wood.

Reclamation Certification Achieved using Remote Sensing

A Model for Safe and Reliable Closure of Environmental Liabilities

Chrissie Smith, P.Ag. PMP, and
Meisam Amani, Ph.D., P.Eng

October 2021

Presentation Outline

- OSE sites and traditional assessment methods
- Exploring the possibility of remote sensing
- Deciding on assessment parameters
- Inputs (data) used for building the remote sensing model
- How each parameter was assessed
  - Methods, data generation and interpretation, accuracies
- Results and conclusions

Introduction to OSE Programs

Oil Sands Exploration (OSE) Wellsites Footprint

Reclamation Drivers

Alberta's Environmental Protection and Enhancement Act:

Reclamation is defined as returning land to 'equivalent capability'

- OSE program approvals require reclamation and submission of a **Reclamation Certificate** Application within 3 years after drilling

- Sites located within Woodland Caribou Range

Aerial Assessments by Traditional Methods

Methods

- A helicopter accesses as many sites as possible in a short time
- Hangs above the site for a few minutes for field notes and a few photos

Execution Challenges

Remote access
Co-habitation with ongoing operations

Disadvantages

Safety
Budgetary contingency
Low quality assessments

Initial Thoughts of Remote Sensing

Imperial

High-resolution satellite imagery applied to monitoring revegetation of oil-sands-exploration well pads

Cynthia K. Dacre, David A. Palandro, Anna Oldak, Alex W. Ireland, and Sean M. Mercer

ABSTRACT

To achieve reclamation certification, oil-and-gas operations in Alberta, Canada are required to monitor the revegetation of idle well pads that no longer support operations. Currently, monitoring is completed by oblique, helicopter-collected photography and on-the-ground field surveys. Both monitoring strategies present safety and logistical challenges. To mitigate these challenges, a remote-sensing project was completed to develop and

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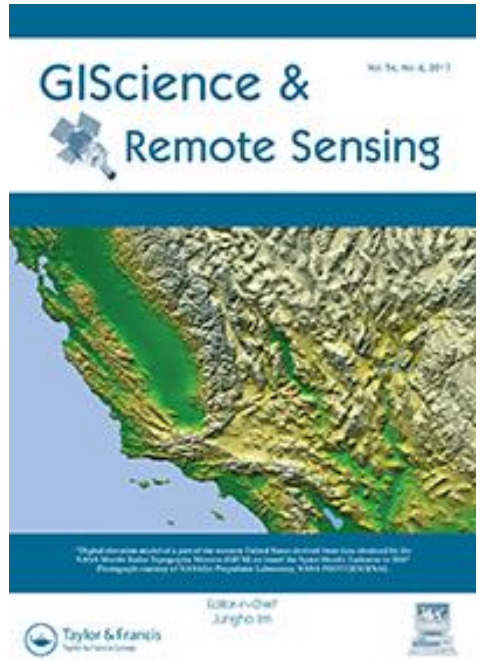

Alberta Energy Regulator

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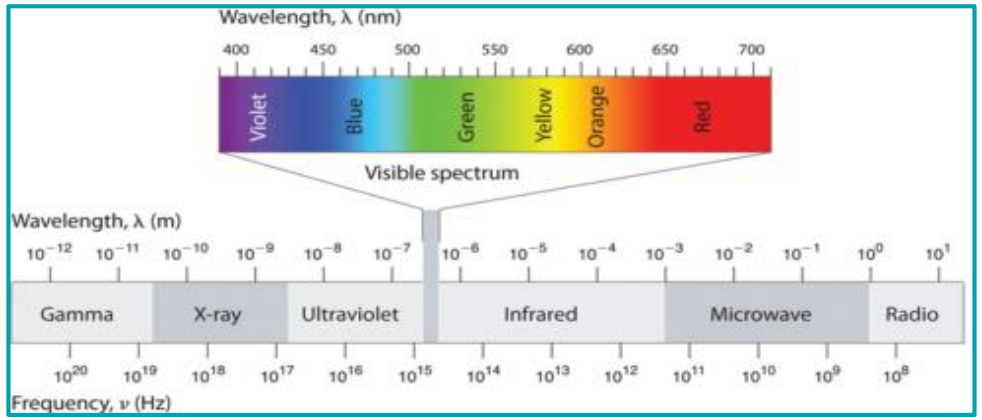
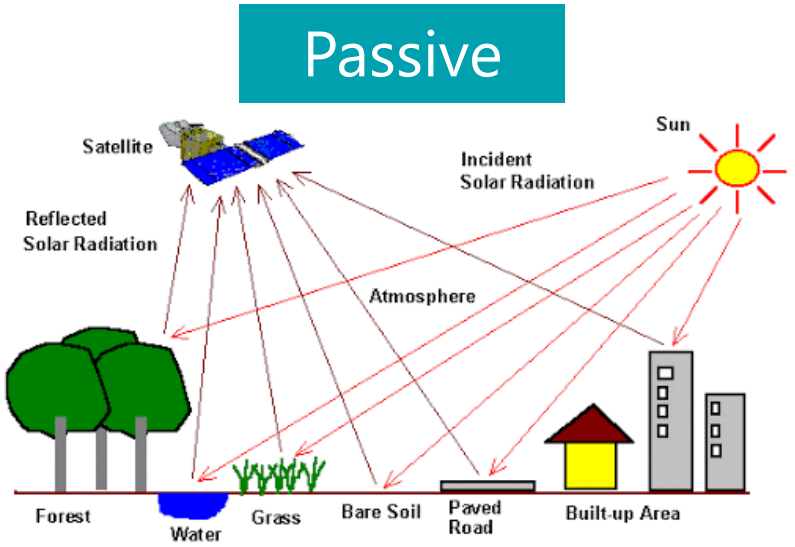
Remote Sensing - Introduction

- Measurement of object properties from UAVs, helicopters, aircrafts, and satellites
- Two basic components of RS systems: a sensor and a platform
- Remote sensors measure electromagnetic radiation
- Two types of RS systems: Passive and Active





Remote Sensing Platforms

Handheld device

Ground-based

Survey vehicle

Helicopter

Drone

Airplane

Satellite

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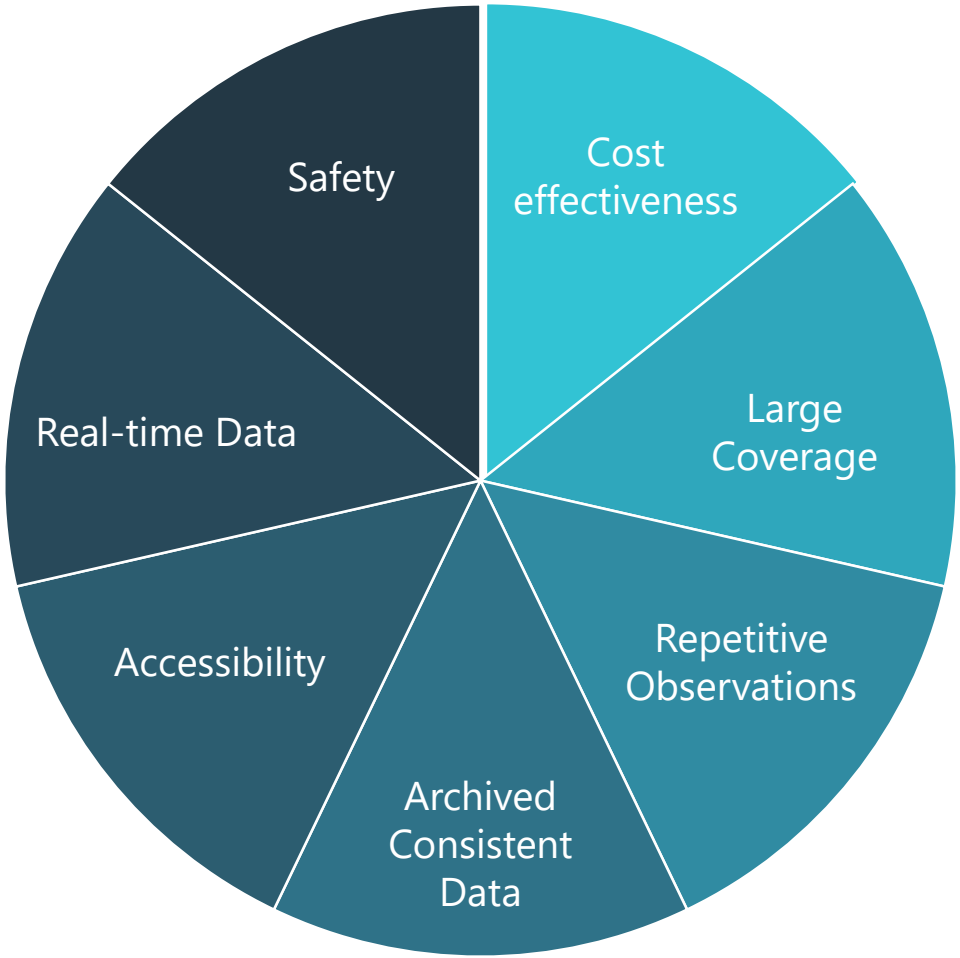
Remote Sensing Advantages



