Innovative Applications of UAV in Wetland Monitoring

An overview of the Blue-UAS and Sensors

Lower Columbia Estuary Partnership

Science Work Group
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OUTLINE

- Broad UAV Applications in Monitoring
- Federal Restrictions on UAV
- Overview of the Blue-UAS Drone and Sensors
- LiDAR data and applications
- Multispectral imagery and applications
- Thermal imagery and applications
- Next steps and topics for discussion

UAV Applications in Monitoring

- Uncrewed Aerial Vehicle (UAV; aka, drone) and remote sensing data have become vital to CEERP,
  - Project design, construction, monitoring, and research of critical uncertainties.
- UAVs allow for higher cost efficiencies, making large-scale monitoring and restoration projects viable.
  - Traditional transect surveys <1% of a site
  - UAVs can survey 100% of a site
- Technological advances in UAVs allow for more data and higher accuracies

Federal Restrictions on UAV use

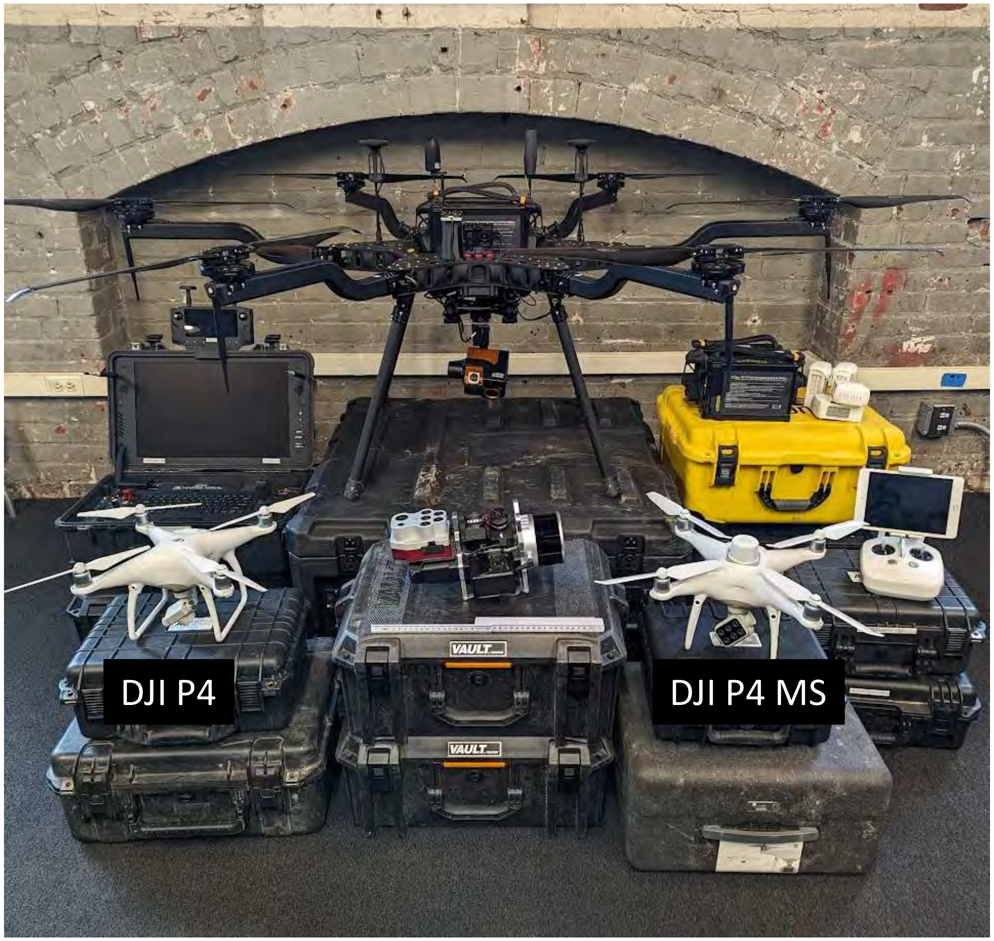
- Rules and regulations implemented by federal agencies and wildlife refuges limit the use of non-USA-made UAVs (US Congress, S.1790; 2020).
- Research and flight permits require the Blue-UAS designated drone to operate over federally owned land (DOI, DOA, DOD, USACE, BLM, NPS, USFS, etc.).
- Upgrading UAVs and sensor technology provides an opportunity to improve the quality and quantity of UAV data

Federal Restrictions on UAV use

Project Name	Federal Land	Landowner
Campbell Slough	Ridgefield National Wildlife Refuge	US Department of the Interior
Colewort Creek	Lewis and Clark National Historical Park	US Department of the Interior
Franz Lake	Franz Lake National Wildlife Refuge	US Department of the Interior
Horsetail Falls	Columbia River Gorge National Scenic Area	US Department of Agriculture
Karlson Island	Julia Butler Hansen National Wildlife Refuge	US Department of the Interior
Otter Point	Lewis and Clark National Historical Park	US Department of the Interior
Sandy River Delta	Columbia River Gorge National Scenic Area	US Department of Agriculture
South Bachelor Island	Ridgefield National Wildlife Refuge	US Department of the Interior
Steamboat Slough	Julia Butler Hansen National Wildlife Refuge	US Department of the Interior
Steigerwald	Steigerwald National Wildlife Refuge	US Department of the Interior
Svenson Island Reference	Lewis and Clark National Wildlife Refuge	US Department of the Interior
Welch Island	Julia Butler Hansen National Wildlife Refuge	US Department of the Interior
West Sand Island	Army Corps of Engineers Dredge Spoils	US Department of Defense
Westport Slough	Julia Butler Hansen National Wildlife Refuge	US Department of the Interior
Woodland Island	Army Corps of Engineers Dredge Spoils	US Department of Defense

DJI Phantom 4/DJI P4 MS

- Restricted by DOI and USACE
- Plug and Play – not customizable
- 28-minute flight time in ideal conditions[1]
- Less than 1 mile range with ideal visual conditions[2]
- 1.3kg takeoff weight; 1.6kg max weight; 7kg transportation weight
- 1ft diagonal wingspan length
- Maximum operating temperature of 104°F
- Equipped with 12MP RGB sensor and a sentera NIR sensor
- DJI P4 MS: 2MP RGB sensor and 2MP 5 band sensor - Blue, Green, Red, Red Edge, and Near Infrared bands
- Single GPS/GLONASS



1. Clear weather, minimal wind, <80°F, and new, non-degraded batteries
2. Clear weather, direct line of site, full signal strength, and a visual observer

Harris Aerial H6 HE+ Electric Hexacopter

- Department of Defense approved
- Fully customizable
- 45-minute flight time in ideal conditions[1]
- 5-mile range with ideal visual conditions[2]
- 15kg takeoff weight; 25 kg max weight; 180kg transportation weight
- 8ft diagonal wingspan length
- Maximum operating temperature of 120°F
- Equipped with:
  - Geocue's Trueview 515b LiDAR sensor
  - MicaSense Altum-PT Multispectral Sensor
  - Workswell WIRIS Enterprise Thermal Sensor

1. Clear weather, minimal wind, <80°F, and new, non-degraded batteries
2. Clear weather, direct line of site, full signal strength, and a visual observer

DOD Approved Sensors

- Geocue's Trueview 515b LiDAR sensor
  - Contains two 20 MP RGB cameras + 1 laser scanner (Hensai Pandar XT32M1X)
  - 32 beams, 2 returns per laser pulse at 640 kHz
  - GNSS enabled -- 5mm precision, 20mm accuracy, 50mm position accuracy = 3cm vertical, 2.5cm horizontal
- MicaSense Altum-PT Multispectral Sensor
  - 5 band multispectral; Red, Green, Blue, Red Edge, Near-IR
  - Thermal (FLIR Longwave-IR)
  - Ultra-high resolution panchromatic imager
- Workswell WIRIS Enterprise Thermal Sensor
  - 16 MPX visual camera; 1.3 MPX thermal
  - 30x optical zoom
  - Accuracy of <2 °C.

Click here to view the full list of drone specs

Acquisition

Pre-flight planning

- Obtain necessary flight permits and notify appropriate parties
  - FAA, landowners, notify nearby airports, NOTAM, LAANC, etc.
- Create Mission Polygon
- Decide on ground control point locations
- Pre-pre-flight checklist

Flight

Preflight check

- Fly the entire site for LiDAR and Multispectral
  - Transfer and backup data
    - Steigerwald (1100 acres) = 3.6TB data
    - Wallooskee (250 acres) = 800GB Data
    - Cunningham Lake (100 acres) = 400GB Data
    - S2023 data ~12 TB raw; ~8TB processed
- Fly targeted locations for thermal
- Software – Mission Planner

Process

LiDAR

- Processed in *LP360*, rasterized in *ArcPro*
- Point cloud
- Create:
  - DEM, Canopy Model
    - Tree counts, BDAs, channel cross sections, elevations

Multispectral

- Processed in *Pix4D*, composited in *ArcPro*
- Orthos, Indices and reflectance maps
- Create:
  - Thermal map, veg indices
    - Model vegetation, map vegetation health, pretty pictures

Thermal

- Processed in *Thermolab*
- Thermal investigations
- Create:
  - Thermograms, thermal videos, images, thermal map

Reports

Digital Elevation Model

Vegetation Map

Thermal Map

Planting Survival Map and statistics

BDA Analysis

Carbon stock map

Quantification of above ground biomass

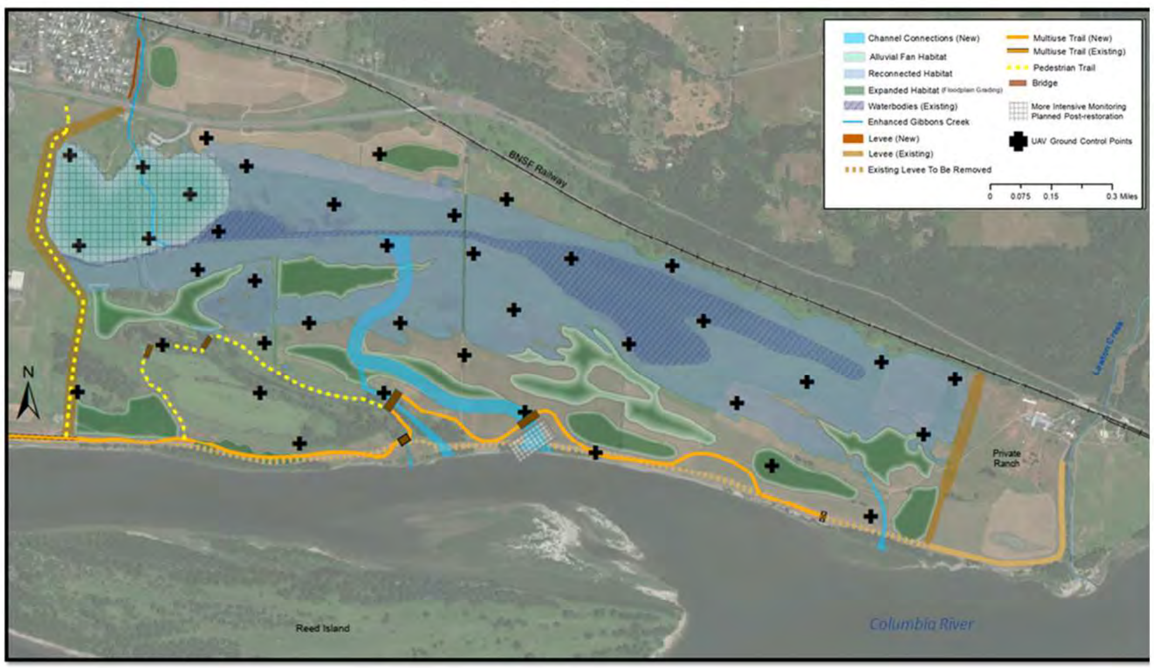
Channel Cross sections

Acquisition

Ground Control Points

Ground Control Points

- 5 per site or 1 every ~30 acres; whichever is greater
  - DJI drones -- 1 every ~10 acres
- Safety #1 concern



