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2021 Virtual Symposium

April 20, 22, 27 & 29, 2021

2021 Conference Planning Committee

PGO gratefully acknowledges the work of the Conference Planning Committee in organizing this symposium.

- Mark Priddle, Chair
- Kristin Hanson
- Robert Hearst
- Mary-Anne Hildebrandt
- Paul Hubley
- Imran Khan
- Roger Phillips
- Kristina Small
- Andrea Waldie
- Craig Waldie
- James Whyte
- Tony Andrews
- Marilen Miguel

Panel Session D

Innovation in Geoscience: Implications of Emerging Technologies and Their Applications

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Panel Session D Co-Chairs

Mark Priddle, P.Geo.

Tony Andrews, PhD

Presentation 1

The Bissett Creek Graphite Deposit and its Role in the Green Economy

Gregory Bowes
Chief Executive Officer
Northern Graphite

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Graphite's Role in the Green Economy
and the Bissett Creek Deposit

Gregory Bowes

April 28, 2021

NORTHERN GRAPHITE CORPORATION

What is graphite?

- One of only two natural, pure forms of carbon (diamonds)
- “Two-dimensional” flake material
- Non-toxic, not a carcinogen
- Not burned as fuel, not a source of CO^2
- Quality/prices vary with flake size and purity
  - *+150/+100/+80/+50/+32 mesh sizes*
  - *“powder, sand, pepper to parsley” in size*
- Corrosion and heat resistant
- Excellent conductor of heat and electricity
- Light weight reinforcement material, natural, dry lubricant
- Synthetic graphite is made from petroleum coke
  - *composite materials incl. golf clubs, tennis racquets, hockey sticks*
  - *electrodes for steel industry*

XL/XXL flake

What is Natural Graphite Used For?

40 per cent of demand is refractories

- Essentially fire bricks that line blast furnaces
- Light weight reinforcement making up 10-25% of the bricks
- Does not melt or corrode
- Thermally conductive additive
- Mainly in steel industry, also cement and glass manufacturing
- Bricks must be replaced periodically
- Consumable in the steel making process, not an alloy

What is Natural Graphite Used For?

35 per cent of demand is multiple smaller markets

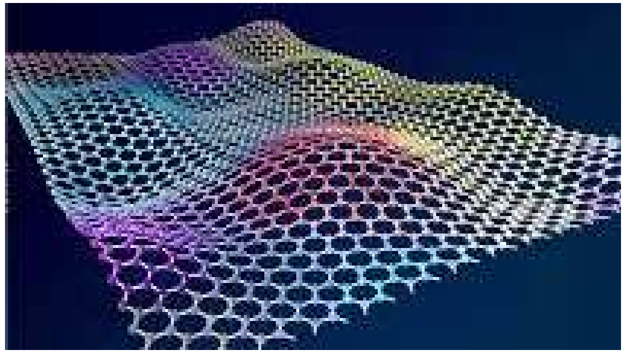
- Pencils
- Brake & clutch parts
- Thermal management in electronics
- Conductive additive in regular batteries
- Gaskets
- Lubricants
- Fire retardants
- Carbon brushes in electric motors
- Insulation products
- Drilling Fluids

Green Energy Applications

25 per cent of demand is mainly lithium ion batteries

- Anode material in a lithium ion battery (and the largest single component)
- Fuel cells
- Vanadium redox flow batteries
- Light weight composite materials (graphene)

What is Graphene?

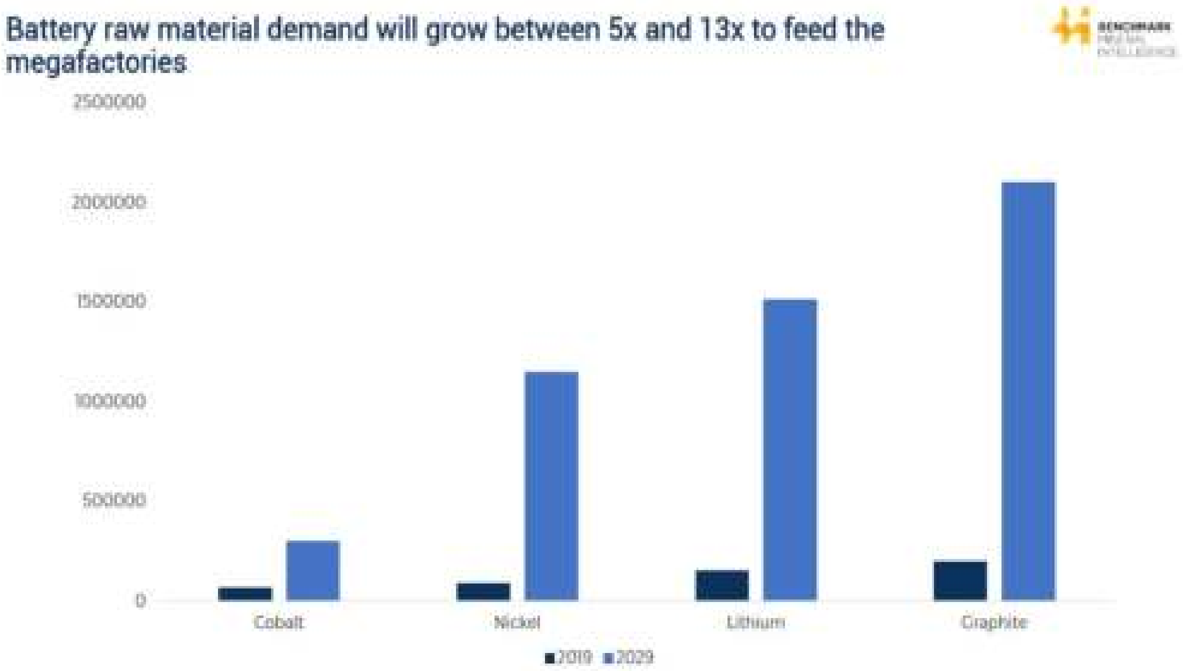


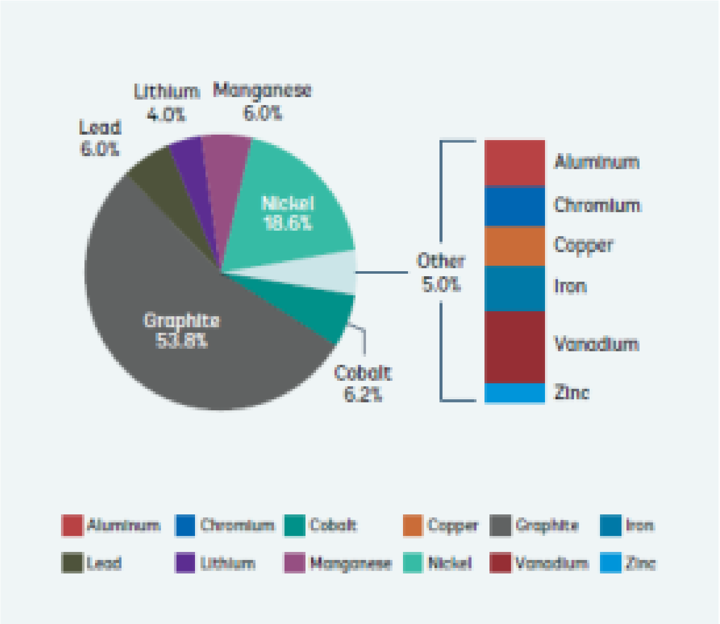
- A one atom thick sheet of carbon atoms arranged in a hexagonal pattern
- 200 x stronger than steel, 100 x more conductive than copper, flexible, transparent
- A graphite flake is hundreds of thousands of graphene layers
- De-lamination of graphite is one production method
- Mainly results in 2-10 layer “near” graphene or “nano” graphite
- Can be added to composite materials to make them stronger, lighter and thermally or electrically conductive
- More fuel efficient vehicles, longer lasting tires, lighter wind turbines, more efficient solar panels etc. etc. etc.

The China Factor

- World flake graphite production is approximately 850,000tpa
- China produces and consumes 70 to 80%
- China produces almost ALL battery anode material
- China has large resources but is forecasting a large supply deficit in 2025 due to EV growth
- Graphite production must more than double to meet the sales forecasts of the automobile manufacturers
- The west needs its own sources of supply
- US and EU have both declared graphite a supply critical mineral

Graphite Demand Growth





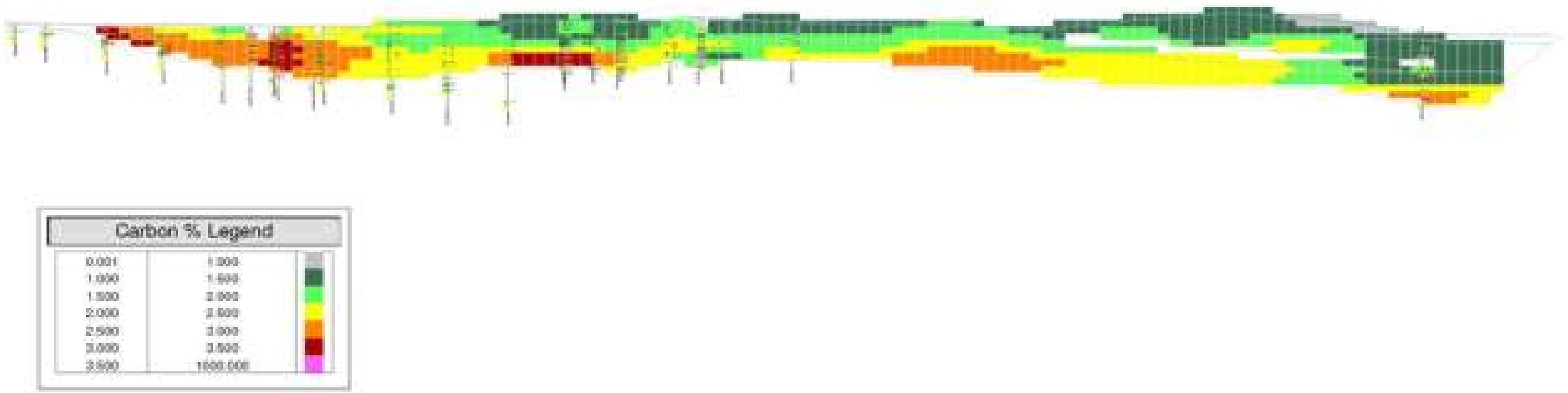
Share of Mineral Demand from Energy Storage (source:IEA)

Bissett Creek Project

- 15km from Trans-Canada highway
- Close to labor, supplies, infrastructure, natural gas supply
- Direct trucking to US markets, five hours from port of Montreal
- Highest percentage of “large flake” in the world
- FS completed for 25,000tpy, 80-100,000tpy capability
- Major mining permit received
- No local/First Nation opposition

Simple Mining and Metallurgy

- Open pit mining, low waste/ore ratio
- Simple flotation flowsheet
- Natural gas power generation
- Co generation plant to dry concentrates
- 97% of tailings non acid generating
- Life cycle/carbon footprint analysis underway



Northern Graphite Summary

- Battery/EV graphite demand growing rapidly, new mines will be needed
- Market needs an alternative to Chinese supply
- Market needs more XL/XXL flake production
- Only North American mine closing
- Most competing projects in Africa
- Highest percentage of XL/XXL flake
- Reasonable capital cost
- Feasibility Study completed, construction ready

NORTHERN GRAPHITE CORPORATION

But graphite prices are still low!

Permitting Status

(for a "benign" project with no local or FN opposition)

- Mine Closure Plan approved in 2013
- Amendment required due to throughput increase
- After seven years of effort and millions spent no other permits have been received
- Class EA, PTTW, LRIA, ESA all outstanding
- The biggest problem is not the regulations
- Government agencies refuse to make decisions, take responsibility for anything or act in a timely fashion
- Ontario is an expensive/difficult place to do business
- Our mines are at a competitive disadvantage and value added processing will take place elsewhere

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Thank you

Presentation 2

Getting the Most Out of Your Data and Efforts: Application of Machine Learning to Geoscience

Rebecca Montsion

PhD Candidate at Laurentian University's Mineral Exploration Research Center (MERC) and the University of Western Australia's Center for Exploration Targeting (CET)

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Getting the most out of your data and efforts

Application of machine learning to geoscience

Rebecca Montsion*, Stéphane Perrouty, Mark Lindsay
rebecca.montsion@gmail.com

Two camps

Unsupervised	Supervised
Exploratory process to understand the **statistical structure** of data (**no prior assumptions**)	To make **predictions/ classification** given **prior knowledge** (labeled training set)

SOME applications with machine learning

Very brief descriptions of techniques and case studies to highlight critical elements of machine learning

Gives discrete results

Classification

Unsupervised

Group points given a set of parameters (exploratory)

E.g., Clustering (k-means, fuzzy c-means, agglomerative, etc.)

Supervised

Based on prior knowledge about what defines a 'class'

E.g., Random Forest, Neural Networks

Parameters: 4 clusters
Variables: X, Y, orientation, colour

Parameters: 4 clusters
Variables: X, Y, orientation, colour

Orogenic Au
Classification ex 1

Carefully select hyper-parameters
(e.g., transformation technique & clustering algorithm)

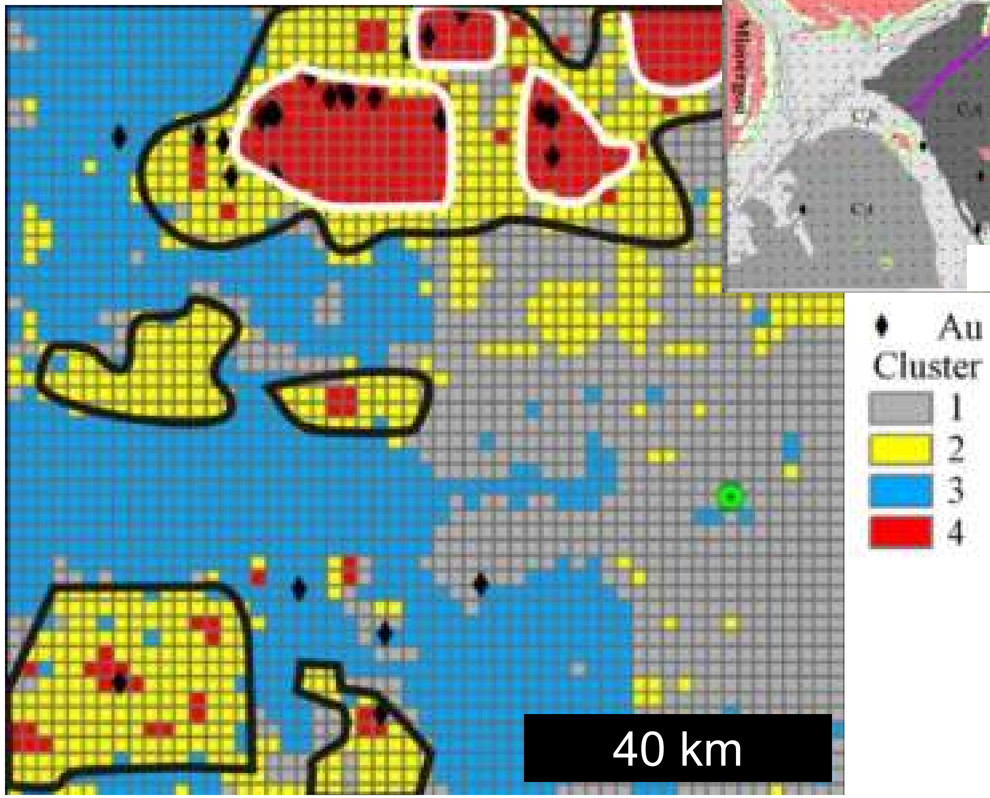
Aim

- Data-driven method to narrow search space

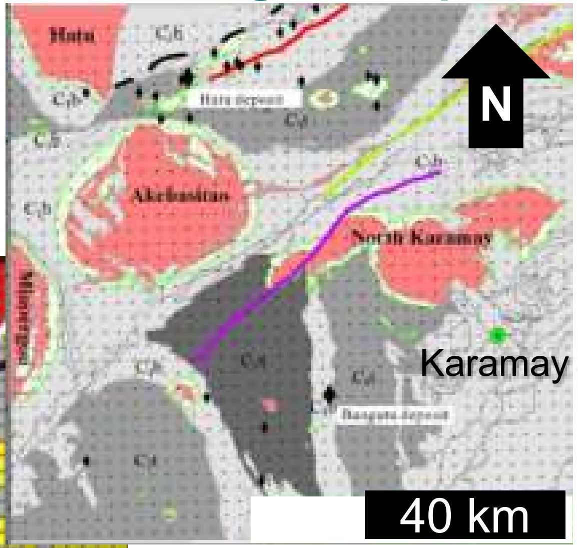
Inputs

- Whole rock geochemistry with ~1 x 1 km sampling grid (N = 1444)
- Interpolated element grids

Cluster analysis



Geological map



Zhou et al. (2018) *Frontiers in Earth science*

Zhou et al. (2018) Frontiers in Earth science

Orogenic Au
Classification ex 1

No transformation (NT)

Poor comparison between abundant and trace elements

Z-score transformation (ZST)

Preserves shape of distribution; Does not deal with 'closure'

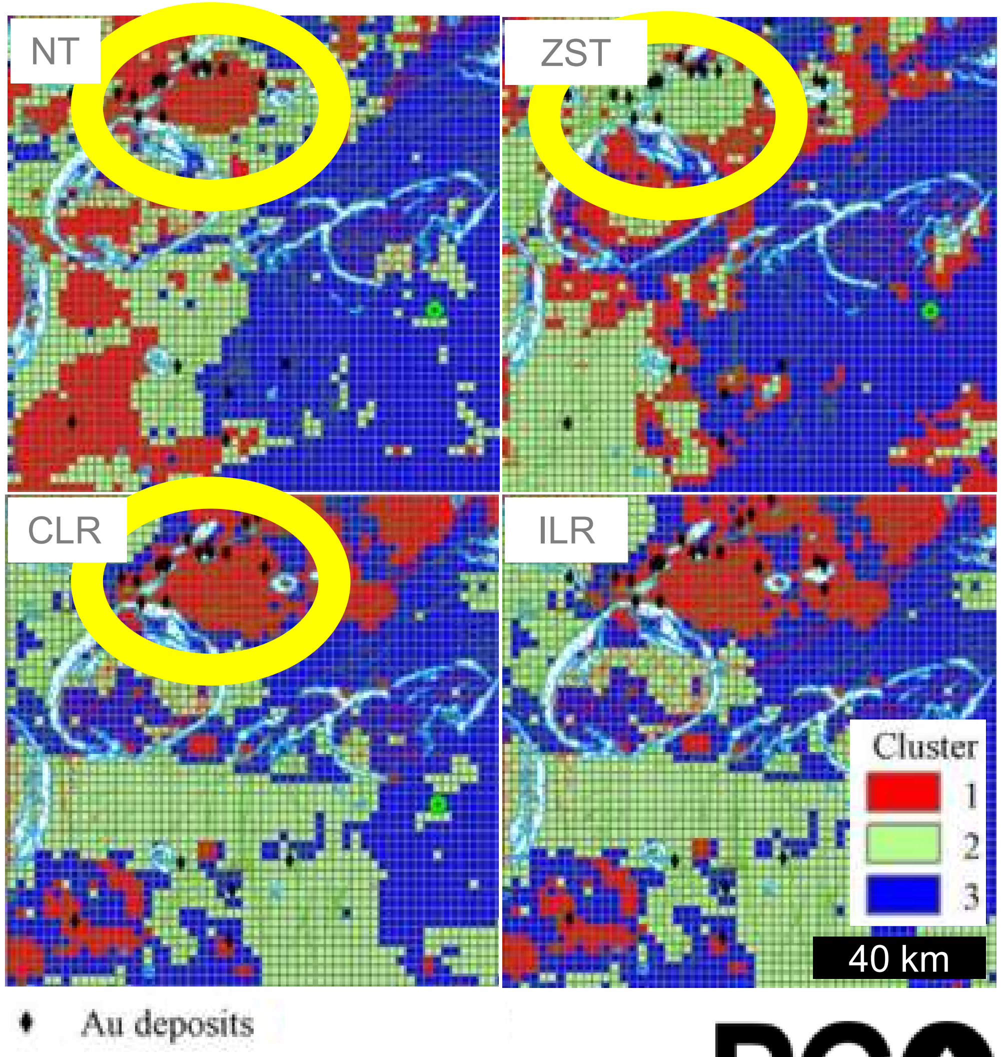
Center Log-ratio Transform (CLR)

'Opens' constant sum; Normal/Gaussian distribution; Some 'spurious correlations'

Isometric Log-Ratio (ILR)

Same as CLR but rotated/reflected to retain only real data correlations

Carefully select hyper-parameters
(e.g., transformation technique & clustering algorithm)



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Classification

Unsupervised

Group points given a set of parameters (exploratory)

E.g., Clustering (k-means, fuzzy c-means, agglomerative, etc.)

