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Credit Valley Conservation — inspired by nature

NATURAL CHANNEL DESIGN MONITORING

WELL-ESTABLISHED METHODS VS. INNOVATIVE TOOLS

Kathy Robitaille-Feick M.Sc., P.Geo
Fluvial Geomorphologist
Brandon Smelt
Aquatic Ecologist

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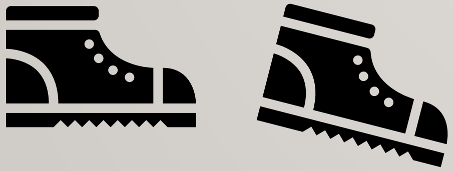
STANDARD METHODS

- Monumented cross sections
- Bathymetric channel profile surveys
- Fixed point photography
- Fish habitat surveys
- Fish community surveys

"Boots on the Ground"



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STANDARD METHODS – PROS AND CONS

- Reliable and Proven
- Reproducible
- Can investigate at the micro-scale
- Can interact with the landscape

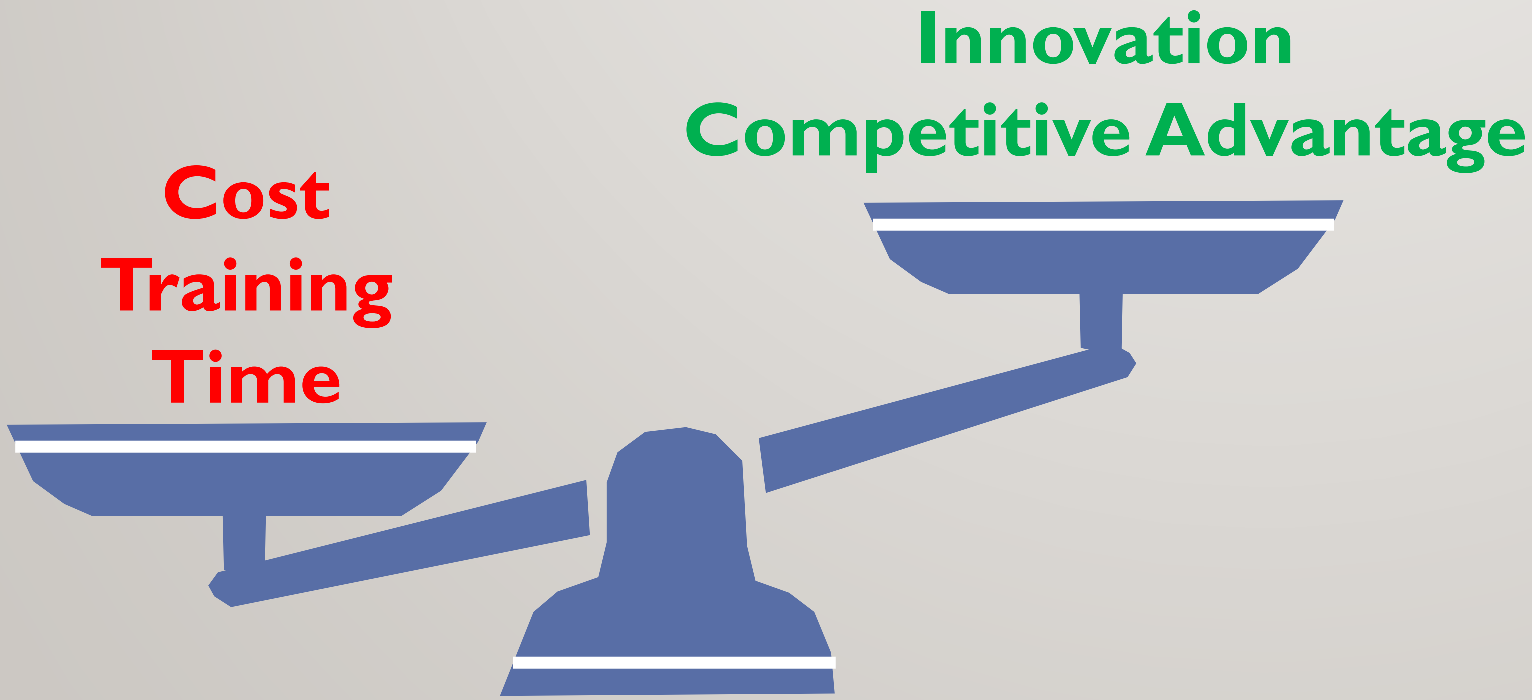
Pros

- Requires field staff ($)
- Data processing time
- Human Error
- Snapshot in time
- Seasonally dependent

Cons

OUTLINE

- High-level overview
- Applicability to post-construction monitoring
- Pros and cons based on
  - Research,
  - Implementation, and
  - Discussions with teams who have implemented these tools/methods

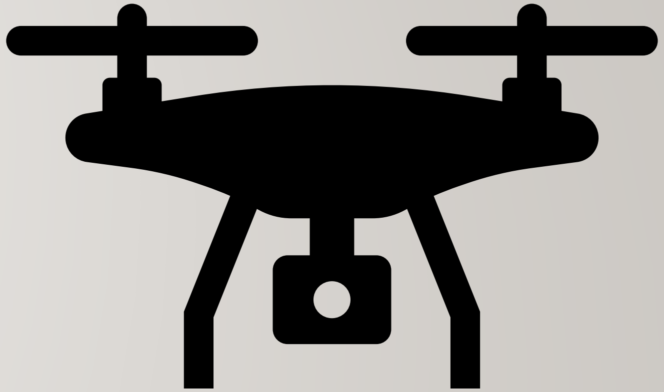


TOOLS/METHODS WE'LL DISCUSS TODAY

- Drones
- Aerial/Satellite Imagery
- LiDAR
- Citizen Science
- AI/Machine Leaning
- Specialized Apps (iPhone LiDAR/ Repic)

