



GOLDER

Experience Using Aerial Drones for Pit Lake Water Sampling and Quarterly Monitoring

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Outline and Objectives

INTRODUCE DRONE WATER SAMPLING

- 1) Define the advantages of drone-based water sampling
- 2) Discuss the equipment and methods used
- 3) Show where drone sampling has been done in USA and Canada
- 4) Provide a case study from the Thompson Creek Mine Pit Lake, Idaho, USA

The Need for Pit Lake Water Quality Monitoring

Pit Lake Fundamentals

- On a global scale, 70% of properties owned by the 6 largest mining companies exist in water stressed regions
- Open pit mining during Operations often leads to pit lakes during Closure
- Water quality in each pit lake is unique: water balance, geology, limnology, geochemistry
- High water quality within pit lakes and down-gradient aquifers/streams is desired

Why Monitor Pit Lakes?

- Provide financial assurance for Closure (e.g., forecast water treatment costs)
- Evaluate current water quality and treatment
- Calibrate predictive models
- Comply with regulatory reporting



Republic Mine Pit Lake, Michigan
<http://www.exploringthenorth.com/republic/mine.html>

Current Boat-Based Sampling Methods

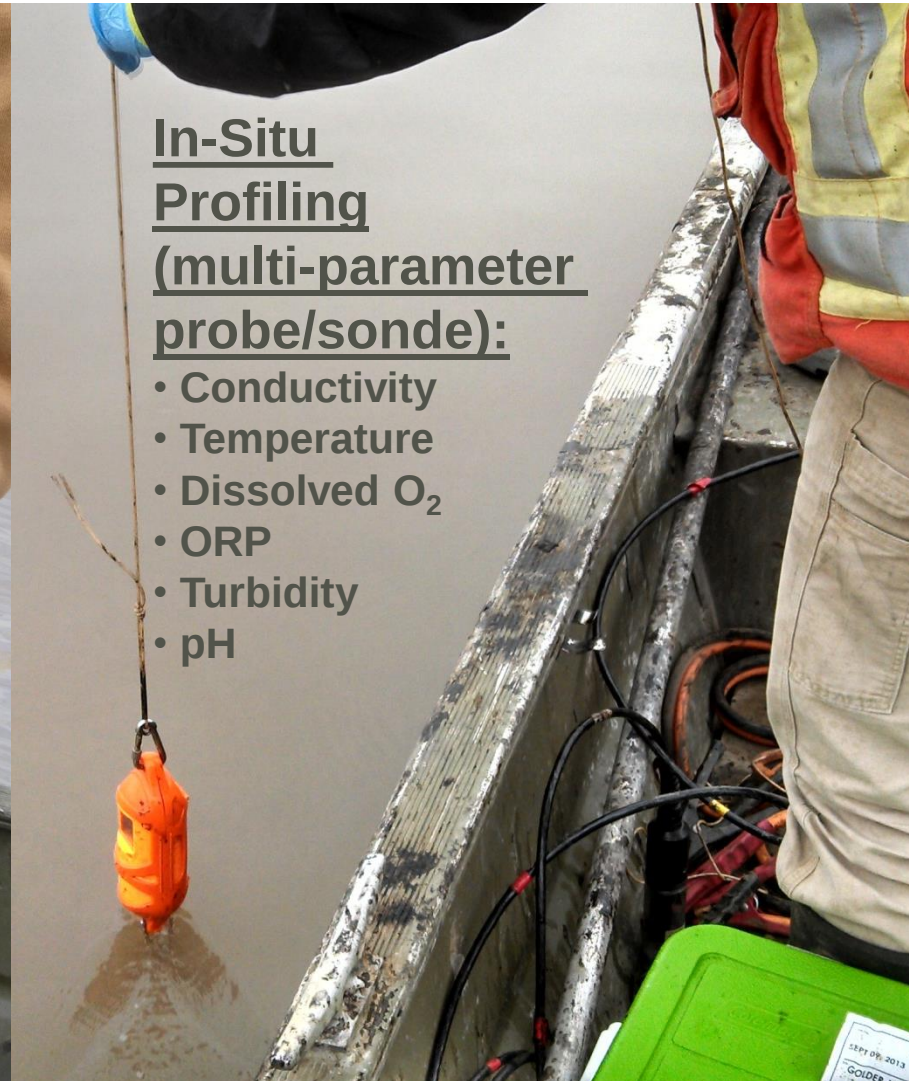
Fixed-Interval Water Sampling

- Van Dorn
- Niskin
- Kemmerer



In-Situ Profiling (multi-parameter probe/sonde):

- Conductivity
- Temperature
- Dissolved O₂
- ORP
- Turbidity
- pH



Boat Sampling has multiple Health and Safety Risks

Direct Fatal Risks:

Landslides generate waves that can capsize a boat

Hypothermia from immersion in cold water

Rock fall from high walls

Drowning

De-gassing of CO₂ and/or H₂S

Factors Compounding Severity:

Loose walls and no shallow zone; cannot get out

Limited communication (no cell reception)