Parameters: 4 clusters
Variables: X, Y, orientation, colour

Supervised

Based on prior knowledge about what defines a ‘class’

E.g., Random Forest, Neural Networks

Parameters: 4 clusters
Variables: X, Y, orientation, colour

Be smart about labels
(e.g., What do they mean? How well do they match your data? Scale/Resolution?)

Mineral mapping drill core

Classification ex 2

Aim

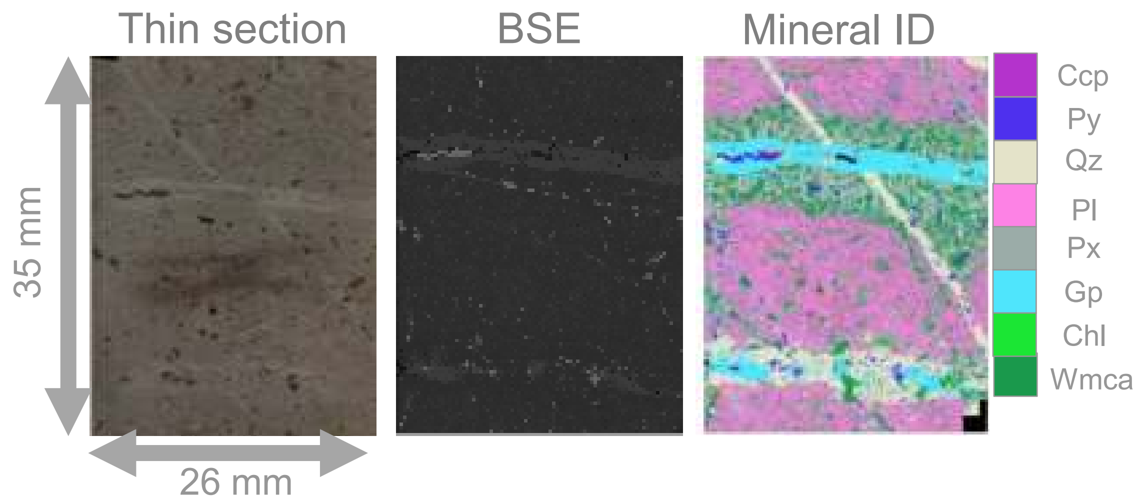
- Reduce subjectivity in core logging

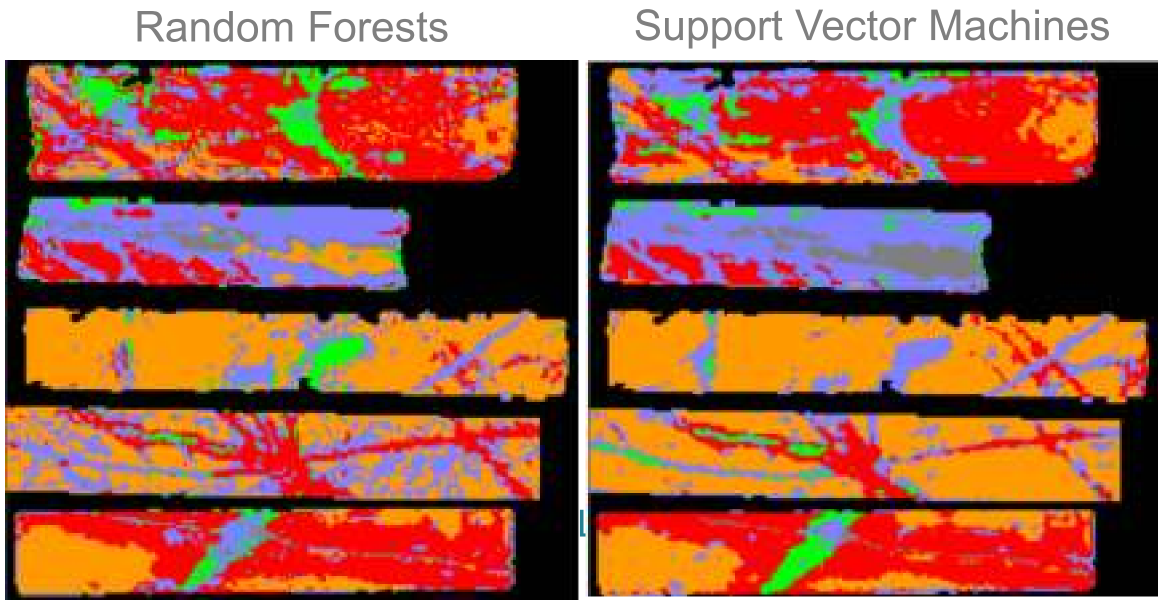
Inputs

- SEM Backscattered Electron (BSE) of thin section
- Hyperspectral scan of core

Methods

- Define ‘labels’ using SEM liberation analysis
- Clustering: Random Forest & Support Vector Machines





Acosta et al. (2019) *IEEE*

Be smart about labels
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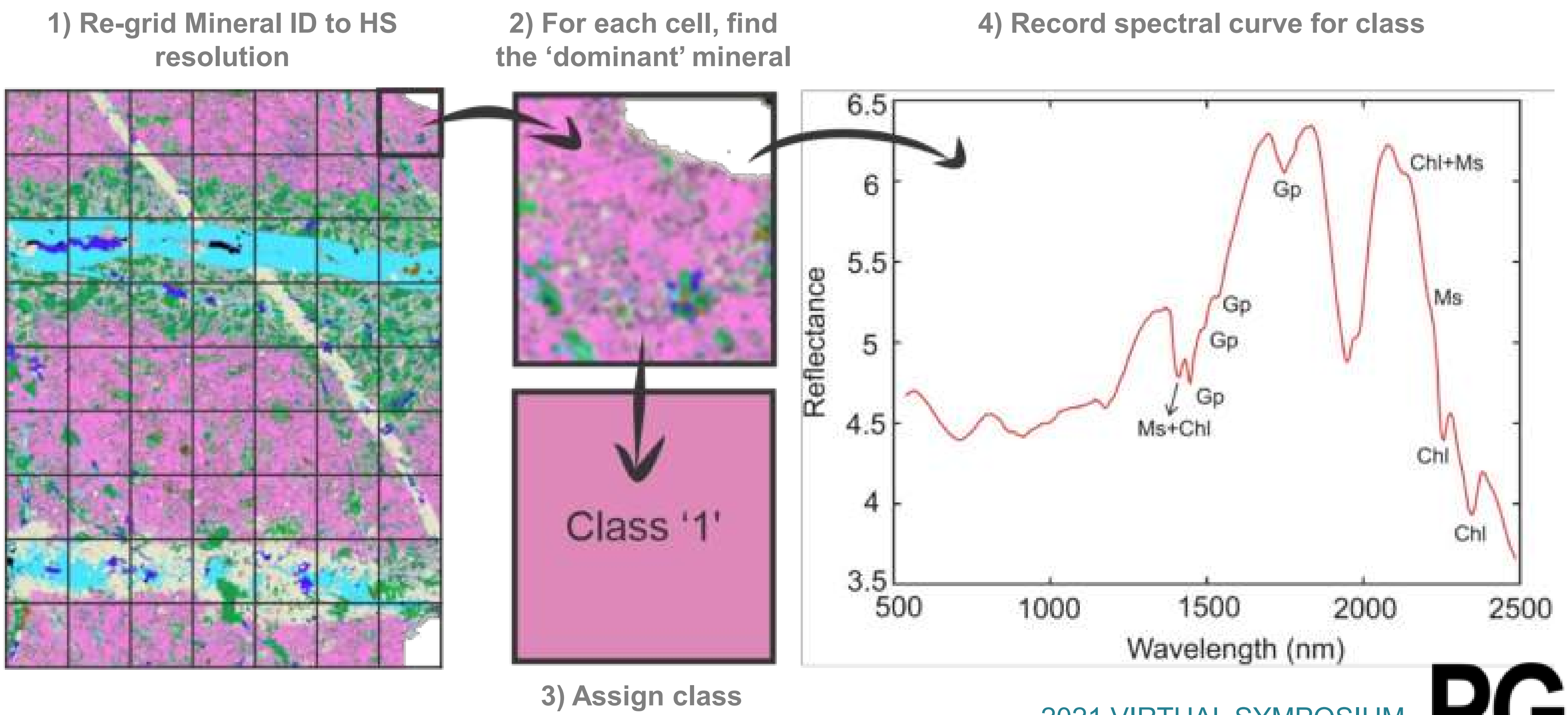
Mineral mapping drill core
Classification ex 2

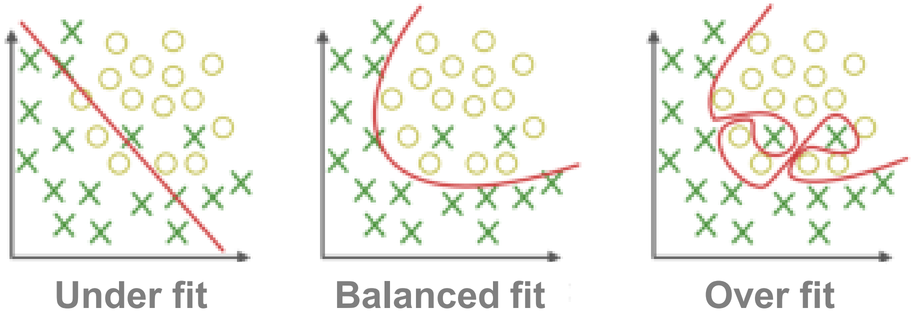


Acosta et al. (2019) *IEEE*

Prediction

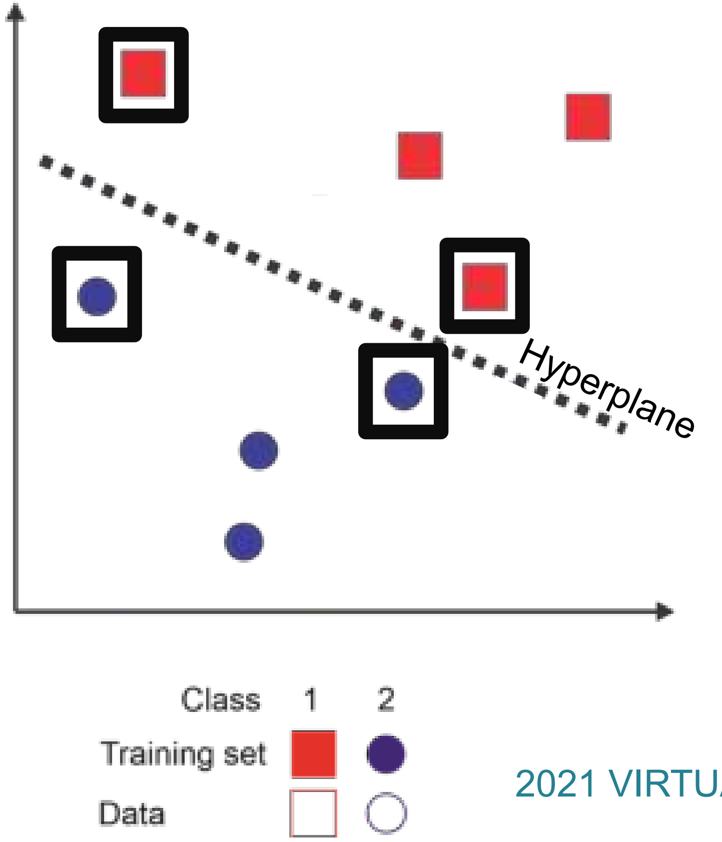
Supervised
Based on prior knowledge, fill in the blank/extrapolate E.g., Regression, Support Vector Machines, Random Forest, Neural Networks

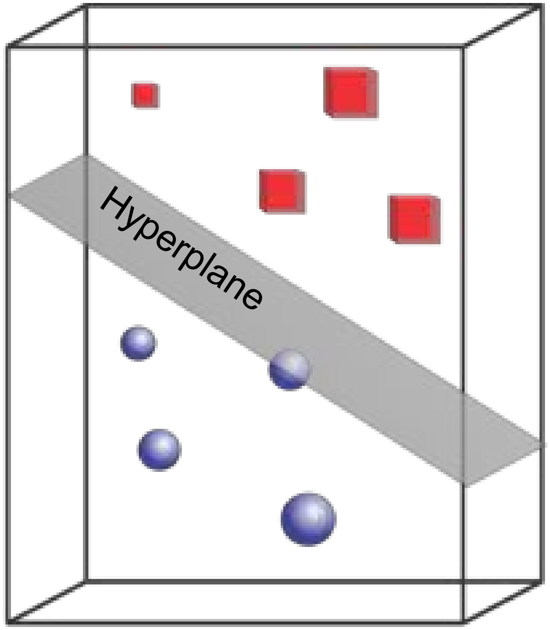
Beware of overfitting/underfitting



Prediction
Support Vector Machines (SVM)

1. Find the edge of training set classes
2. Draw a threshold/boundary
3. Plot all the other data
4. Classify accordingly

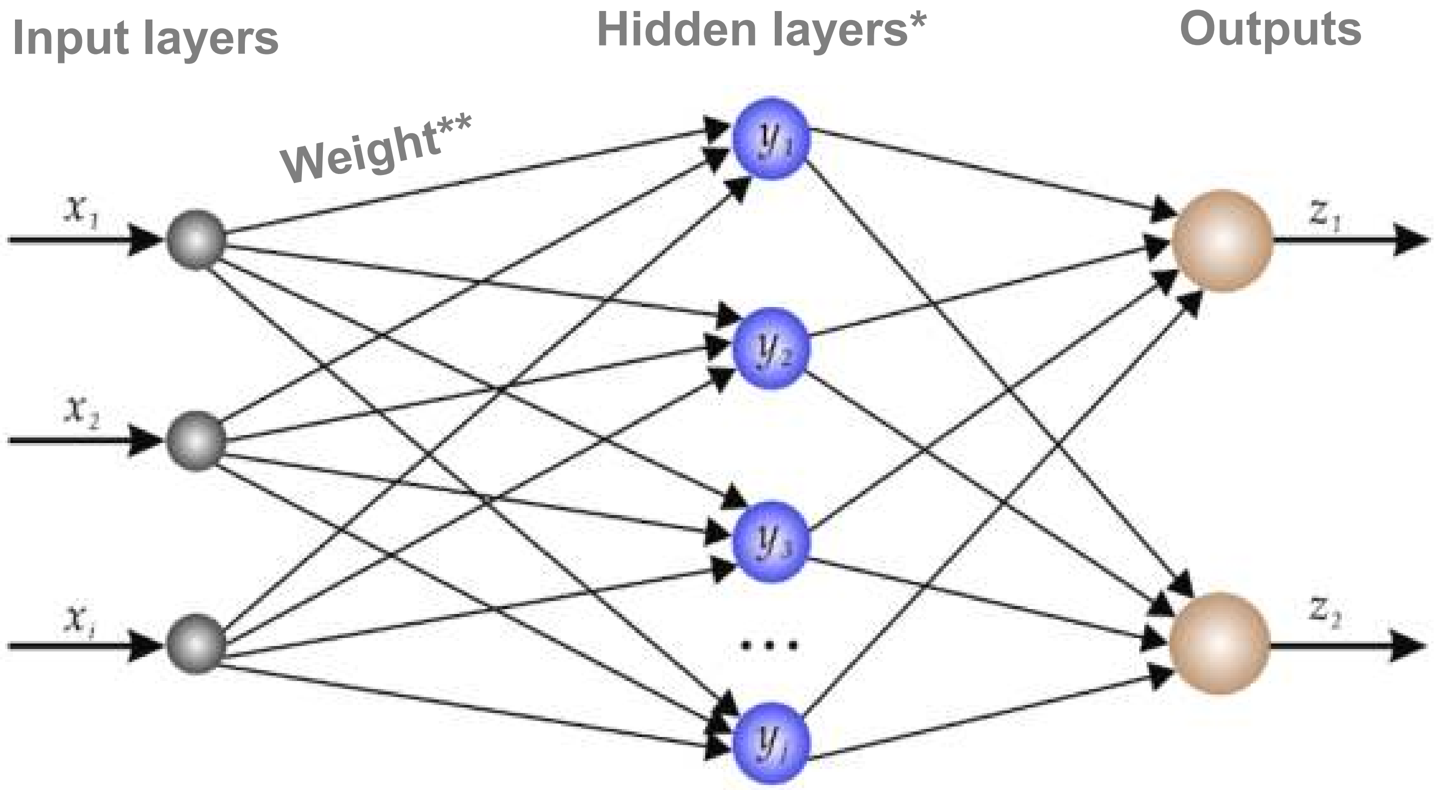




Difficult to interpret
****Spatially aware****

Prediction
Neural Networks (NN)

1. Input several layers (e.g., grids of data)
2. Apply a range of weights to each neuron
3. Combine weighted inputs with 'math'



*>2 hidden layers = 'deep learning'

** Weights can be imposed by someone or auto-selected

From Sun et al. (2019) *Ore Geology Reviews*

Easily interpreted
****Not spatially aware****

Prediction
Random Forests (RF)

Phase 1 – Building trees

1. Randomly subsample points from training set (bagging)
2. Randomly select a subset of input layers
3. For each layer (node):
   a. *Compute a threshold*
   b. *Classify based on threshold*

From Jedamski, 2019, *LinkedIn Learning*

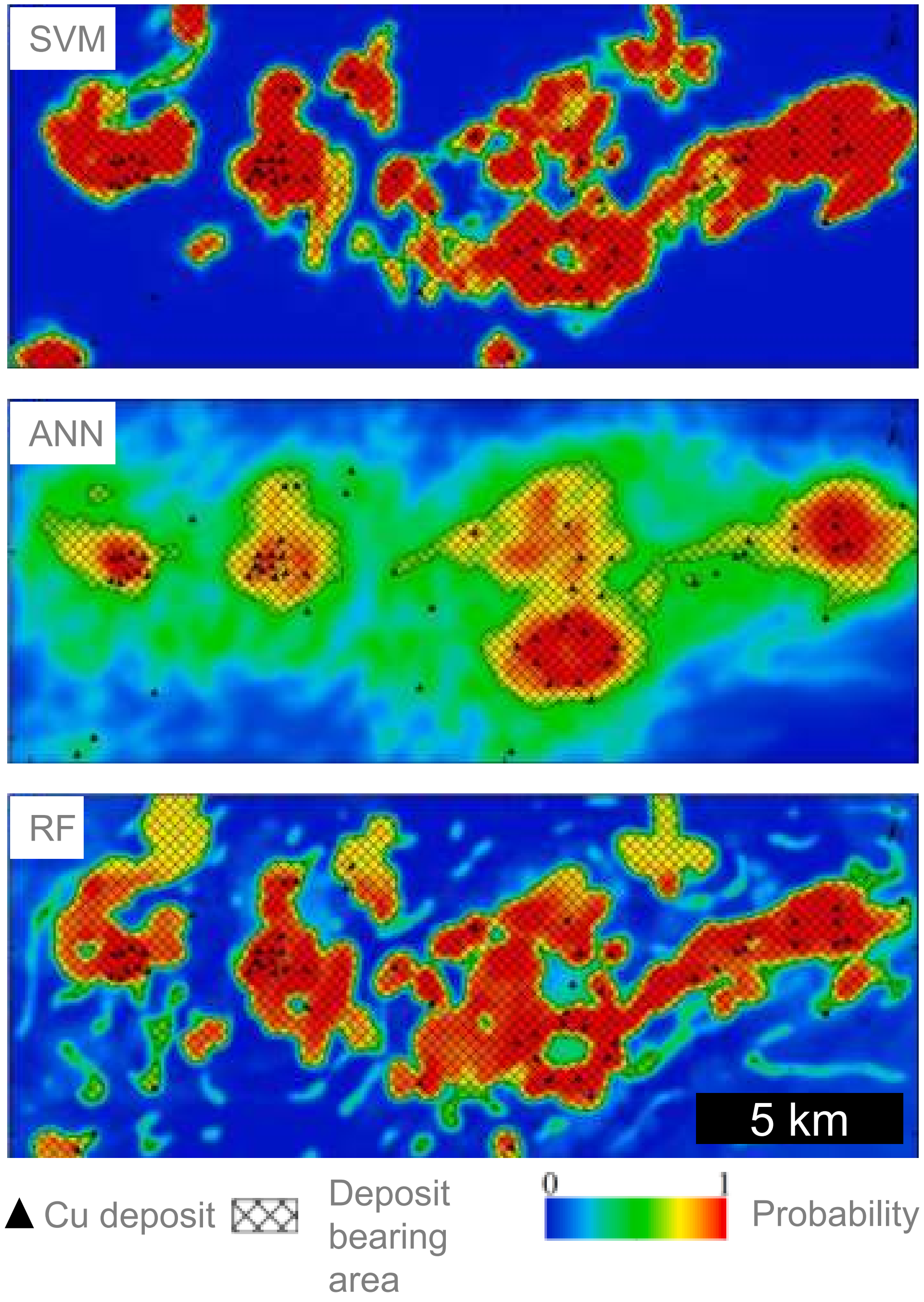
Cu-rich skarns
Prediction example

Aim

- Data-driven method to narrow search space
- Quantitative datasets/results for enhanced interrogation

Methods

- 12 layers representing relevant features in mineral system
- Prediction of Cu
  - *Support Vector Machines (SVM)*
  - *Artificial Neural Network (ANN)*
  - *Random Forests (RF)*



From Sun et al. (2019) *Ore Geology Reviews*

Be smart about training
(e.g., Balanced? Representative? Biased?)