Various accuracy levels depending on multiple factors

Some field data is still required

Regulatory Criteria

Alberta Government

Directive

Vegetation

- Percent ground cover
  (grass, forbes, mosses)
- Tree heights
  (estimate to 0.25 m)

Title:	**Coal and Oil Sands Exploration Reclamation Requirements**
Number:	**AEP, Land Policy, 2015, no. 7**
Program Name:	**Land Policy Branch**
Effective Date:	**January 25, 2010**
This document was updated on:	**December 2, 2015**
ISBN No.	**987-1-4601-2653-0 (PDF)**

Landscape

- Match surrounding land
- Ponding

‘Coal and Oil Sands Exploration Reclamation Requirements’

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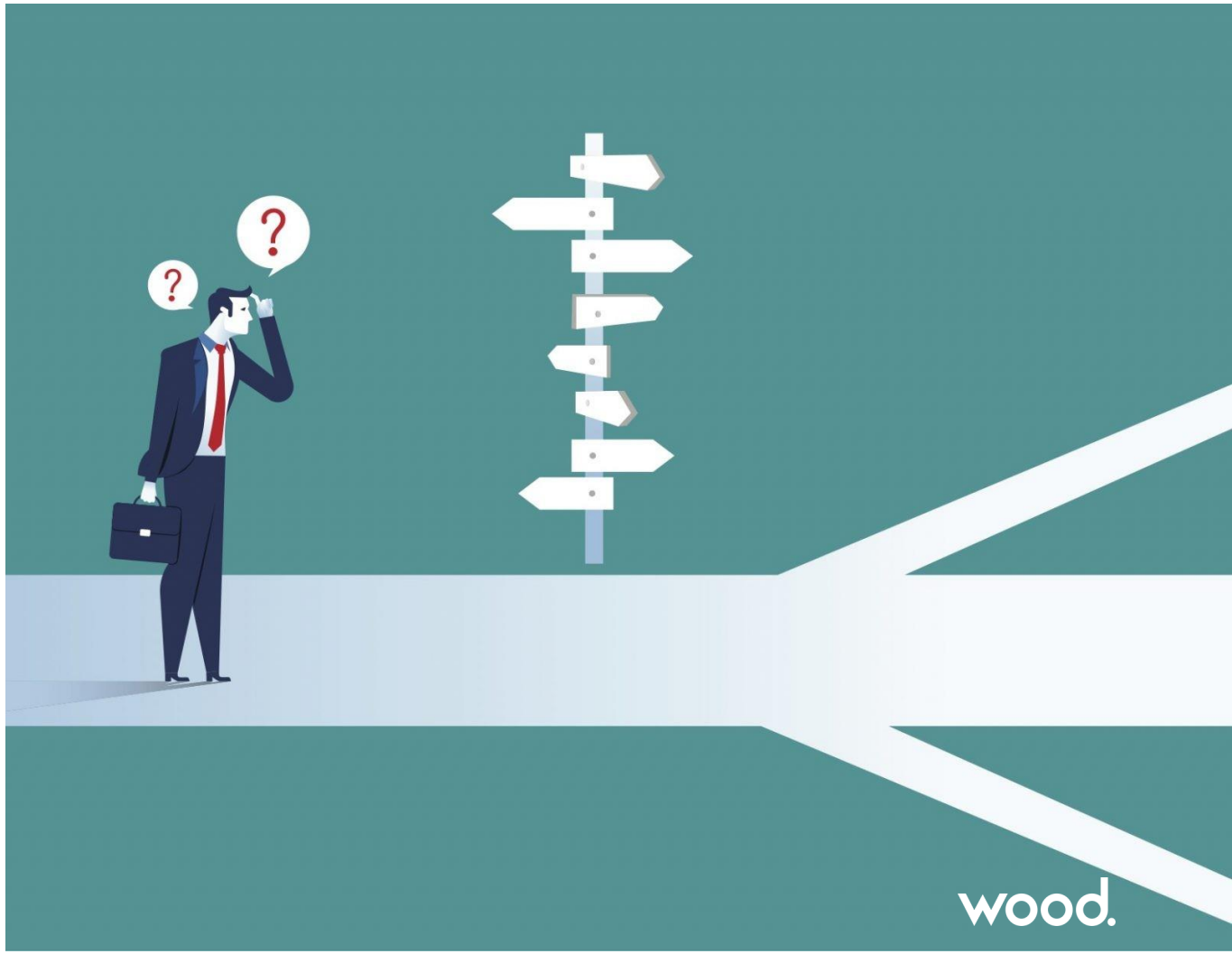
What Parameters to Assess? To what degree?

All reclamation parameters in the OSE Guidelines.

The additional parameter of species diversity.

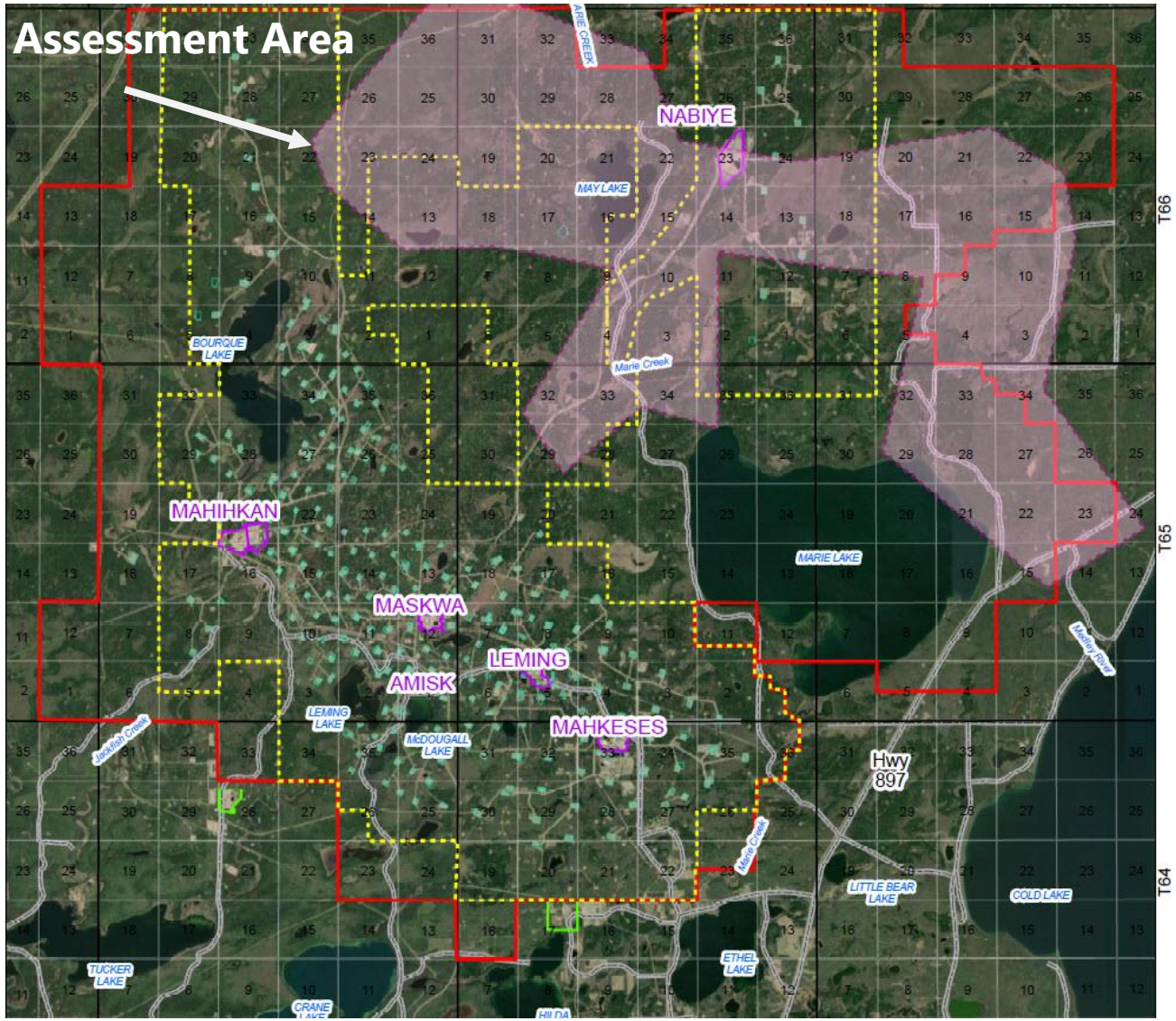
In the same level of detail as helicopter assessments or better.