Limited access for first responders



Accessing a pit lake is also a risk: **Working on or near water is dangerous**

OCTOBER 6, 2017: KENTUCKY UTILITIES' GHENT GENERATION STATION



Drones reduce Health and Safety (HS) risks associated with pit lake sampling

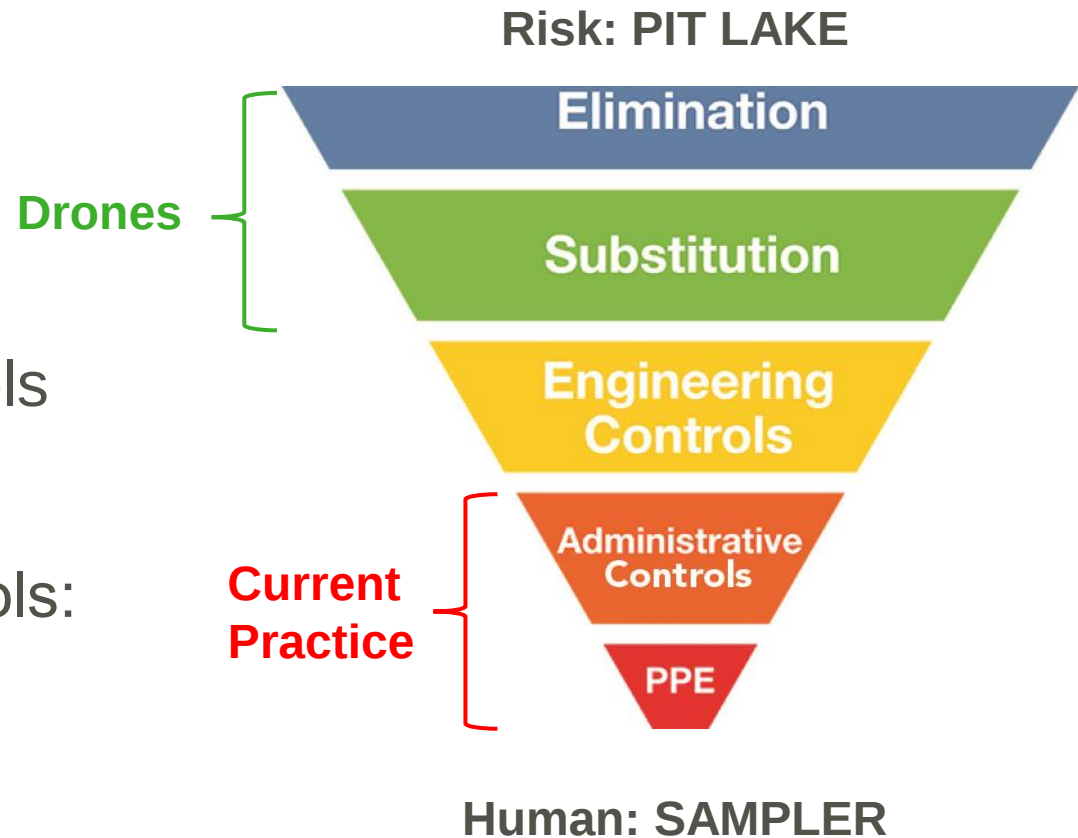
GOLDER'S HIERARCHY OF RISK CONTROLS

Boat sampling uses “lower-order” HS controls:

- Personal protective equipment (PPE)
- Administrative Controls

Drones sampling uses “higher-order” HS controls:

- Elimination
- Substitution



Other Benefits of Drone Sampling vs. Boat Sampling

INTRODUCTION

Financial Benefits (cheaper)

- Boat sampling can cost upwards of \$50,000 (US\$) per day for boat, boat pilot, staff, PPE
- Requires periodic maintenance of “boat ramp”; \$75,000 to \$100,000 (US\$)
- Drone sampling typically <\$15,000 (US\$) per day; does not need access

Sample Frequency (more data)

- Smaller equipment and shorter mobilization time than boat sampling
- Fewer staff required
 - Pilot
 - Spotter/Sampler
- Cost savings can be used for additional data collection

Golder Drone Water Sampling Program

- Large sample volume (1.75 L)
- Simple (no messenger or second RC device)
- Light weight = longer flights
- Collects samples from discrete depths to 100 m



Equipment: Drone, Pilot and Profiler

DRONE WATER SAMPLING



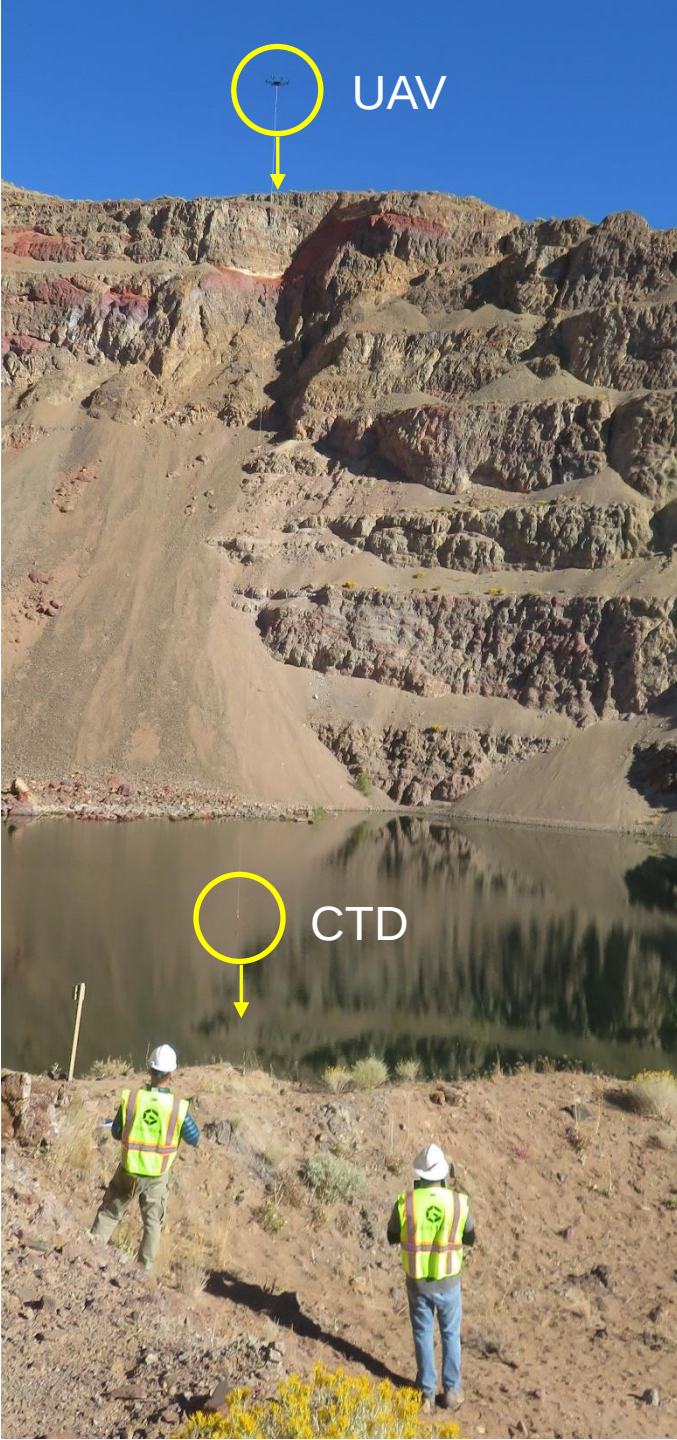
DJI Matrice 600 Pro Drone (widely used)

- Lifts 6 kg
- Licensed Commercial Pilot in jurisdiction:
 - Transport Canada (Canada)
 - Federal Aviation Administration (USA)