Drone Flights – how do they work

Launching and positioning for flight lines

Drone Flights – how do they work

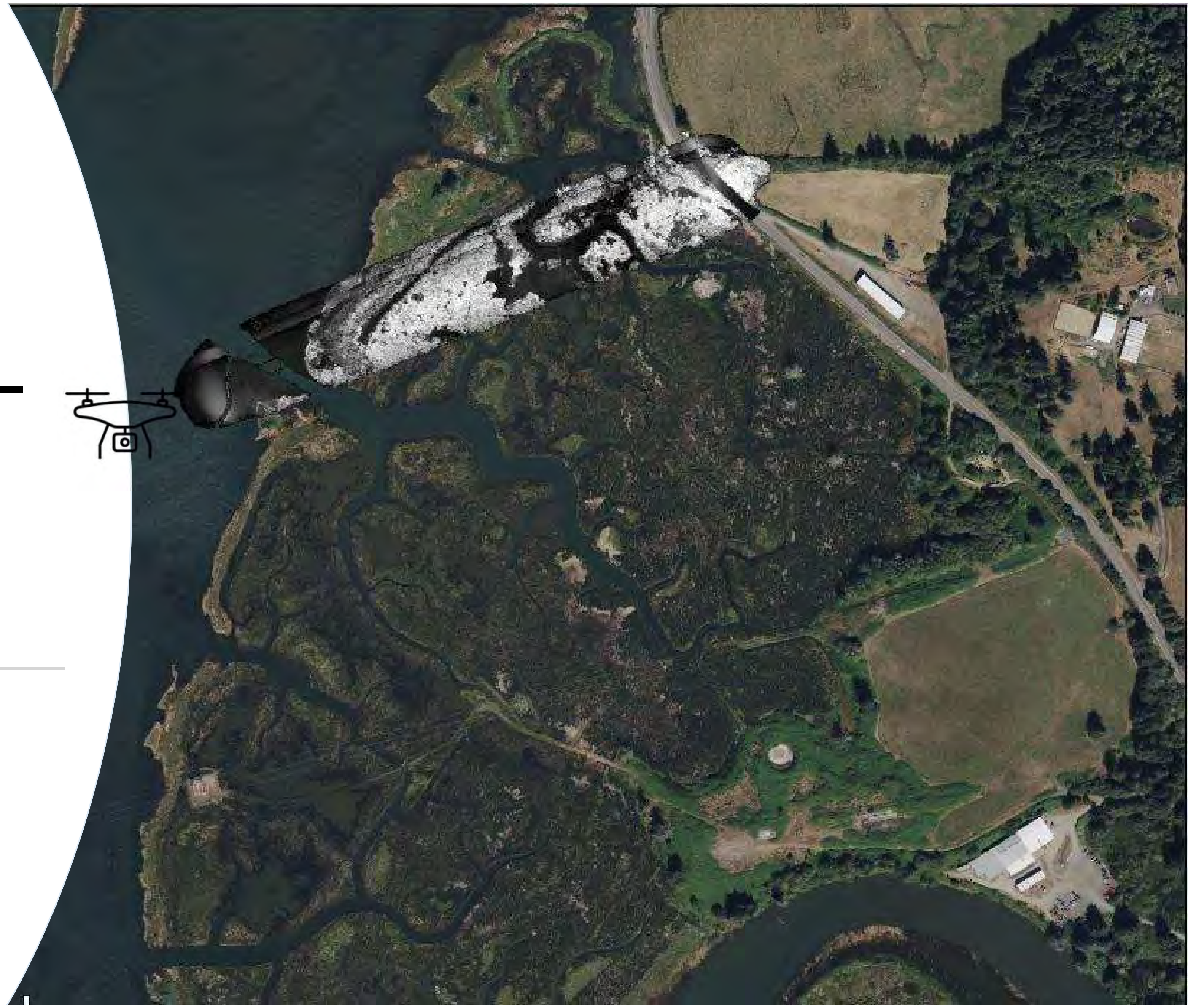
Pass 1

Drone Flights – how do they work

Pass 2

Drone Flights – how do they work

Pass 3



Drone Flights – how do they work

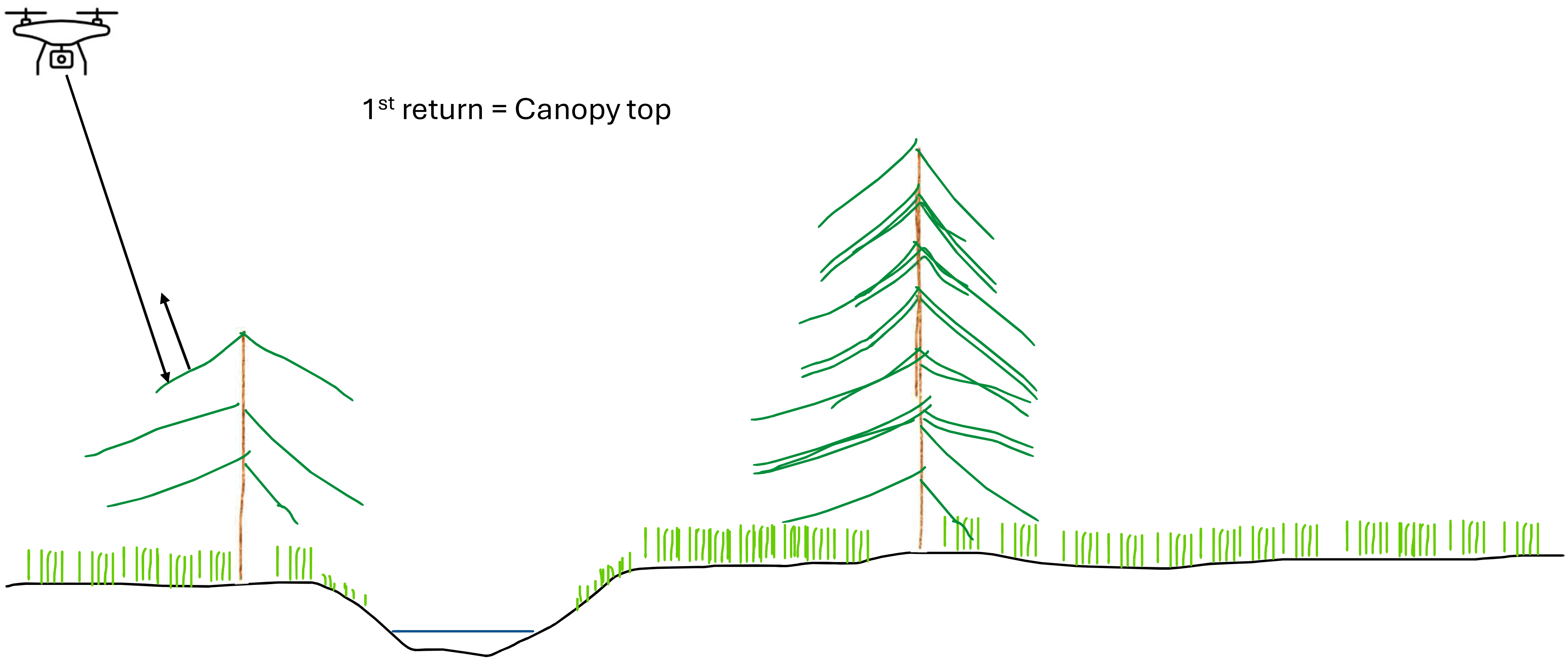
Pass 112

LiDAR

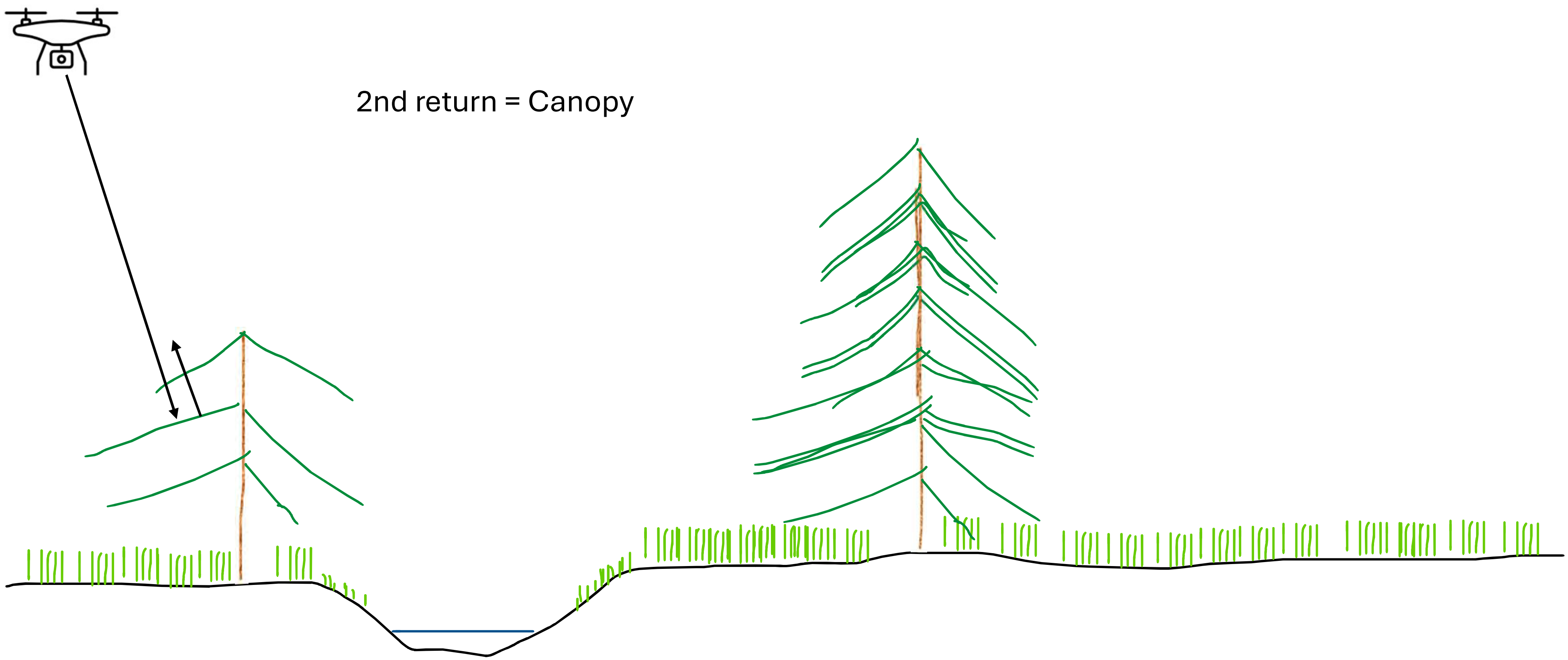
LiDAR – how does it work

- Geocue's Trueview 515b LiDAR sensor
  - Contains two 20 MP RGB cameras + 1infrared laser scanner (Hensai Pandar XT32M1X)
  - 32 beams, 2 returns per laser pulse at 640 kHz
  - GNSS enabled -- 5mm precision, 20mm accuracy, 50mm position accuracy = ~3cm vertical, 2.5cm horizontal
  - 80m max range at 20% reflectivity