DRONES

- Autonomous and remotely controlled aerial vehicles
- Can be flown using a pre-programed routine or by a piolet remotely
- Can use specific sensors to capture more information



Traditional Fieldwork

Drone Imagery

DRONES

Use of UAV Monitoring to Identify Factors Limiting the Sustainability of Stream Restoration Projects (Langhammer et al., 2023)

- Long-term, optical RGB (red, green, blue) UAV (drone) monitoring as a basis for visual assessment
- UAV-based 3D reconstruction (i.e., topographic maps)
- Based on six years of monitoring in three restored streams in Czech Republic

2D RGB Orthoimages
- Channel Geometry - Planform
- Channel Vegetation and organic debris (Presence of aquatic vegetation and woody debris)
- Flow – Impacts of artificial in-channel structures
- Longitudinal continuity as affected by artificial structures
- Vegetation type/ structure on banks and adjacent land
- Adjacent land use (partial)

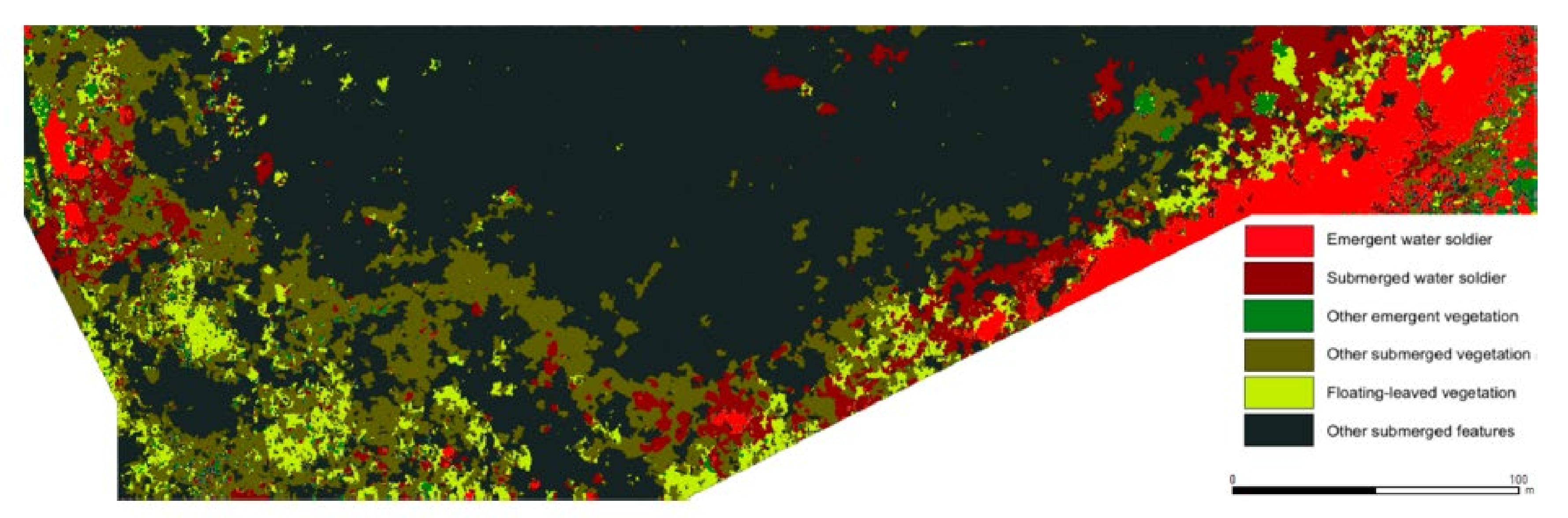
3D Channel Model
- Channel Geometry – longitudinal profile and cross-sections
- Erosion/ Deposition character
- Bank Structure
- Channel-floodplain interactions (degree of lateral connectivity and degree of lateral movement)

Unsuitable
- Channel Substrate – spatial resolution is not satisfactory
- Adjacent land-use – limited spatial coverage of the floodplain due to limited flight times

Key Findings:
- UAV monitoring "has the potential to provide reliable and feature-rich special information, enabling the assessment of the critical geometric and qualitative aspects of stream restoration"

DRONES

An Object-Based Image Analysis Workflow for Monitoring Shallow-Water Aquatic Vegetation in Multispectral Drone Imagery (Chabot et al., 2018)



- The use of drones to monitor both emergent and submerged aquatic vegetation
- Assessed 5 study sites totaling ~60 ha with a max depth of 2 m.
- Object-based image analysis to determine emergent, floating, and submergent vegetation

Accuracy

92% emergent
84% submergent

Usability

No coding required

Applications

Adaptable and transferable

DRONES

- Fast
- Affordable
- High resolution & accuracy
- Time-stamped
- Geo-referenced
- Key feature extraction (signs, infrastructure, erosion, etc.)
- Advanced cameras & LiDAR for elevation data
- Large surface area coverage