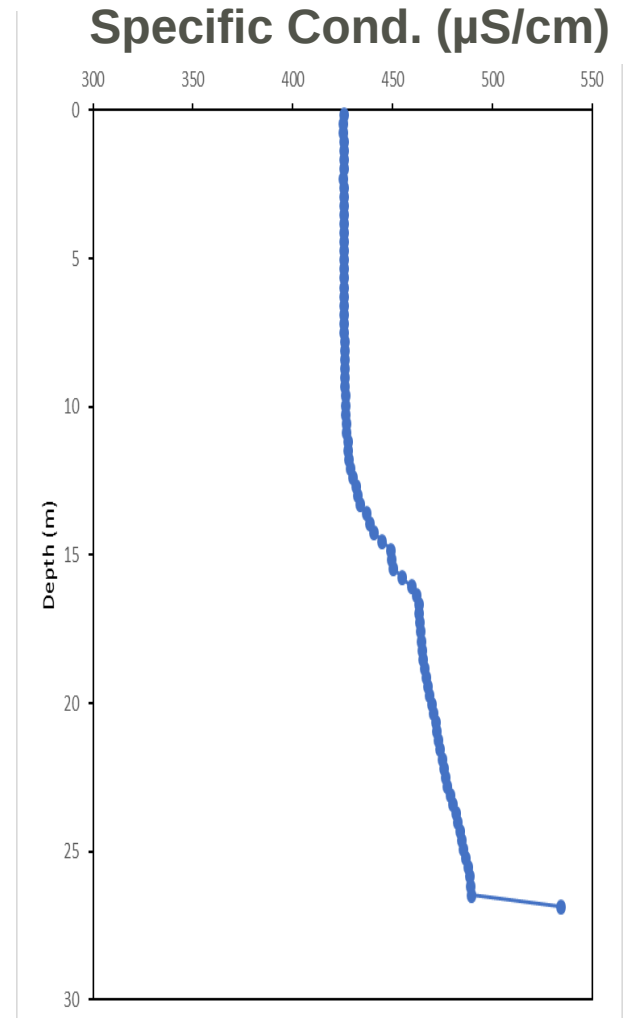
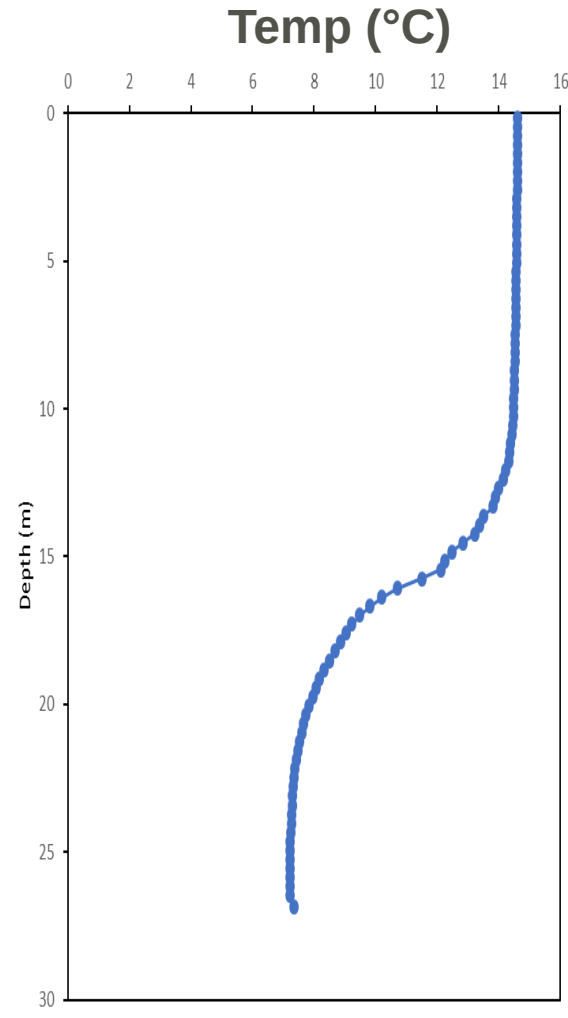
YSI CastAway (0.45 kg) Conductivity-Temperature-Depth (CTD) probe

- 5 measurements/second
- Measurements collected during descent and ascent
- Maximum depth of 100 m



First flight

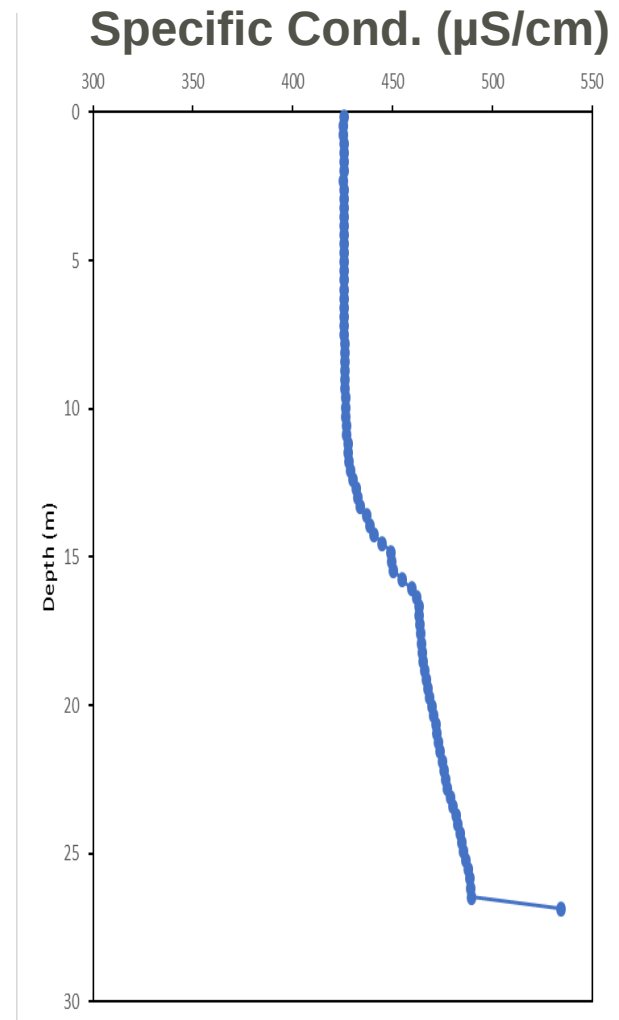
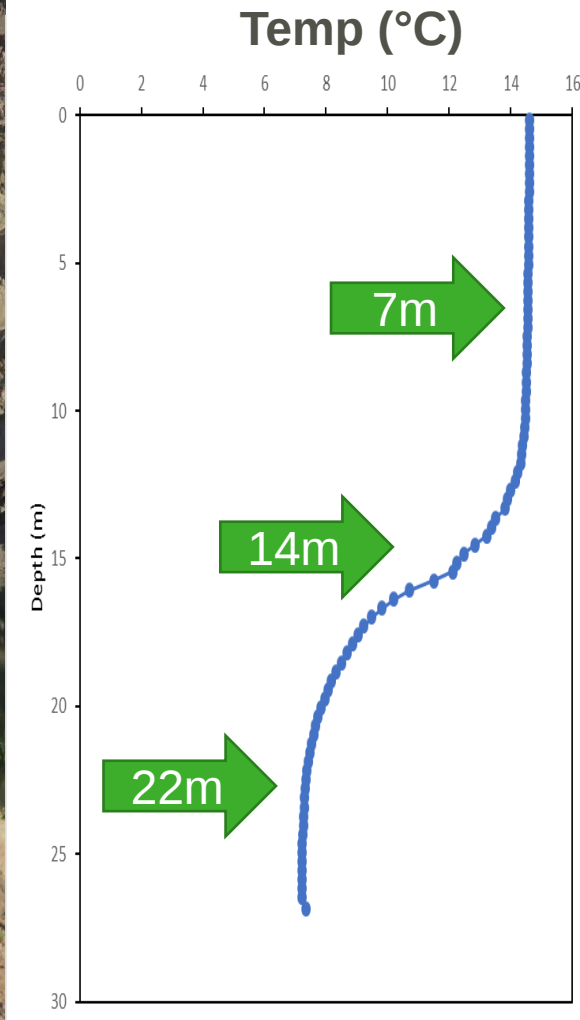
SOUNDING, PROFILING, PLANNING, & DEPTH VALIDATION