LiDAR – how does it work

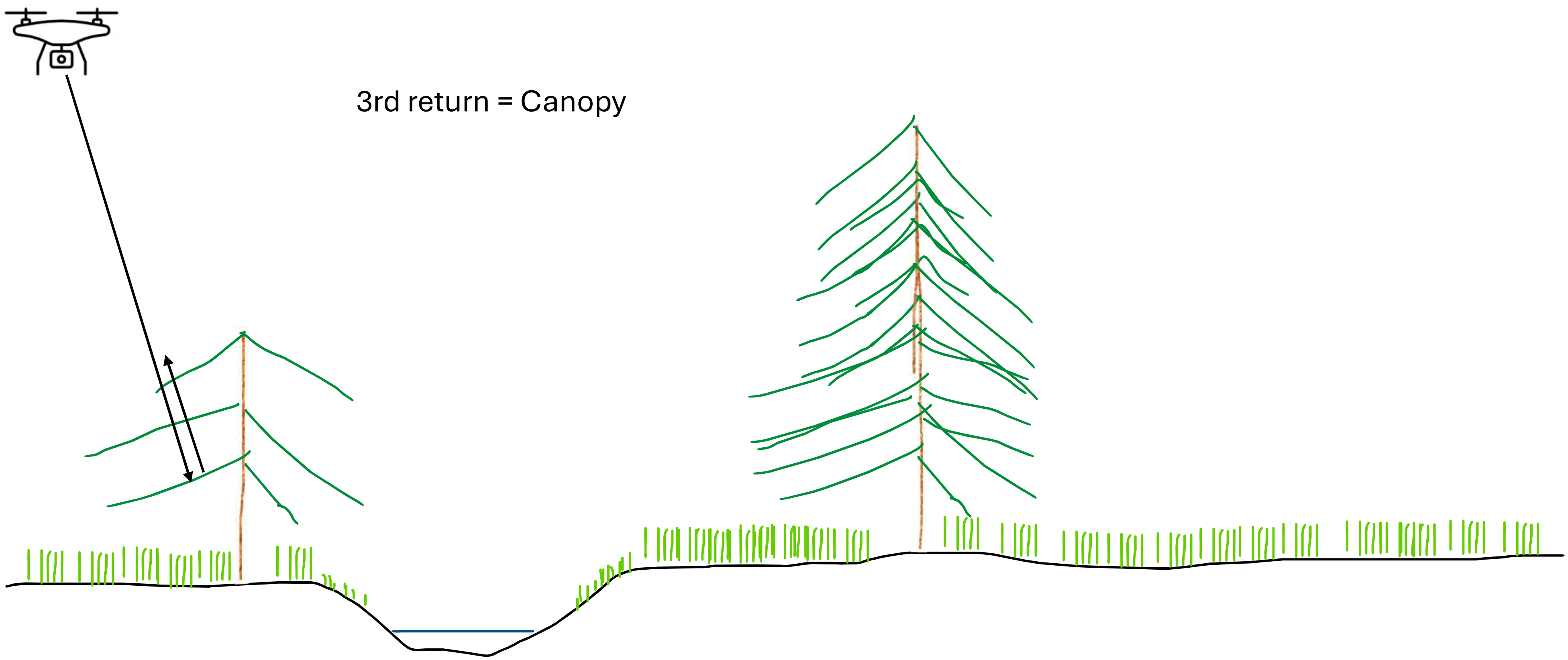


LiDAR – how does it work

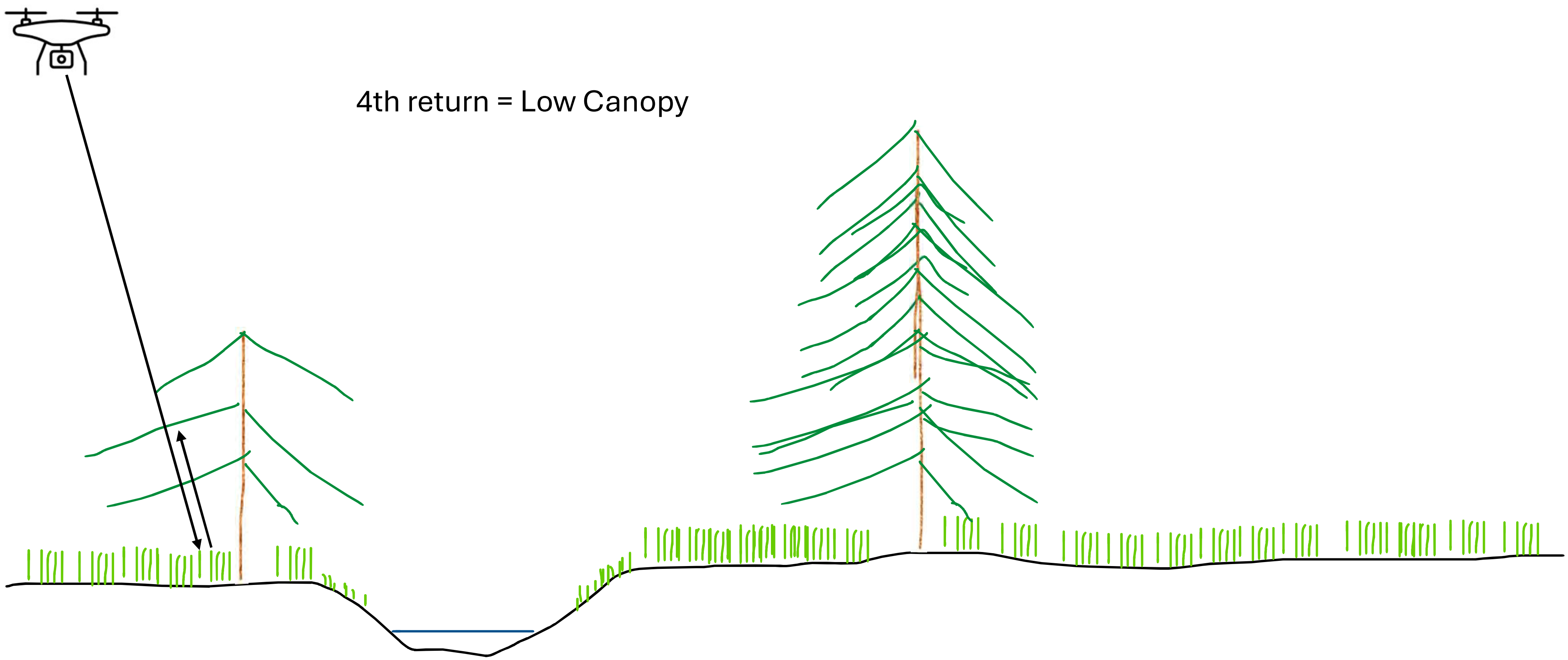


LiDAR – how does it work

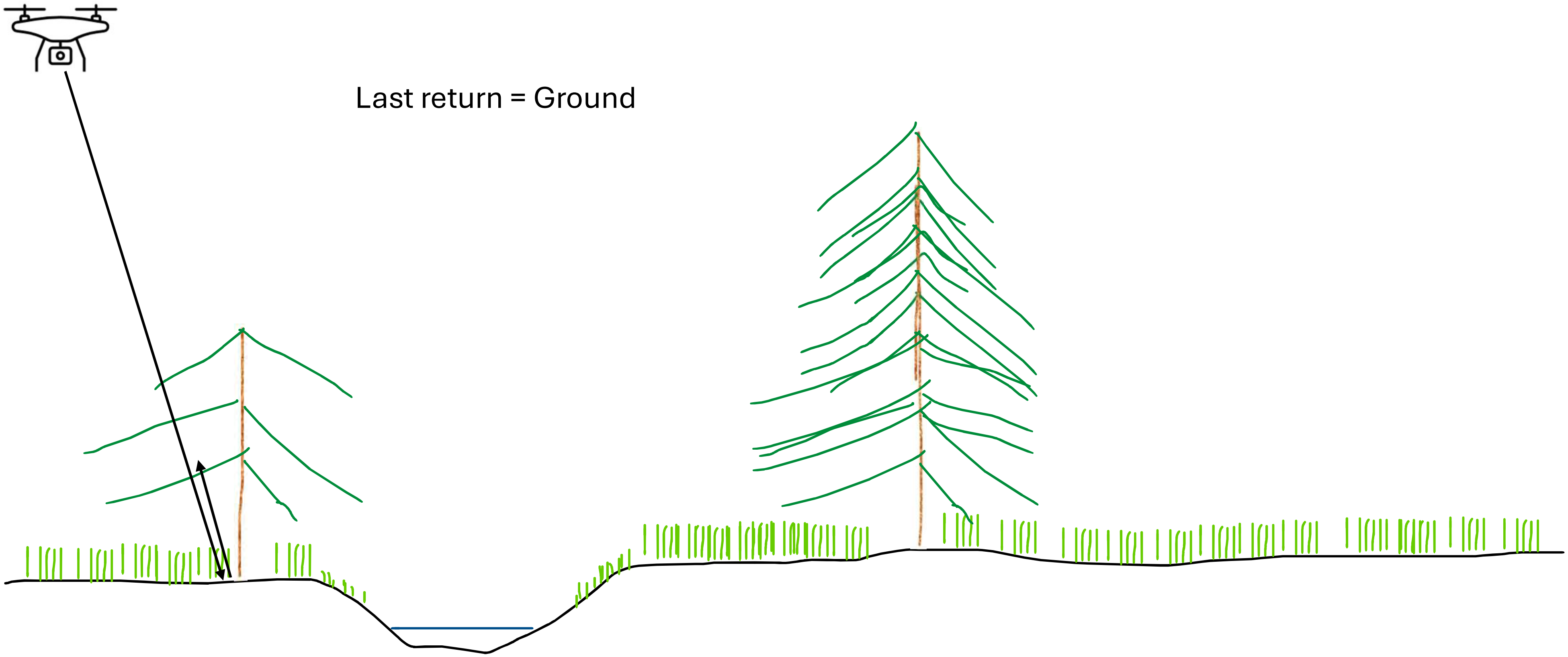
3rd return = Canopy



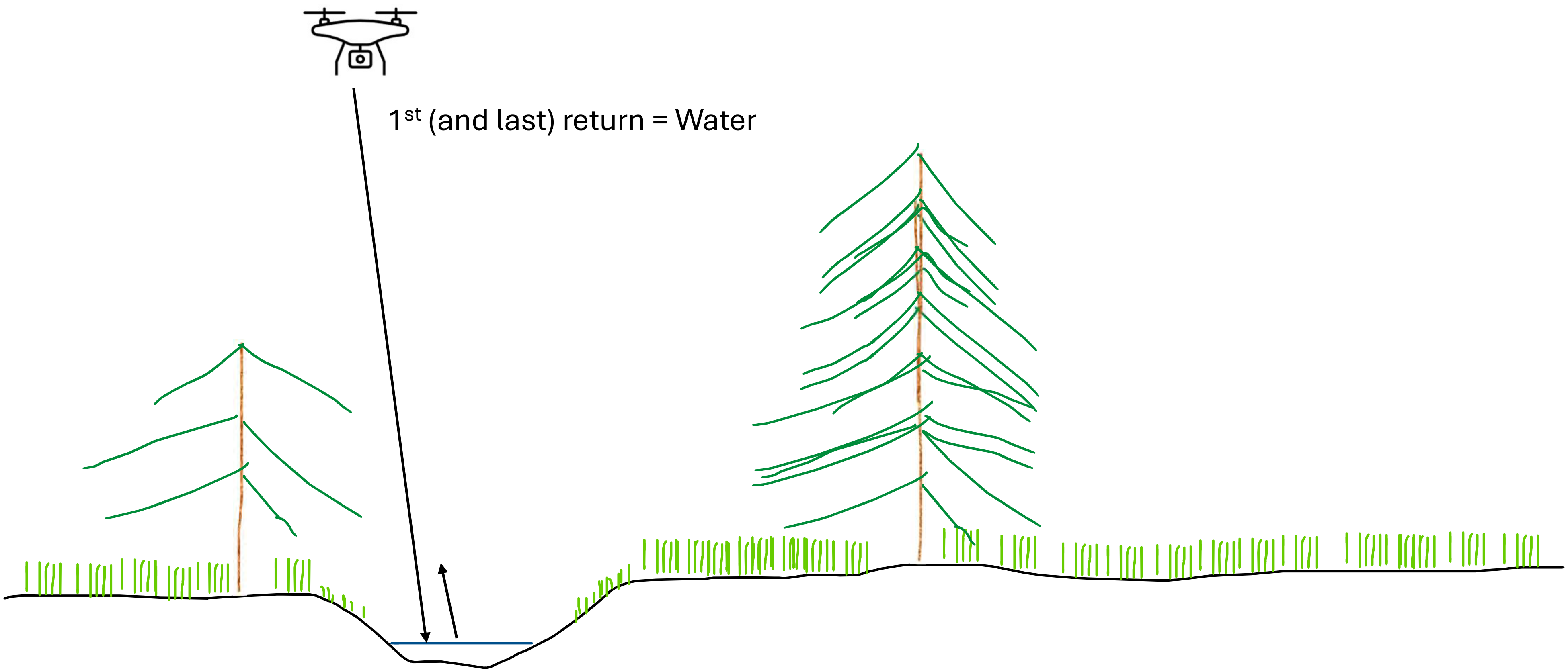
LiDAR – how does it work



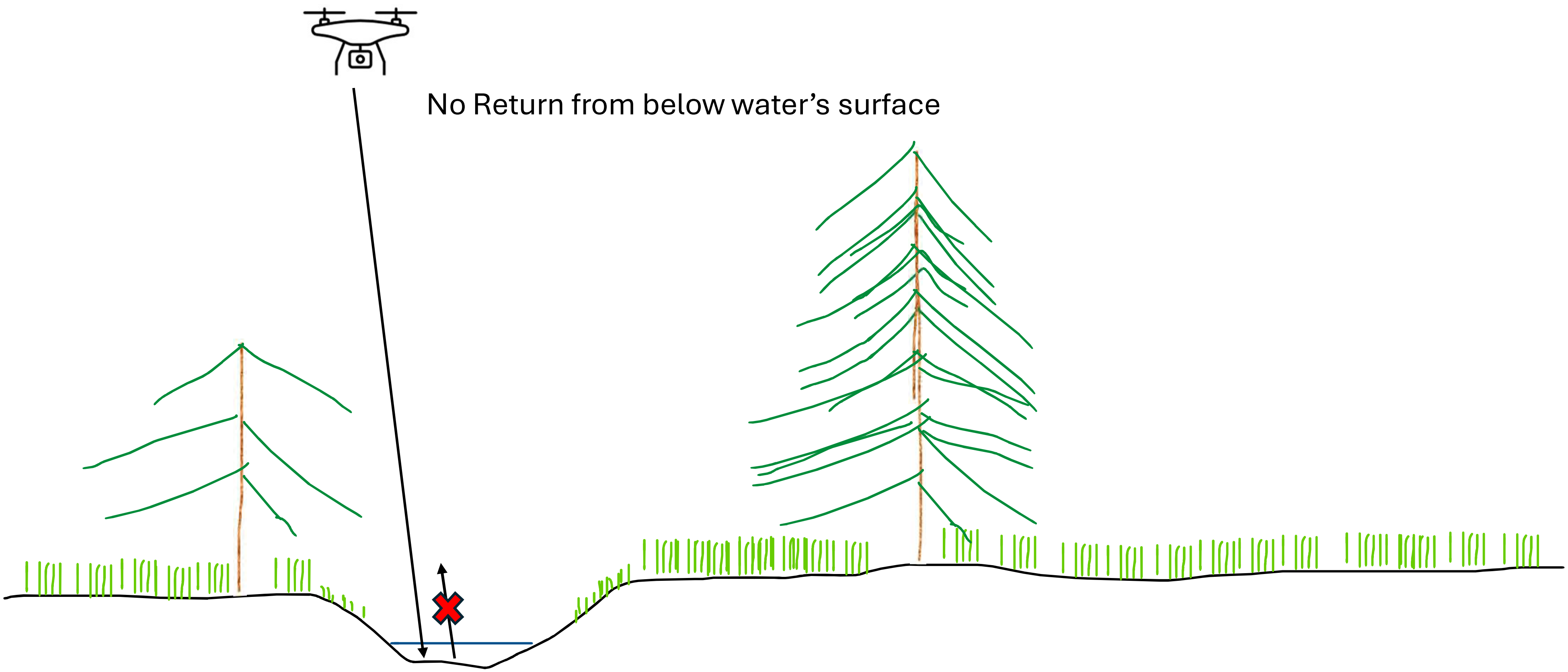
LiDAR – how does it work



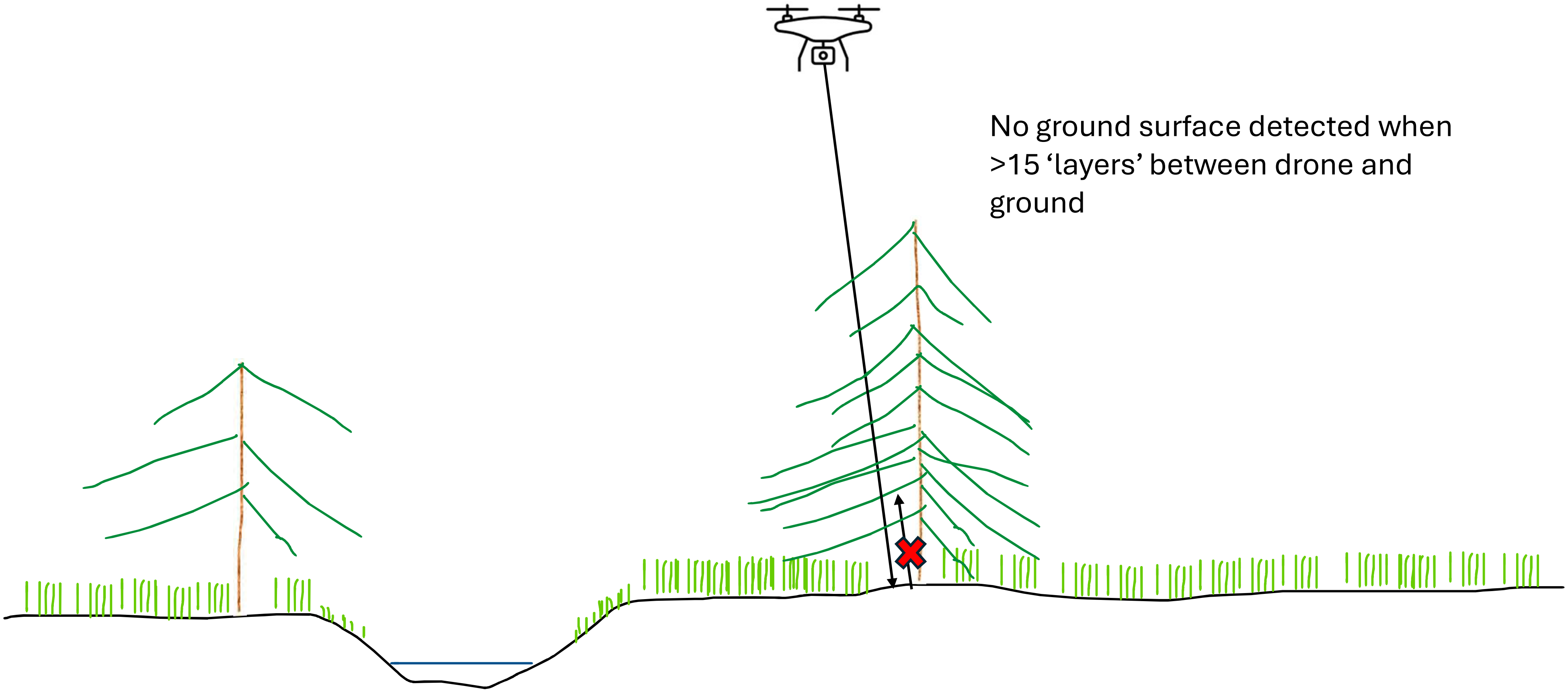
LiDAR – how does it work



LiDAR – how does it work



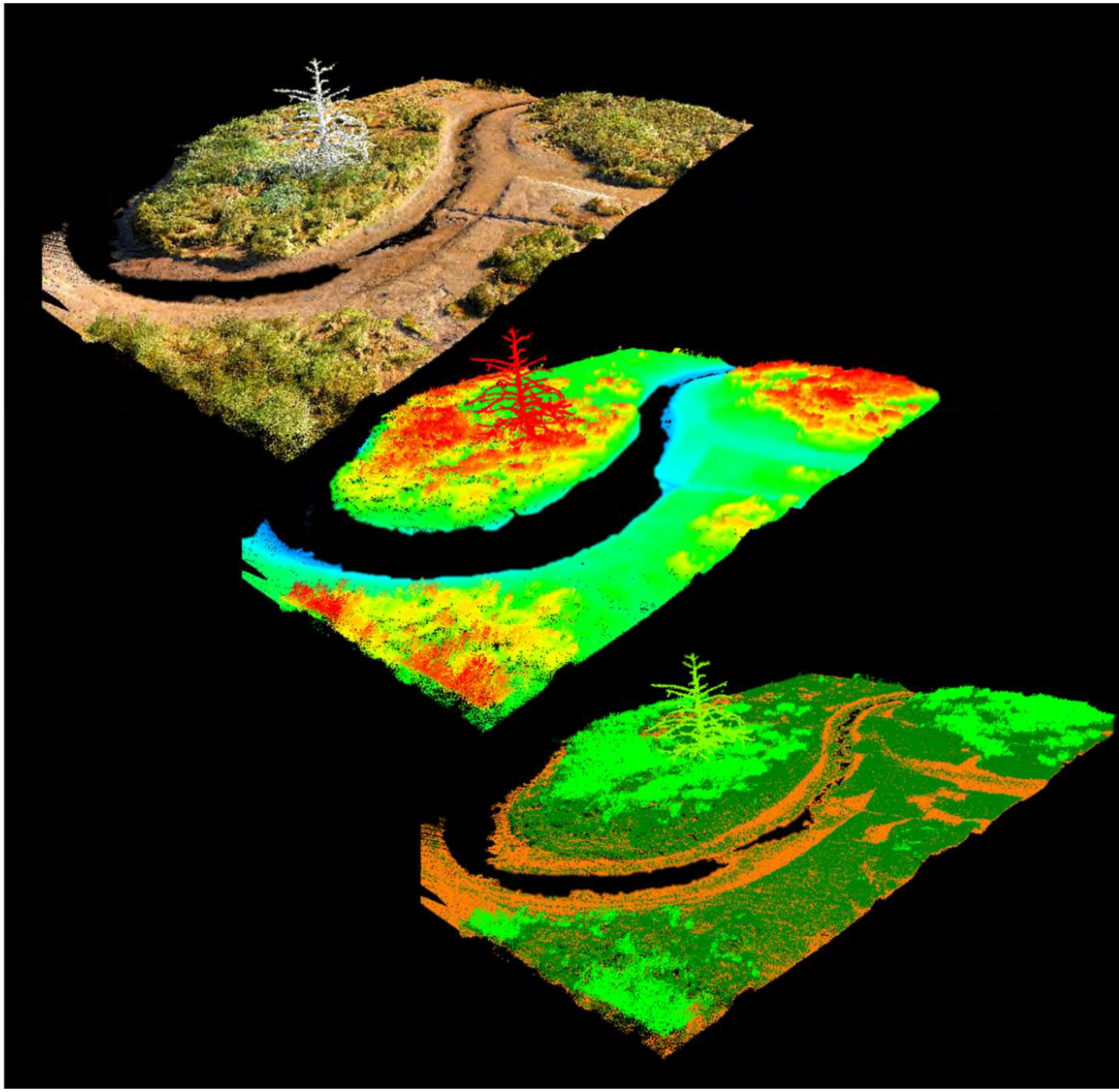
LiDAR – how does it work