Cu-rich skarns
Prediction example

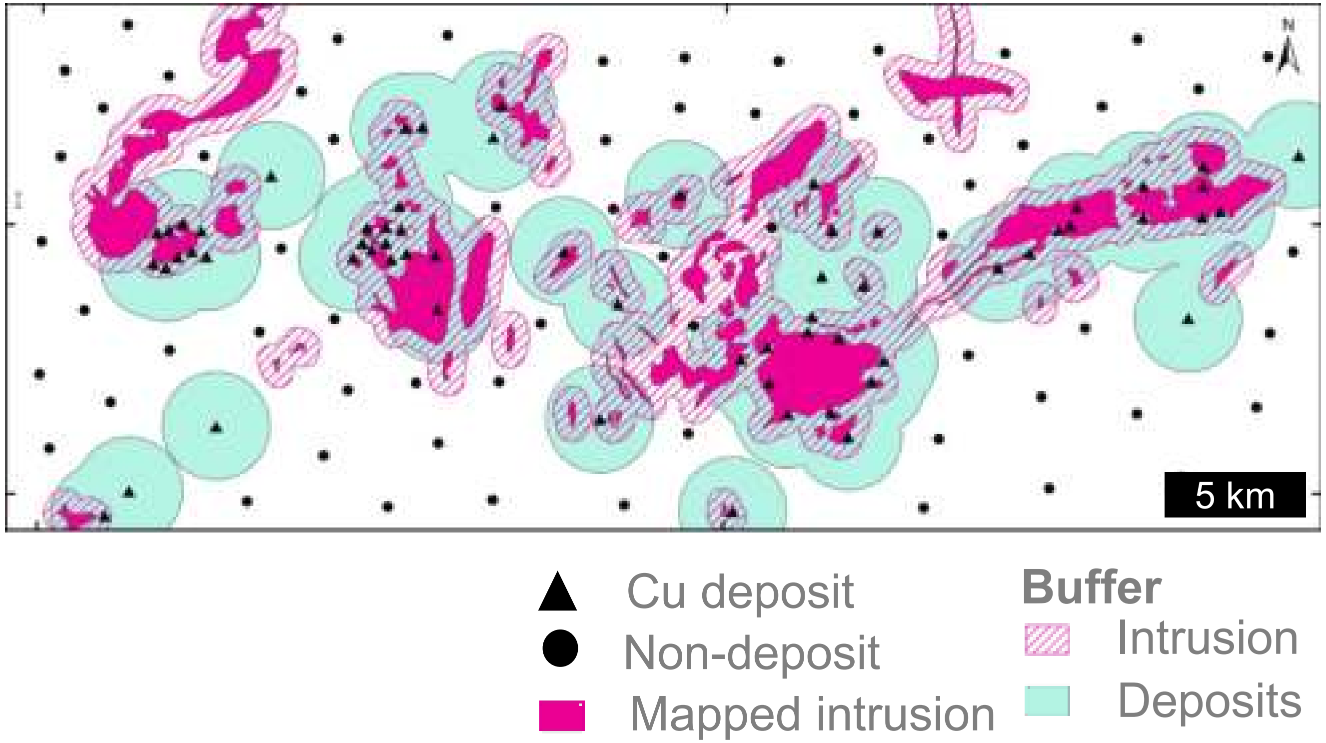
Picking training sets

Positive:

- 63 Known deposits

Negative:

- 63 Random locations
  - *>= 1 838 m from known deposits*
  - *>= 500 m from prospective lithologies*



Barriers to success

Data availability

- Source (e.g., geochemical, geophysical)
- Type (e.g., discrete/point, continuous/ gradient)
- Sample distribution (e.g., dense, clustered, sparse)

Preconceptions

- Data selected
- Data processing/Feature engineering
- Training sets

Test for success

- Limited by small number of ‘positive’ training points

Cautions

1. Know what **question** you want to ask
2. Know what your **data** can actually tell you
3. Be mindful of **biases** throughout your workflow
4. Strategically select appropriate **hyperparameters**

E.g., transformations, interpolation techniques, modeling algorithm

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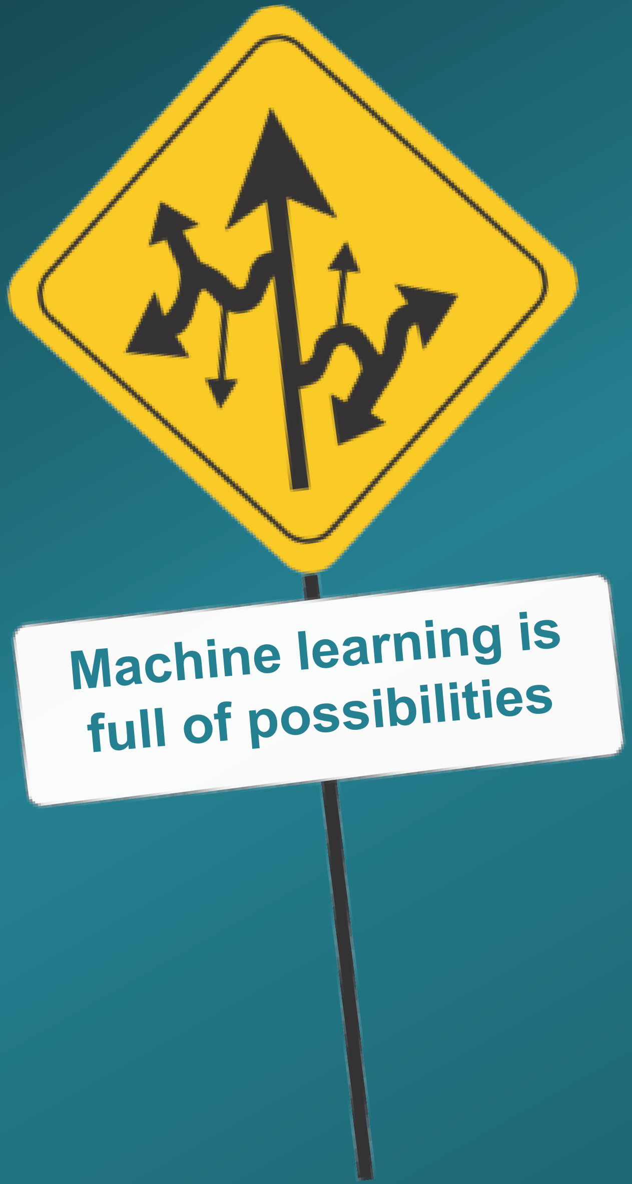


Thank you

rebecca.montsion@gmail.com

Carefully select hyper-parameters
(e.g., transformation technique & clustering algorithm)

Orogenic Au
Classification ex 1

Methods

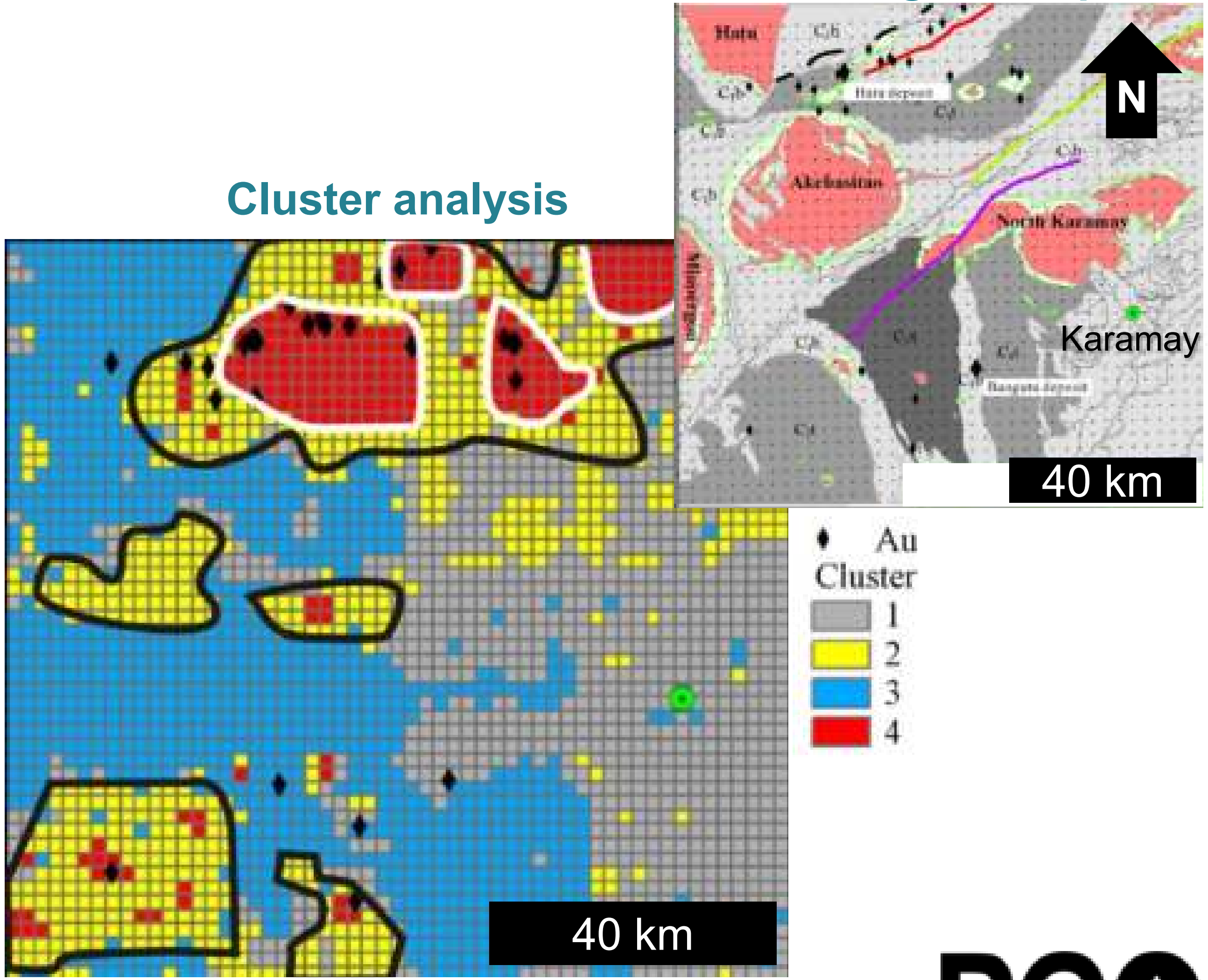
- Element associations (R-type clustering)
- Clusters of similar samples (Q-type)
  - *U-Mo-Au- Sb-B-Hg-W-As-Ag*

Conclusions

- R-type sensitive to transformation type
- Q-type is best with Center/Isometric Log-Ratio Transform using k-means or fuzzy c-means

Geological map

Cluster analysis



Zhou et al. (2018) *Frontiers in Earth science*

Be smart about labels
(e.g., What do they mean? How well do they match your data? Scale/Resolution?)

Mineral mapping drill core

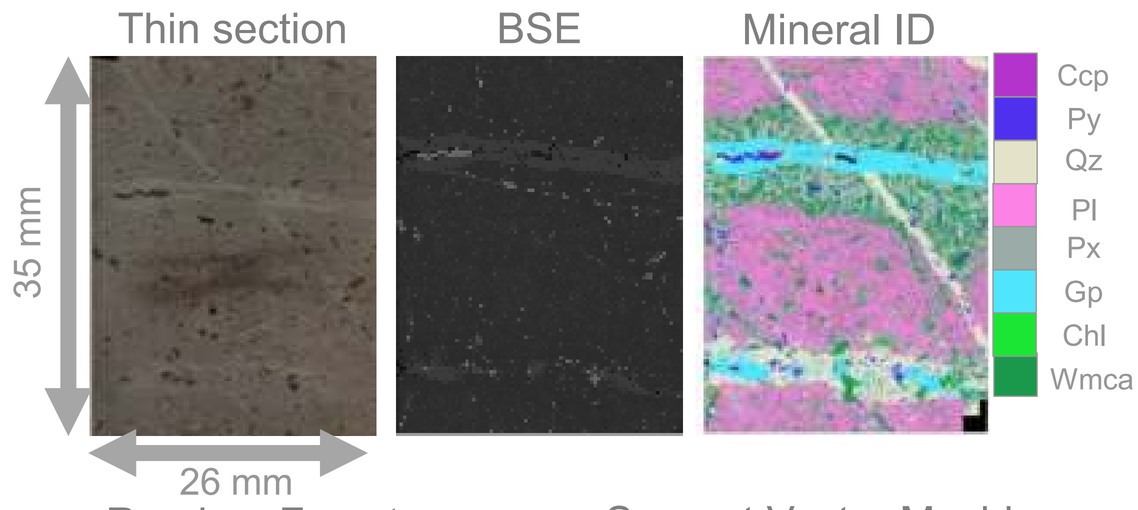
Classification ex 2

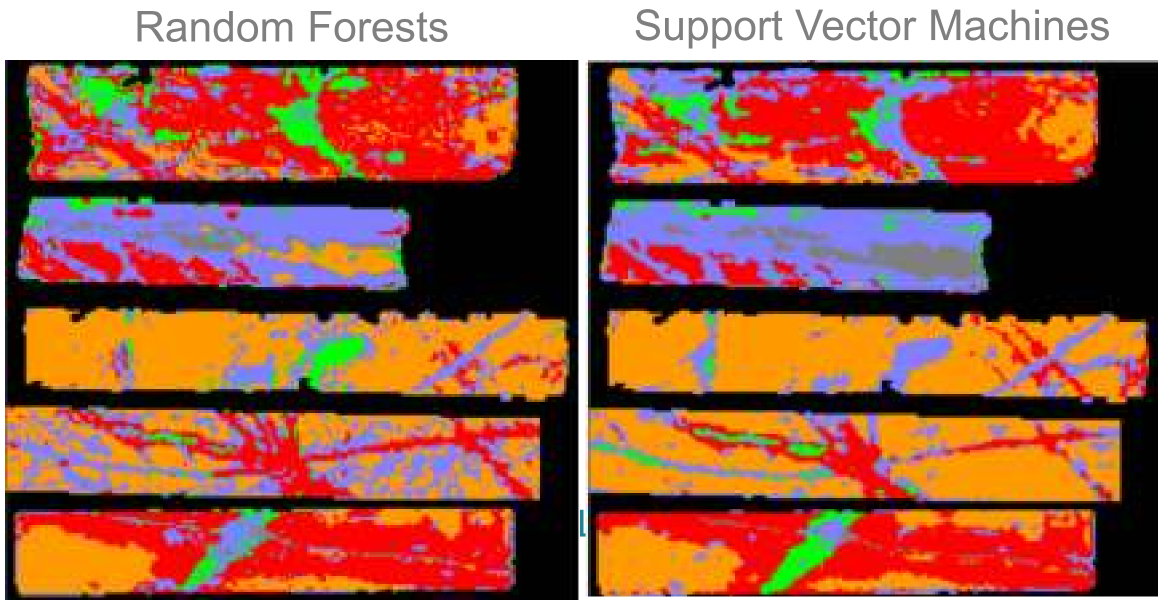
Methods

- Define ‘labels’ using SEM liberation analysis
- Random Forests: An ensemble of decision trees combined to vote on ‘most likely’
- Support Vector Machines: Finds the edges of classes and sets a midpoint field boundary

Conclusions

- Fusing methods (SEM and HS) makes core logging more robust





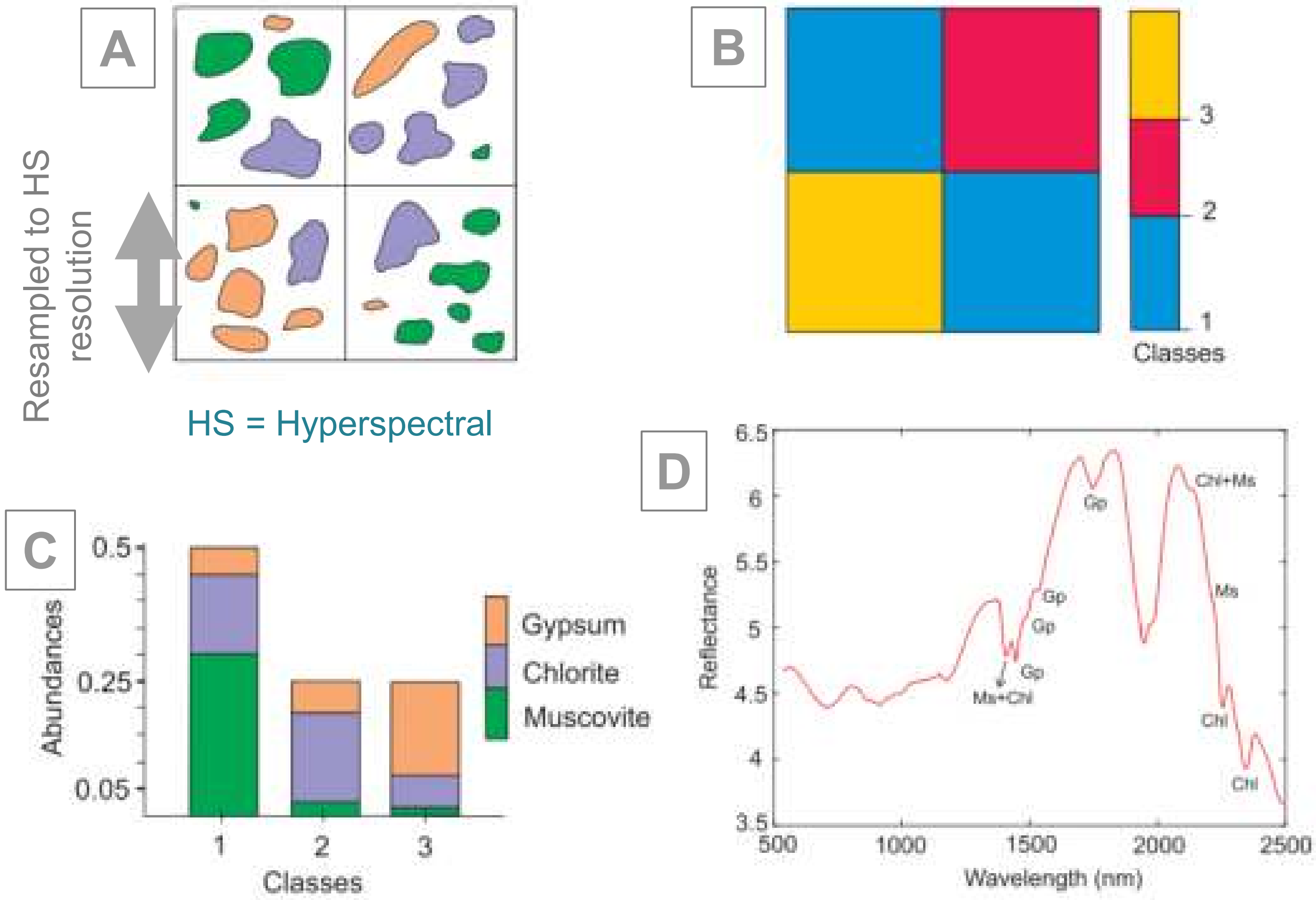
Acosta et al. (2019) *IEEE*

Be smart about labels
(e.g., What do they mean? How well do they match your data? Scale/Resolution?)