First flight

SOUNDING, PROFILING, PLANNING, & DEPTH VALIDATION



Equipment: Water Sampling

SUSPENDED BELOW DRONE



- Surface sampling cone
- Pressure transducer



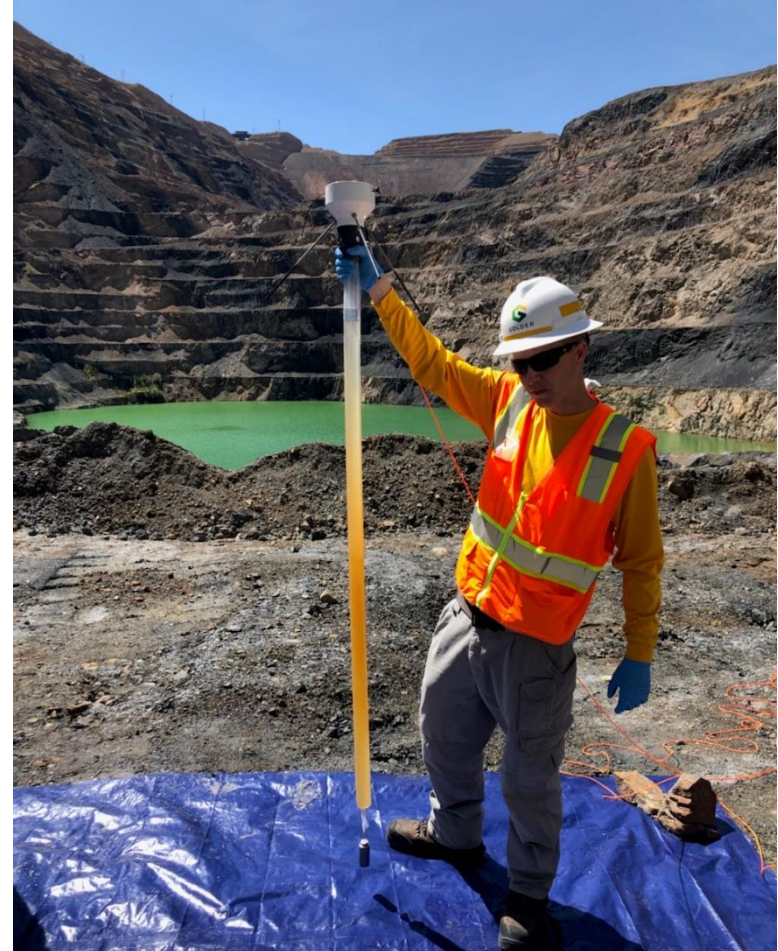
HYDRA Sleeve™
Simple by Design
Discrete Interval, No-Purge Ground Water Sampler

Additional Opportunities

Multiparameter Sonde Deployment



Image from: <https://www.ysi.com/exo2>



Sediment Sampling

- In Situ Parameters (**Ex Situ measurements have high error**): **pH**, **DO**, **ORP**, Turbidity, Fluorescent Dissolved Organic Matter (FDOM; a proxy for Total Organic Carbon), Chlorophyll *a*, Blue-Green Algae
- **Sediment Sampling**: Mineralogy of suspended particulate matter

Methods Accepted by Regulators and Editors

OPEN ACCESS:

[HTTPS://LINK.SPRINGER.COM/ARTICLE/10.1007/S10230-020-00673-Y](https://link.springer.com/article/10.1007/s10230-020-00673-y)

Mine Water and the Environment

<https://doi.org/10.1007/s10230-020-00673-y>

TECHNICAL ARTICLE

A Validated Method for Pit Lake Water Sampling Using Aerial Drones and Sampling Devices

Devin Castendyk¹ · Jimmy Voorhis¹ · Bradley Kucera²

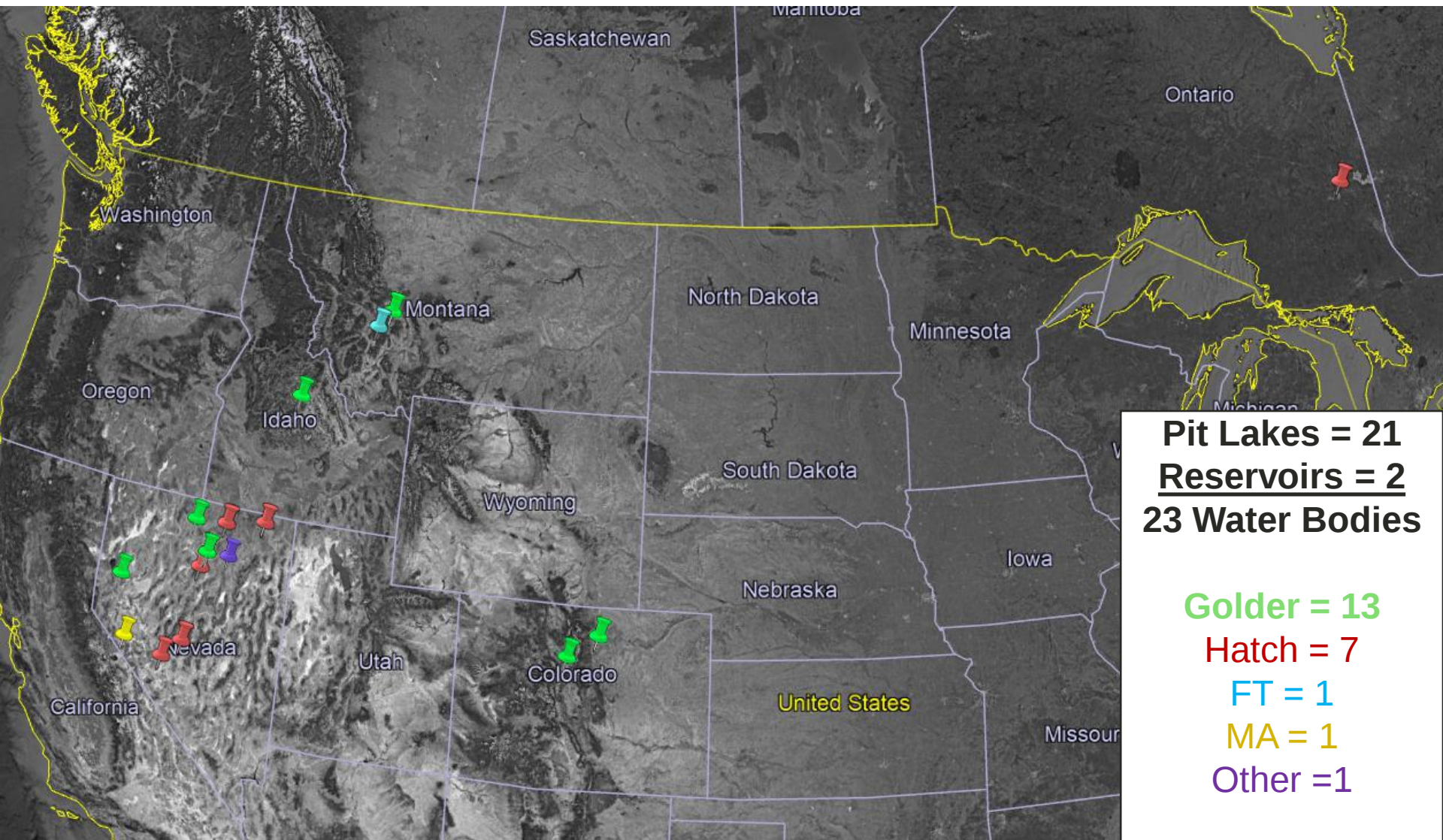
Received: 3 March 2019 / Accepted: 28 February 2020