No ground surface detected when >15 ‘layers’ between drone and ground

LiDAR – how does it work

- Top = Visible Light
- Middle = Elevations
- Bottom = Classified
  - Dark green = low veg
  - Light green = high veg
  - Orange = ground
  - Black = no data (water)



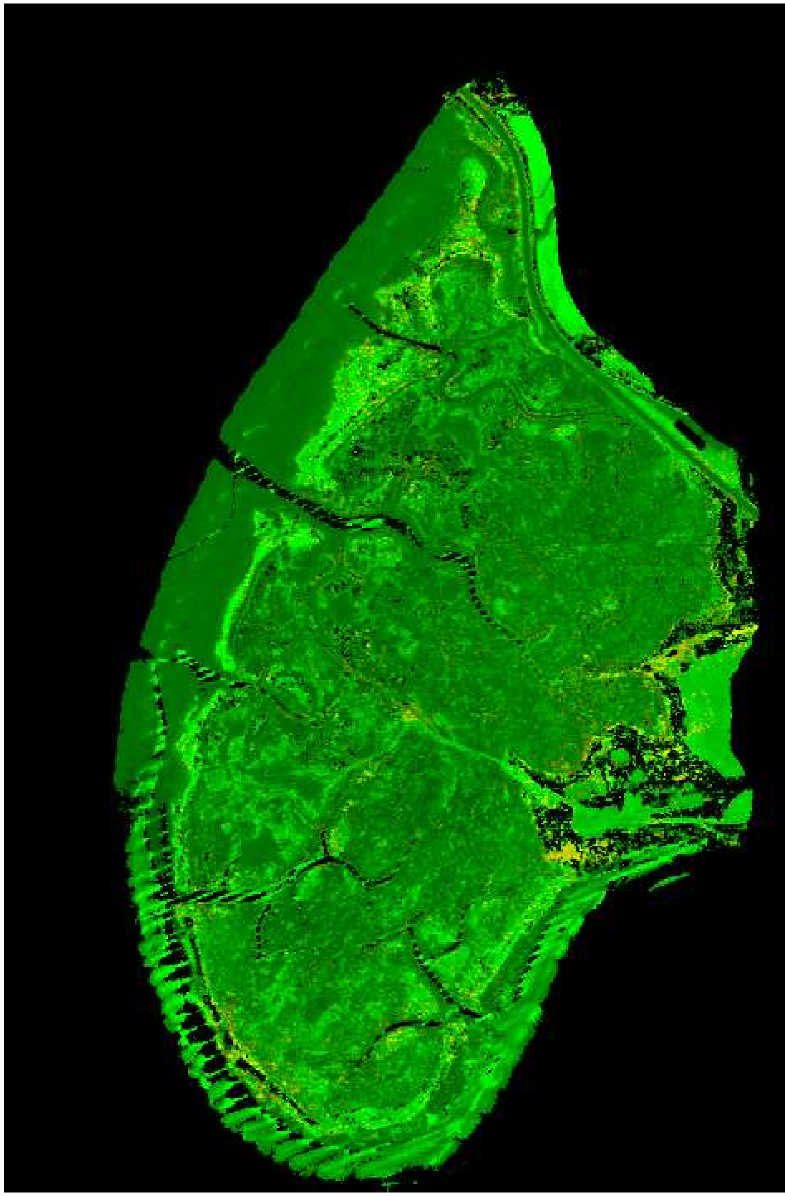
LiDAR Accuracy and Precision

LCEP LiDAR

- ~3cm precision across wetland
- ~5cm vertical accuracy across wetland (as compared via Topcon RTK)
- ~1500 points per square meter (GSD of ~2 cm)
- Survey designed for wetland