Pros

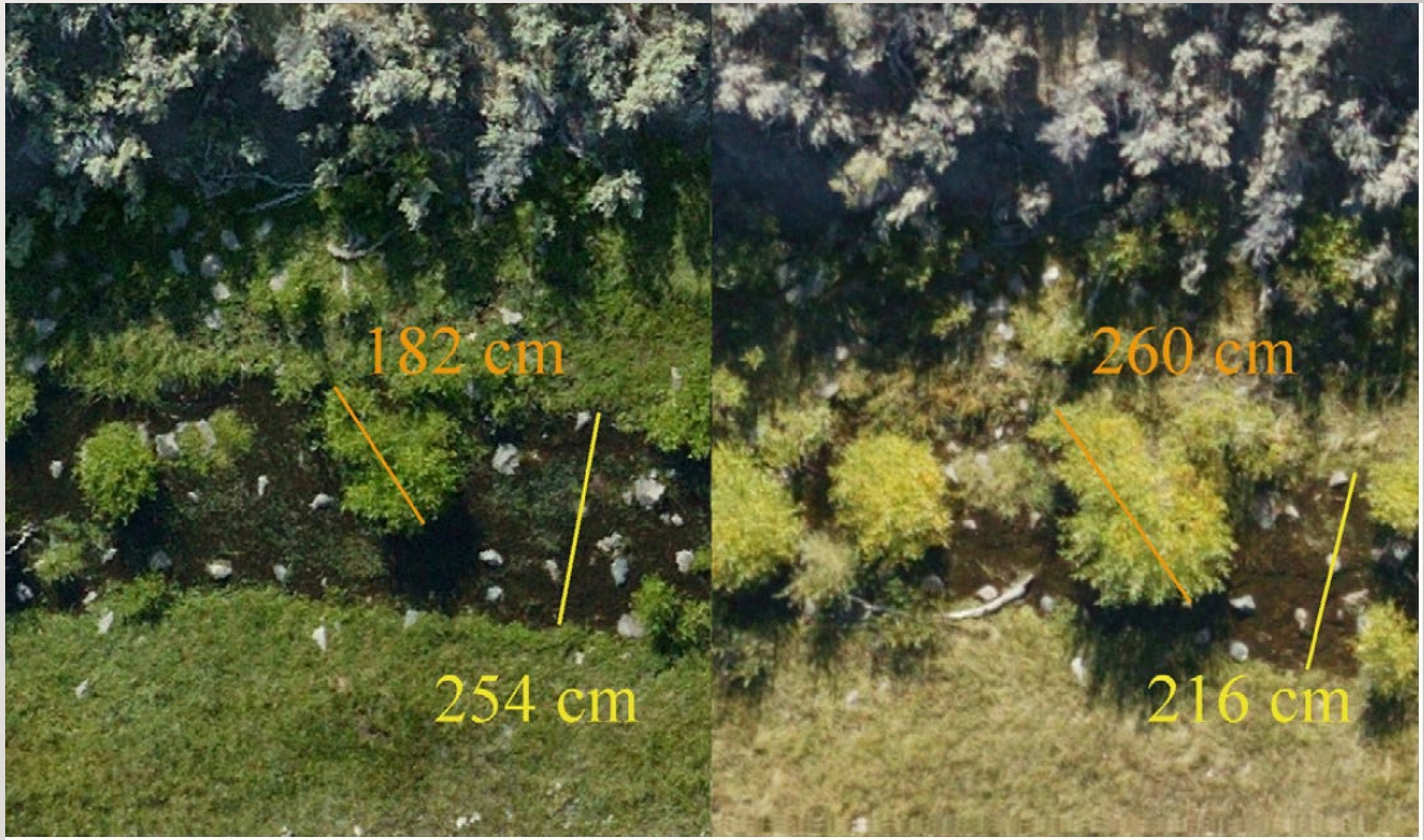
- Specialized training
- Fly-space and privacy issues
- High investment & maintenance costs
- Weather dependent
- Processing time
- Limited flight time (15-30 mins)
- Traditional surveys (total station, GPS) more detailed
- Vegetation interference
- Line of sight required for pilots

Cons

AERIAL/ SATELLITE IMAGERY

Riparian monitoring using 2-cm GSD aerial photography (Booth, Cox, and Simonds, 2007)

- Measured key landscape features from aerial photography to assess riparian functioning
  - Late-summer open water width,
  - Number and location of late-summer dry channels,
  - Widths of riparian areas, and
  - Willow coverage
- Assessment compared to previous field assessments



Key findings:

- 4 staff hours to complete assessment using aerial imagery
- 36 staff hours to complete assessment in field
- Yielded similar results

AERIAL/ SATELLITE IMAGERY

- No field visits needed
- Updated imagery available daily, monthly, annually, etc.
- Free satellite imagery
- Available since the 1920s in many regions
- Time-stamped data
- Long-term monitoring (10 years) with annual assessments and field visits every 2-5 years
- 10 years needed to capture multiple channel-forming events (Downs & Kondolf, 2002)
- Large surface area coverage (ideal for watershed monitoring)
- Information on sediment aggradation and erosion

Pros

- No topographic information
- Costly to requisition
- Resolution-dependent
- Land cover can be a hinderance
- Weather-dependent (e.g., cloud cover)
- Requires manpower
- Time-consuming to interpret

Cons

LIDAR

- Canadian government has recently been adding to its open-access, high-resolution datasets across the country
- Depends on resolution – ideally want it to be 1-2 m or better

Learning from LiDAR: Applications to Natural Channel Design (2024) – Robin McKillop

Key Findings

- LiDAR data is available, commonly public, from a variety of sources ad in a variety of formats
- LiDAR data, where available, should be reviewed, analyzed and/or interpreted in association with any NCD project
- LiDAR data viewers should become default screening tools, just like Google Earth

Photo credit: Professor Joe Mason (Geomorphologist) Digital elevation model of the Ohio River, at the border of SW Indiana/NW Kentucky, SW of Evansville, USA, showing the hills (red), flatter areas (green) and the river floodplain (tints of blue from dark (high) to almost white (low).

LIDAR

Channel Morphological Change Monitoring using High-Resolution LiDAR-Derived DEM and Multi-Temporal Images (Andualem et al., 2024)

- Used high-resolution aerial imagery and LiDAR-derived DEM for monitoring channel morphology
- Digitized and analyzed in ArcGIS Pro
- Can identify areas of channel erosion and deposition
- Can take cross-sections