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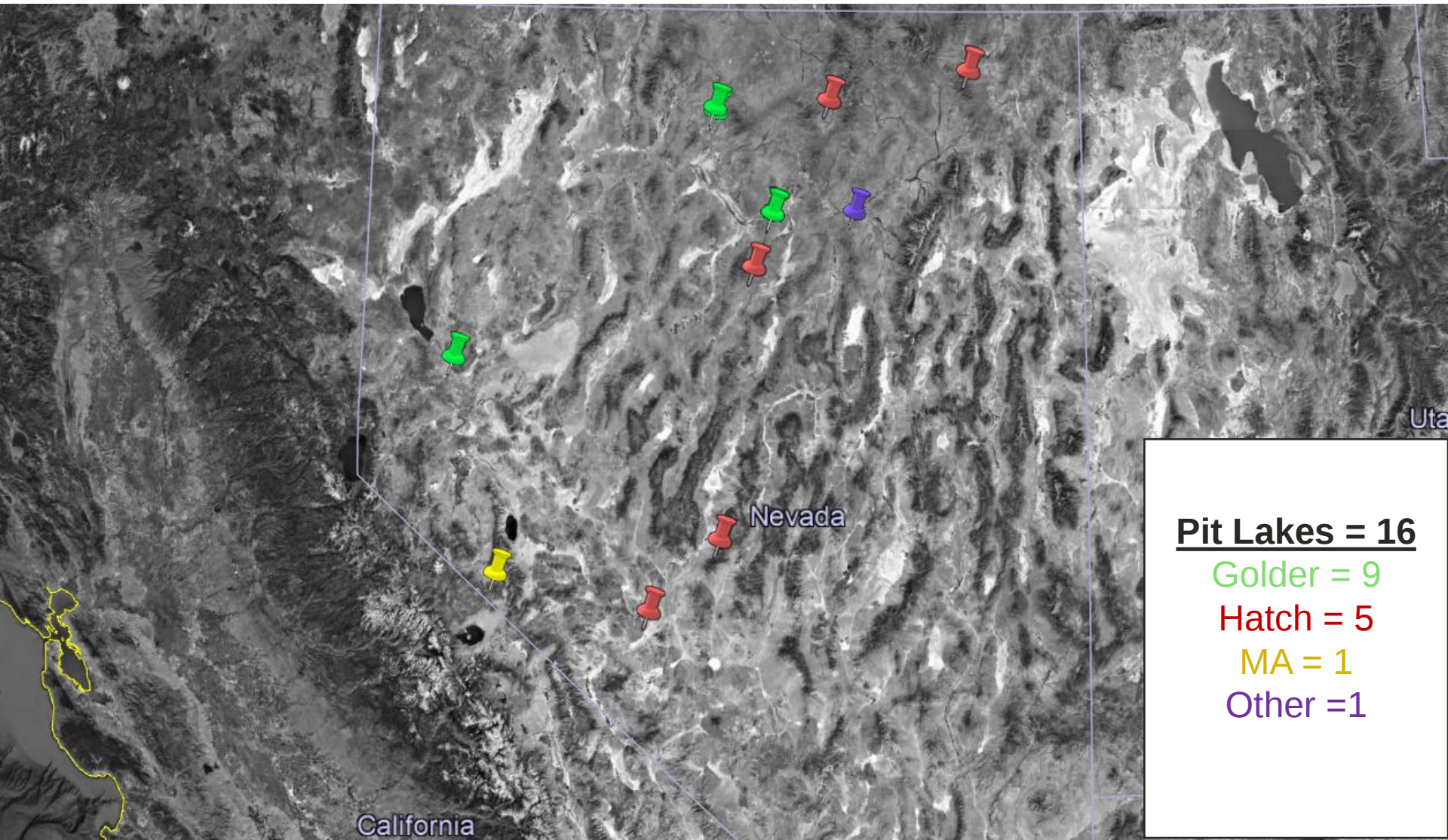
- Golder's method reviewed by Montana Dept. Env. Quality and U.S. Bureau of Land Management
- US Geological Survey used similar method to sample a crater lake in a Hawaiian volcano



Pit lake and Reservoir Sampling: 2017 to 2020



In Nevada Alone: 16 pit lakes sampled with drones



Why use drone sampling in Nevada?