Assessment Area

Imagery and LiDAR captured for the assessment area in early summer 2020

Covers several sites in two OSE programs and 145 km^2



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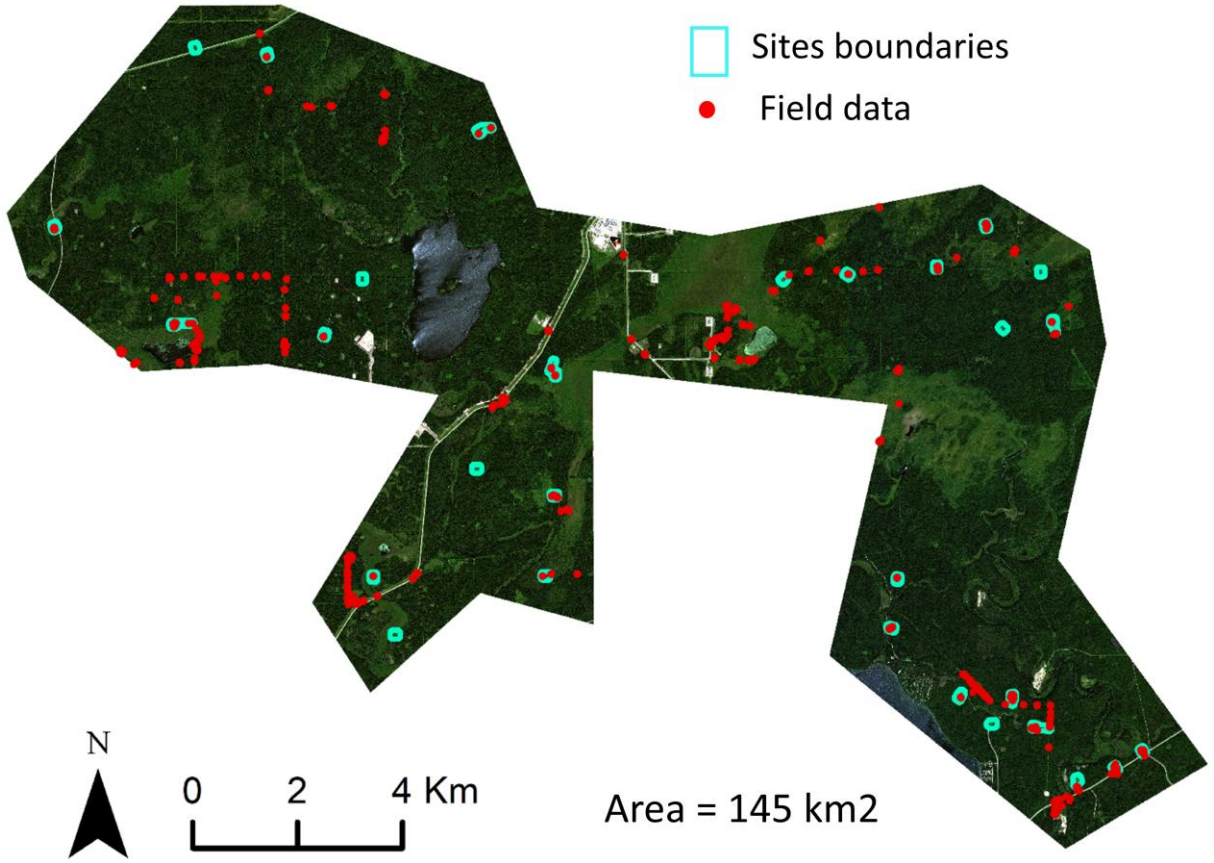
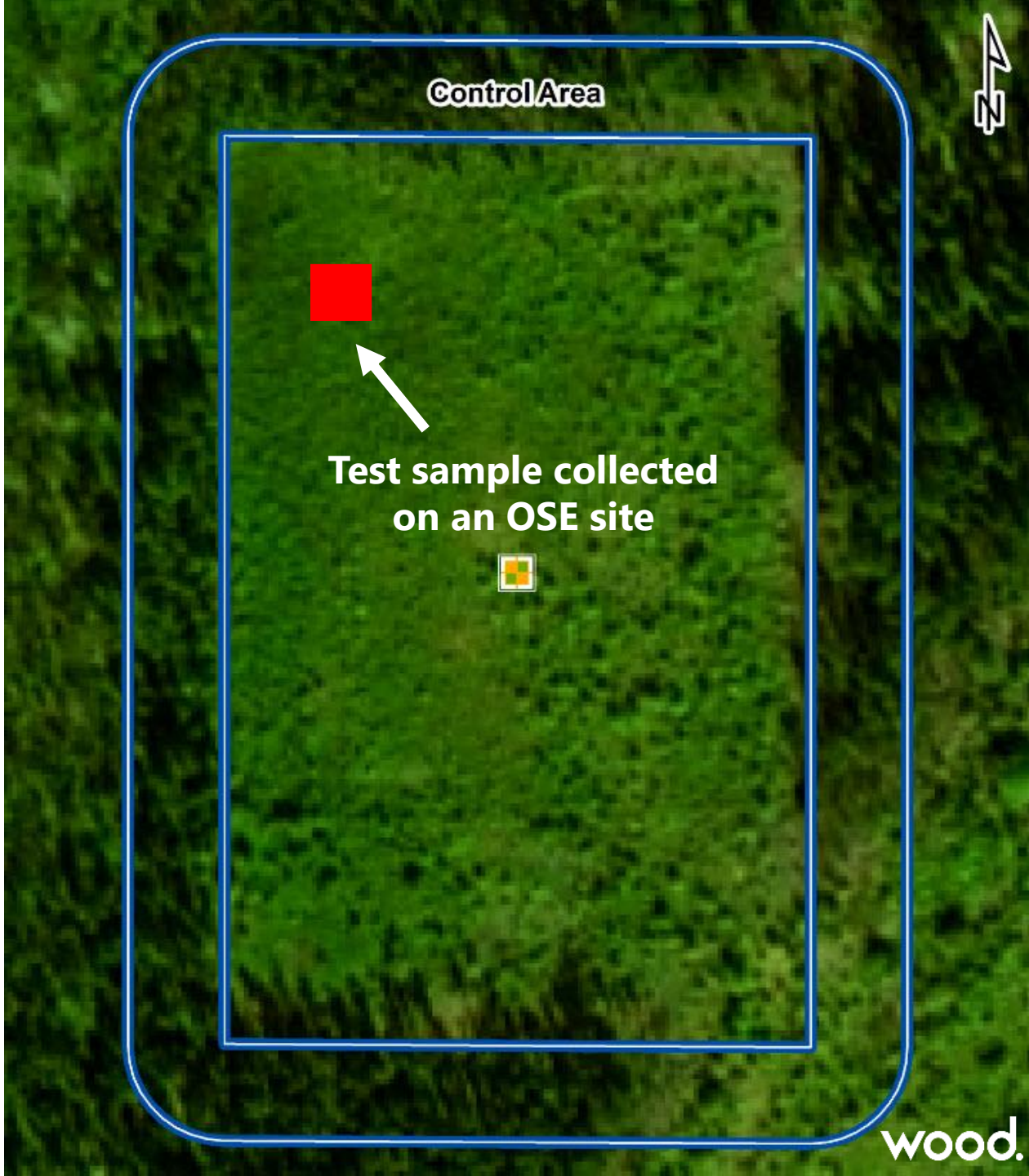
Field Data Collection