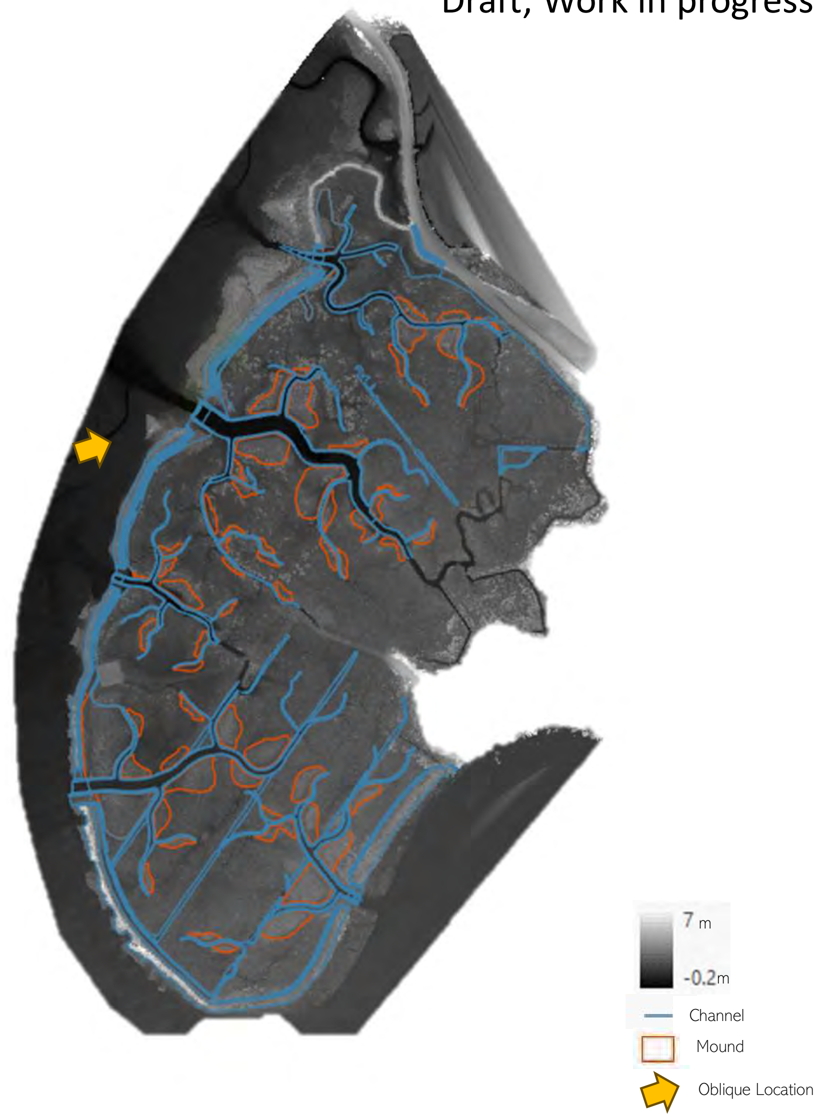
QL1 LiDAR ("Standard" LiDAR; USGS)

- 6 cm precision
- 10 cm accuracy
- >8 points per square meter
- Survey designed for roads and hard surfaces

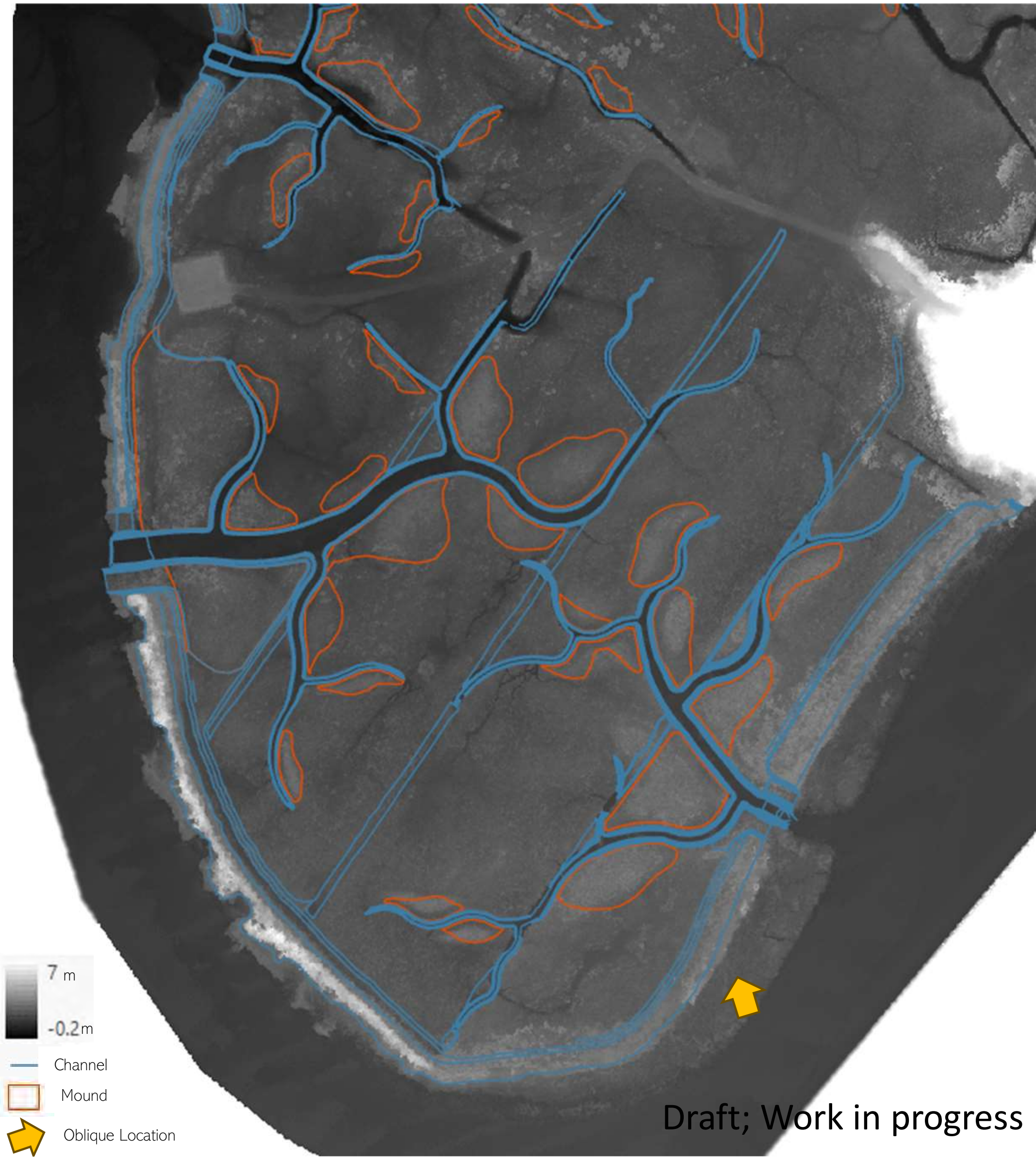


Draft; Work in progress

LiDAR – Tracking channel development



LiDAR – Tracking channel development



LiDAR – Tracking channel development

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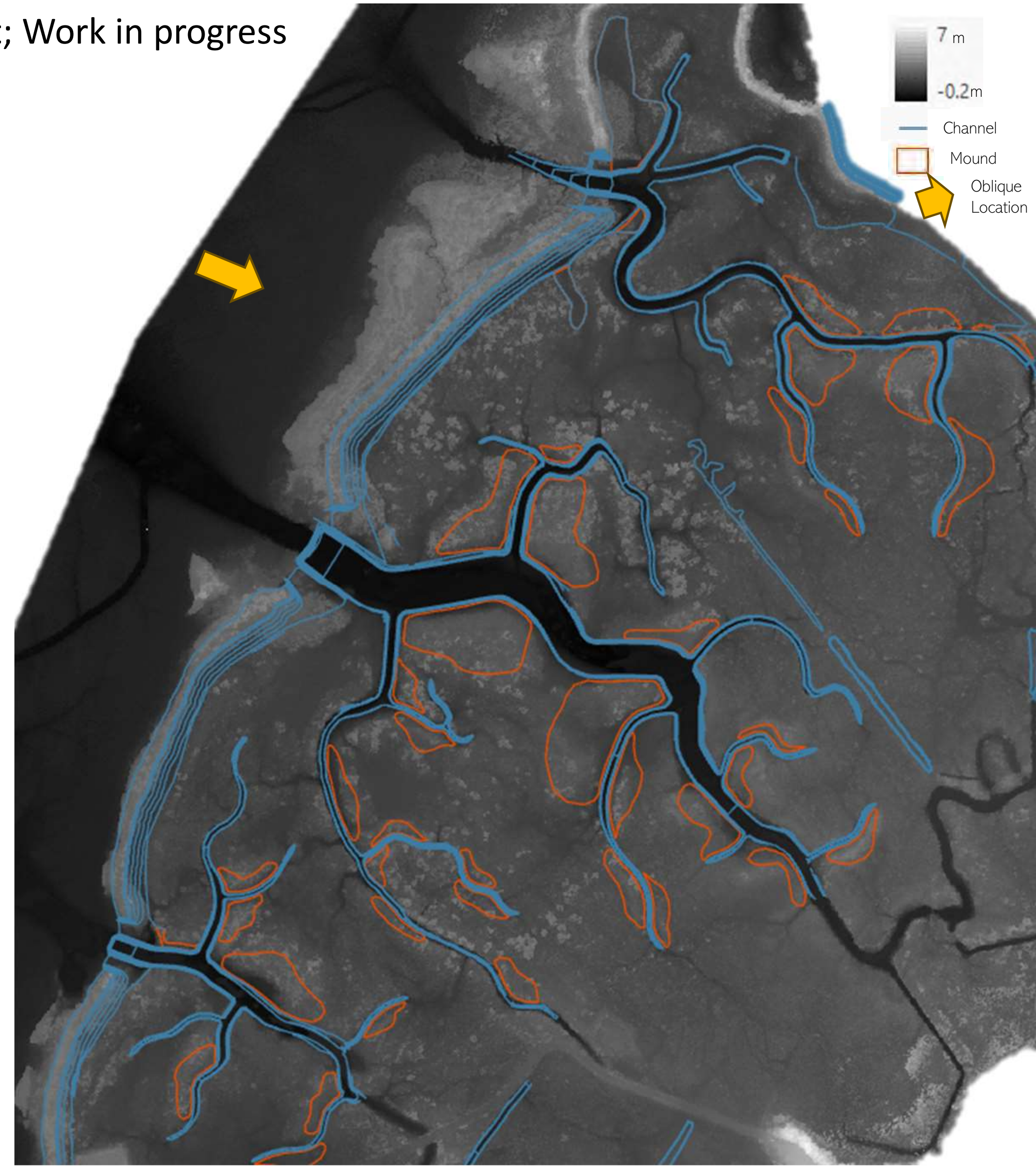
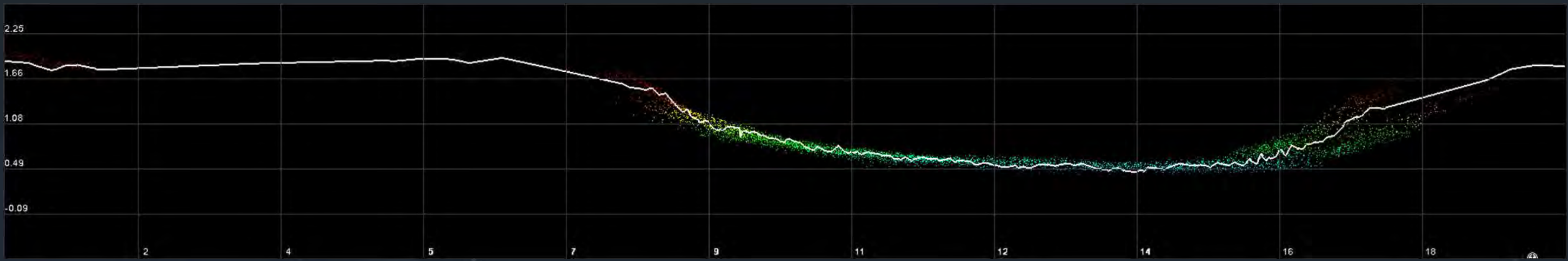
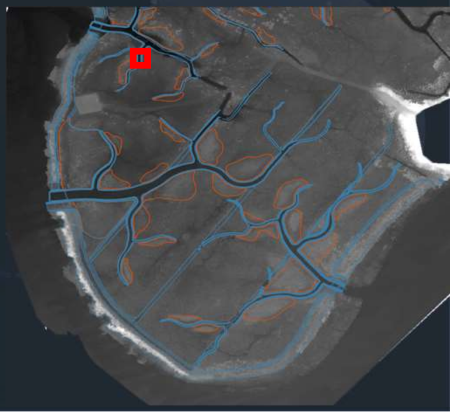