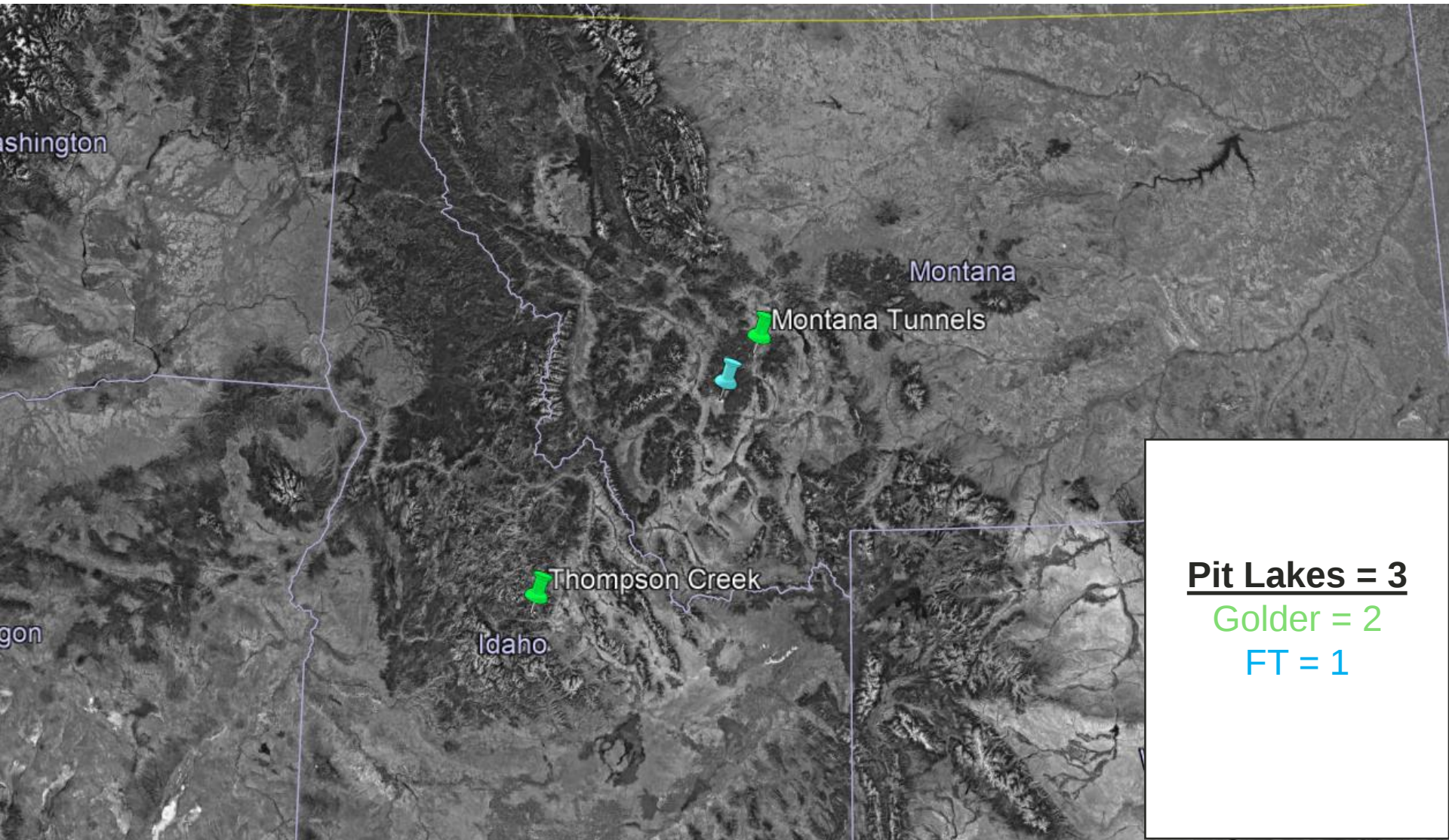
PIT LAKE SAMPLING

High number of existing pit lakes ($n \geq 44$)

Nevada Department of Environmental Protection requires pit lakes deeper than 25 feet (7.6 m) be sampled at three depths: Surface Layer, Transitional Layer, Deep Layer

- Possibly most stringent sampling/monitoring requirement for pit lakes in the United States
- Provides geochemical structure of pit lake
- Elsewhere, only surface water samples are collected (if any)

Case Study: Thompson Creek Pit Lake, Idaho



Pit Lakes = 3

Golder = 2

FT = 1

History of Thompson Creek Pit Lake

- 
- Open pit molybdenum mine: 1983-2014
 - Care and Maintenance Phase: 2014-present
 - For Financial Assurance, needed to estimate the cost of water treatment to either pump dry and reopen, or go to Closure. Therefore, needed water samples
 - December 2016 – landslide generated a huge wave that caused substantial equipment loss
 - Raised health and safety concerns for boat-based samplers (wave could capsize boat)
 - No further water sampling

Thompson Creek Pit Lake, Idaho



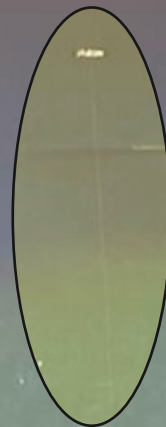
2016
Landslide

November 13, 2018

One CTD profile to 92 m

Eight 1.75-L samples collected from:

- 3 m
- 8 m
- 15 m
- 17 m
- 36 m
- 40 m
- 55 m
- 83 m



Drone

June 6, 2019

One CTD profile to 101 m

Four pairs of samples (3.5 L total volume) collected from:

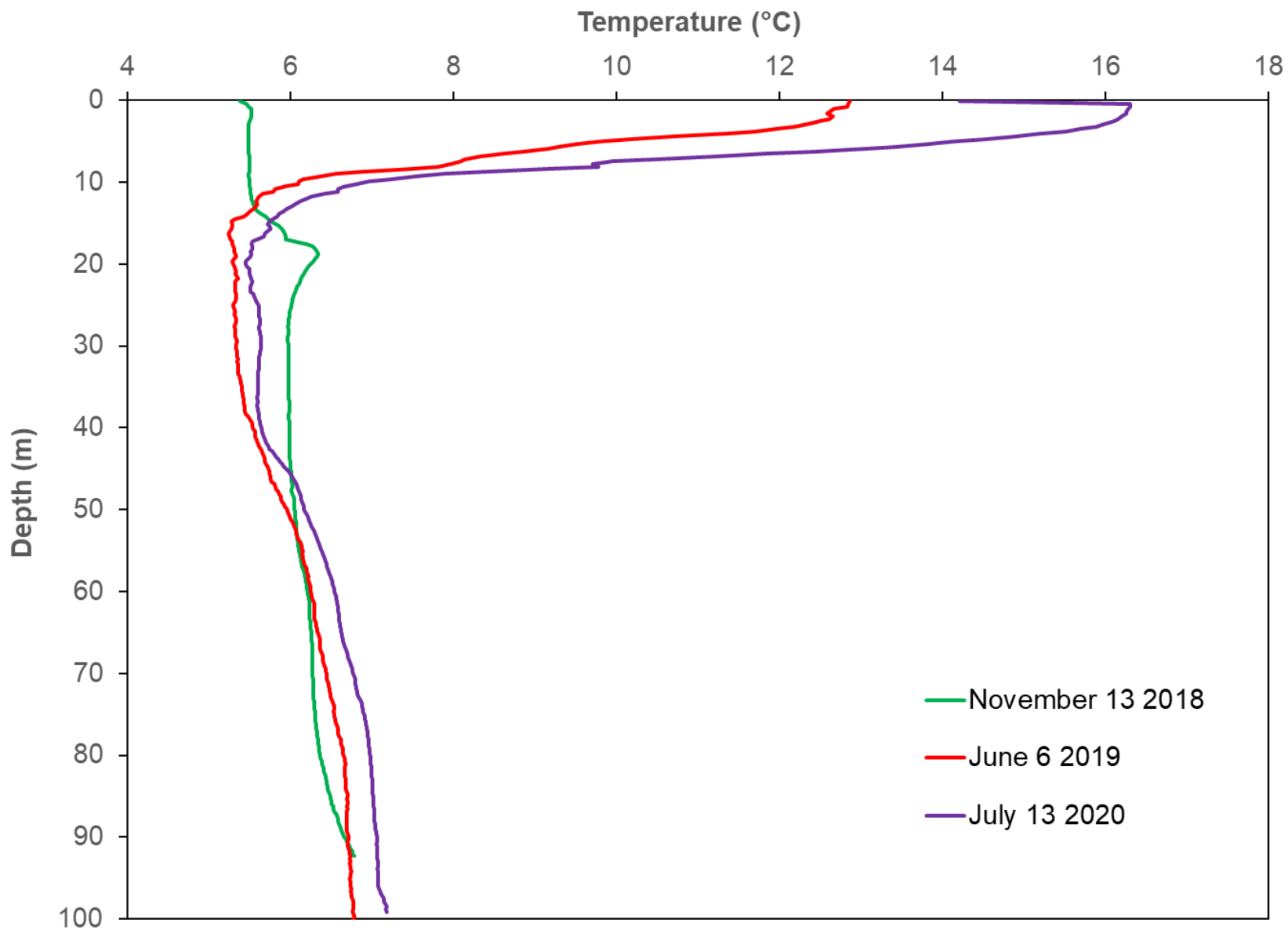
- 6 m
- 23 m
- 43 m
- 92 m

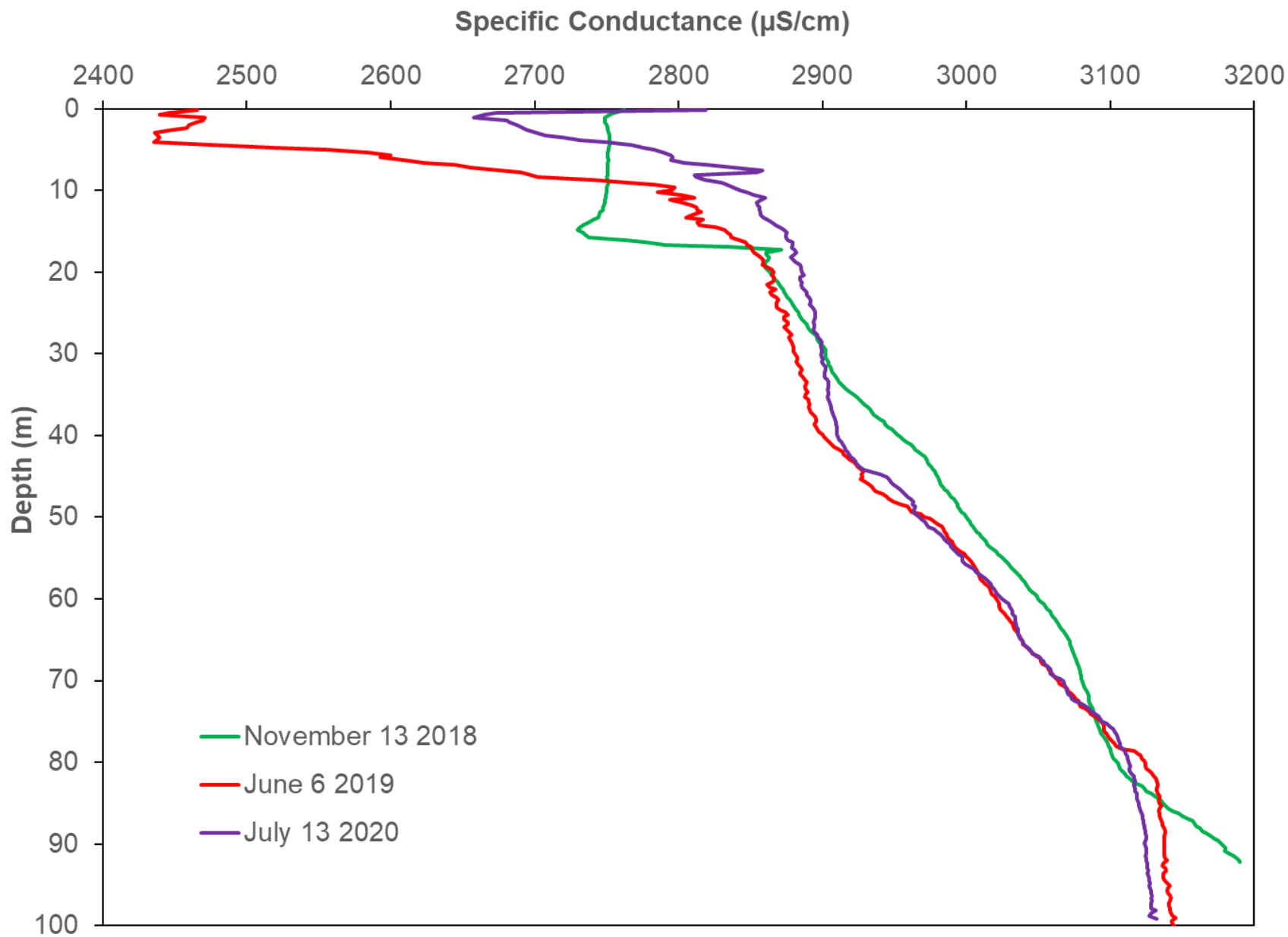
July 13, 2020

Two CTD profiles to 67 and 99 m

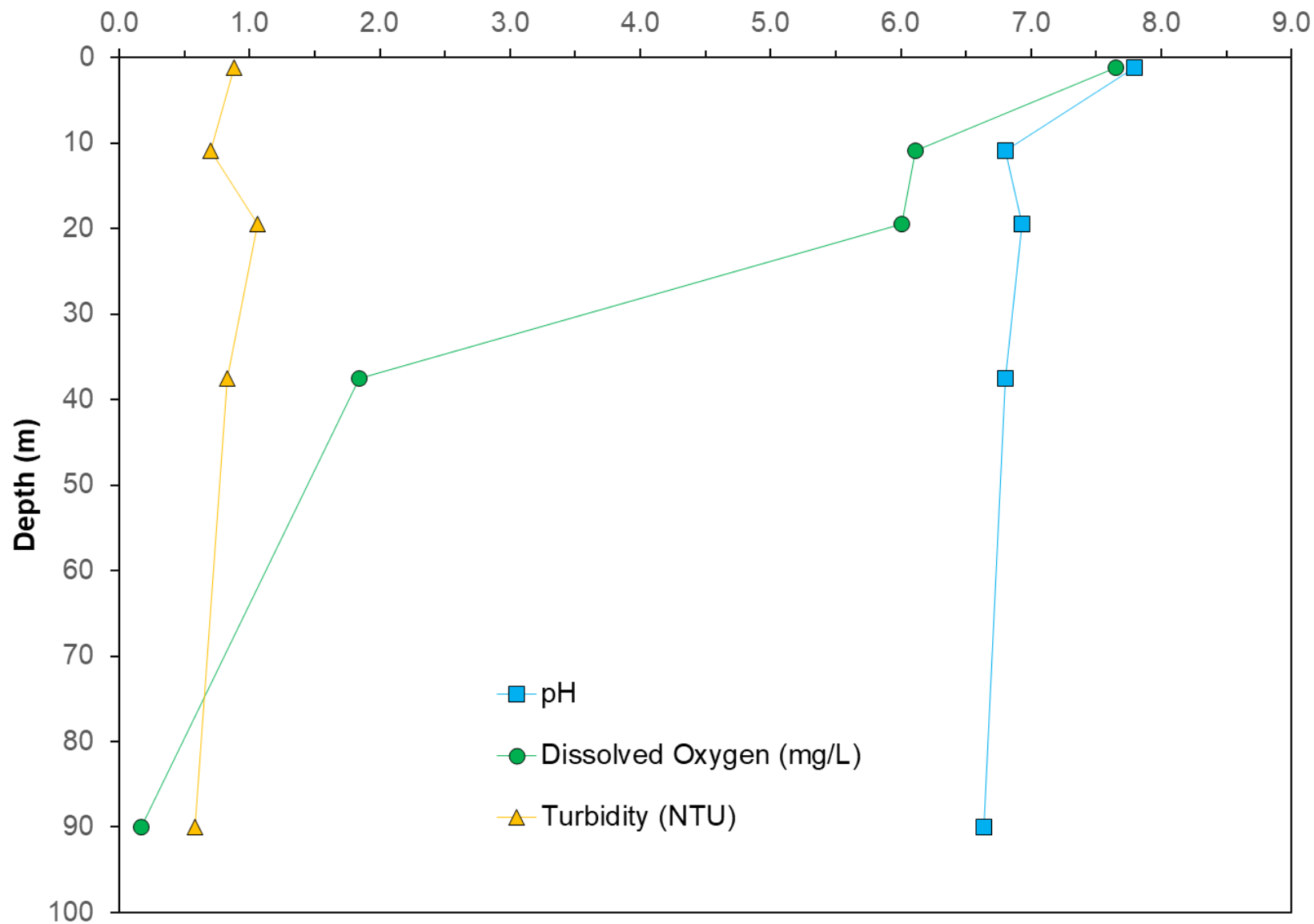
YSI EXO: 1, 11, 20, 38, 90 m (hold for 2 min. each depth)