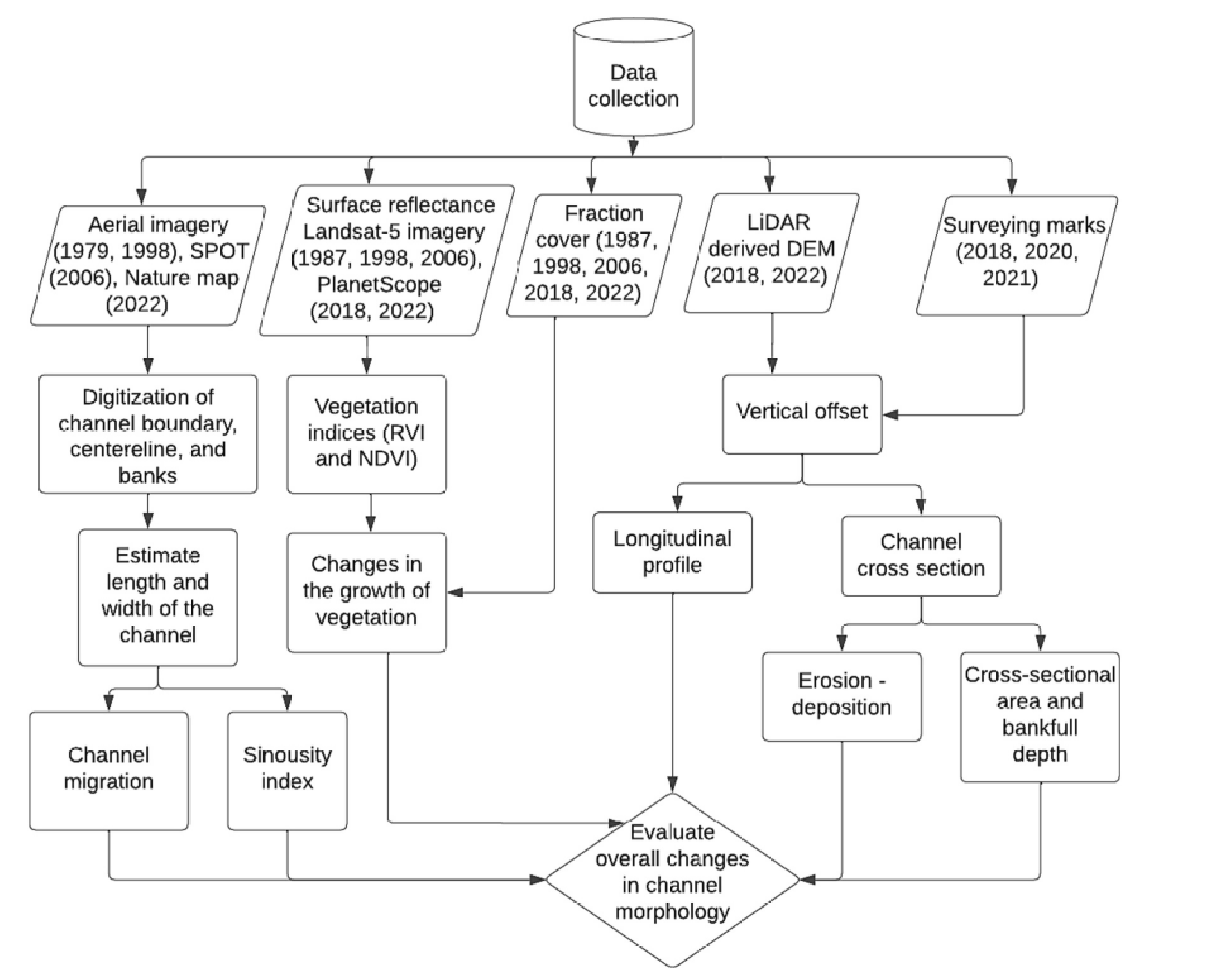
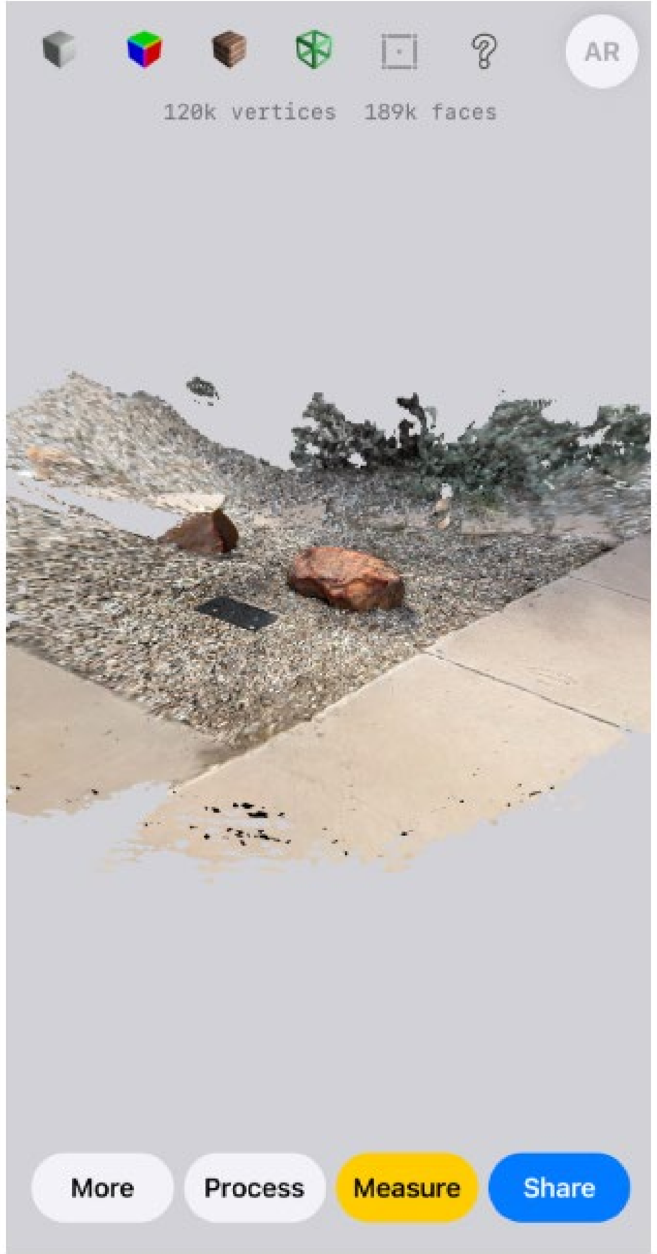


Fig. 2. Channel morphology investigation framework proposed and utilized in this study.