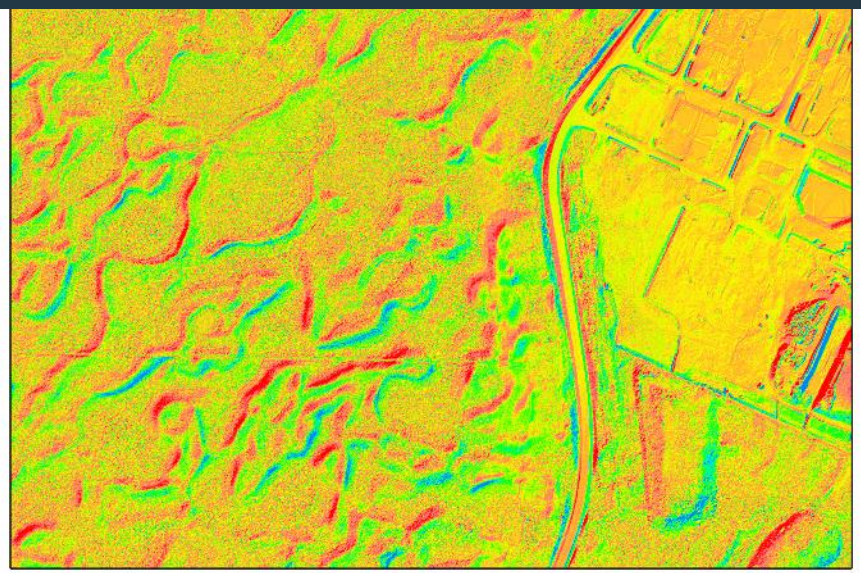


Remote Sensing Data

Very High-Resolution Satellite Imagery

- Worldview-2 satellite imagery
- Spatial resolution: 50 cm
- No. of spectral bands: 8

LiDAR Imagery



- Airborne Imaging LiDAR system
- Point density: 12.6 points/m^2
- Spatial resolution: 30 cm
- Vertical accuracy: 10 cm

Four categories of parameters were assessed…

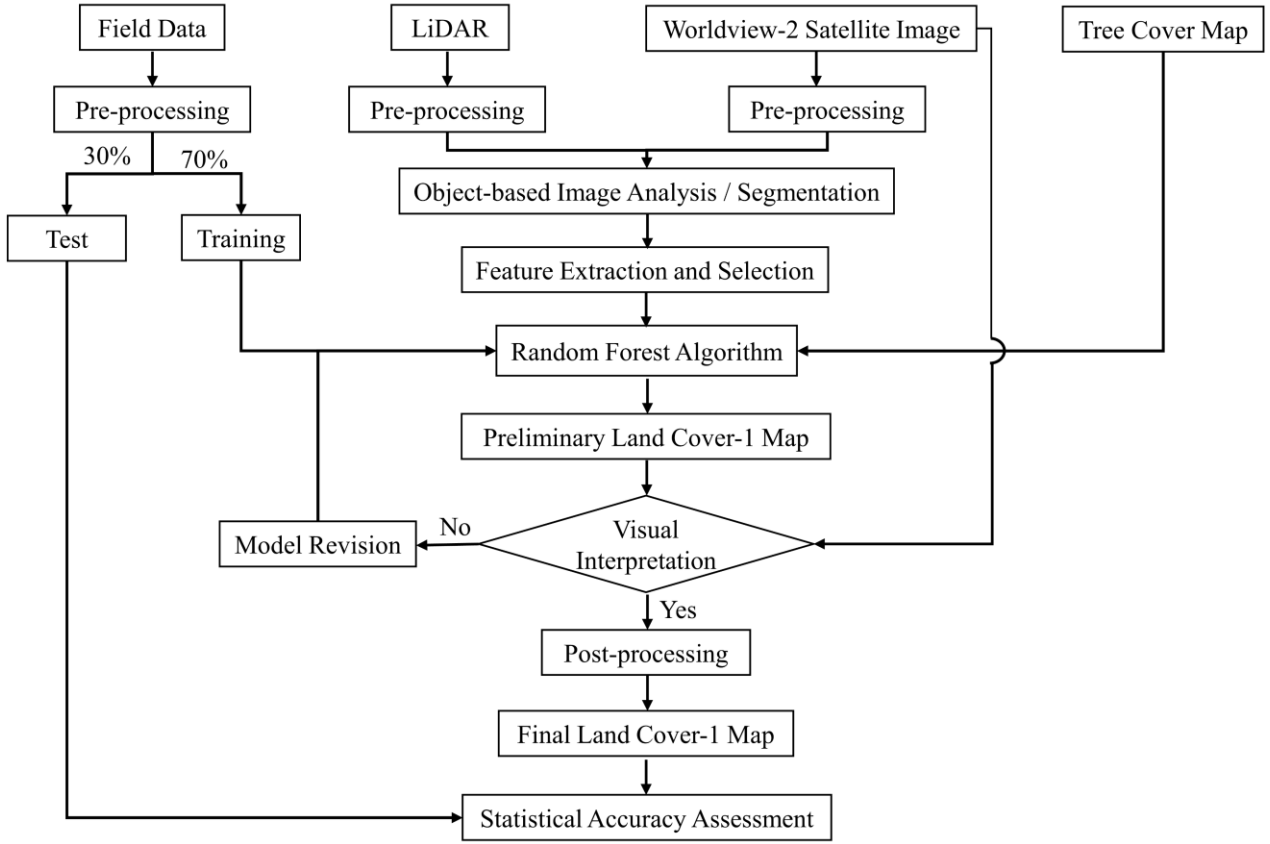
Methods

Interpretation of Results

Accuracy

Land Cover Classification: Method

- Satellite image + LiDAR + field data
- Object-based image analysis
- Tens of spectral, textural, and ratio indices
- RF machine learning algorithm
- Comprehensive post-processing



Published over 30 journal papers about land cover classification

(see https://www.researchgate.net/profile/Meisam-Amani/research for more details)

Land Cover Classification:

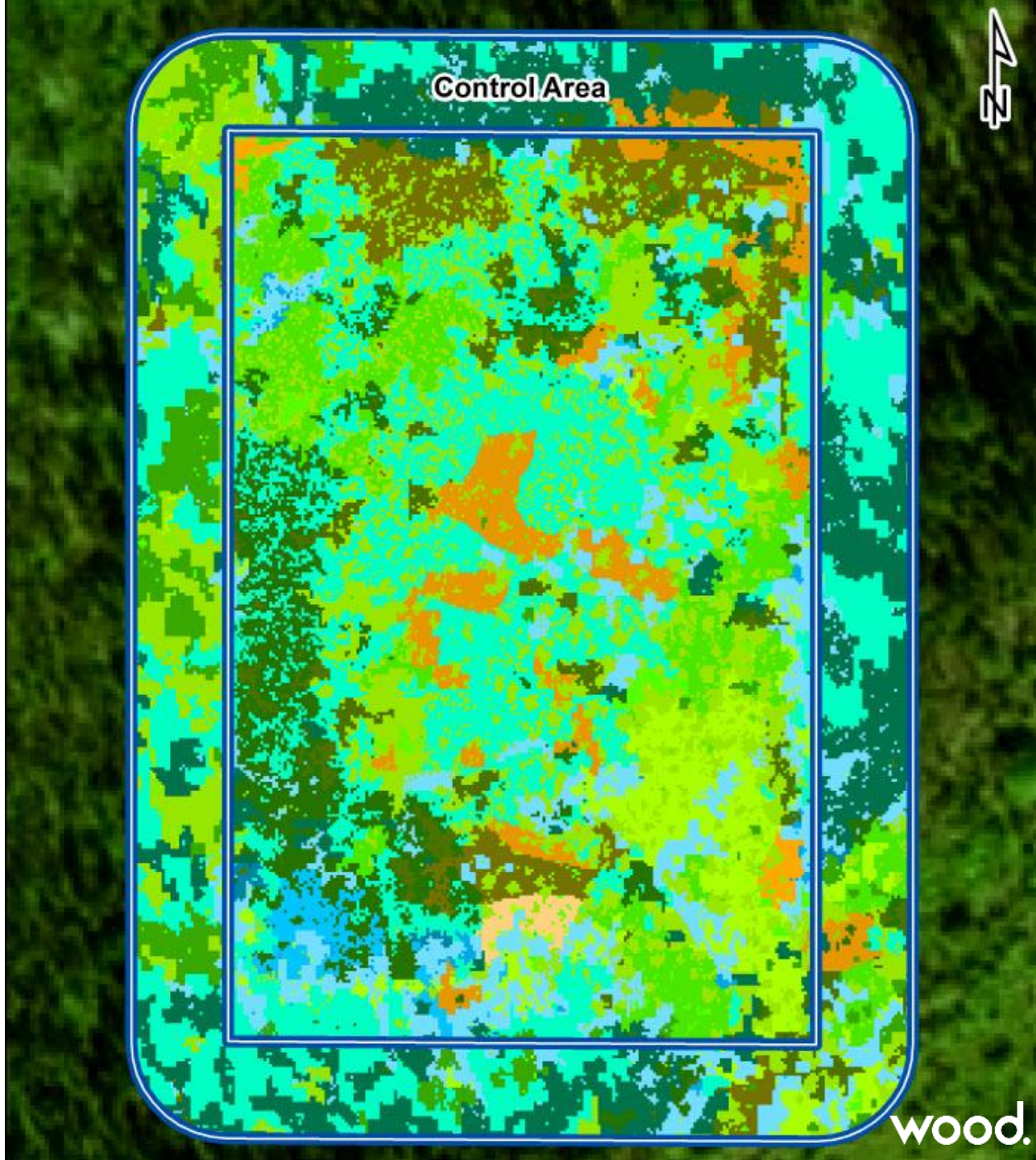
Results – Primary Classes

Break sites down into the main landscape units

Peatland vs. Forested

Legend

- Infrastructure
- Forested: Treed
- Forested: Shrubby
- Forested: Bryophyte
- Forested: Other Vegetation
- Upland: Other Vegetation
- Upland: Low Vegetation
- Peatland: Treed
- Peatland: Bryophyte
- Peatland: Shrubby
- Peatland: Other Vegetation
- Peatland: Surface Water / Emergent Vegetation
- Peatland: Low Vegetation
- Wetland: Treed
- Wetland: Shrubby
- Wetland: Other Vegetation
- Wetland: Surface Water / Emergent Vegetation
- Wetland: Low Vegetation Cover



Land Cover Classification:

Results - Sub Classes

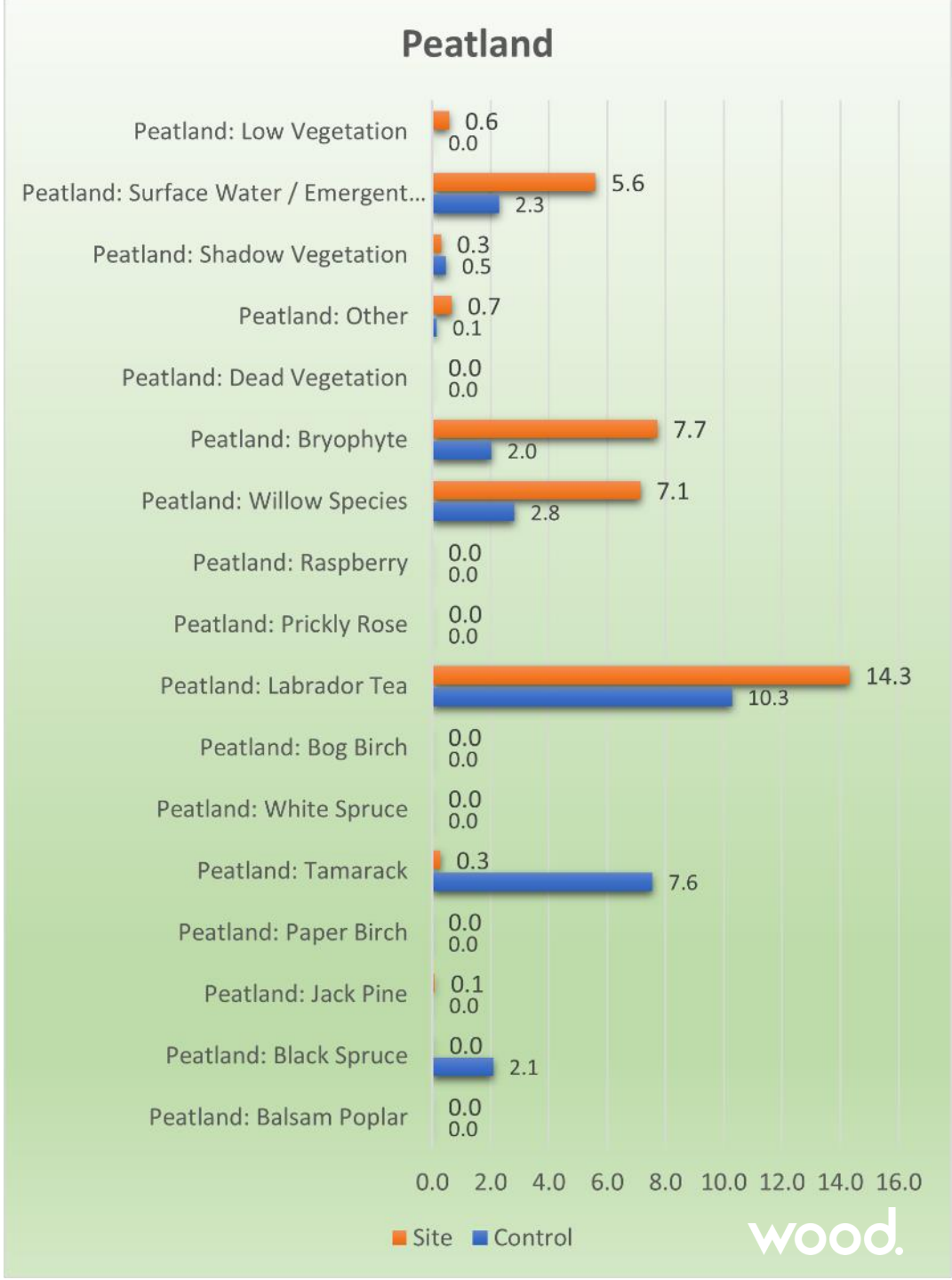
(Percent Cover)