Mineral mapping drill core
Classification ex 2

'Soft labelling'

1. New grid based on HS resolution (A)
2. Determine dominant mineral (A)
3. Assign 'class' (B)
4. Degree of membership (C)
5. Record type-curves for each class (D)



Acosta et al. (2019) *IEEE*

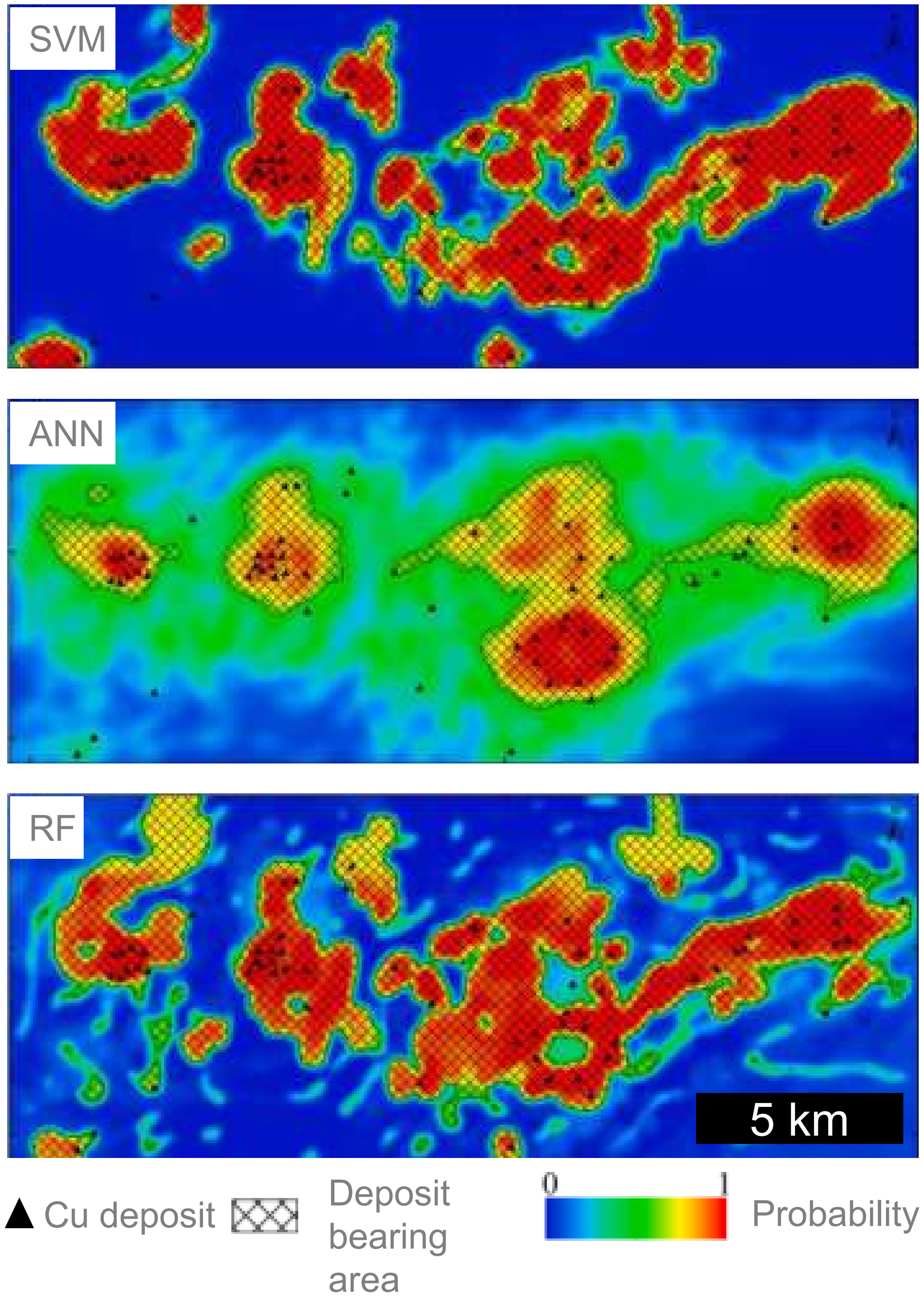
Cu-rich skarns
Prediction example

Methods

- Identify relevant aspects of mineral system
- Generate 12 representative layers
- Train layers with known mineralization and 'random' non-deposit sites
- Prediction of Cu
  - *Support Vector Machines (SVM)*
  - *Artificial Neural Network (ANN)*
  - *Random Forests (RF)*

Conclusions

- RF most stable against variation in parameters and most accurate predictions

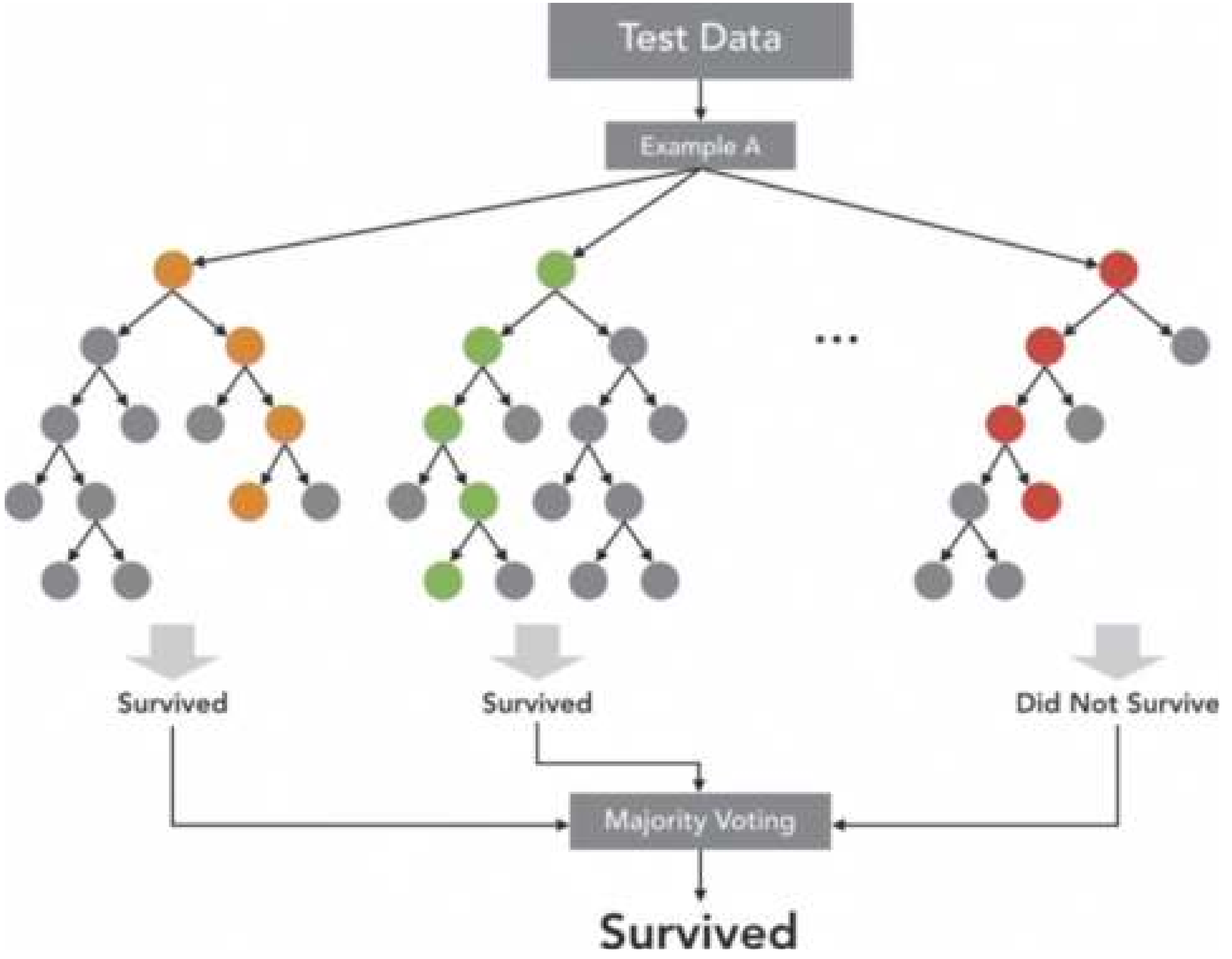


From Sun et al. (2019) *Ore Geology Reviews*

Prediction
Random Forests (RF)

Phase 2 – Prediction

1. Feed in subsets of all data
2. Run it through the trees
3. Majority voting



From Jedamski, 2019, *LinkedIn Learning*

Presentation 3

Water Management and Big Data – Are We There Yet?

Steve Holysh
Senior Hydrogeologist
Co-Program Manager, Oak Ridges Moraine Groundwater Program

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Water Management and Big Data – Are we there yet?

Steve Holysh, P.Geo

April 29, 2021


DILBERT
BY SCOTT ADAMS
CONSULTANTS SAY THREE QUINTILLION BYTES OF DATA ARE CREATED EVERY DAY.
DilbertCartoonist@gmail.com
IT COMES FROM EVERYWHERE. IT KNOWS ALL.
ACCORDING TO THE BOOK OF WIKIPEDIA, ITS NAME IS "BIG DATA."
BIG DATA
BIG DATA LIVES IN THE CLOUD. IT KNOWS WHAT WE DO.
IN THE PAST, OUR COMPANY DID MANY EVIL THINGS.
BUT IF WE ACCEPT BIG DATA IN OUR SERVERS, WE WILL BE SAVED FROM BANKRUPTCY.
LET US PAY.
$
www.dilbert.com
7-29-12
IS IT TOO LATE TO SIDE WITH EVIL?
SHHHH! IT HEARS YOU.

Big Data and Water - Basics

1. *Storage System; Handling Process; Analysis Mechanism*
2. *Five Vs*
    - Volume – generally >1 terrabyte
    - Velocity – generated at a high rate
    - Variety – structured + unstructured (video/social media, etc.)
    - Veracity – inaccuracy and uncertainty
    - Value – must contain new knowledge or improve efficiency
3. *Focus on data quality rather than quantity (clean, calibrate, validate sensors)*
4. *Measure only what is useful*
5. *Think dynamics – not steady state*
6. *Recognize different time scales*
7. *Consider how to handle outliers and extraordinary events*

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Big Data and Water - Examples

1. Water and wastewater distribution systems – flow/pressure sensors in pipes looking for leaks/anomalous water use
2. Sensors to automate irrigation systems
   1. *Climate (temp, radiation, wind speed, humidity,)*
   2. *Crop (height, leaf area index, density)*
   3. *Soil (moisture, infiltration)*
3. Global/Regional Climate Models
4. Sensors track river/estuarine system water quality
5. Ontario – 2014-15 – initiation of integrated environmental monitoring of Grand River Watershed - SOWC/Grand River/IBM/UofWaterloo)

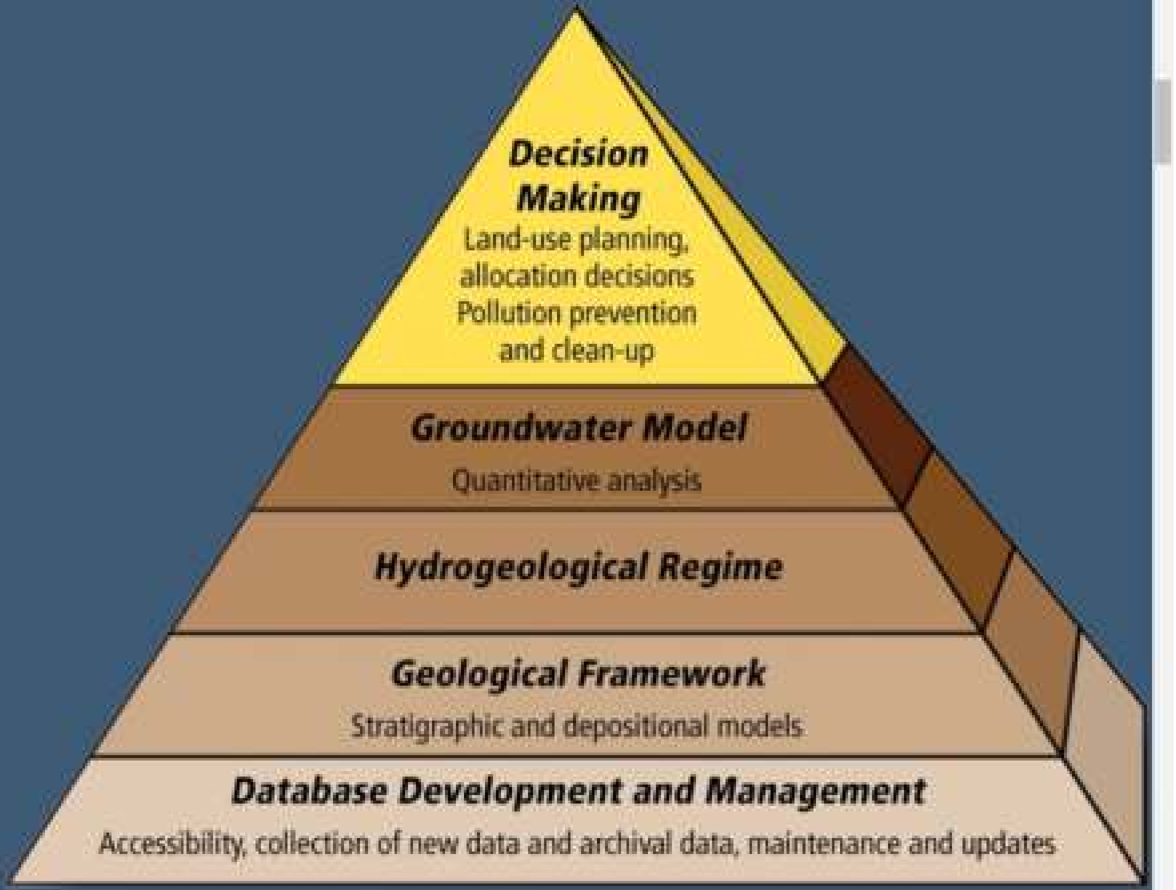
At every level of government in Ontario there are many different departments, ministries and agencies all collecting water-related data –

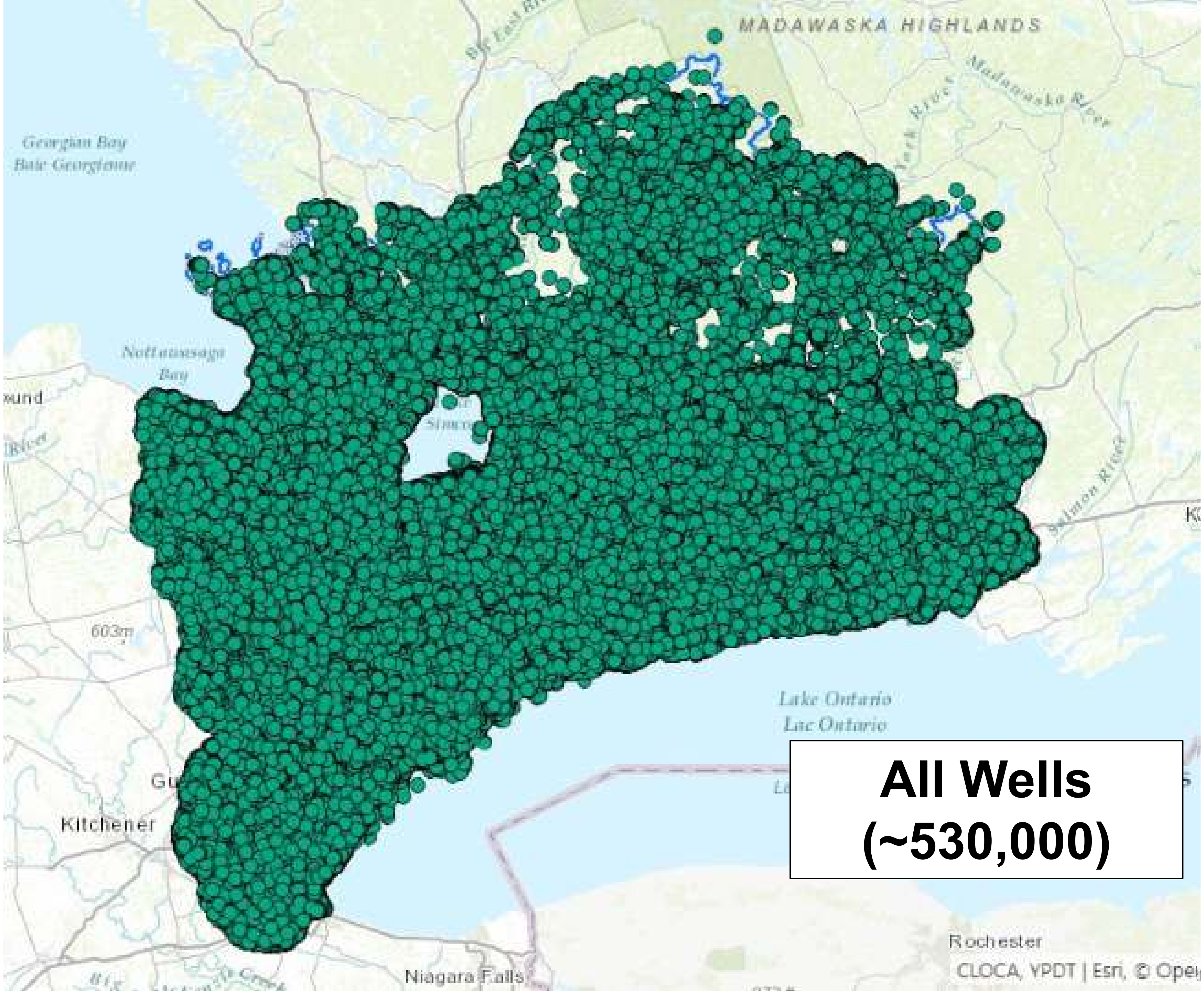
• often in the same aquifers/water bodies, and

• often without knowing what others are collecting.

Commonly, these data are stored on individual computers and files, and then used only once to inform the decisions for which they were collected.

These data become lost and therefore unusable as input to longer term decision making.





All Wells (~530,000)

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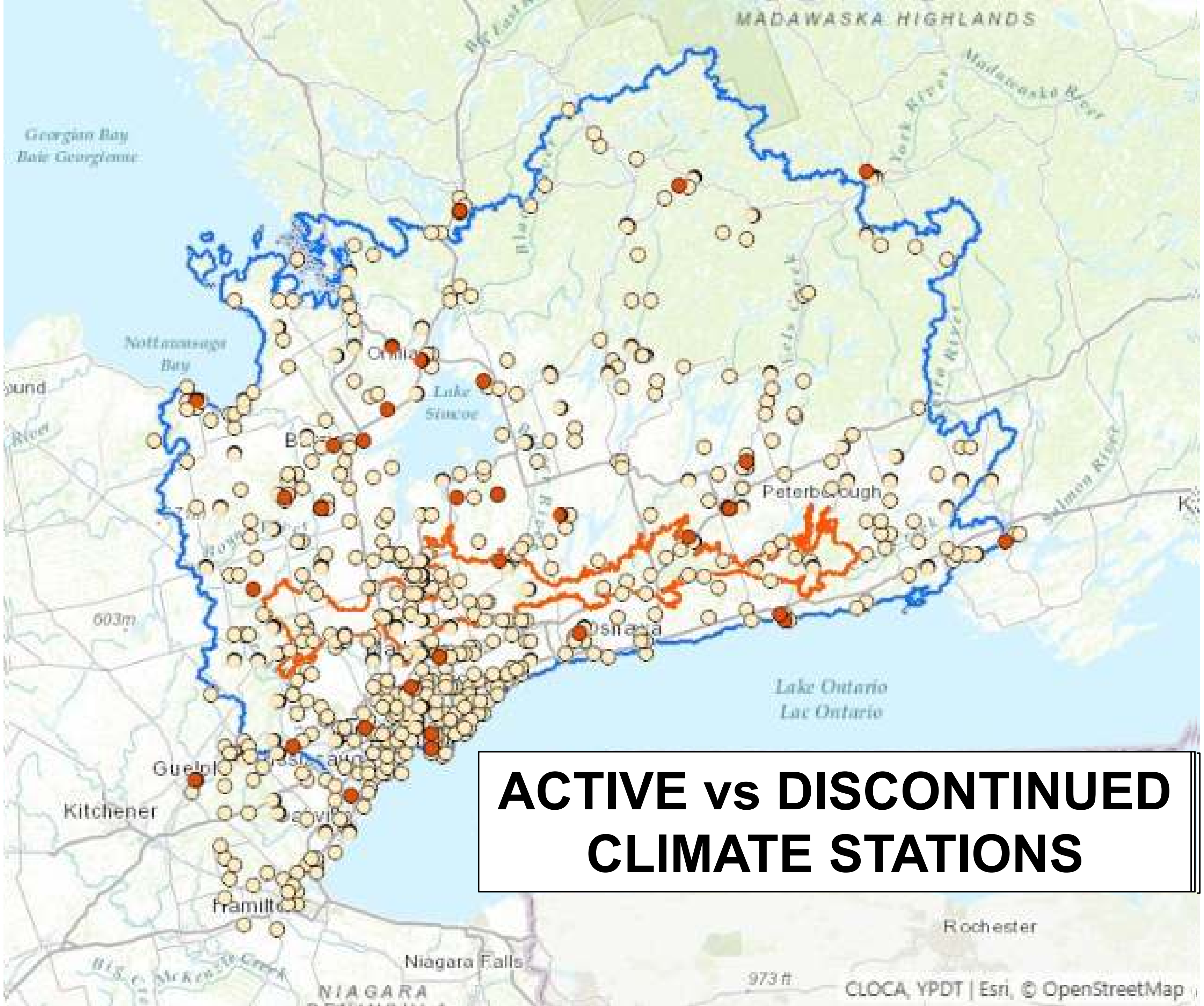
ACTIVE vs DISCONTINUED CLIMATE STATIONS