SPECIALIZED APPS - LIDAR

Camera system and lidar scanner on iPhone 13 Pro.


Textured mesh overlay while generating scan.



Completed scan of object and surrounding area.

- Good for scanning large objects and distances

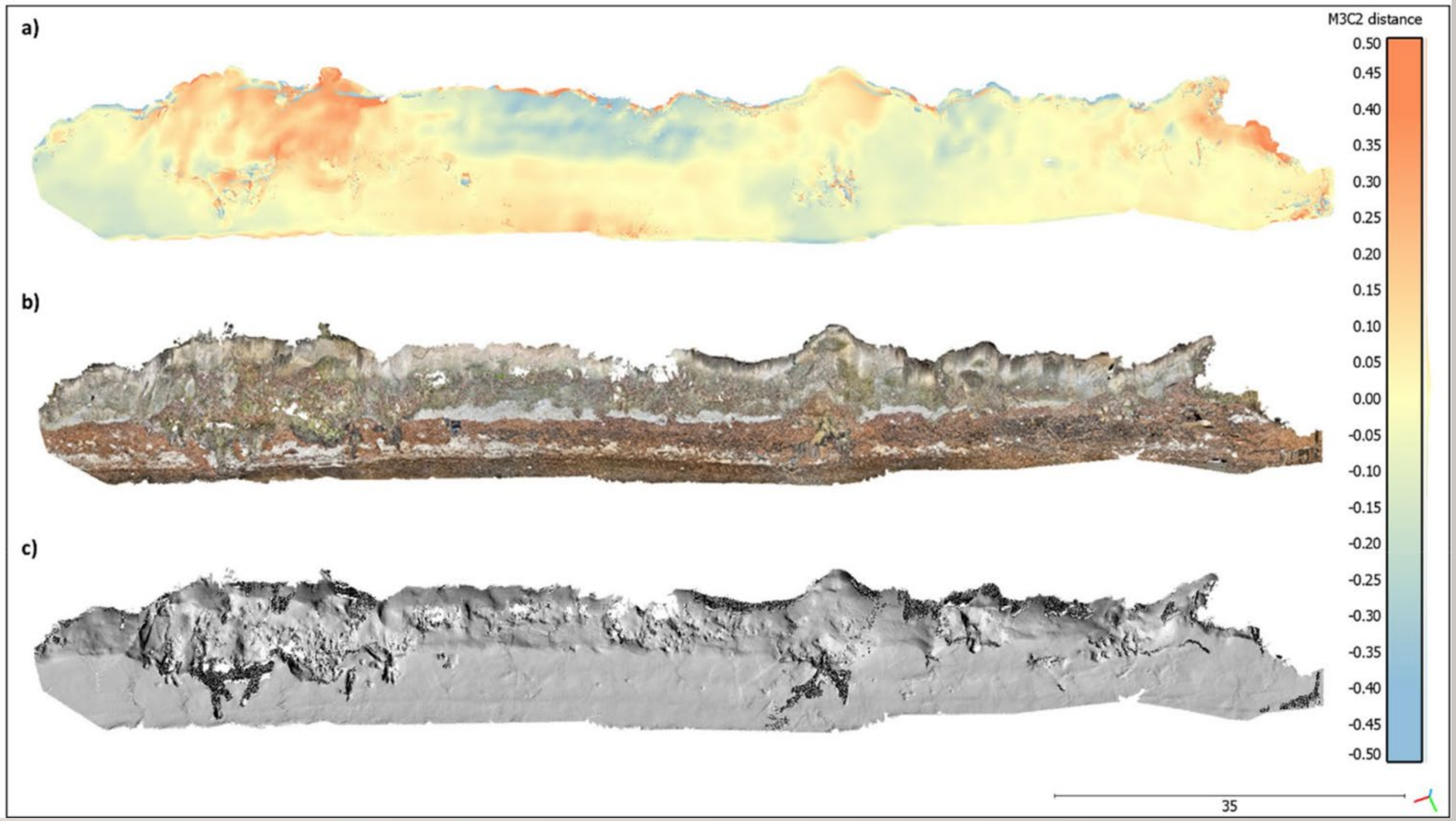
SPECIALIZED APPS - LIDAR

Evaluation of the Apple iPhone 12 Pro LiDAR for an Application in Geosciences (Luetzenburg, et al., 2021)

- Used iPhone liDAR to scan the entire coastal cliff and beach at Roneklint (length: 130 m, width: 15 m, height: 10 m)

Key Findings:

- "Photo position and orientation cannot be used for satisfactory model registration, making elaborate model post processing necessary, enabling only experts to use the advantages of smartphone photogrammetry"



M3C2 distances in meter between SfM MVS reference point cloud and iPhone point cloud, fne registration error RMS: 0.052 m computed on 5 million points with a theoretical overlap: 75%, point clouds subsampled to 0.05 m minimal nominal spacing between points with normal directions and projection diameter calculated at 1.33 m for each point (a), textured iPhone LiDAR model of the clif (b) iPhone LiDAR hillshade model of the clif (c). Scale bar in bottom right indicates 35 m.