Minimum requirement

- *Dominant species identification*
- *Low vegetation*

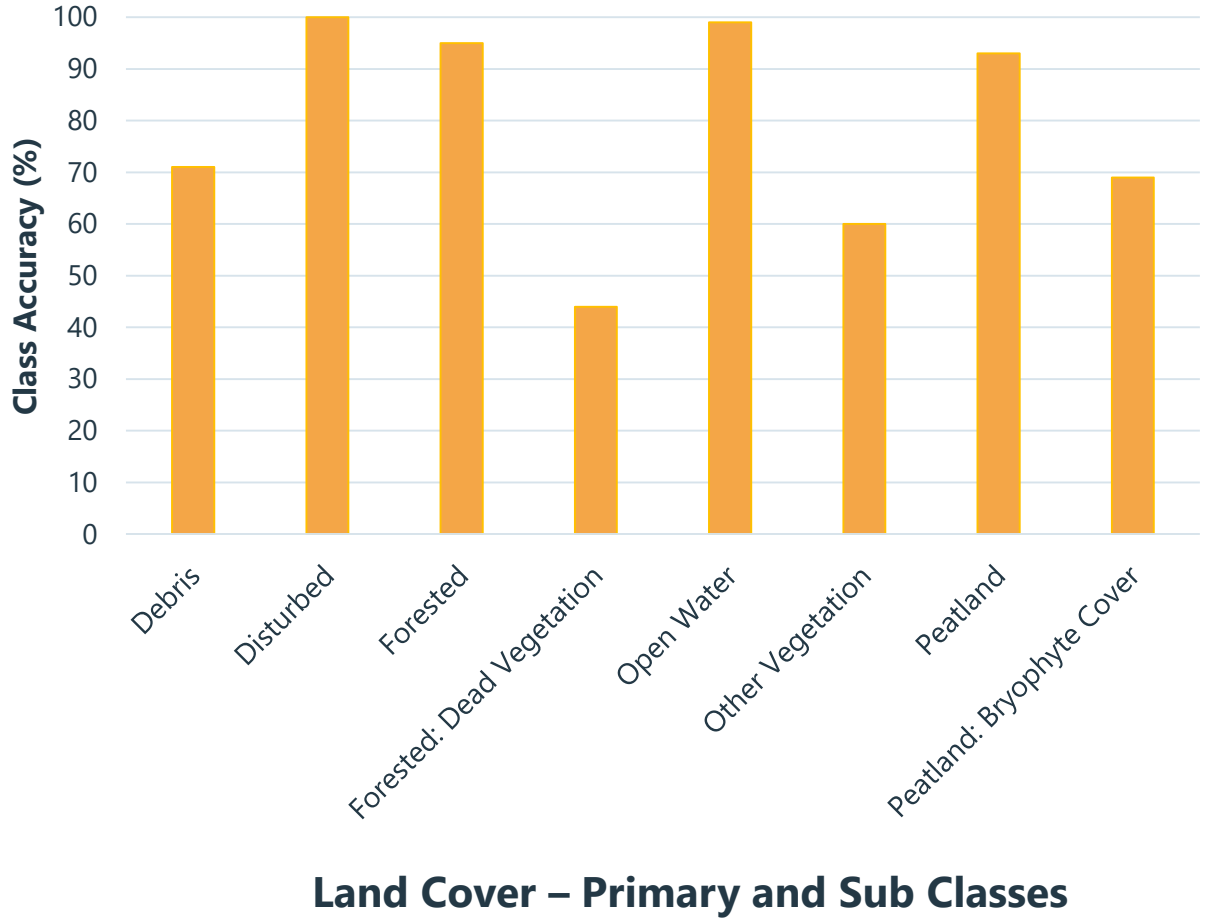
Above and beyond OSE criteria

- *Bryophyte cover (moss)*
- *Dead vegetation*



Land Cover Classification: Statistical Accuracy Level

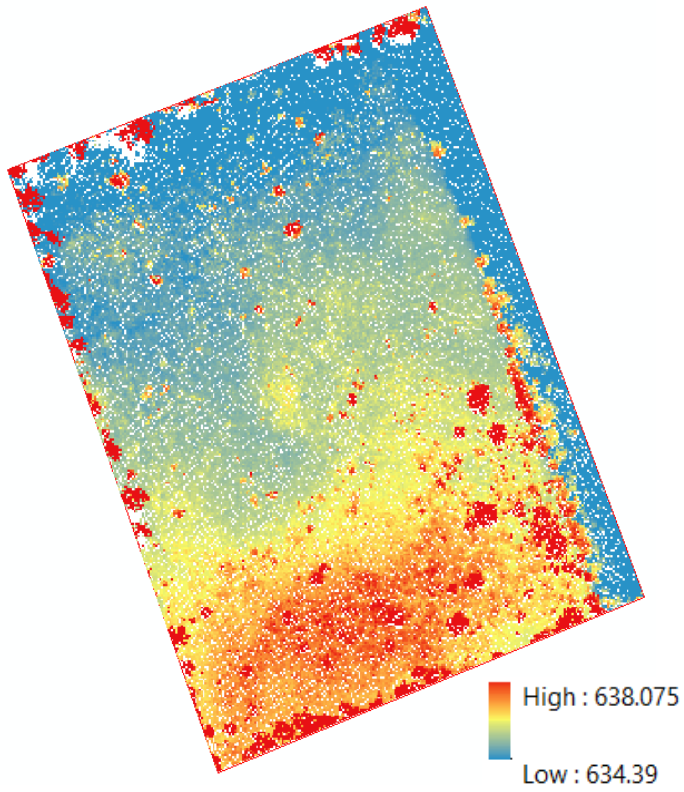
- Generated from confusion matrix
- Various accuracy measures
- Overall Accuracy:
  - Primary Classes (land type) - 84%
  - Sub Classes (percent plant cover) - 70%



Land Cover – Primary and Sub Classes

Woody Species Detection: Method

Digital Surface Model



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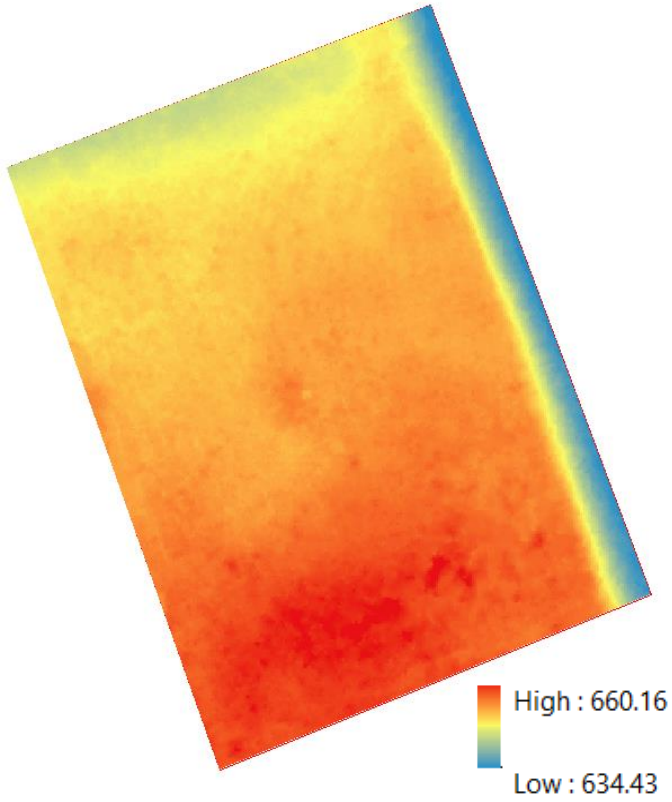
Digital Elevation Model



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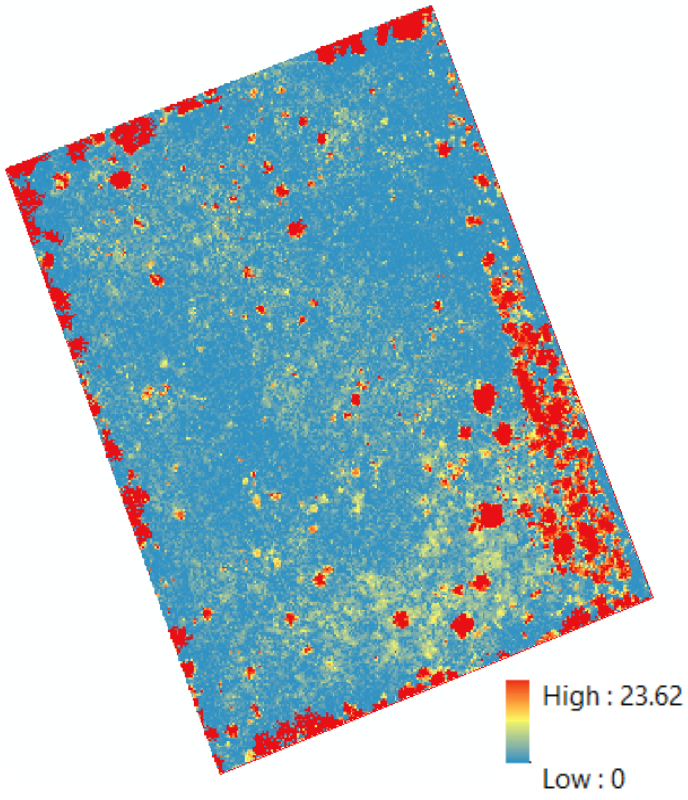
Canopy Height Model