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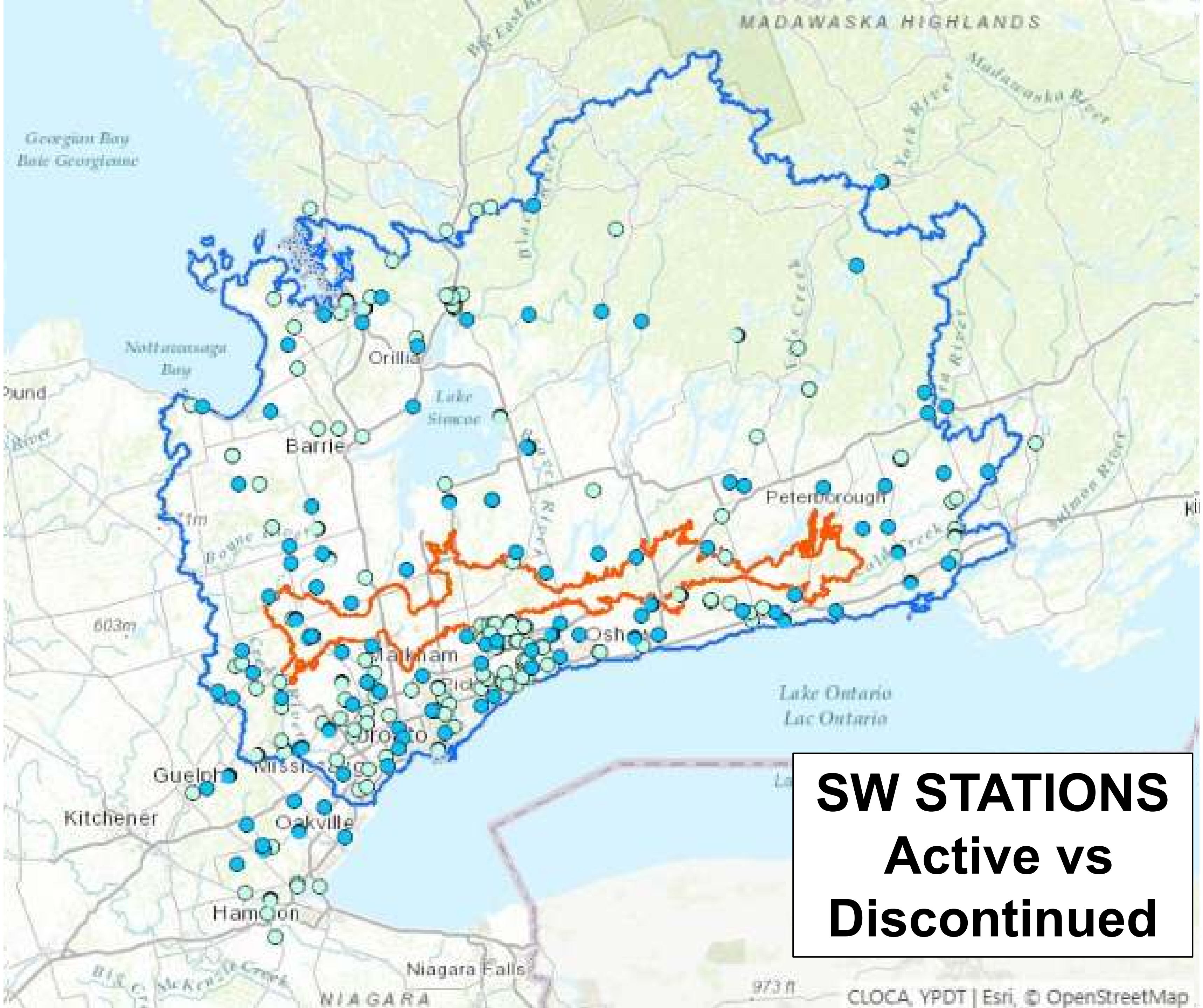

SW STATIONS Active vs Discontinued

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Main ORMGP Data Holdings

- Wells/BHs – 532,324 wells (1,491 Monitoring Wells)
  - *120.3 million water levels*
  - *644,000 water quality parameter analyses*
  - *1.2 million pumping records*
  - *1.94 million geological layers*
- Climate – 820 Stations
  - *28.6 million temporal records (mostly Temp and Precip)*
- Stream – 16,078 Stations
  - *1.61 million flow measurements*
- ~12,000 Consultant/Gov't Reports
- Numerical Models ~ 1 Terrabyte

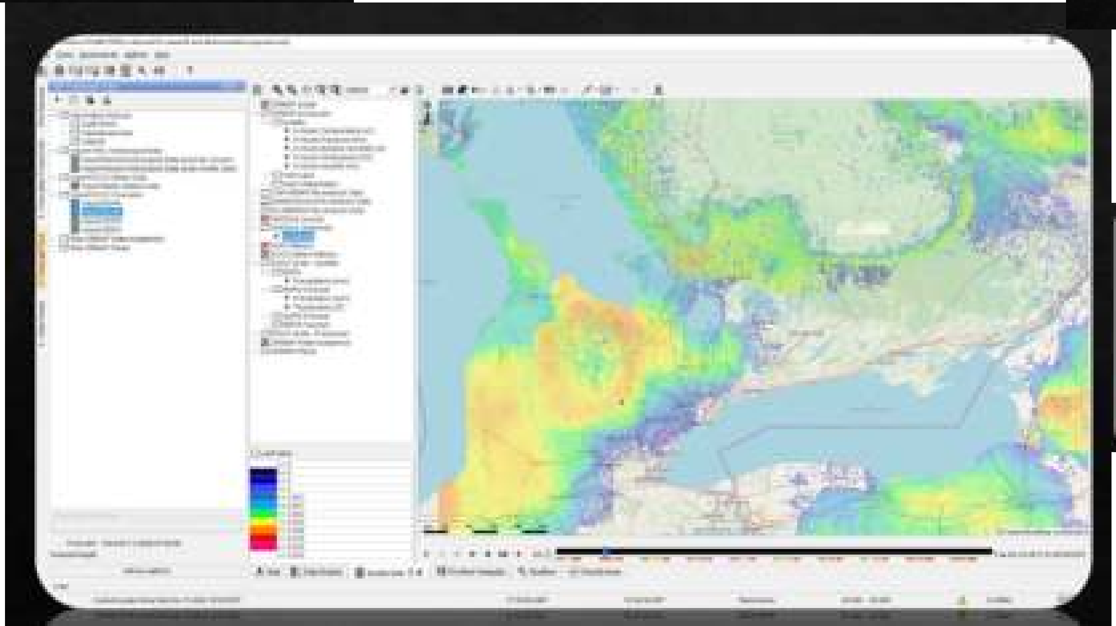
Point Data vs Grid Data

Grid

- Many points in space
- Field
- Distributed
- 2D
- Timeseries
- Multiple metrics

Non-scalar (Gridded) Data Sources

- CaPA-RDPA: precipitation, 10km resolution, 6-hourly, since 2002
- CaPA-HRDPA: precipitation, 2.5km resolution, 6-hourly, since 2016
- SNODAS: SWE, snowmelt, 30m resolution, daily, since 2010
- Earth2Observe global re-analysis data 2005-2015 (Precipitation, temperature, PET)
- Forecast products: GDPS, GEPS, RDPS, REPS, etc...
- <u>Models:</u> Inputs and outputs



Delft-FEWS

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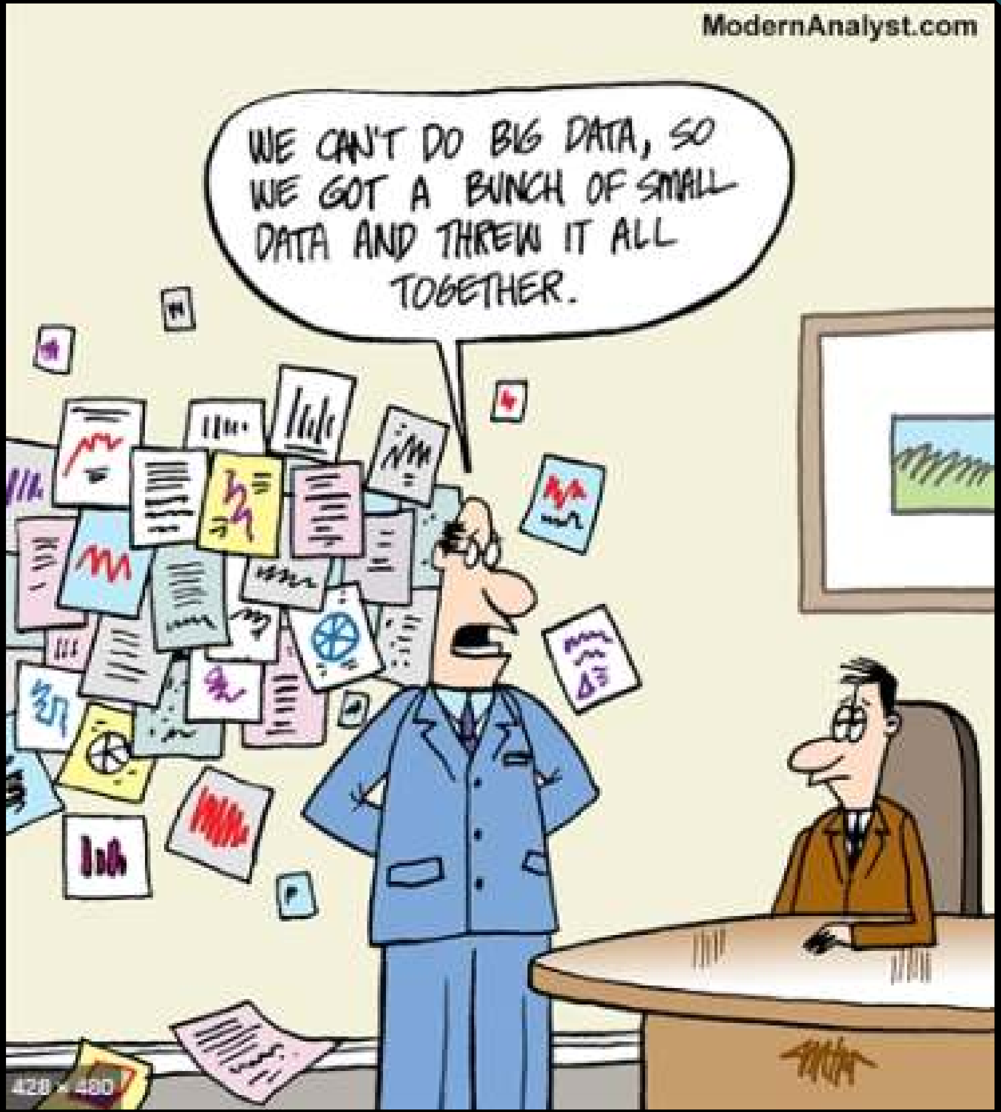

Key ORMGP Data Tenets

- ‘Opportunistic’ data acquisition
- Importance of numerical modelling
- Treat data with respect – hydrogeological data (water and geology) should not only be used once
- Data at site scale can be used regionally and regional data can be applied at site scale
- Access to raw data insufficient – use the data!

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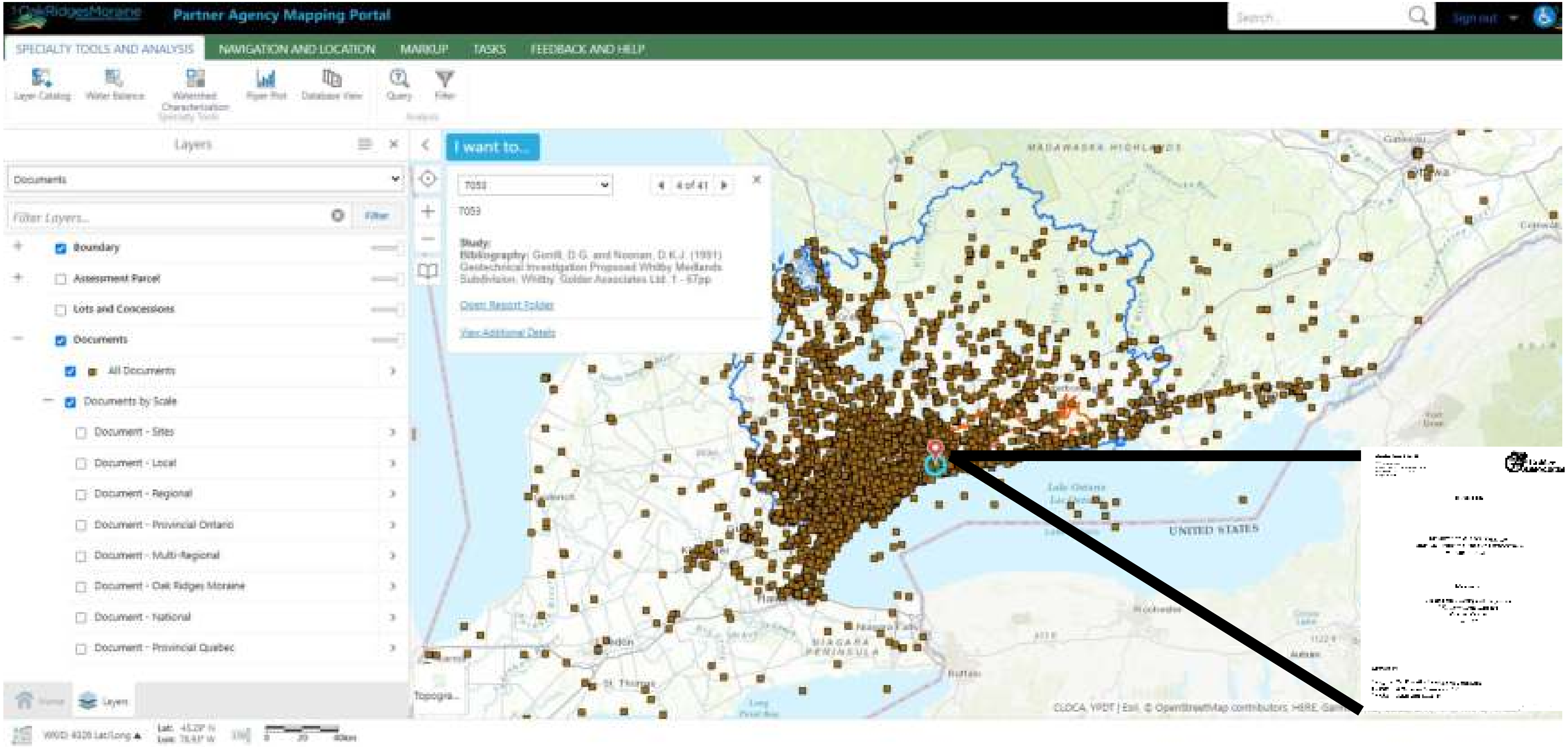
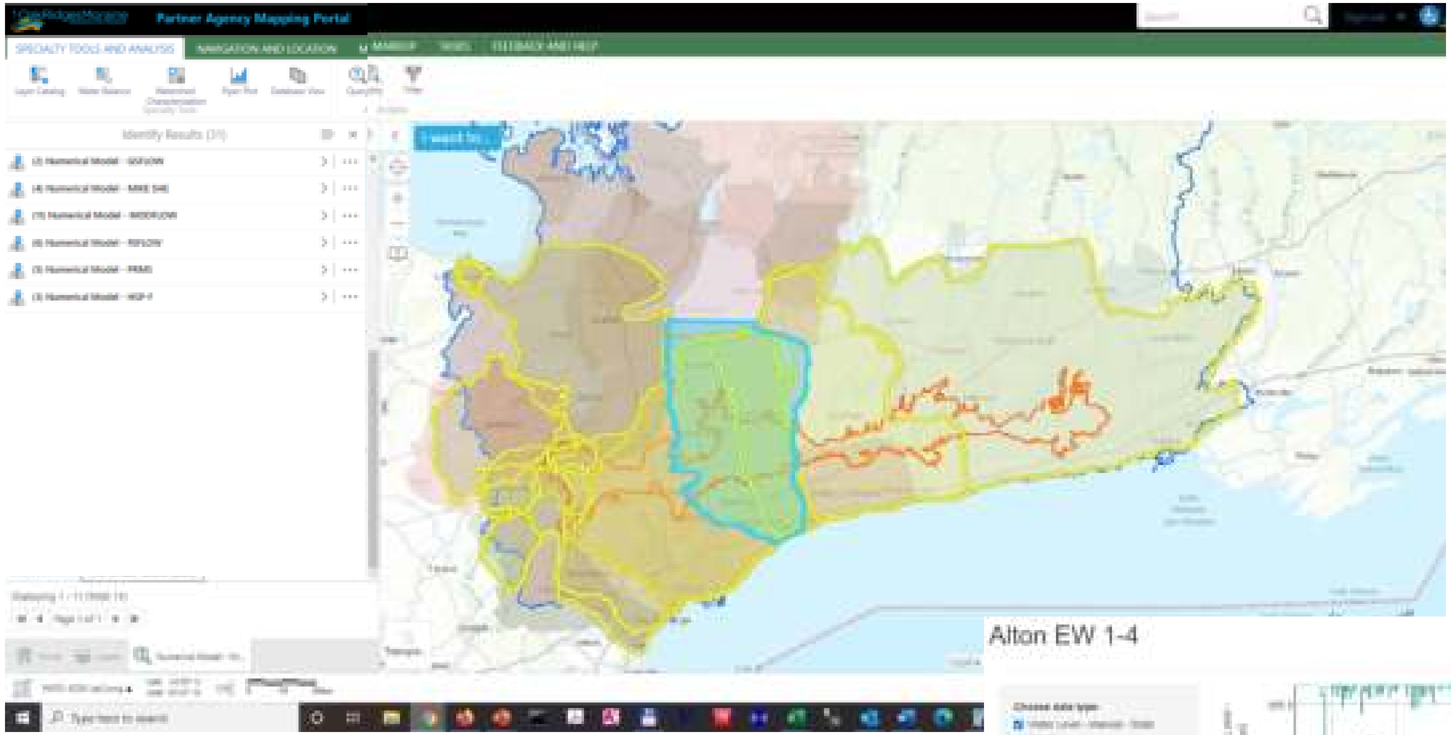
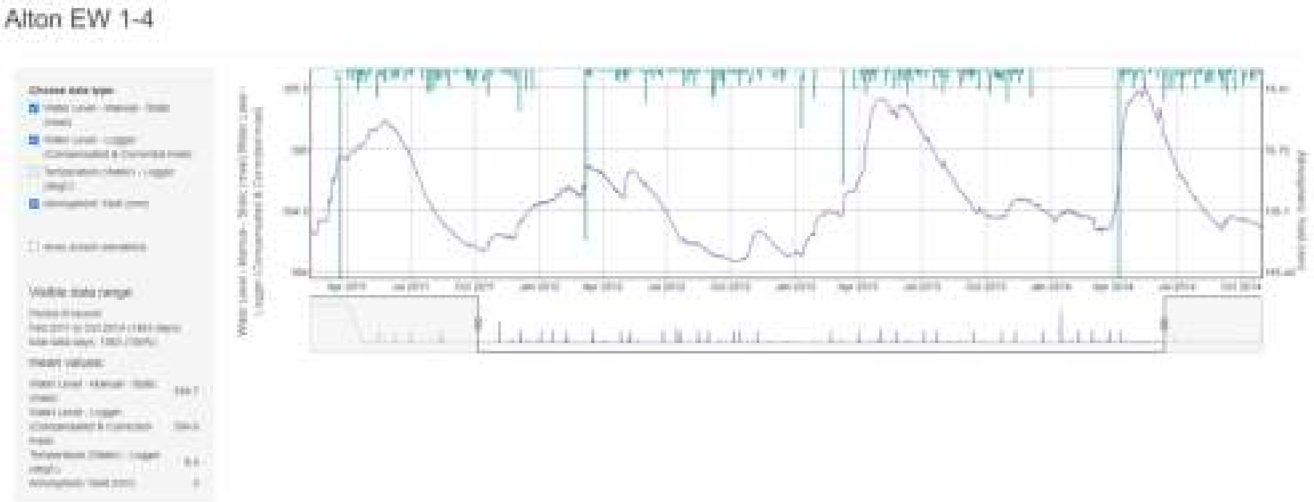
‘Opportunistic’ Data Acquisition



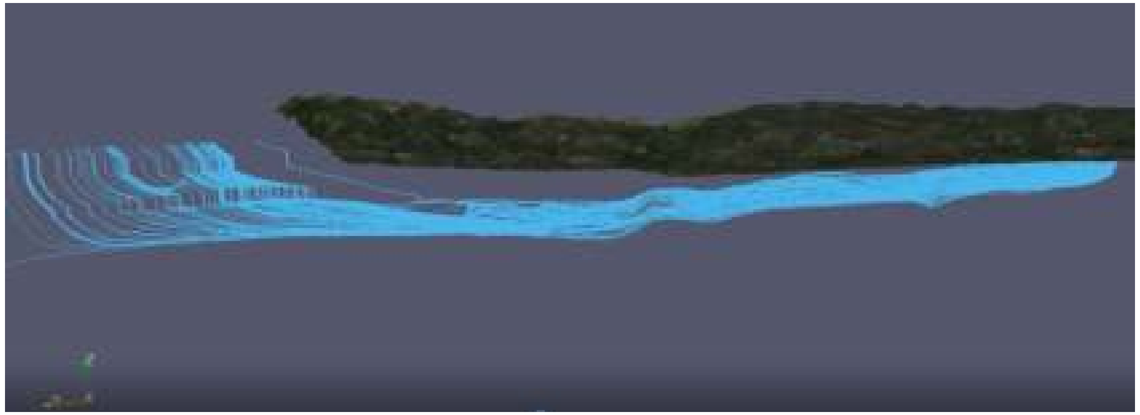
Importance of Numerical Models





Importance of Numerical Models

- Hydrogeologists – Fully integrate water cycle data
  - *Climate Science – starting to recognize role of GW in atmospheric process (shallower WT – higher ET)*
  - *Hydrologists – frequently have treated groundwater system as 'black box'*
  - *Hydrogeologists – in trying to fully understand flow system dynamics – forced to incorporate: 1) water inputs (precip/ET, runoff, recharge); 2) flow through subsurface; 3) discharge to streams*
- Data QA/QC tools