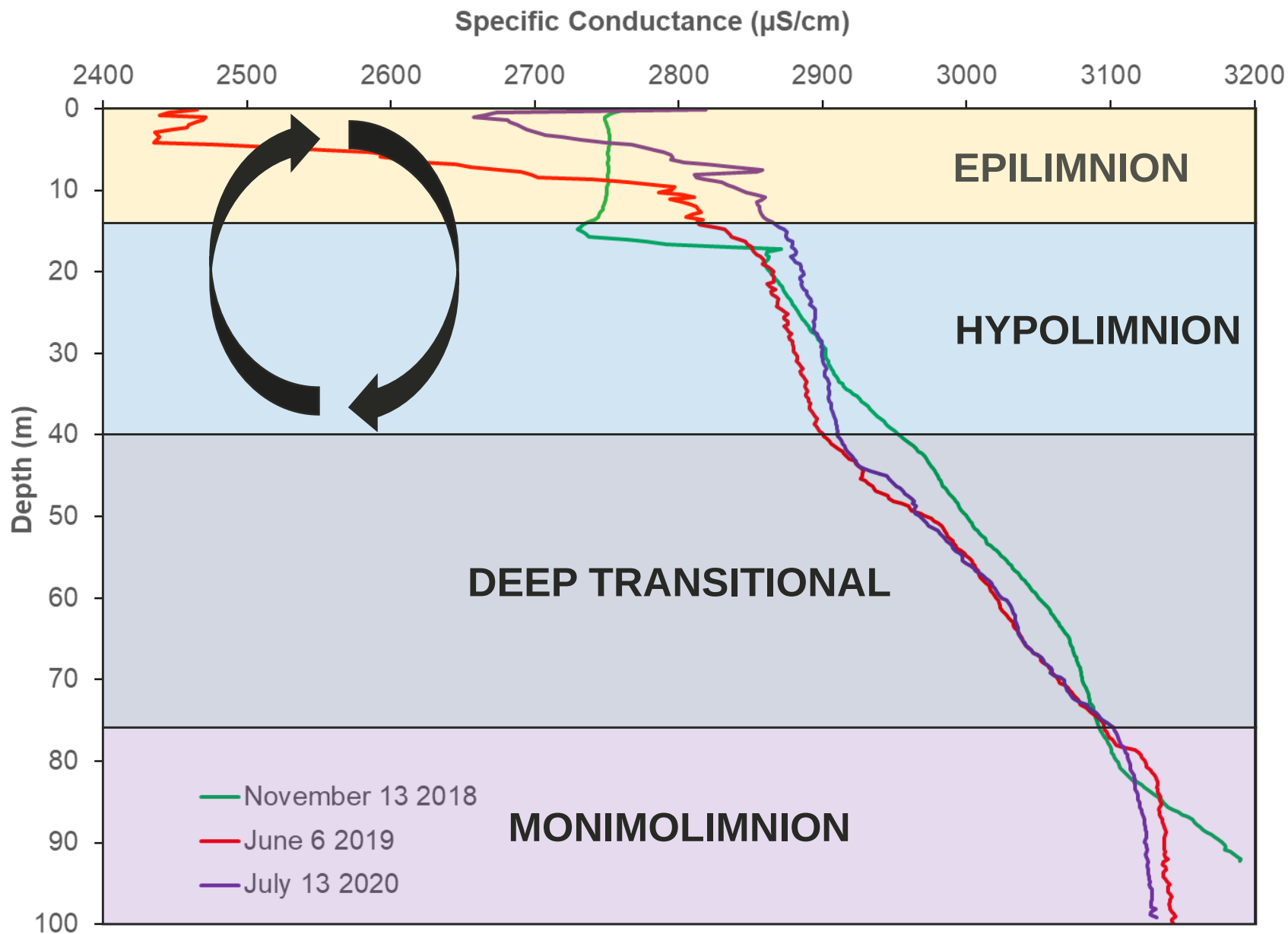
- 2 m (four samples, 7 L volume)
- 19 m (two samples, 3.5 L volume)
- 39 m (two samples, 3.5 L volume)
- 90 m (two samples, 3.5 L volume)





July 13, 2020: In Situ Values





Conclusions

~~DRONES ARE THE FUTURE OF PIT LAKE WATER SAMPLING~~

- Drone-based sampling of pit lakes has multiple advantages to boat-based sampling: Safety, Cost, Frequency
- Drones can complete almost all aspects of pit lake monitoring needed for water quality management: (1) sampling at depth (92 m is current record); (2) in situ profiles; and (3) sediment sampling
- Methods published and approved by regulators
- From 2017 to 2020: 21 pit lakes, 2 reservoirs, and 1 volcanic lake; becoming “Best Management Practice” in the USA and Canada
- For Thompson Creek (and other pit lakes) drones allowed data collection to resume, leading to financial assurance for Closure
- Drones improve pit lake management without putting humans at risk

Video of Drone in Action:

https://www.youtube.com/watch?v=Xr-tK4W_pzE

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*Goldier Canada
Drone Sampling
Program*

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GOLDER DRONE WATER SAMPLING PROGRAM



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Denver Water



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Thank you.