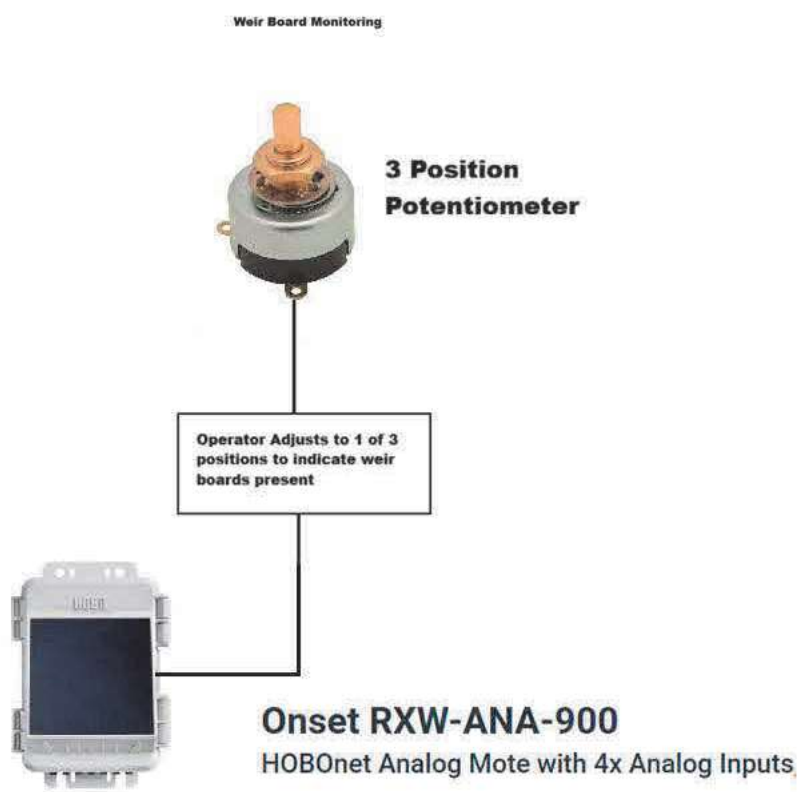
From May 1st 2025, products produced in EU and Singapore have an import surcharge reflected in the price.

List price: $559.50

These sensors are -$500-600 each. We would need one for each of the 3 sluice gates.

Weir Board Position at Wambold Dam

To monitor what boards are in position, I am suggesting 6 toggle 2 position switches which are manual set by an operator rather than monitoring boards directly. It is unlikely the boards will remove them unless an extreme weather event occurs. Ideally the switch positions can be digitized to 0 or 1 and can be transmitted utilizing the HOBO cellular connection. If a board is removed it affects the flow calculation.



Precipitation/Rain Gauges

This system will have two rain gages. One will be located next to the data logger at Kroll and one will be located at Nature Road. Havuing two gages will provide redundance in case one fails and will allow us to average the precipitation data across two locations.

Home / Products / S-RGA-M002

PART NUMBER - S-RGA-M002

0.01" Rain Gauge (2m cable) Smart Sensor

$575.00

Measures rainfall with intensity up to five inches per hour with a resolution of 0.01 inch, and 1% accuracy for rainfall rates up to 1"/hour. *Requires a data logger.

Quantity *

1 ADD TO CART REQUEST A QUOTE

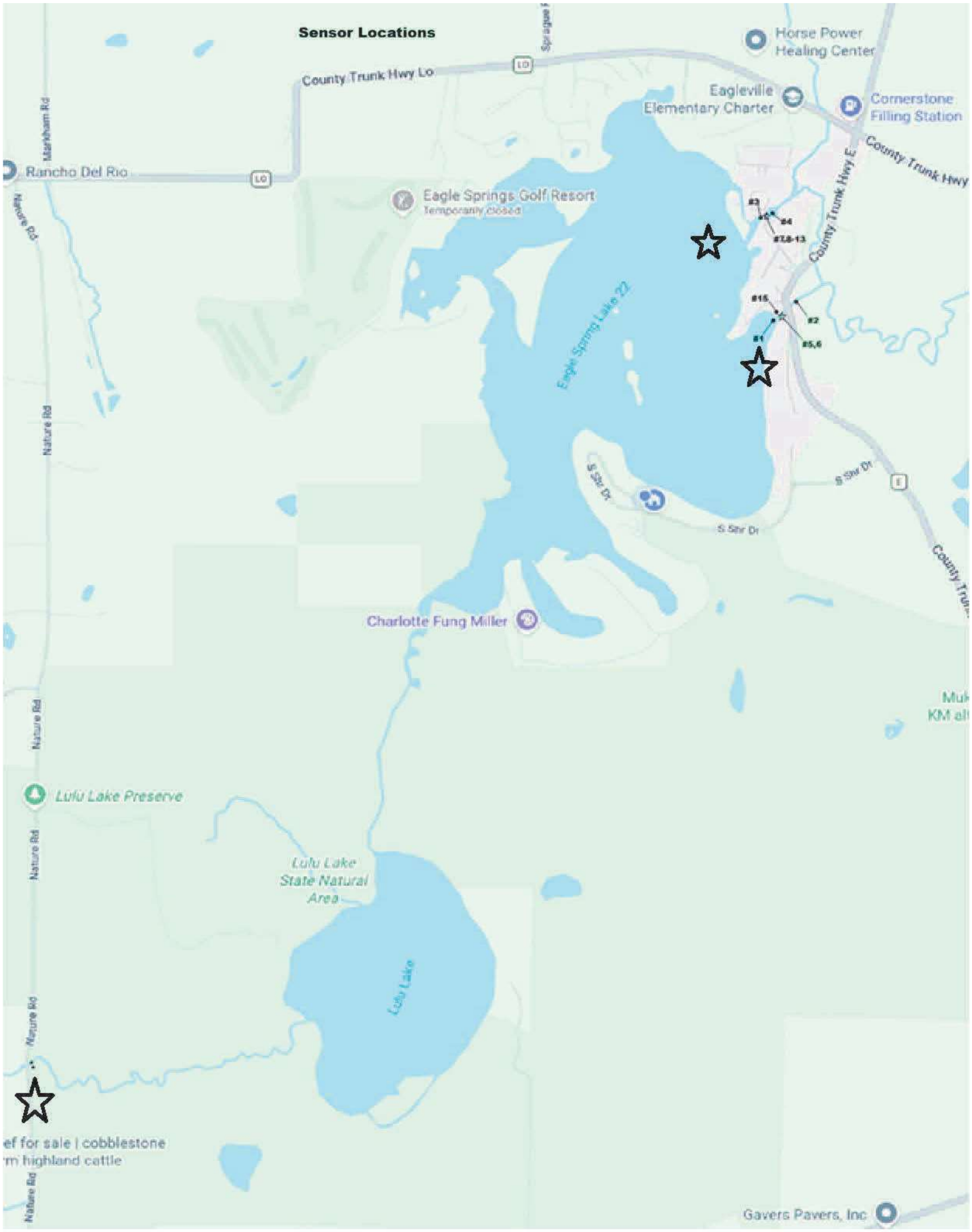


Figure 27 Insturmentation located in (3) locations indicated by the stars