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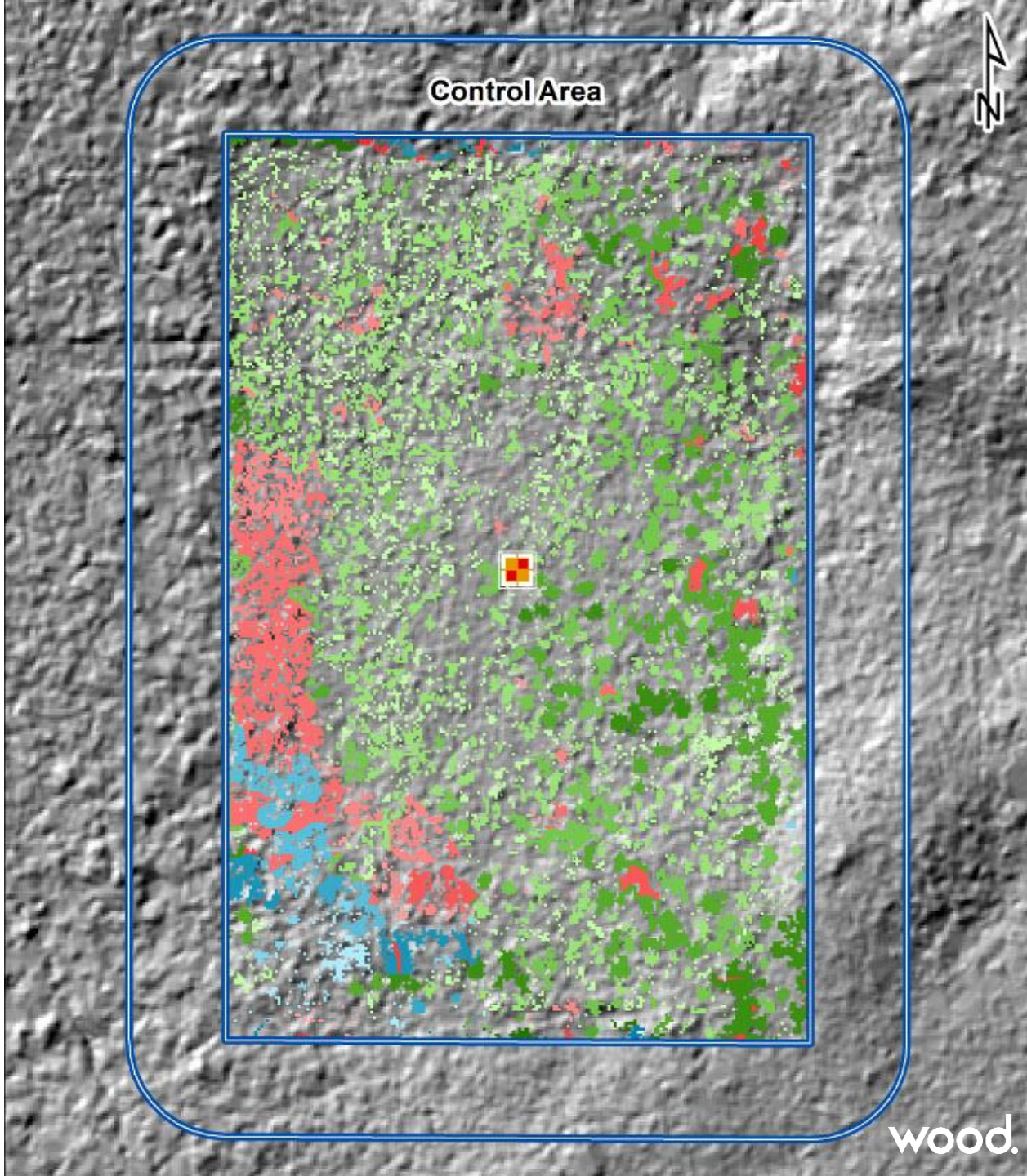
Woody Species: Results

Minimum requirement

- *Height Estimation*

Above and beyond OSE criteria

- *Canopy cover*
- *Stem Count*

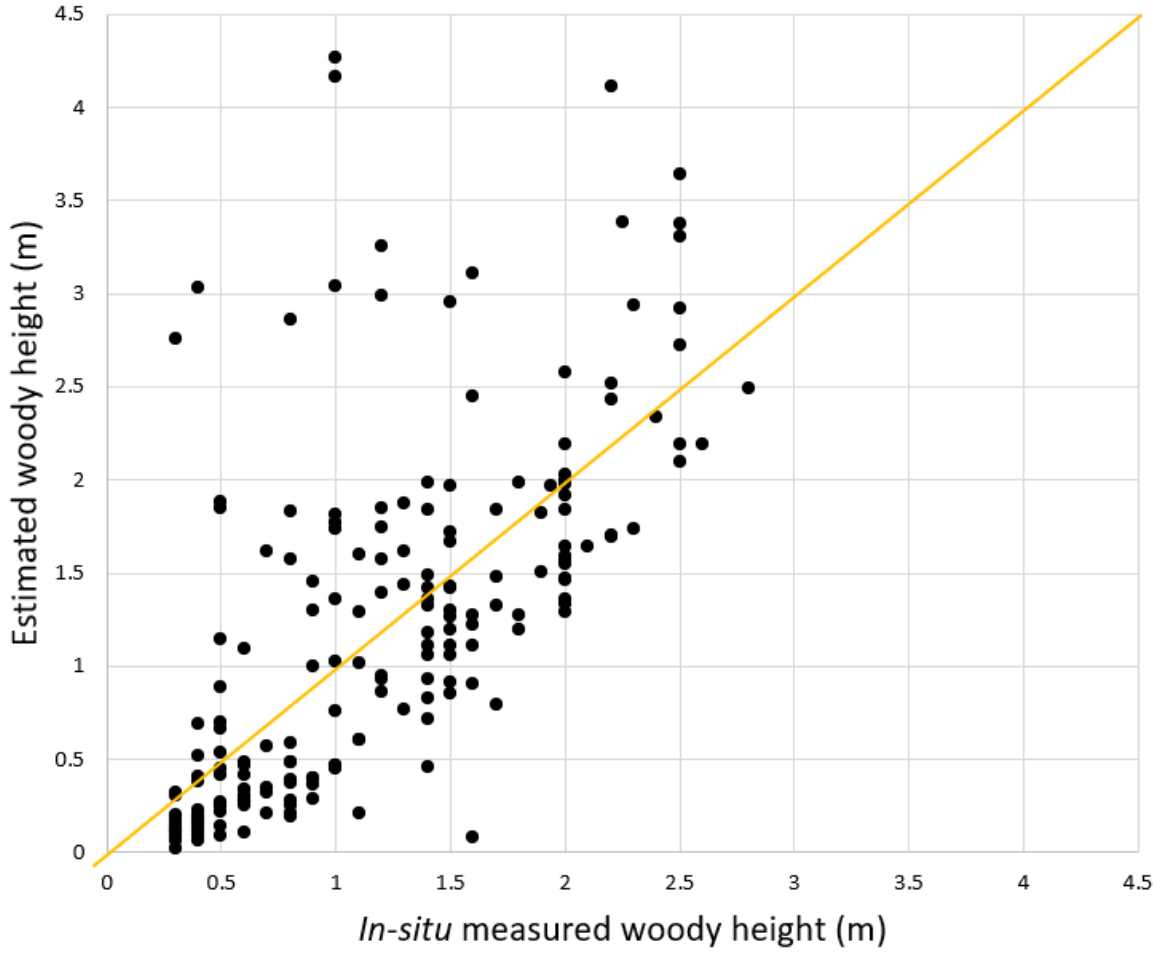


Woody Species Heights (m)

Peatland	Upland	Wetland
Peatland, ≥2.00	Upland, ≥2.00	Wetland, ≥2.00
Peatland, 1.00 - 2.00	Upland, <0.25	Wetland, <0.25
Peatland, 0.75 - 1.00	Upland, 1.00 - 2.00	Wetland, 1.00 - 2.00
Peatland, 0.50 - 0.75	Upland, 0.75 - 1.00	Wetland, 0.75 - 1.00
Peatland, 0.25 - 0.50	Upland, 0.50 - 0.75	Wetland, 0.50 - 0.75
Peatland, <0.25	Upland, 0.25 - 0.50	Wetland, 0.25 - 0.50

Woody Species Detection: Statistical Accuracy Level

- Detection accuracy: 100%
- Height accuracy: Mean Absolute Error = 0.5 m
- Remote sensing provides more information and more accuracy compared to helicopter survey