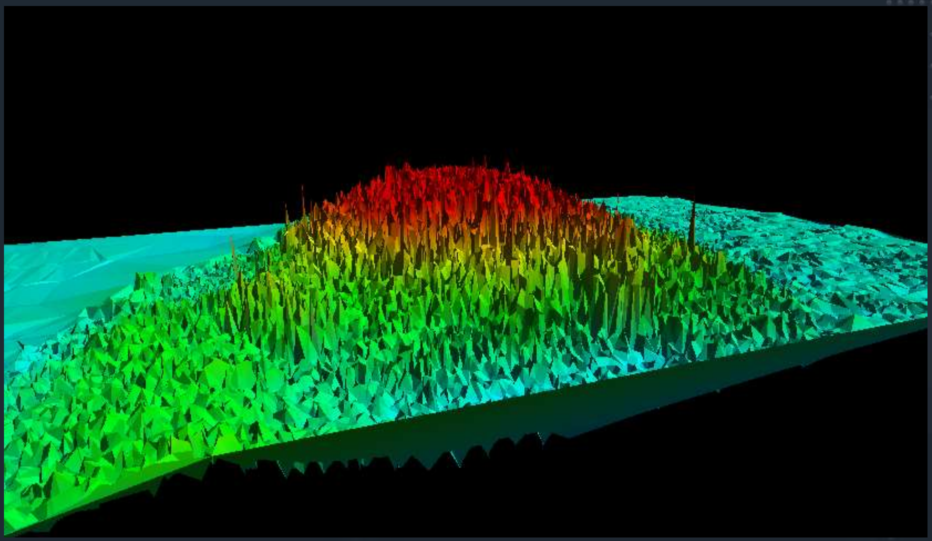
Channel Cross sections

- Augments and enhances manually collected cross sections
- Must be dry
- Moving ~1m per frame upstream



Beaver Dams

Stream elevation profile; downstream on left

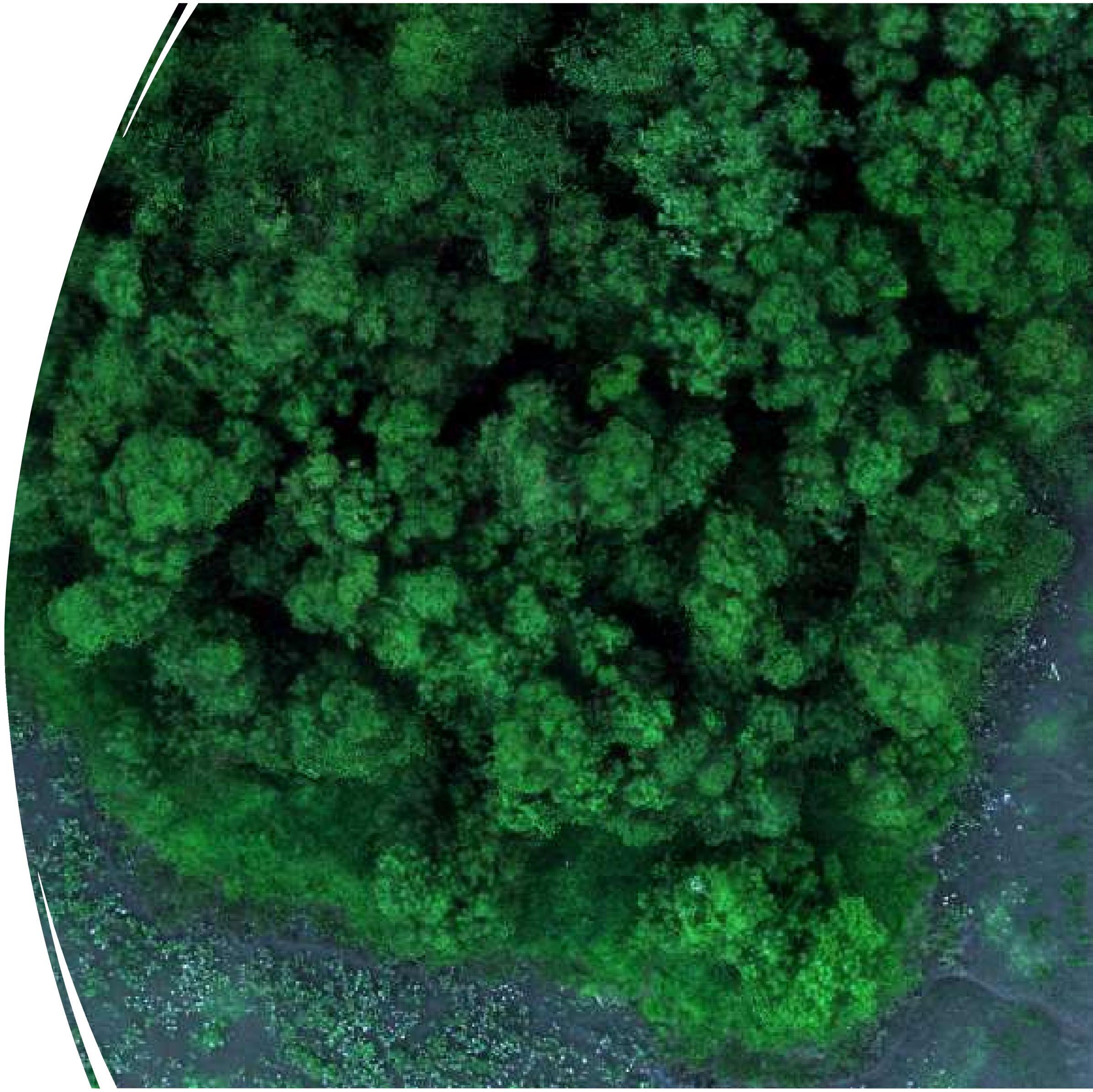


Beaver Dams

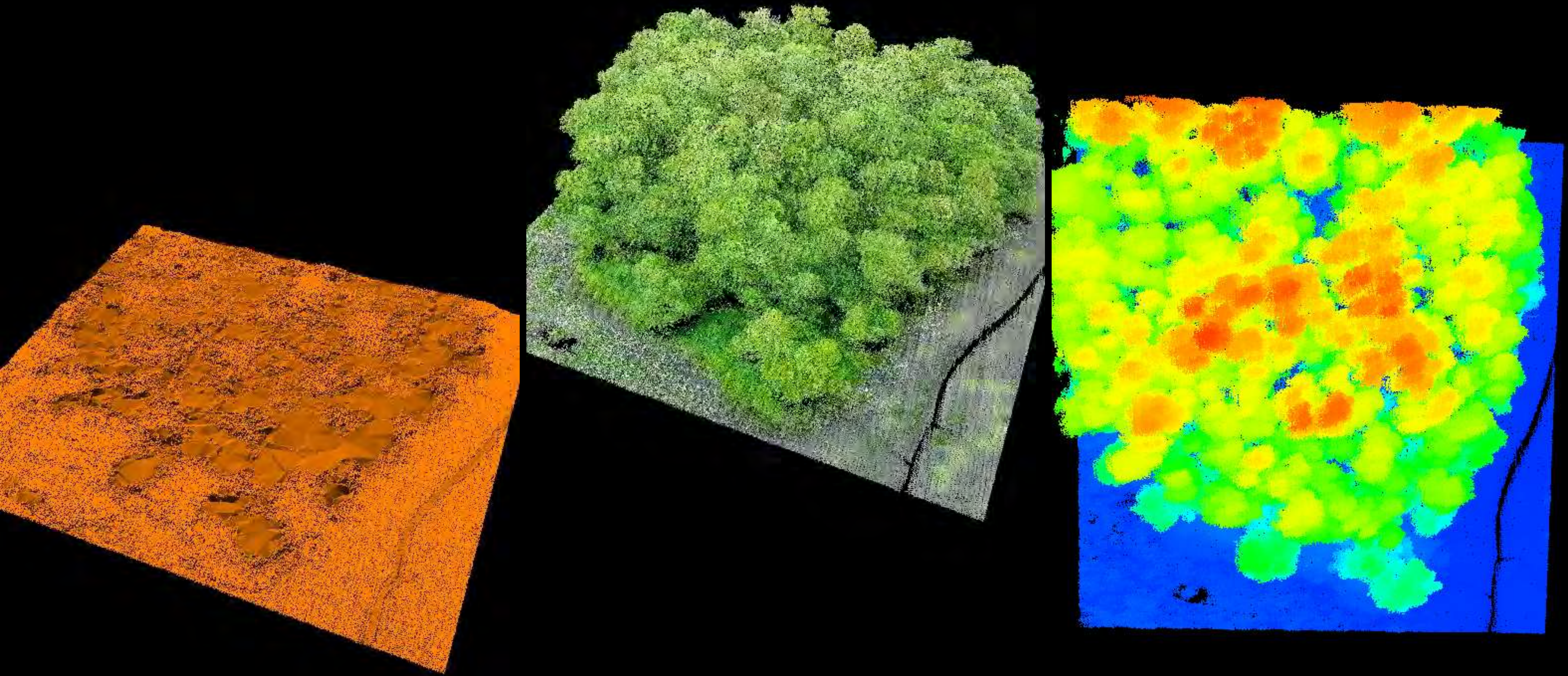
- Mid-Lake dam.
- ~1.3 meters above water surface; ~7 meters wide
- Volume of ~90 cubic meters

Trees

- Even areas with very thick canopies can create accurate ground DEMs.
- Full leaf-on conditions do reduce the quality of LiDAR from <QL0 to ~QL1.
- Leaf-off conditions create <QL0 LiDAR
- Tree counts, carbon stock, speciation, etc.

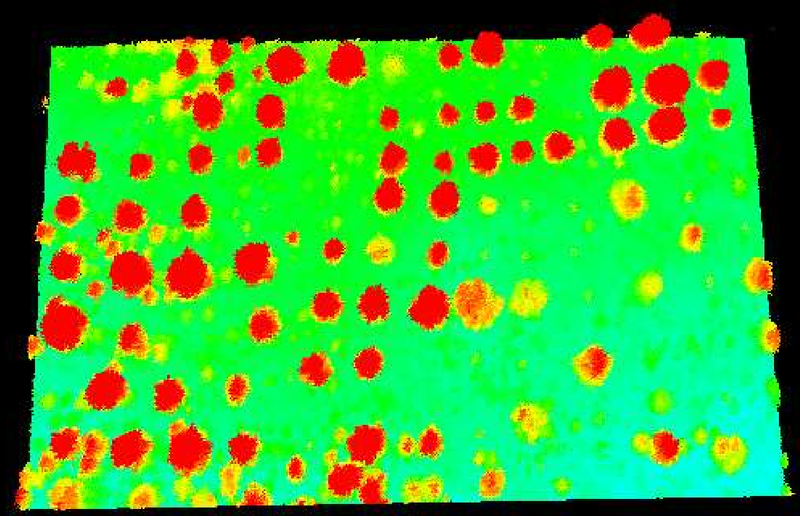


LiDAR Trees



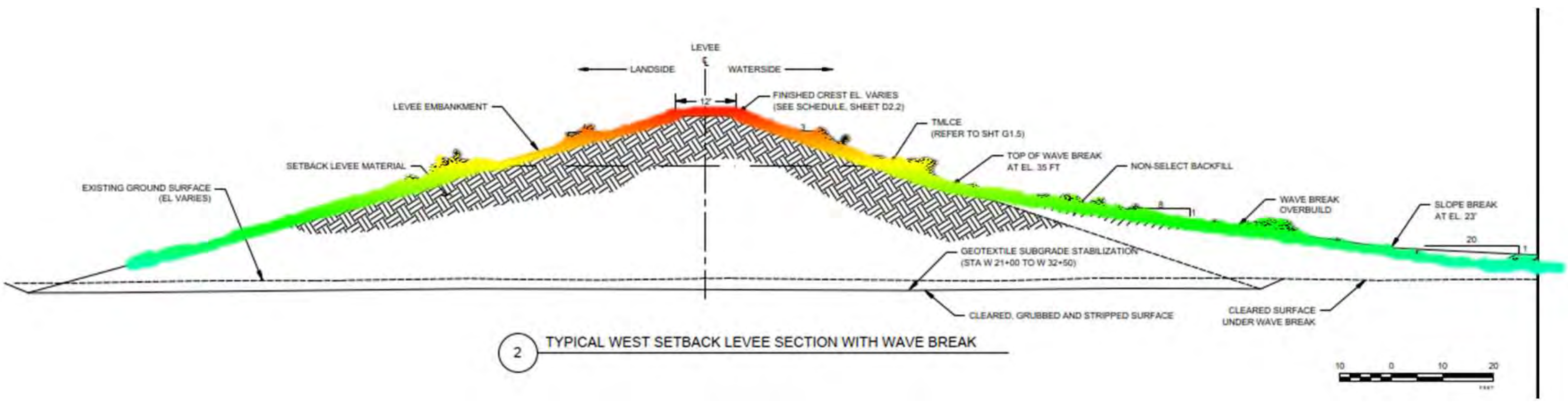
LiDAR Trees – Tracking Planting Survival