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LIDAR

- No field visits needed
- Updates available
- Free satellite imagery
- Open-source LiDAR data in many regions
- Time-stamped data
- Long-term monitoring (10 years) with annual assessments and field visits every 2-5 years
- 10 years needed to capture multiple channel-forming events (Downs & Kondolf, 2002)
- Large surface area coverage (ideal for watershed monitoring)
- Information on sediment aggradation and erosion
- Topographic data provided

Pros

- Costly to requisition
- Resolution-dependent
- Requires manpower
- Time-consuming to interpret
- Limited water penetration
- Weather-sensitive

Cons

CITIZEN SCIENCE

The Fish Doorbell

Operates each spring as fish travel upstream to reproduce

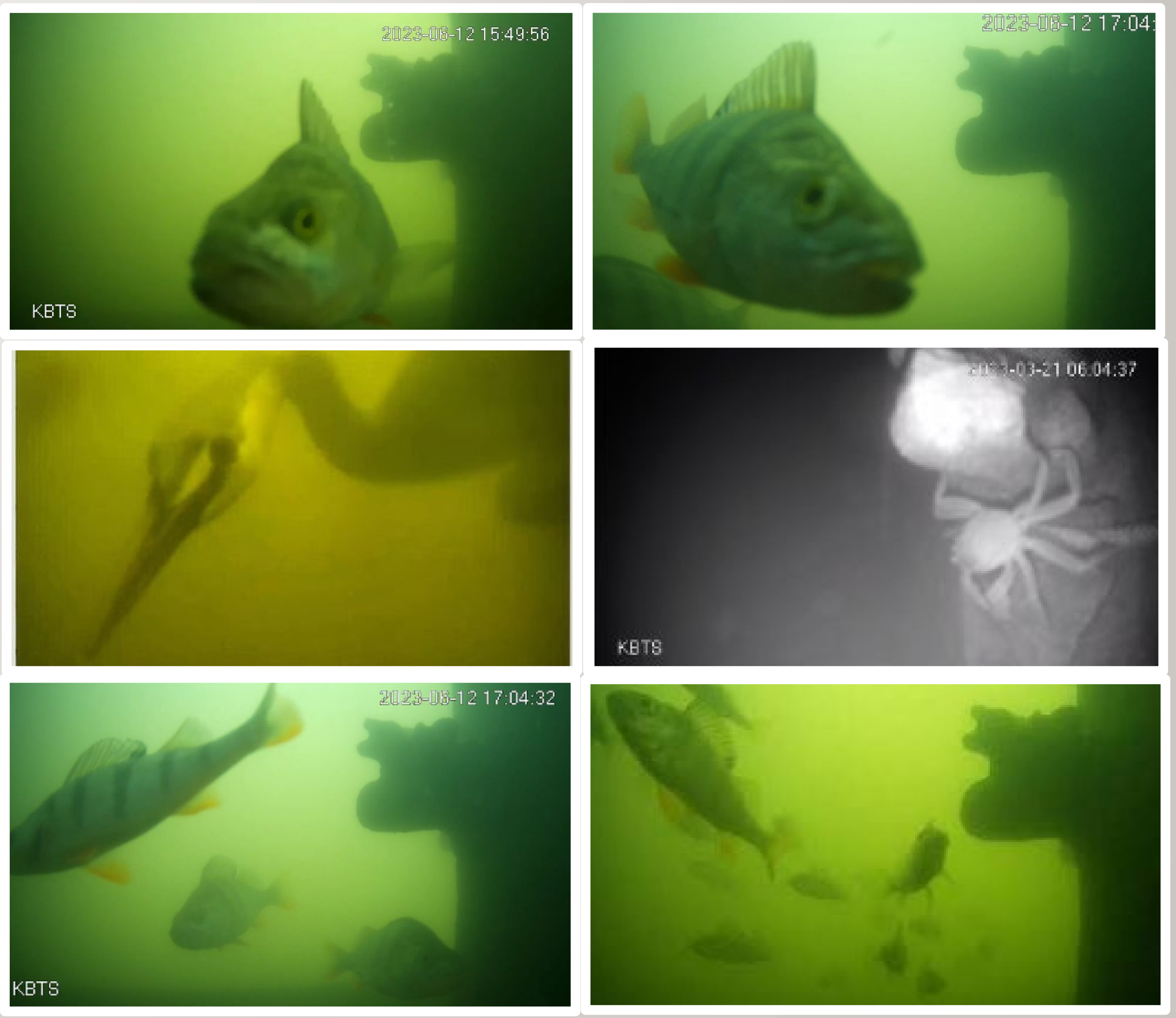
Livestream underwater camera

Digital doorbell for online viewers

Allows fish passage and educates public

2.7M Unique online visitors in 2024

Opened March 3, 2025



CITIZEN SCIENCE

Pros

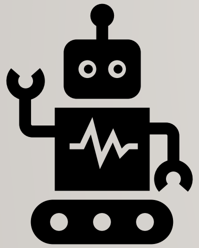
- Can be an inexpensive way to build a large database
- Can have data collected over a long period of time
- Time Stamped
- Users could submit real-time photographic images or recorded videos

Cons

- Requires public awareness and buy-in
- Limited ability to QA/QC
- Human error or lack of training
- In some cases, could be done through AI detection (more reliable and consistent dataset)

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

Artificial Intelligence (AI)



Systems designed and programmed to perform tasks that require human intelligence

Machine Learning (ML)

A component of AI which involves training algorithms with large datasets

Improves over time without additional programming

AI Data Analysis

- Algorithms processing large datasets quickly and accurately, uncovering patterns and insights that might be missed by manual analysis

AI Computer Vision

- Processing and analyzing digital images and videos to extract meaningful information

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

Automating the Analysis of Fish Abundance Using Object Detection: Optimizing Animal Ecology With Deep Learning (Detria et al., 2020)

- Used ML to automate fish counting
- Developed models using an object detection framework to identify and count luderick (*Girella tricuspidata*)
- Models were trained on a dataset of 6,080 annotations

Key Findings

- Accuracy
  - ~92% accuracy in testing
  - Improved score over marine experts by 7.1% and citizen scientists by 13.4%
- Efficiency
  - Faster and cheaper compared to manual methods
- Consistency and Transferability
  - Consistent and transferable across different survey locations
  - Difficult in shallow and turbid environments