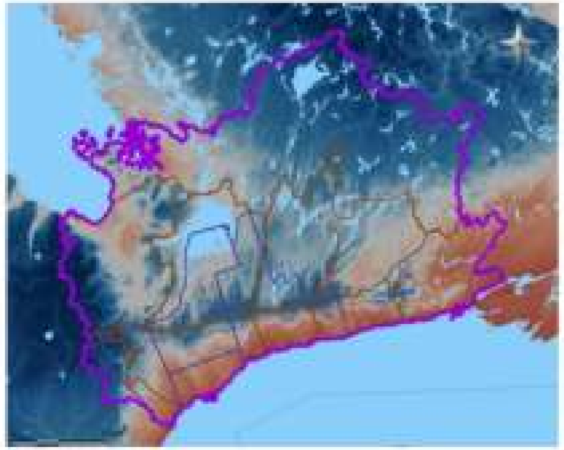


Respect for Data

York Peel Durham Toronto (YPDT) Ground Water Management Study
Conservation Authorities Moraine Coalition (CAMC)

YPDT-CAMC Database Manual
Version 6 (Dated Version 20160831)
Draft - December 4, 2017

Authors: M. Doughty, S. Holysh, R.E. Gerber, M. Marchildon, R. Smith

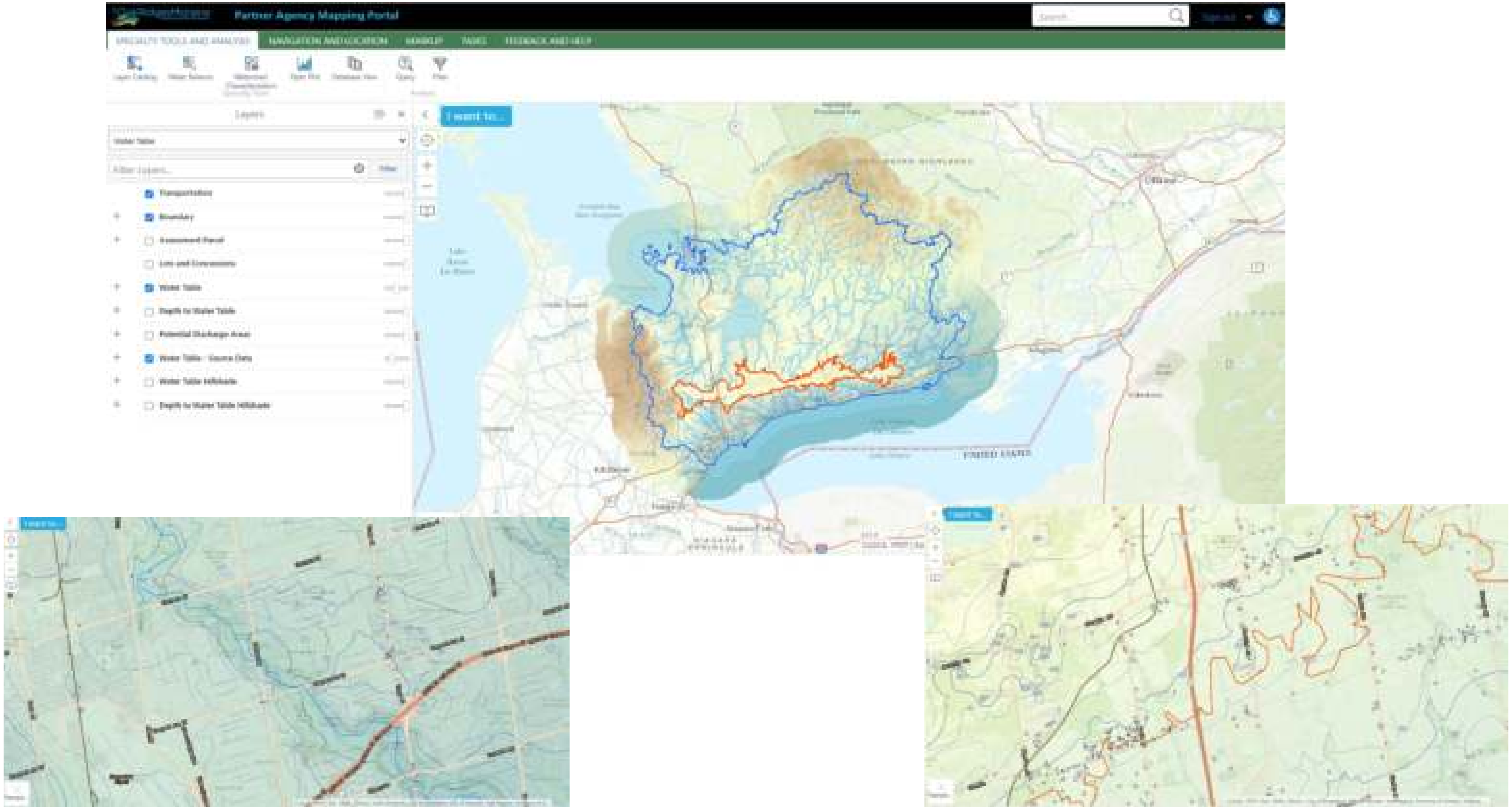


CAMC/YPDT Technical Report Number 01-2017

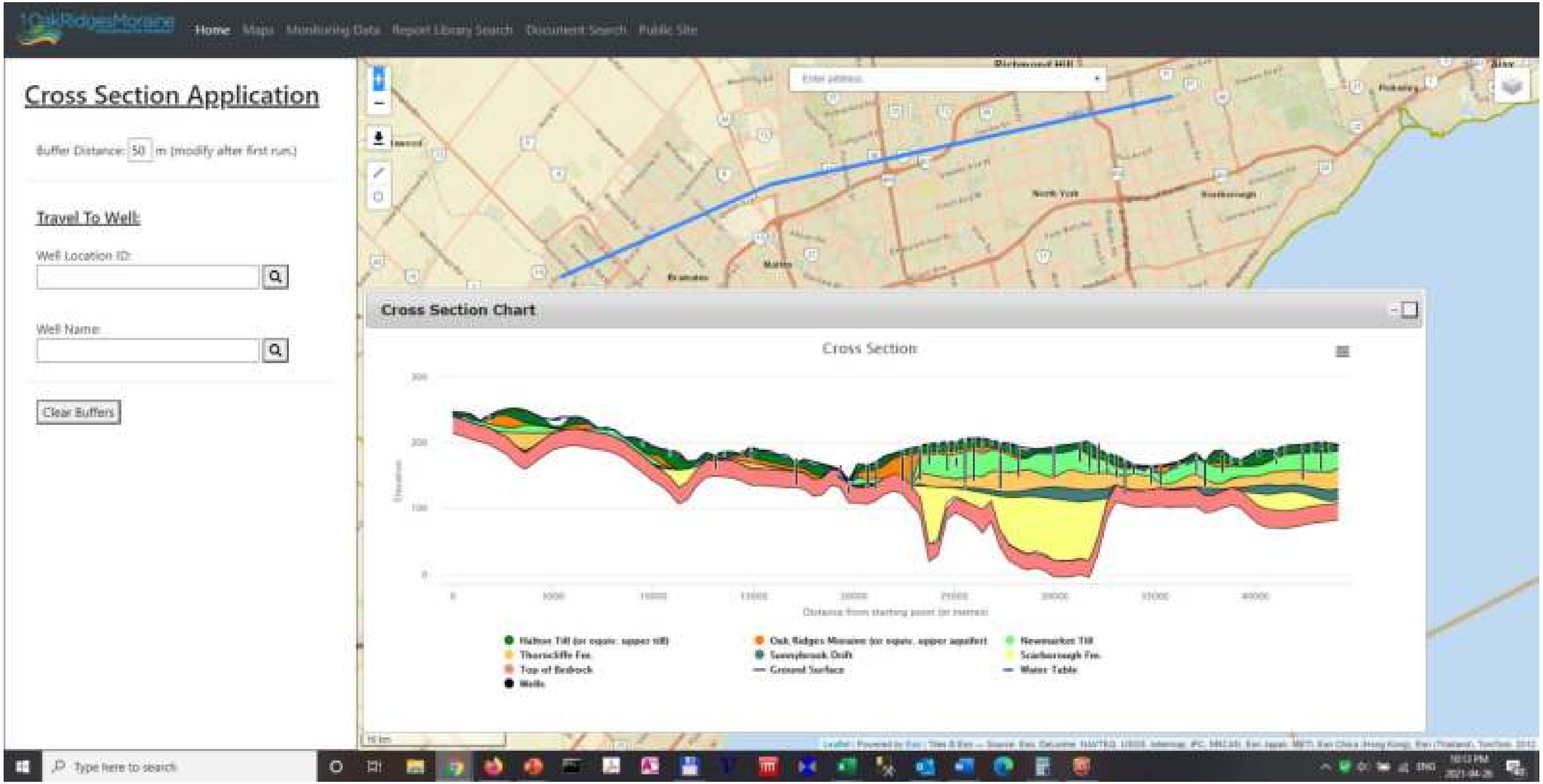
Table of Contents

Big Data = Big Database Manual (542 Pages)

Regional vs Site Scale Data



Make Use of the Data



ORMGP - GW INFRASTRUCTURE

	(Millions $)
• Program Cost (2001 – 2020)	$ 14.0
• BHs/Wells (550K/1.3 million m)	$ 162.5
• *Assume $40/ft drilling)*	
• Water Quality (116K samples)	$ 32.6
• *Assume $280/sample)*	
• Monitoring WLs (>100 million)	$ 18.1
• *Assume quarterly 1-day site visits for every 15 monitoring wells*	
• Documents/Reports (~12K)	$ 595.3
• *Assume $50,000/Report*	
• Numerical Models (~70 Models)	$ 24.0

EST. ORMGP INFRASTRUCTURE VALUE $833 MILLION

Big Data and Water

Closing Thoughts

- Emphasis on ’real time’ data and on ‘real time’ decision making
    - Time scale of land use change/policy making is not necessarily ‘real time’
    - Need time to ‘see’ subtle changes in environment that might lead to societal land use changes
    - Expectations - don’t want to sacrifice monitoring if no “real time” decisions come forth
- Think about users and decisions to be made – ORMGP generally focuses on scale of land use change (site to watershed) – data/interpretations/tools/analysis focused at this scale
- ‘Open Data’ movement – good initiative
- Data ownership still ‘muddies the waters’ – NFT’s?

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HYDROLOGICAL PROCESSES
INVITED COMMENTARY

Completing the loop: from data to decisions and back to data

Stuart Hamilton*

Key Take Aways

- “Well-maintained data appreciate in value like a vintage car.”
- “As our models increase in sophistication we should be investing in more comprehensive monitoring to shed light on how well the models reflect reality.”
- “Each and every hydrologist needs to imagine what their information needs might be in 20 years time, and from that perspective consider what monitoring decisions need to be made today in order to supply those information needs.”

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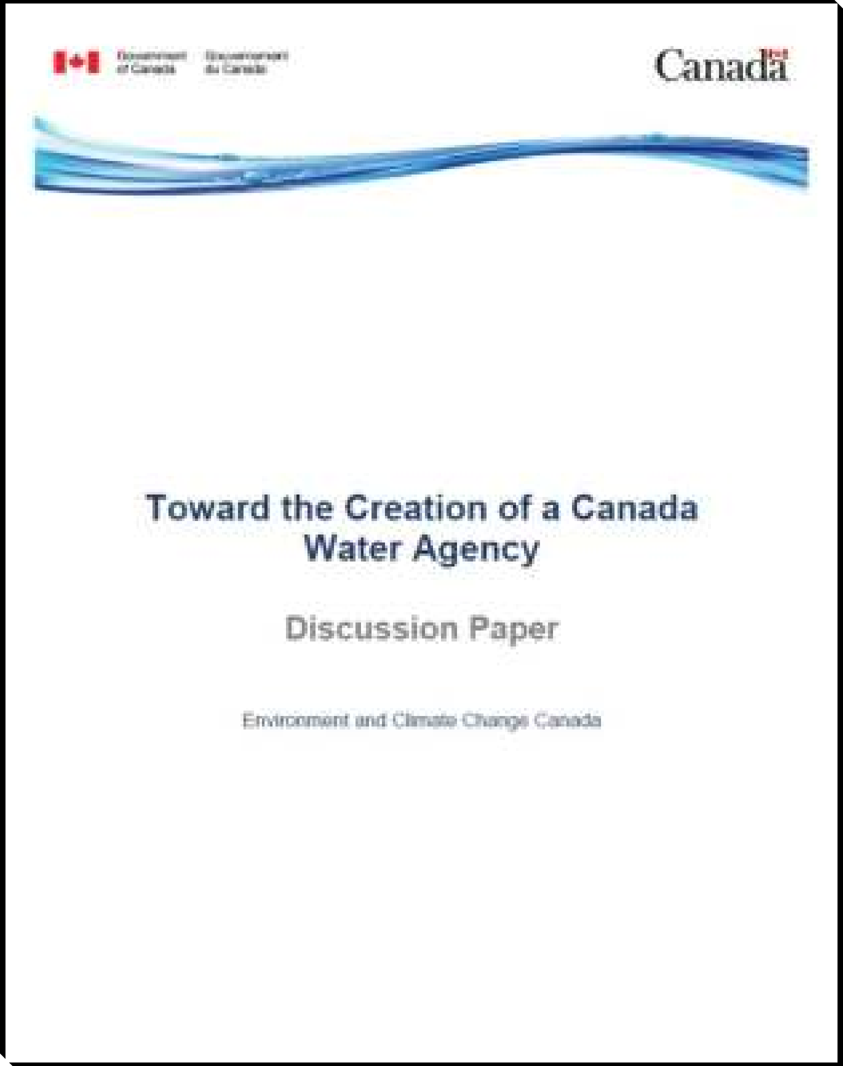
Federal Water Policy
Canada
water
saga
A Story of Water management in Ontario
1956 - 1968
On the Table:
Water, Energy and North American Integration
September 4, 2007
Embargoed until 9:00 am Sept. 10, 2007
Andrew Nikiforuk
MUNK CENTRE
Federal Water Framework
C.D. Howe Institute
BACKGROUNDER
THE WATER SERIES
Protecting Groundwater:
The Invisible but Vital Resource
2015
Canadian Municipal Water
PRIORITIES REPORT
Canadian Municipal Water Consortium
Report in Focus
Freshwater:
The role and contribution of Natural Resources Canada
Canada
CCME
Review and Assessment of Canadian Groundwater Resources, Management, Current Research Mechanisms and Priorities
Canadian Water Sustainability Index (CWSI)
Project Report
BURIED TREASURE


Canada
Toward the Creation of a Canada Water Agency
Discussion Paper
Environment and Climate Change Canada

Canada Water Agency

- Goal - “work together with the provinces, territories, Indigenous communities, local authorities, scientists, and others to find the best ways to keep our water safe, clean and well-managed.”

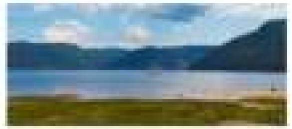
DataStream
Lake Winnipeg
Mackenzie
Atlantic

DataStream is a powerful online platform for sharing information about freshwater health.

Visit Mackenzie DataStream

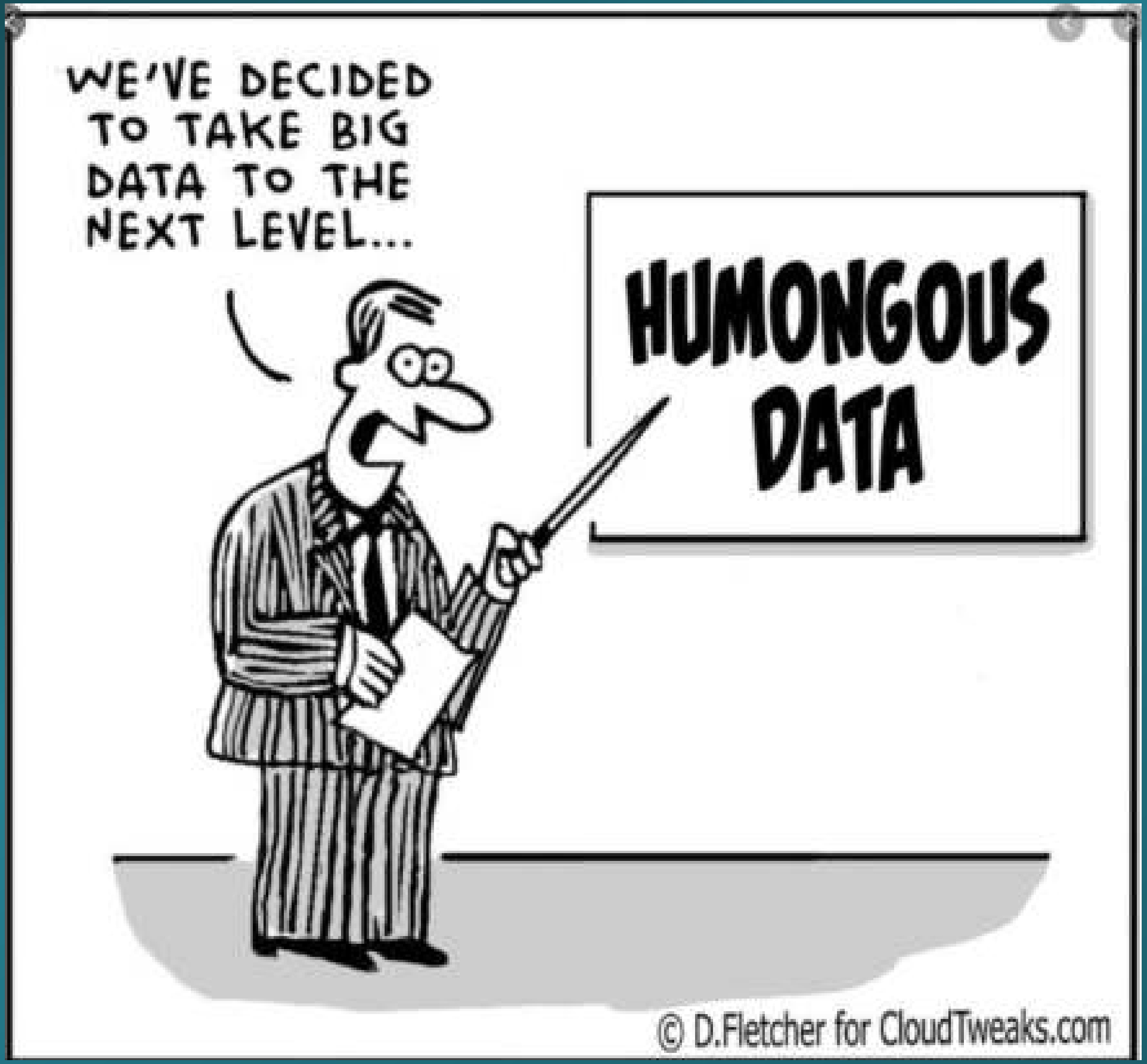
Visit Atlantic DataStream

Visit Lake Winnipeg DataStream



Great Lakes DataStream - coming fall 2021

U.S. Initiatives



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Thank you

Presentation 4

Teaching, Learning and Research with Electronic Circuits: Measurement and Monitoring of Environmental Phenomena

Nicholas Kinar

Centre for Hydrology of University of Saskatchewan

Global Institute for Water Security

2021 VIRTUAL SYMPOSIUM

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Teaching, Learning and Research with Electronic Circuits: Measurement and Monitoring of Environmental Phenomena

Dr. Nicholas J. Kinar

29 April 2021

In Saskatoon, Saskatchewan, we acknowledge we are on Treaty 6 Territory and the Homeland of the Métis. We pay our respect to the First Nations and Métis ancestors of this place and reaffirm our relationship with one another.

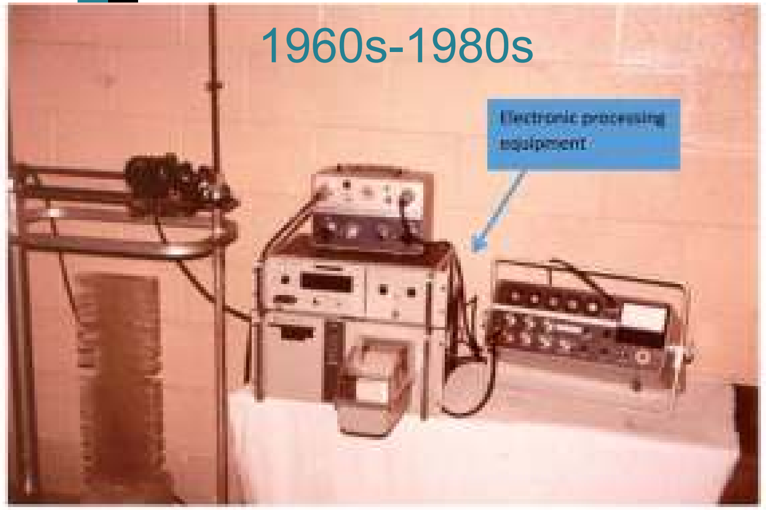
Who Am I?