- Evaluate the effectiveness of plantings in restoration sites.
- LiDAR point cloud provides information on:
  - Density, count, height, mean coverage
  - Survival ratio
  - Growth rates



SRM0

LiDAR – checking as-built specs



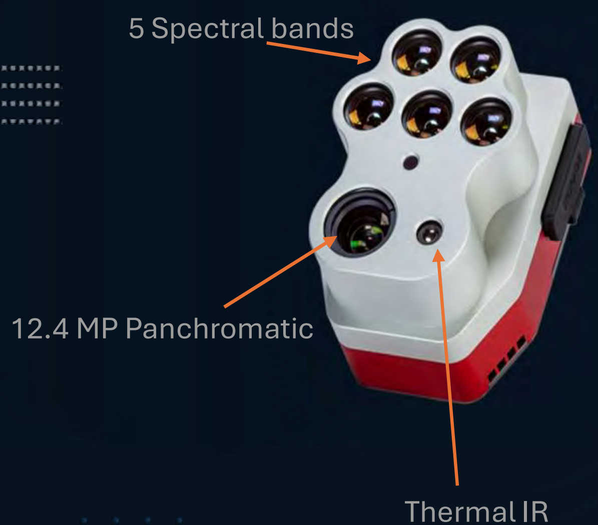
Slide 50

SRM0 Was I supposed to do this??
Sneha Rao Manohar, 2024-06-04T13:49:27.142

IE0 0 I will discuss it!
Ian Edgar, 2024-06-04T14:48:07.670

Multispectral

Multispectral Imagery and it's applications



MicaSense Altum-PT Multispectral Sensor

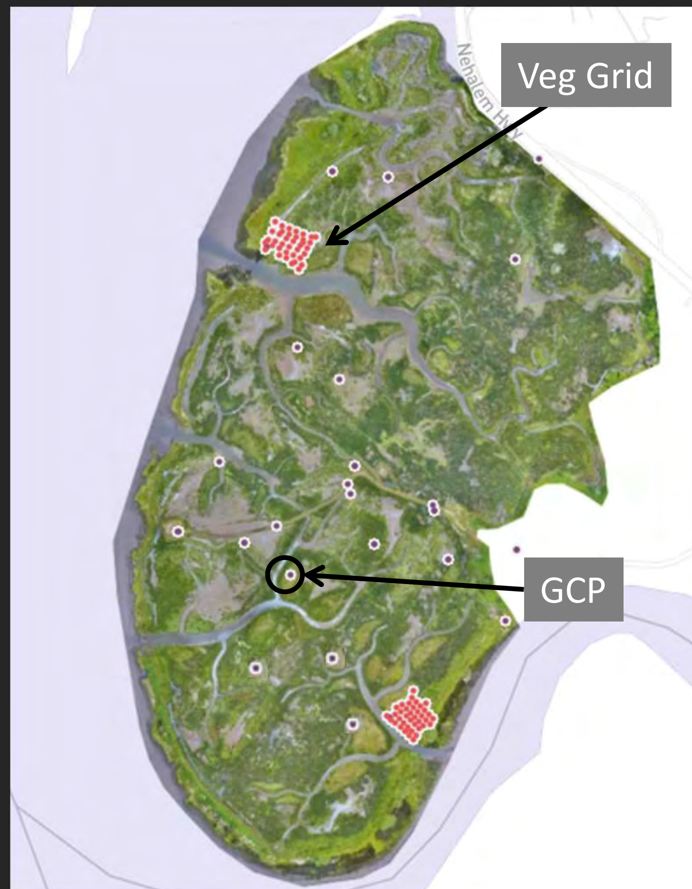
- 5 band multispectral; Red, Green, Blue, Red Edge, Near-IR (3.2 MP per band)
- Thermal (FLIR Longwave-IR)
- Ultra-high resolution panchromatic imager (12 MP)
- ~1.25 cm per pixel for non-thermal
- 17cm per pixel for thermal
- RTK Enabled (Emlid Reach RTK)
- Software: Mission Planner, Pix4D, ArcPRO
- **3-4 times more data than DJI P4 Multispectral!**

Blue	**RGB Composite, Orthomosaics, discerning soil and vegetation types**
Green	**RGB Composite, Orthomosaics, bathymetry**
Red	**RGB Composite, Orthomosaics, Vegetation Analysis**
Red Edge	**Vegetation health and stress, turbidity**
NIR	**Plant biomass, delineation of water bodies**

FIELD DATA COLLECTION USING DJI DRONES

Wallooskee Field Survey Work with DJI Drones

- ✓Vegetation Grids – 70 plots (1 m^2) –Detailed (% cover) species data and co-located RKT data
- ✓Ground Control Points (GCPS) –31 Locations - RTK, Photos Points, and Dominant Species Recorded



UAV Flight

- ✓300 ft
- ✓80% fore and side lap
- ✓Flown over 2 days

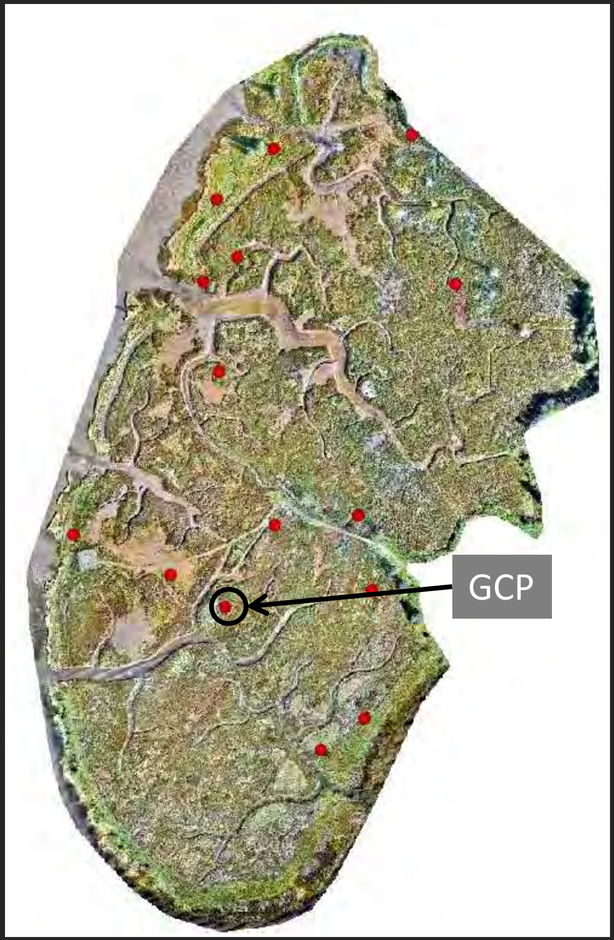
Pix4D Processing Outputs: 3.73 cm ground sampling distance

- RGB – Image seen to the left
- DSM – Digital Surface Model
- DTM – Digital Terrain Model
- NIR – Near Infrared
- NDVI - Normalized Difference Vegetation Index

Field Data Collection using the current setup

Wallooskee Field Survey Work with Harrier HE

- ✓Ground Control Points (GCPS) –15 Locations - RTK, Photos Points, and Dominant Species Recorded



UAV Flight

✓300 ft

✓80% fore and side lap

✓Flown in 3 hours

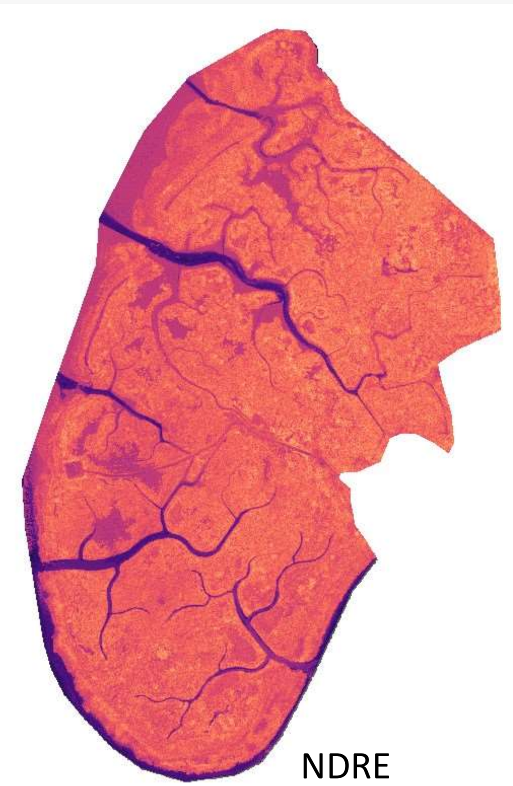
Pix4D Processing Outputs: 3.1 cm ground sampling distance

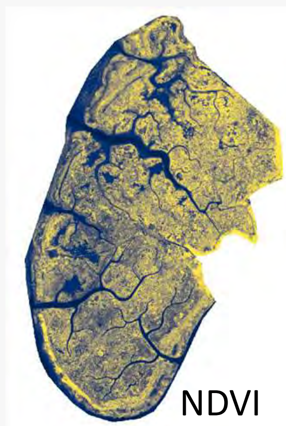
- DSM – Digital Surface Model
- DTM – Digital Terrain Model
- NIR – Near Infrared
- RGB composite – Image seen to the left
- NDVI - Normalized Difference Vegetation Index
- LWIR – Long Wave Infra-red

Multispectral Imagery – Products and Applications

- Individual spectral bands can be composited to create an RGB map.
- LWIR map – also called thermal infrared map, mapping thermal signatures of the vegetation community
- Individual spectral bands are tools to evaluate:
  - ✓ Riparian Buffer effectiveness
  - ✓ Monitor water quality parameters such as turbidity and chl-a

Products can be used to answer questions that go beyond vegetation communities.





Multispectral Imagery – Vegetation Indices

- Combining commonly used vegetation indices to study vegetation assemblages at sites.
- NDRE and EVI allow classification of vegetation in that are not at peak growth.
- Higher accuracy in resulting vegetation models.
    - Assess vegetation health around restoration sites
    - Identify invasive species
    - Evaluate the impact of restoration efforts

NDVI = Normalized Difference Vegetation Index
NDRE = Normalized Difference Red Edge Index
EVI = Enhanced Vegetation Index

Integrating Products with Machine Learning and AI

- Machine learning model and AI-driven raster analysis
  - Random Forest and Convolutional Neural Network (CNN)