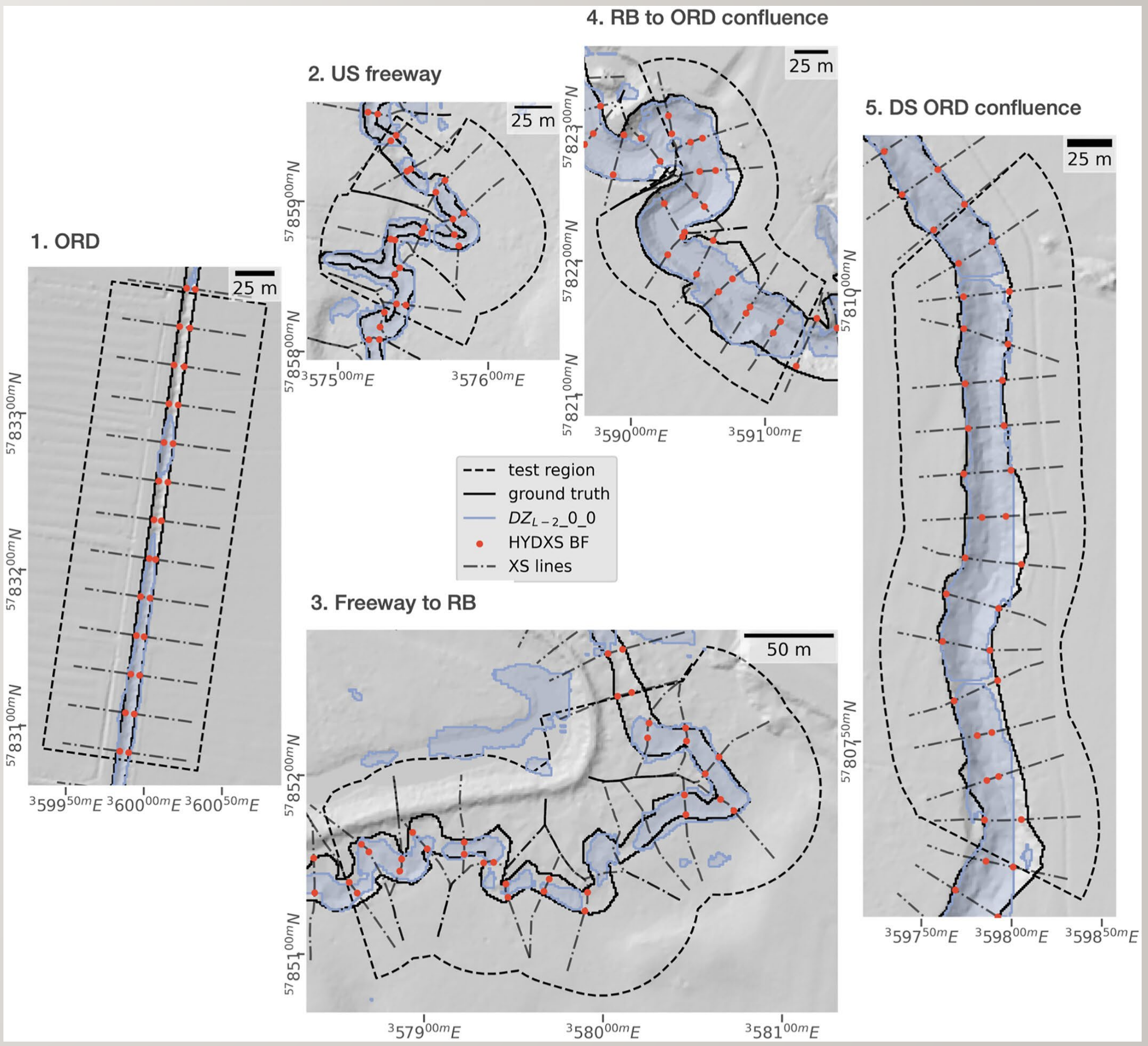
ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

Artificial Intelligence and Object-Function Methods can Identify Bankfull River Channel Extents (Gerber et al., 2024)

- Used 2 automated methods to identify bankfull
  - A cross-sectional method - HydXS
    - Identifies the elevation which maximizes hydraulic depth
  - A neural network image segmentation model
    - Based on a pretrained model, retrained with images from a DEM

Key Findings

- Overall, the cross-Sectional method outperformed the neutral network method
  - Performed well on channels 7.5 – 26 m wide
- The neural network image segmentation method performed better in larger channels
- Overall precision accuracy of 0.87