Hydrology Paper of the Day
@KinarNicholas

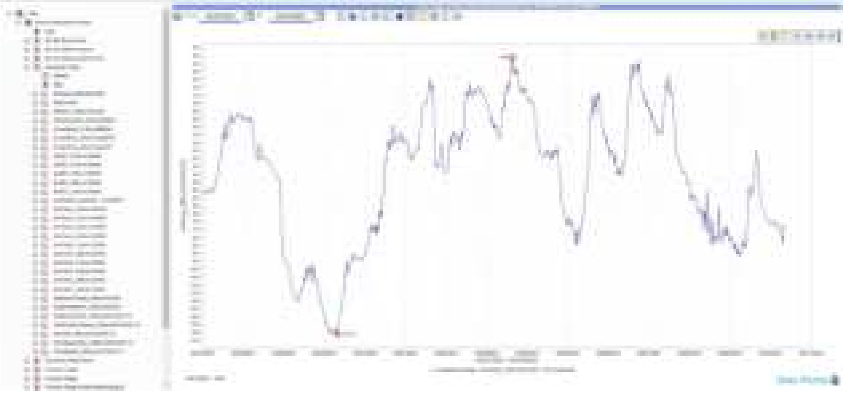
I design, build and test novel electronic circuits that can be used to quantify environmental phenomena and provide data inputs for models used for prediction and forecasting.

Environmental Measurement Systems

1960s-1980s



1990s-2010



2010-present

Kinar, N. J. and Pomeroy, J. W.: Environmental Electronic Sensing Systems, in: Geography, Oxford University Press Bibliographies, *in typesetting*, 2021

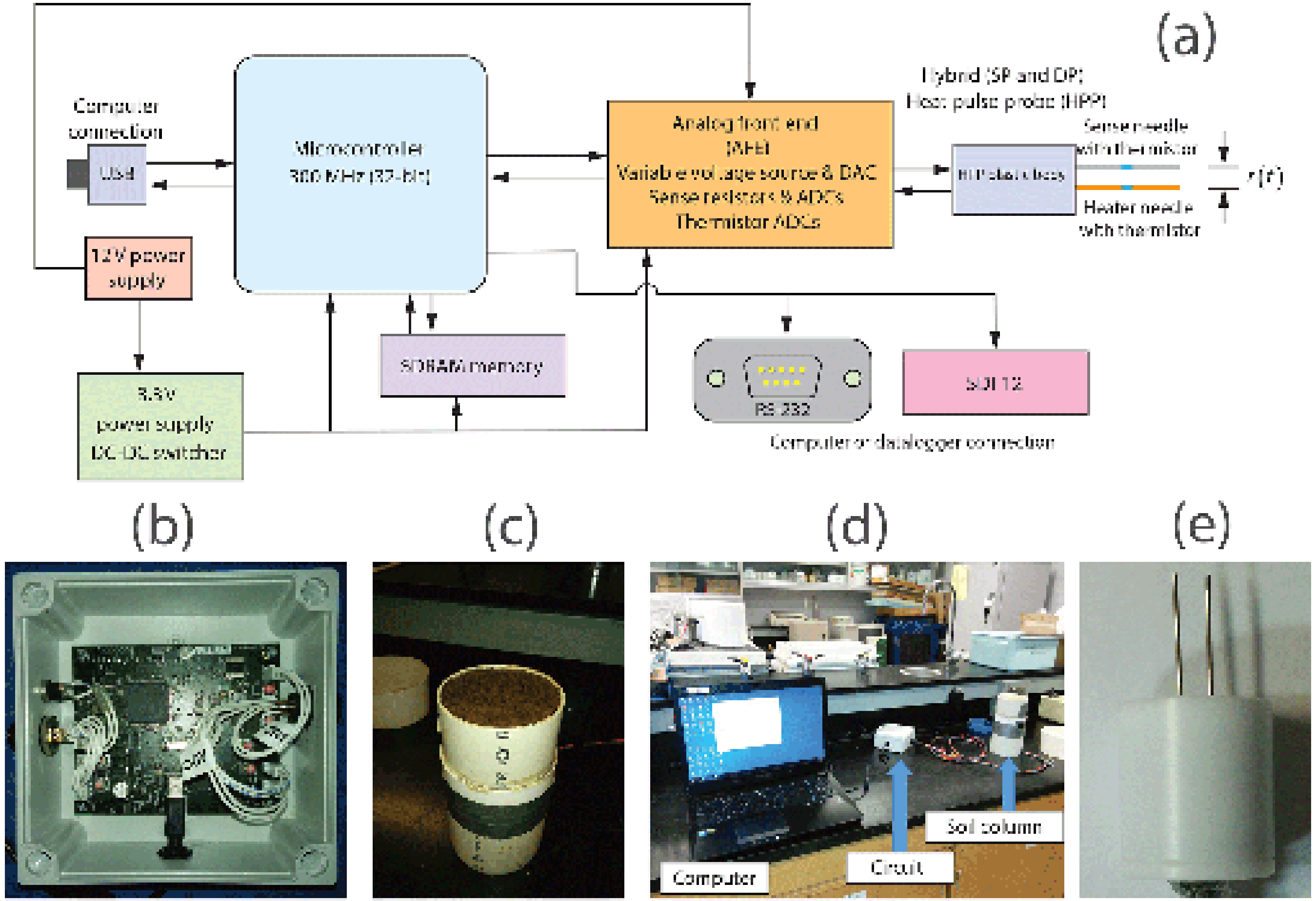
Kinar, N. J. and Pomeroy, J. W.: Measurement of Terrestrial Snow, in: Geography, Oxford University Press Bibliographies, https://doi.org/10.1093/obo/9780199874002-0225, 2021

Kinar, N. J. and Pomeroy, J. W.: Measurement of the Physical Properties of the Snowpack, 53, 481–544, https://doi.org/10.1002/2015RG000481, 2015.

Electronic Circuits and Systems

Chione (System for Acoustic Sensing of Snow)

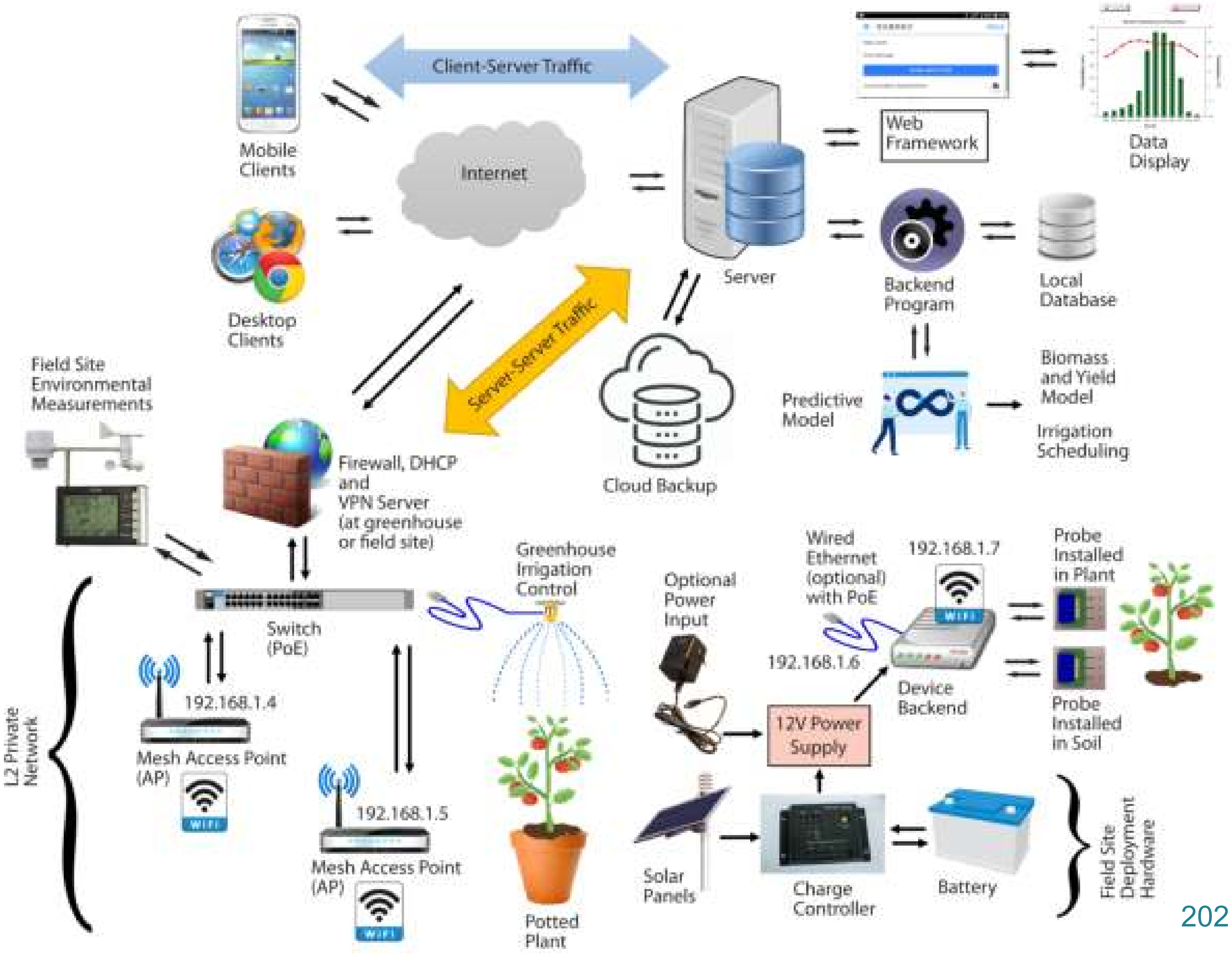
Kinar, N. J. and Pomeroy, J. W.: SAS2: the system for acoustic sensing of snow, Hydrol. Process., 29, 4032–4050, https://doi.org/10.1002/hyp.10535, 2015.



Self-Calibrating Heat Pulse Probe (SCHEPP)

Kinar, N. J., Pomeroy, J. W., and Si, B.: Signal processing for in situ detection of effective heat pulse probe spacing radius as the basis of a self-calibrating heat pulse probe, 9, 293–315, https://doi.org/10.5194/gi-9-293-2020, 2020.

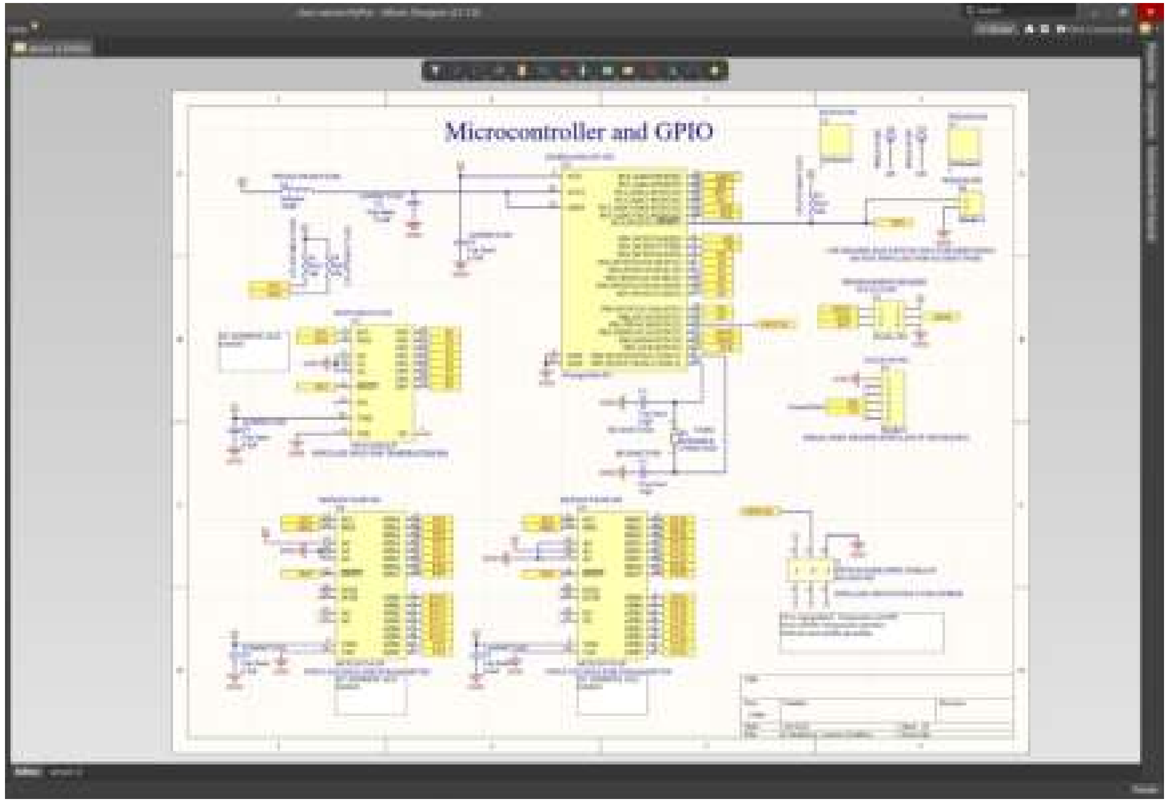
Internet-of-Things (IoT)

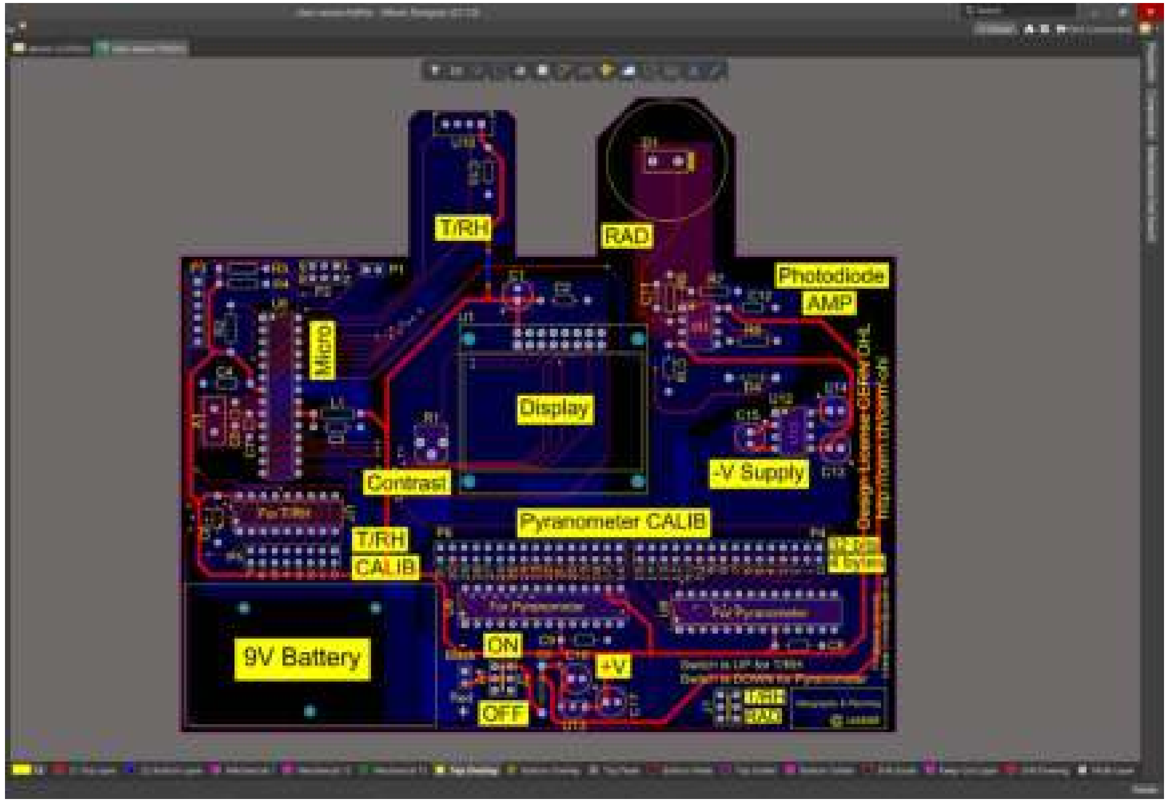


https://www.go-fair.org

- **Findable** for humans and computers
- **Accessible** metadata and data products
- **Interoperable** – can be utilized with software and other datasets
- **Reusable** – data is clearly described and useful for other studies

Circuit Boards and Open Source Hardware

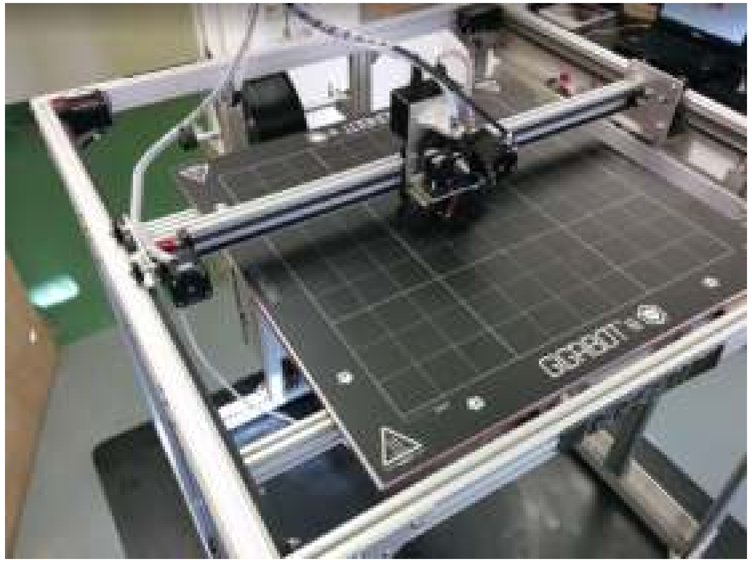


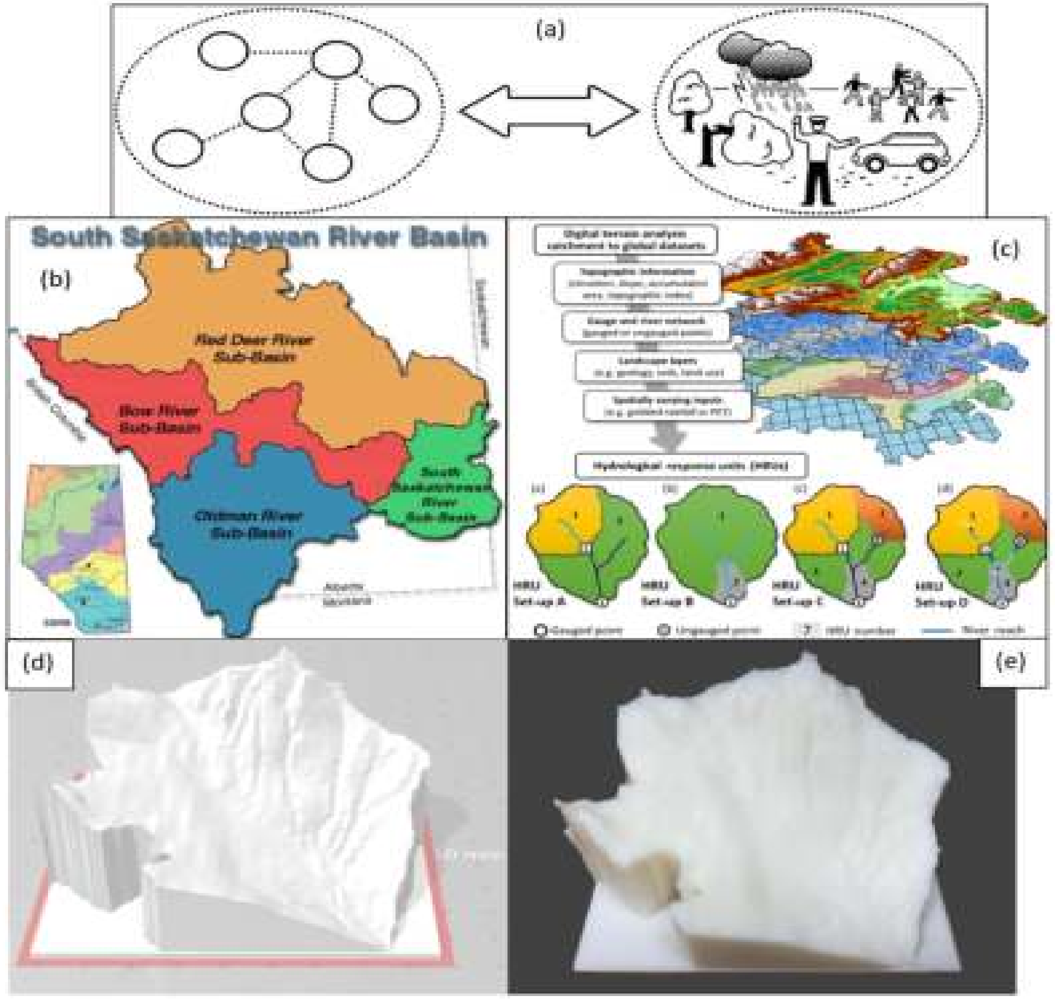


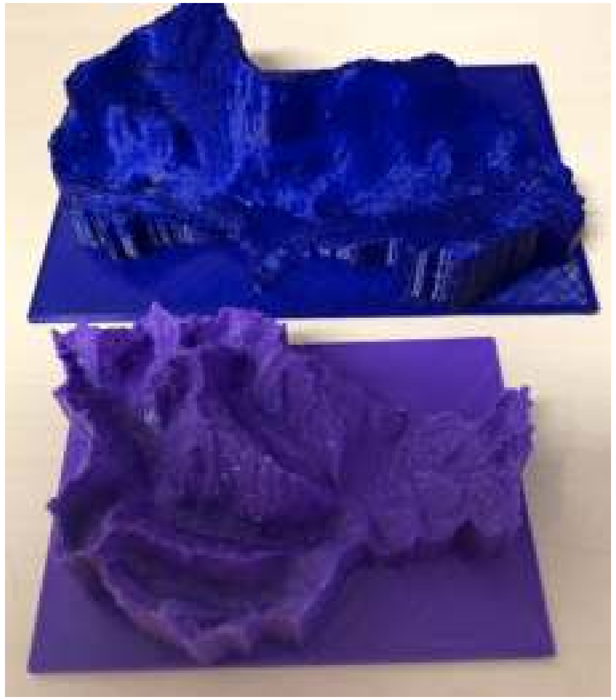
A schematic is similar to a map showing connectivity and a PCB has “layers” similar to a GIS!