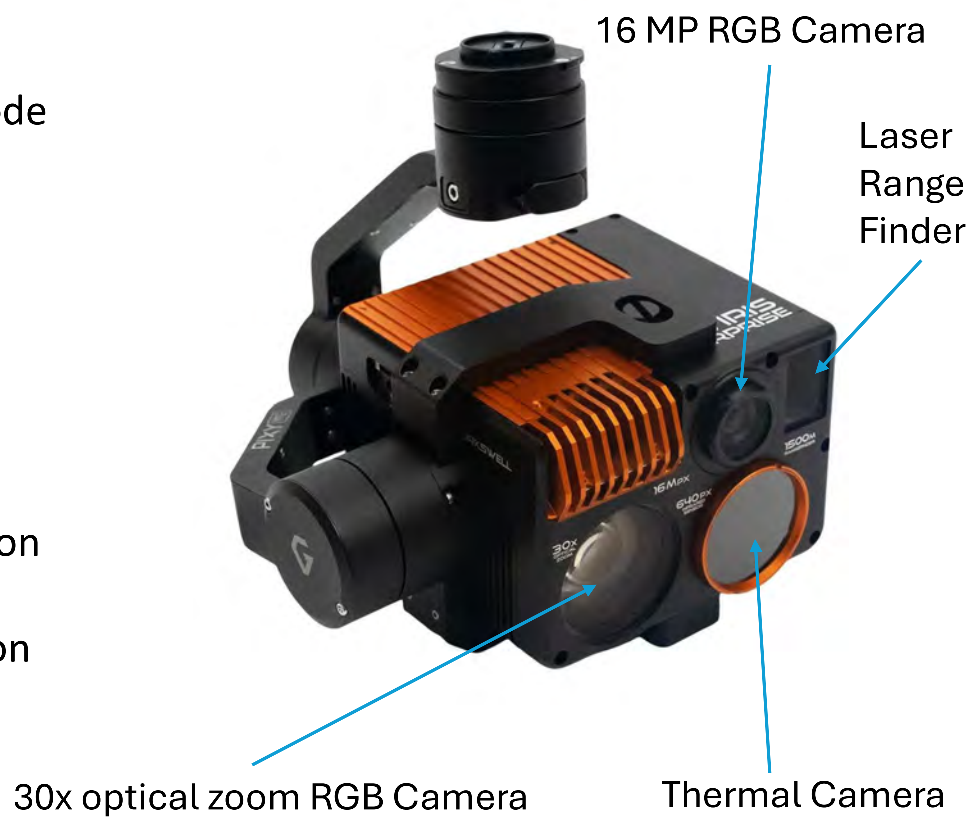
- Data Layers:
  - Spectral bands: Blue, Green, Red, Red Edge, NIR, Panchromatic
  - Vegetation Indices: NDVI, EVI, NDRE
  - LiDAR: Ground DEM, Canopy surface

Thermal

Thermal Imaging in restoration

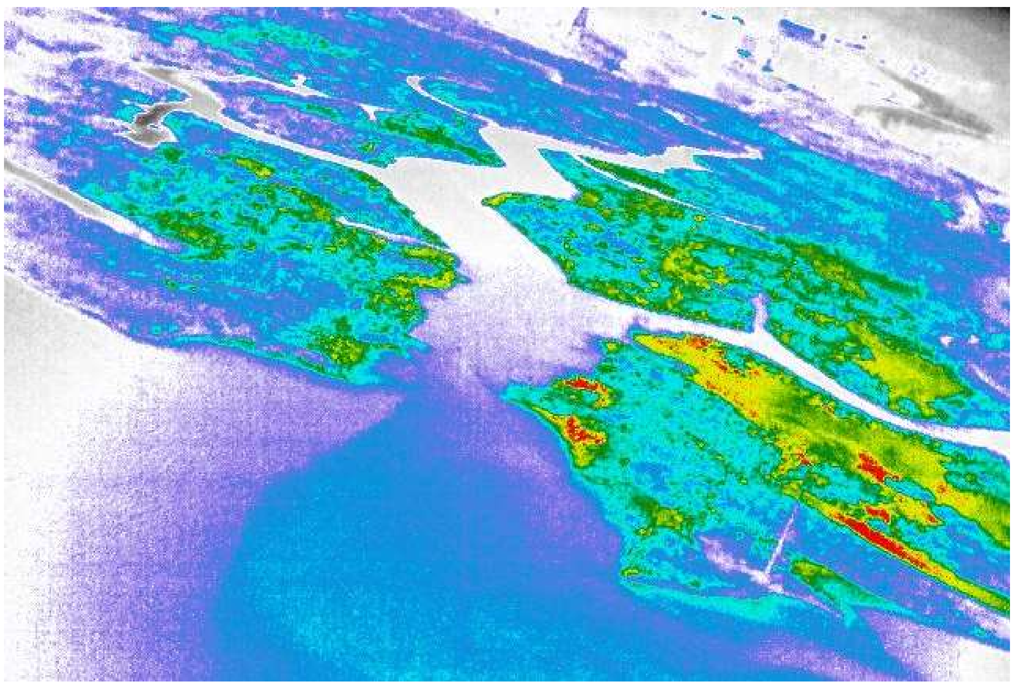
- Digital RGB cameras with 16 MP fixed camera and 30x optical zoom camera
- IR resolution: 640 x 512 pixels, with Super Resolution Mode up to 1.3 Megapixels (MP)
- Spectral range: 7.5 – 13.5 µm
- Integrated Laser Rangefinder for accurate distance measurements

- Applications include
  - Assess water temperature patterns for optimal salmon habitat
  - Identify areas with potential erosion or sedimentation issues
  - Assess vegetation health and riparian buffer zones



Draft initial analyses; Work in progress

Relative Thermals of Wallooskee-Youngs



Surface temperatures

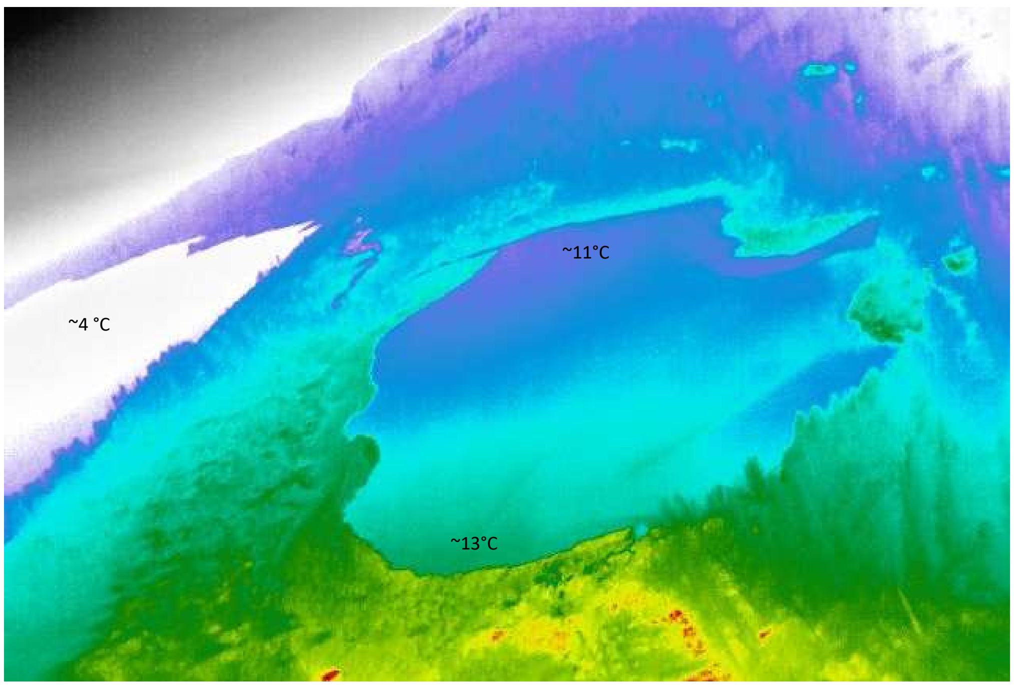
Cold  Hot

*Temperature accuracy beings to drop significantly after 1.5 km

**Temperatures NOT ground-truthed

Draft initial analyses; Work in progress

Relative Thermals of Franz Lake Wildlife Refuge



Surface temperatures

Cold — Hot

*Temperature accuracy beings to drop significantly after 1.5 km

**Temperatures NOT ground truthed

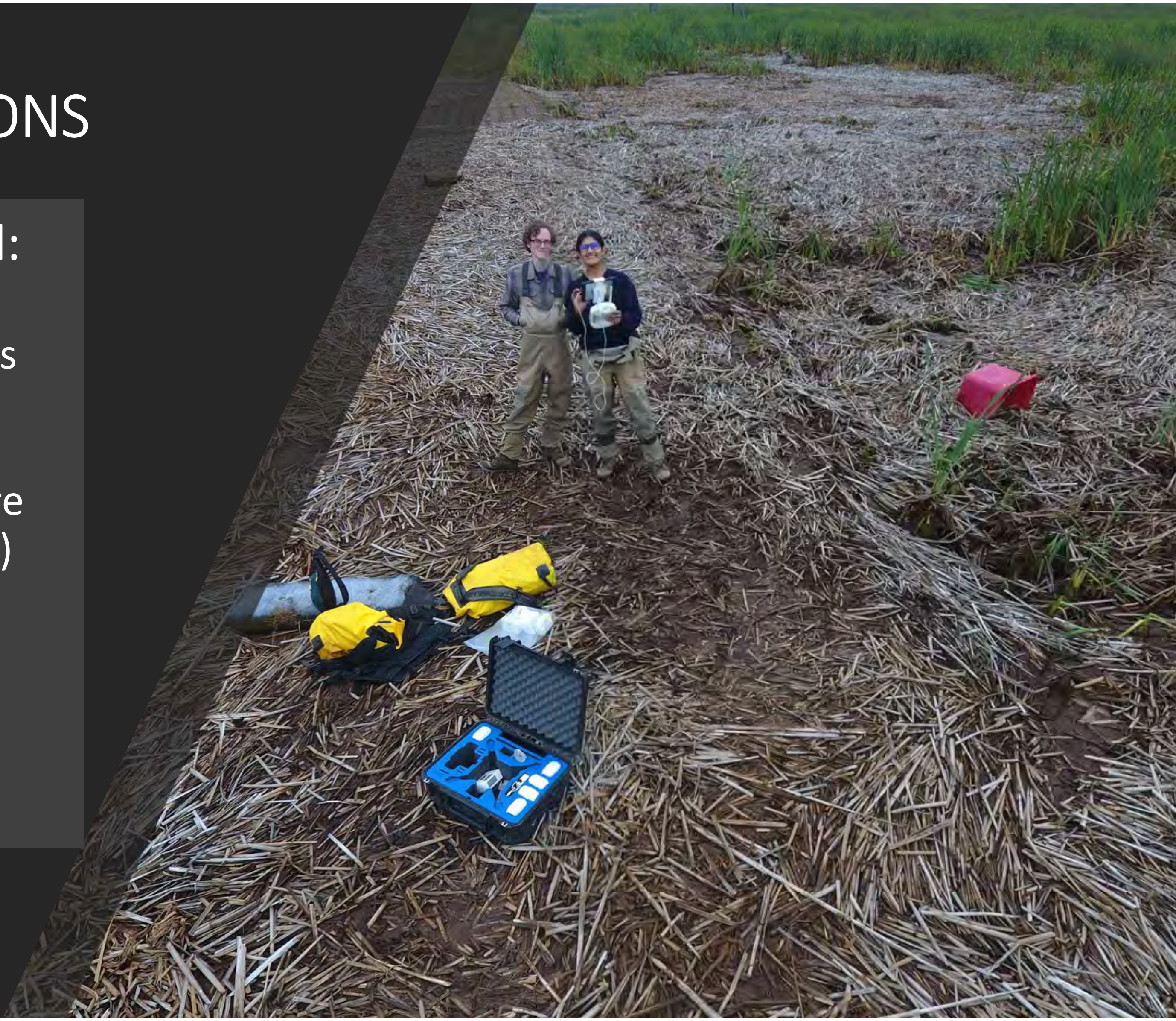
Reporting and Research Applications

RESEARCH APPLICATIONS

Pre-restoration can be used:

- When combined with hydrologic model scenarios these data can be used to predict shifts in habitat conditions across the entire site (also a SLR application)

- Assist in restoration planning, design, and adaptive management



Research Applications – Wetland Plant Community

In the past we have focused on monitoring conditions using transects and 1-m^2 plot data (<1-5% of the site would be monitored)

- Model those results across the entire site using the UAV sensor data and ArcGIS image classification
- Example - **Shift from collecting data from 0.02 acres to 200 acres**
- **Track site-wide change overtime**
- **Predict shifts from SLR/Climate Change, Restoration, Management**

Research Applications Continued

Our research plan is to also include

- Tracking channel & over all site topographic development
- Evaluate above ground biomass (carbon stocks)
- Thermal sensing

Next steps

- Refine protocols for thermal sensing.
- Utilize LiDAR to evaluate sediment dynamics at restoration sites, and topographic changes
- Develop predictive model for vegetation development at restoration sites using machine learning.
- Develop site-wide biomass and ecosystem health analyses
- Work closer with sponsors to develop sampling plans that align with their restoration goals
- Migrate to an AI vegetation model over the machine learning model

Contact us if you have any questions:

Sneha Rao – snehar@estuarypartnership.org
Ian Edgar – iedgar@estuarypartnership.org

Research Partners

Thank you!

- **Identification of Goals and Objectives for Monitoring including performance metrics**

- **Development of Site Sampling Plan**
  - Identification of research questions and any desired deliverables
  - Project preplanning: flight plan, permitting requirements, locations of ground control points, etc.
  - QA and data processing – calibration, interim products and steps for review/comments, verification, final products
  - Roles of LCEP and partners
  - Next steps