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AI AND MACHINE LEARNING

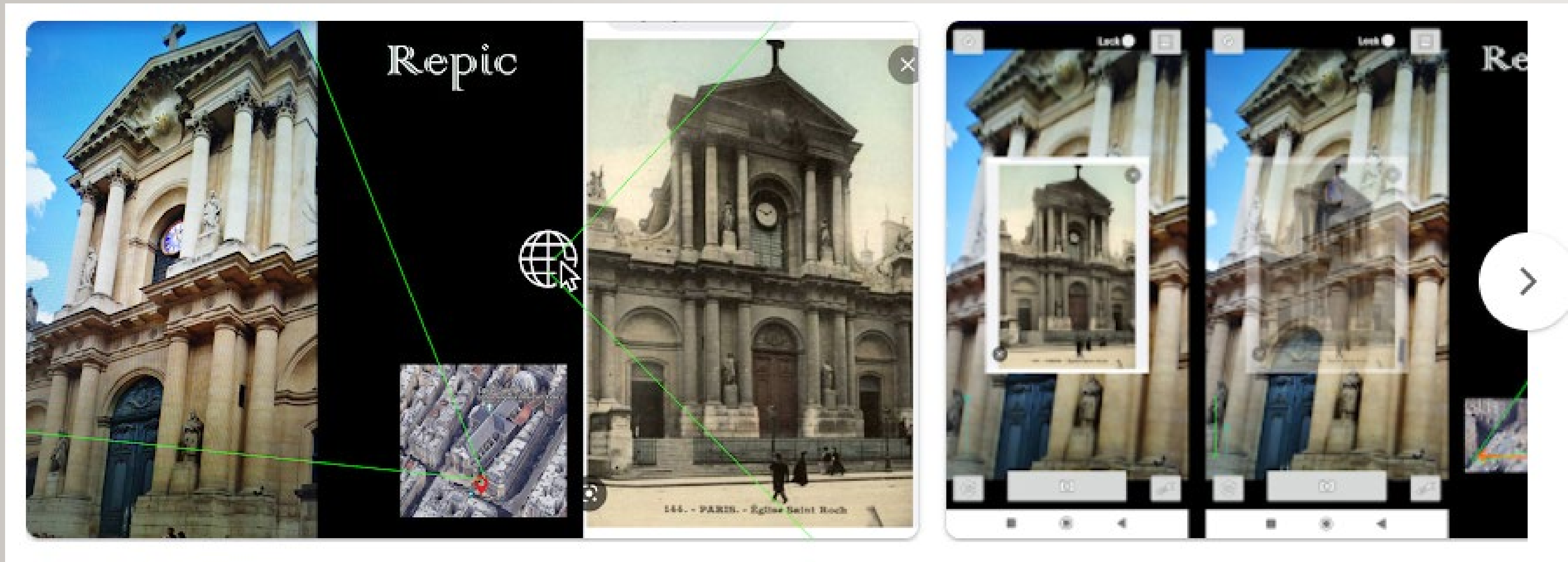
Pros

- Eliminates human error (after initial setup)
- Reduces processing time
- Easily add new data
- Open-source tools reduce development time
- Reproducible workflow
- Applicable methods for other opportunities
- Speeds up data collection and reporting

Cons

- Requires extensive data curation, QA/QC, and processing
- Limited data availability
- Risk of oversimplification
- Time and cost to train AI
- Full QA/QC of results needed for trust

SPECIALIZED APPS – REPIC (GOOGLE APP STORE)



Allows you to take the same picture using a 50% transparent overlay

KEY TAKEAWAYS

- Various methods are being developed that have application to natural channel design post-construction monitoring
- There are pros and cons to every method
- Lots of progress happening right now in academia!

- Drones
- Aerial/Satellite Imagery
- LiDAR
- Citizen Science
- AI/Machine Leaning
- Specialized Apps (iPhone LiDAR/ Repic)

WANT TO KNOW MORE?

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MORE INFORMATION?

Drones

- Use of UAV Monitoring to Identify Factors Limiting the Sustainability of Stream Restoration Projects (Langhammer, 2023) - https://www.mdpi.com/2306-5338/10/2/48
- Federal Hydrologic and Hydraulic Procedures for Flood Hazard Delineation (Natural Resources Canada, 2019) - https://publications.gc.ca/collections/collection_2020/rncan-nrcan/m45/M45-113-2019-eng.pdf
- Channel morphological change monitoring using high-resolution LiDAR-derived DEM and multi-temporal imageries (Andualem et al., 2024) - https://www.sciencedirect.com/science/article/pii/S0048969724012439
- An Object-Based Image Analysis Workflow for Monitoring Shallow-Water Aquatic Vegetation in Multispectral Drone Imagery (Chabot et al., 2018) - https://www.mdpi.com/2220-9964/7/8/294

Aerial/Satellite Imagery

- Riparian monitoring using 2-cm GSD aerial photography (Booth et al., 2007) - https://www.sciencedirect.com/science/article/abs/pii/S1470160X06000719

LiDAR

- Learning from LiDAR: Applications to Natural Channel Design (McKillop, 2024) - https://sourcetostream.com/app/uploads/2024/05/s2s-2024-day2-track2-presentation10-mckillop.pdf
- Channel Morphological change monitoring using high-resolution LiDAR-derived DEM and multi-temporal imageries (Andualem et al., 2024) - https://www.sciencedirect.com/science/article/pii/S0048969724012439
- iPhone lidar with applications for the geosciences | OpenTopography - https://opentopography.org/blog/iphone-lidar-applications-geosciences
- Evaluation of the Apple iPhone 12 Pro LiDAR for an Application in Geosciences (Luetzenburg et al., 2021) - https://www.nature.com/articles/s41598-021-01763-9

Citizen Science

- The Fish Doorbell - https://visdeurbel.nl/en/the-fish-doorbell/
- Agroclimate Impact Reporter - agriculture.canada.ca - https://agriculture.canada.ca/en/agricultural-production/weather/agroclimate-impact-reporter

AI/Machine Learning

- Using Machine Learning in Minnesota's StreamStats to Predict Fluvial Sediment (USGS, 2025) - https://pubs.usgs.gov/fs/2025/3005/fs20253005.pdf
- Automatic Features Detection in a Fluvial Environment through Machine Learning Techniques Based on UAVs Multispectral Data (Pontoglio et al., 2021) - https://www.mdpi.com/2072-4292/13/19/3983
- Geospatial Artificial Intelligence (GeoAI) in the Integrated Hydrological and Fluvial Systems Modeling: Review of Current Applications and Trends (Gonzales-Inca et al., 2022) - https://www.mdpi.com/2073-4441/14/14/2211
- Machine learning insights of anthropogenic and natural influences on riverbed deformation in a large lowland river (Amanambu an Mossa, 2024) - https://www.sciencedirect.com/science/article/abs/pii/S0169555X23004063
- Artificial Intelligence and Objective-Function Methods Can Identify Bankfull River Channel Extents – (Gerber et al., 2024) - https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2023WR035269
- Artificial intelligence for geoscience: Progress, challenges, and perspectives (Zhao et al., 2024) - https://www.sciencedirect.com/science/article/pii/S2666675824001292
- Automating the analysis of fish abundance using object detection: optimizing animal ecology with deep learning (Detria et al., 2020) - https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2020.00429/full

REPIC

- Repic – Camera Overlay – Apps on Google Play - https://play.google.com/store/apps/details?id=com.arneast.repic&hl=en_CA

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