CERN Open Hardware License (OHL)
https://ohwr.org/project/cernohl/wikis/home

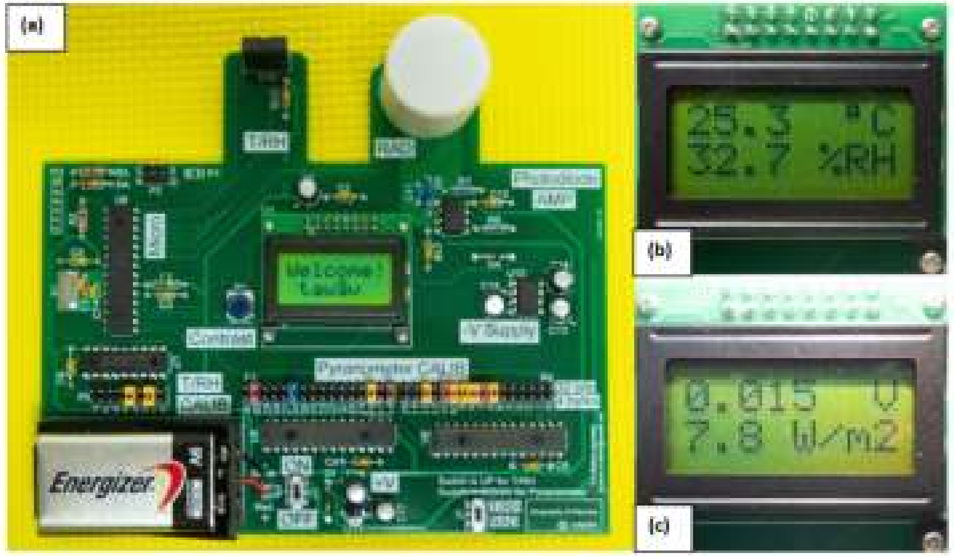
3D Printing to Teach Hydrology





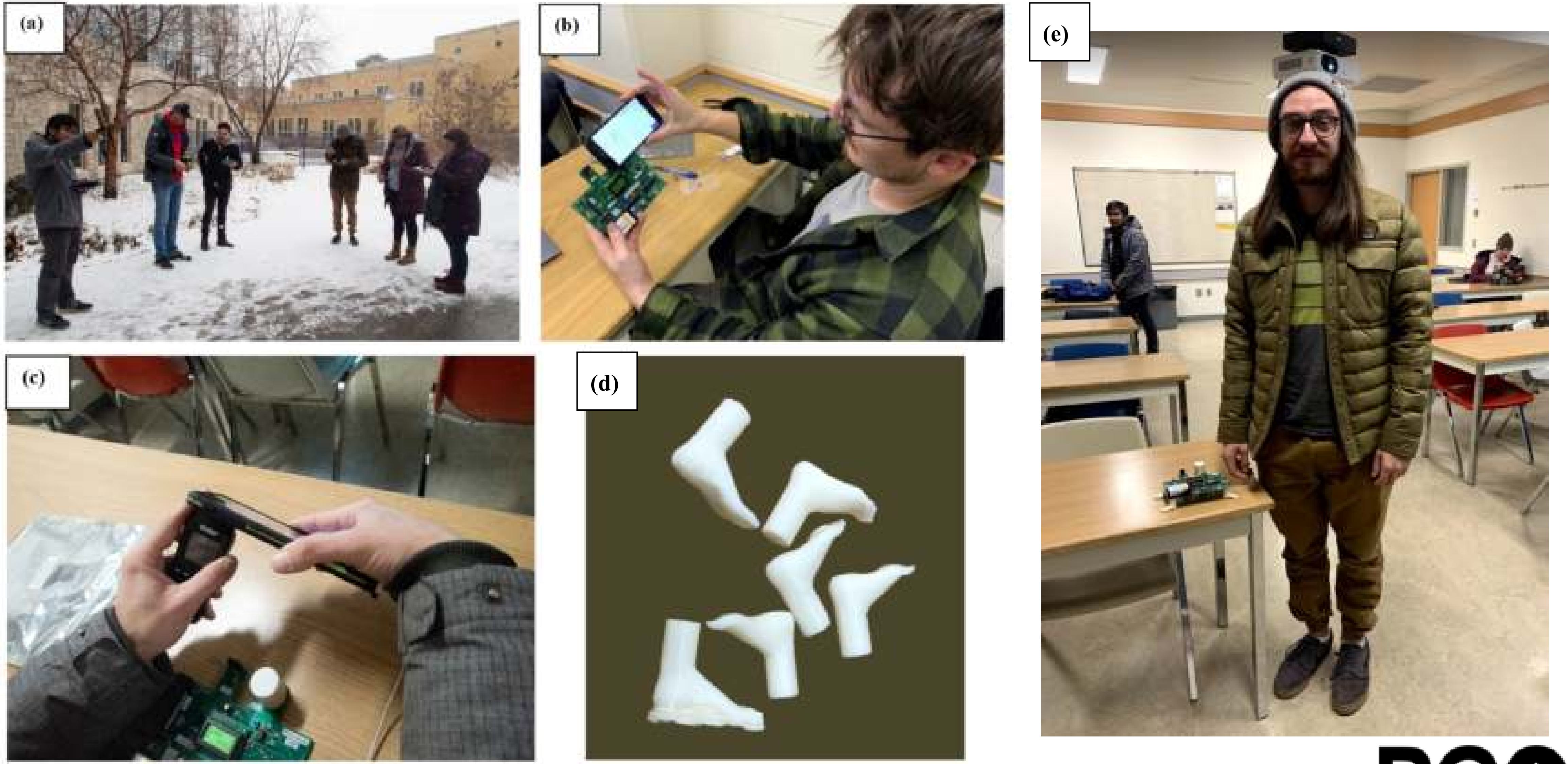


Electronic Circuits and Teaching Hydrology



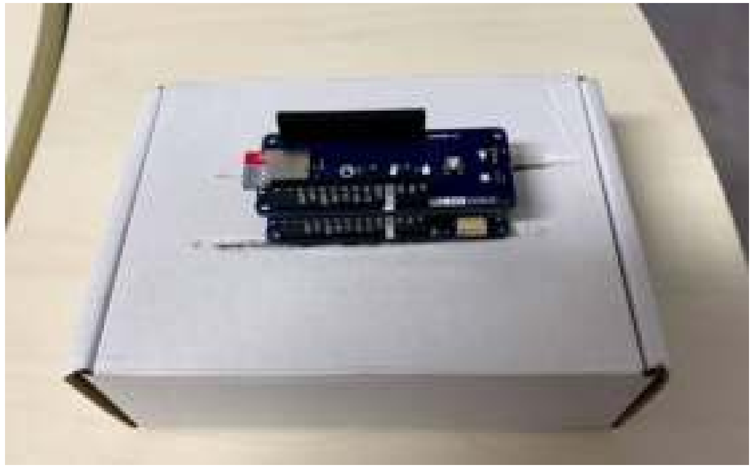
Kinar, N. J.: Introducing Electronic Circuits and Hydrological Models to Postsecondary Physical Geography and Environmental Science Students: Systems Science, Circuit Theory, Construction and Calibration, Geoscience Communication. 2021

Electronic Circuits and Teaching Hydrology



Kinar, N. J.: Introducing Electronic Circuits and Hydrological Models to Postsecondary Physical Geography and Environmental Science Students: Systems Science, Circuit Theory, Construction and Calibration, Geoscience Communication. 2021

Teaching Microcontroller Programming



- Arduino open source platform programmed in C++
- Serves as a datalogger for environmental measurements

3D Printing and Water Quality Measurements

3D Model

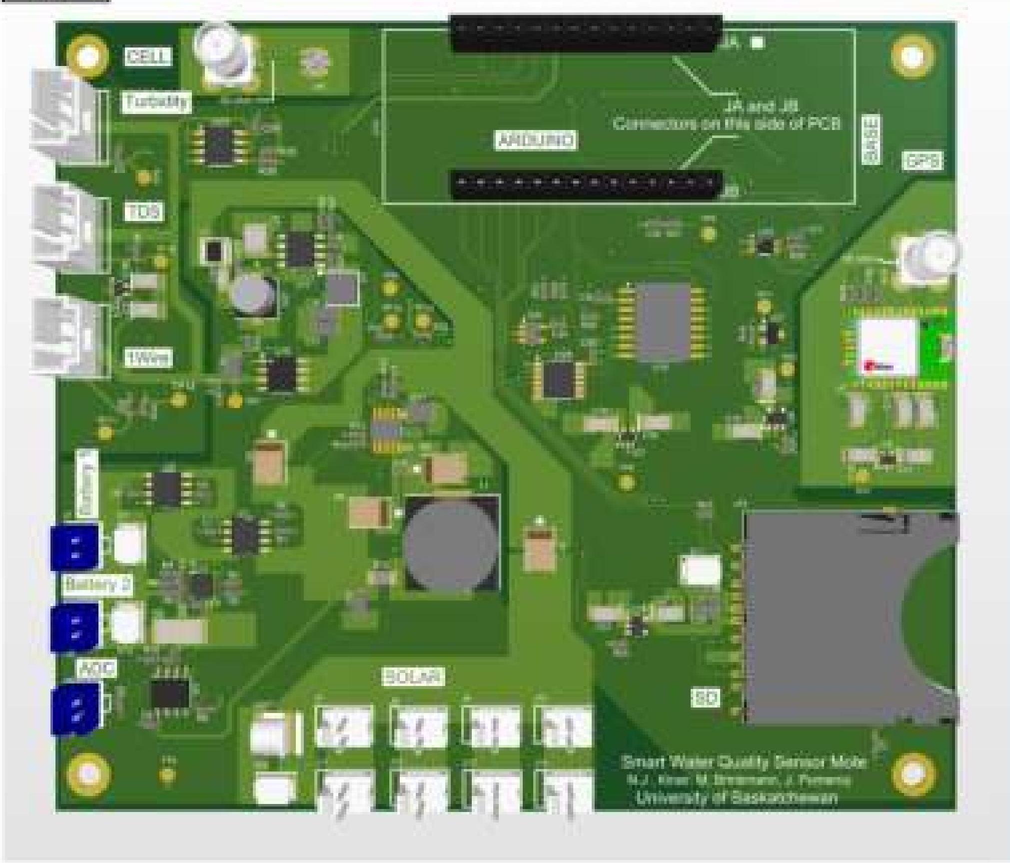
Tank Testing

Does it Float?

Kinar, N.J. and Brinkmann, M. Development of a Sensor and Measurement Platform for Water Quality Observations: Design, Sensor Integration, 3D Printing, and Open-Source Hardware. Environmental Monitoring and Assessment, *submitted*. 2021.

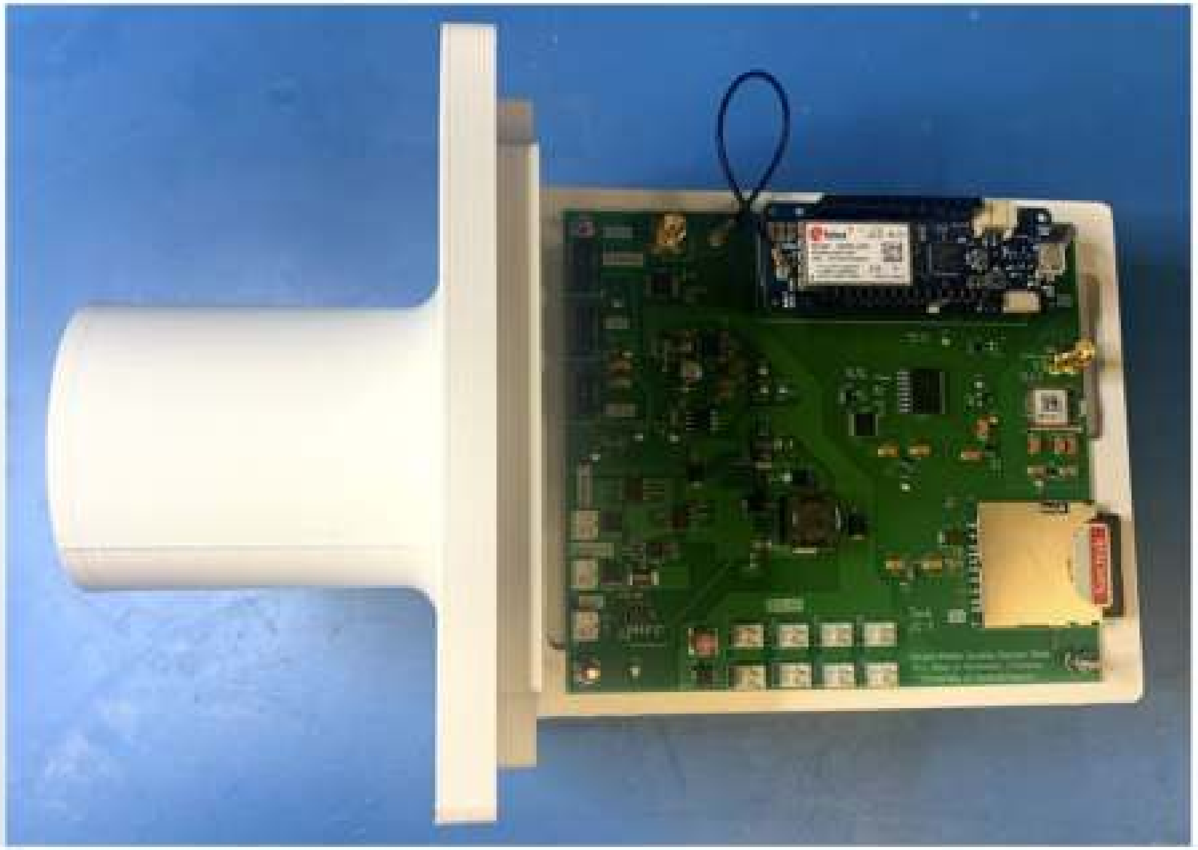
3D Printing and Water Quality Measurements

(a)



3D Model

(b)



Actual Circuit Board

Kinar, N.J. and Brinkmann, M. Development of a Sensor and Measurement Platform for Water Quality Observations: Design, Sensor Integration, 3D Printing, and Open-Source Hardware. Environmental Monitoring and Assessment, *submitted*. 2021.

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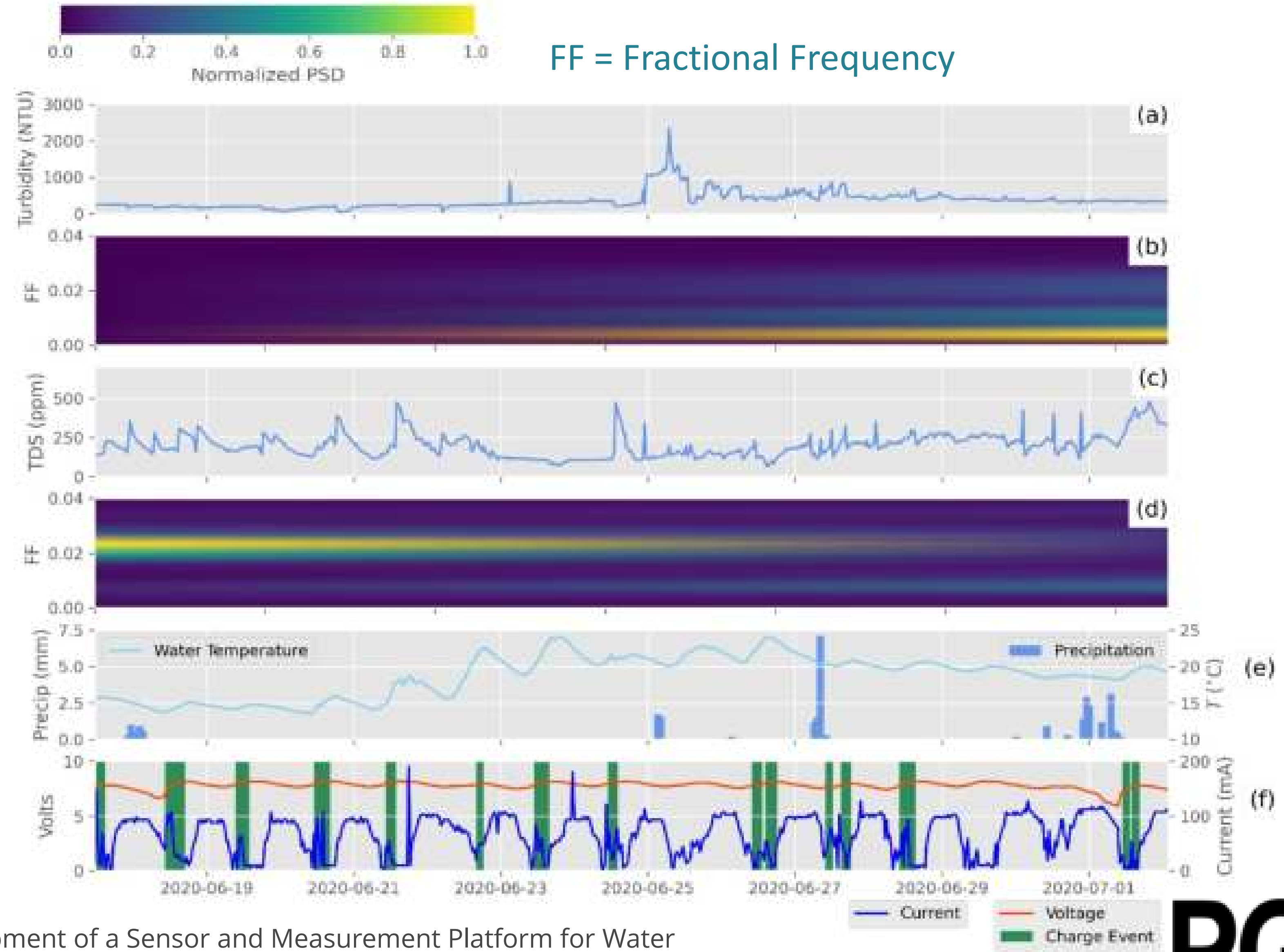
3D Printing and Water Quality Measurements

Aspen Ridge Forebay
City of Saskatoon



FF = Fractional Frequency

Preprint

https://www.researchsquare.com/article/rs-449278/v1

Kinar, N.J. and Brinkmann, M. Development of a Sensor and Measurement Platform for Water Quality Observations: Design, Sensor Integration, 3D Printing, and Open-Source Hardware. Environmental Monitoring and Assessment, *submitted*. 2021.

Backyard / At Home Science – Everyone Can Participate

Thanks

- Dr. John Pomeroy, Director of Global Water Futures and Centre for Hydrology
- Coldwater Centre, Canmore, Alberta
- Dr. Markus Brinkmann, Toxicology Centre and Centre for Hydrology
- Global Institute for Water Security (GIWS)
- Smart Water Systems Lab (SWSL) and associates
- Judy Kinar for delicious Michigan-style pizza made in a special pan

Symposium contact information

Marilen Miguel
mmiguel@pgo.ca

Thank you for joining us!

Visit www.pgo.ca for upcoming events.