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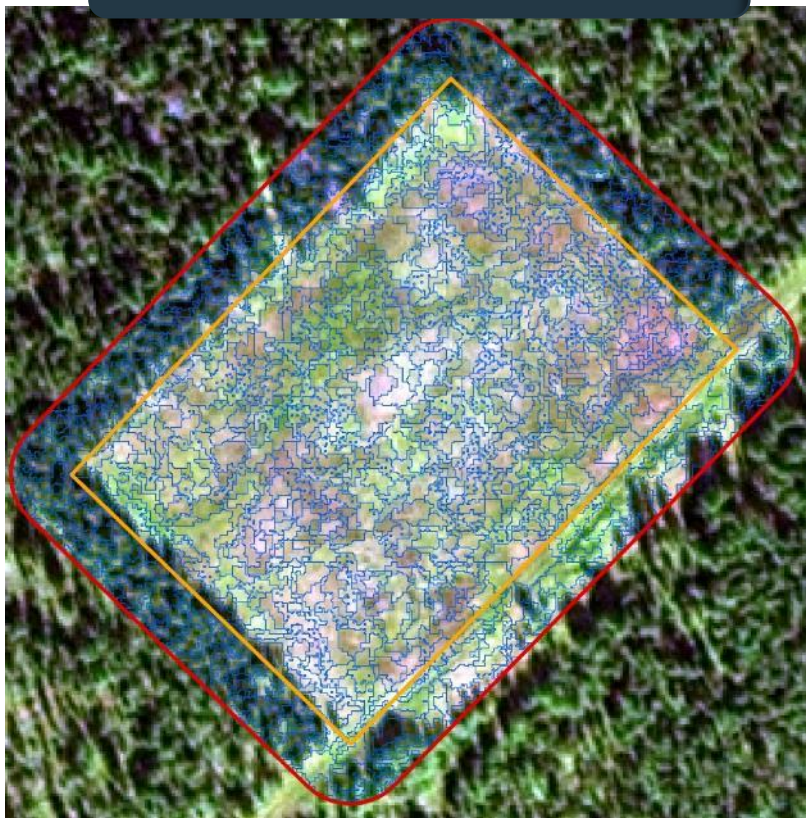
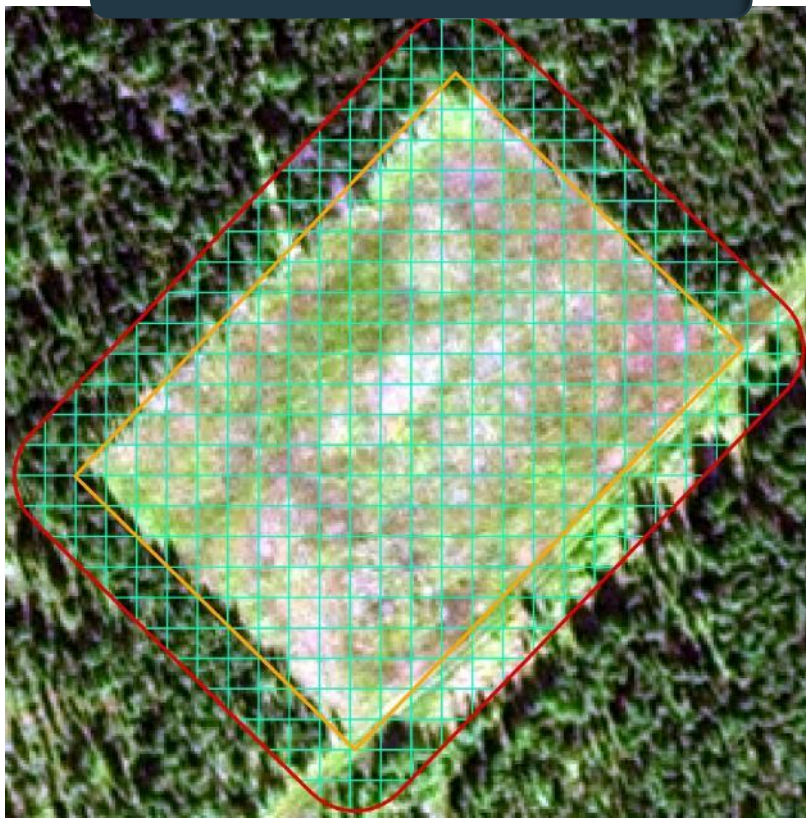
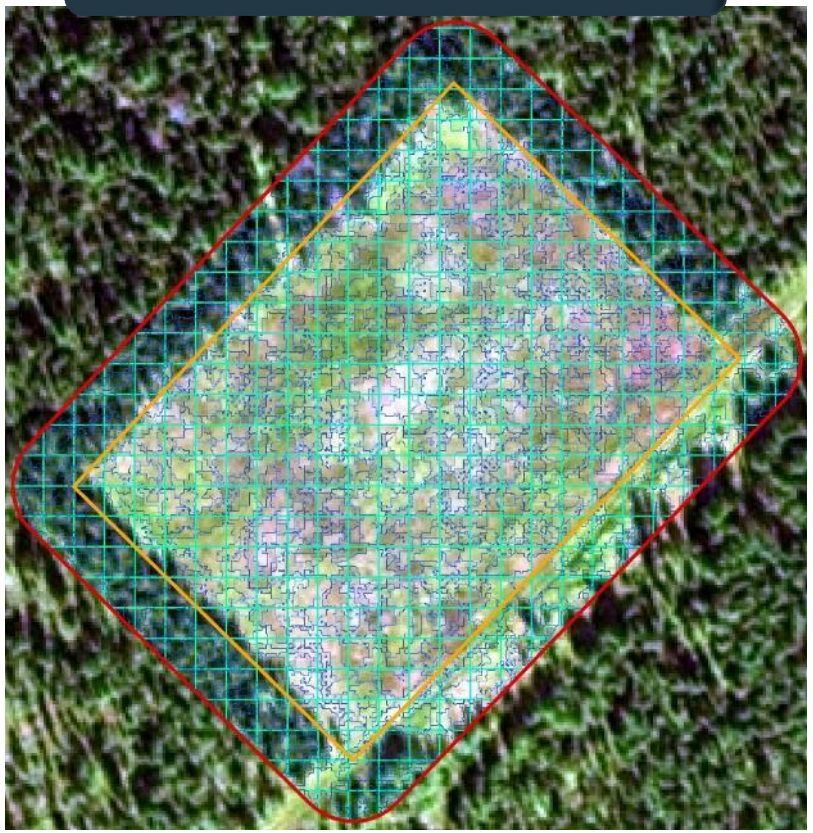
Species Diversity Mapping: Method

Segmentation → 5 x 5 m plots → Number of Species



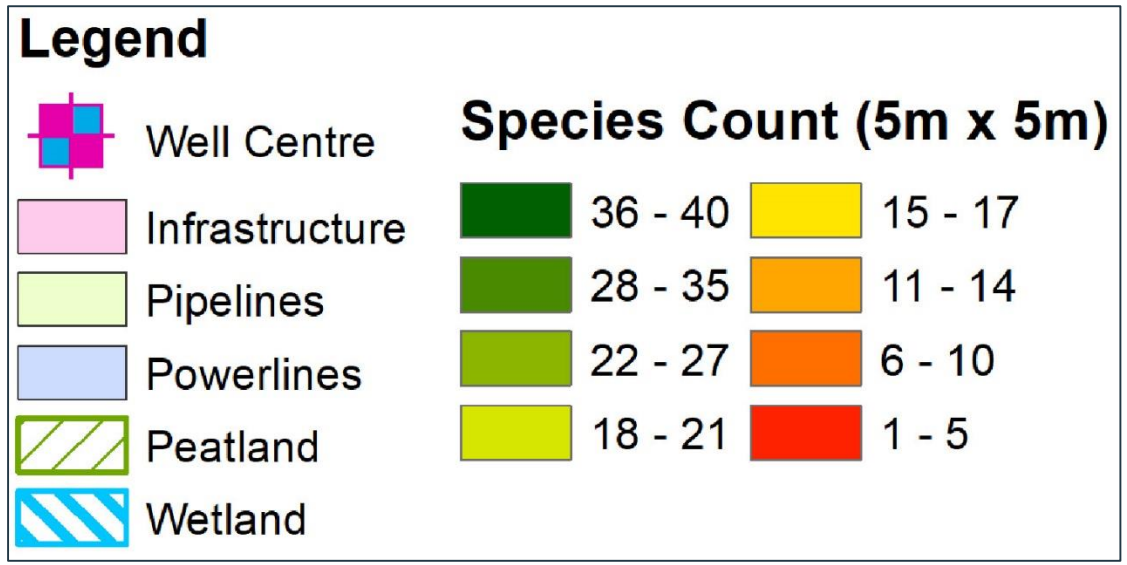


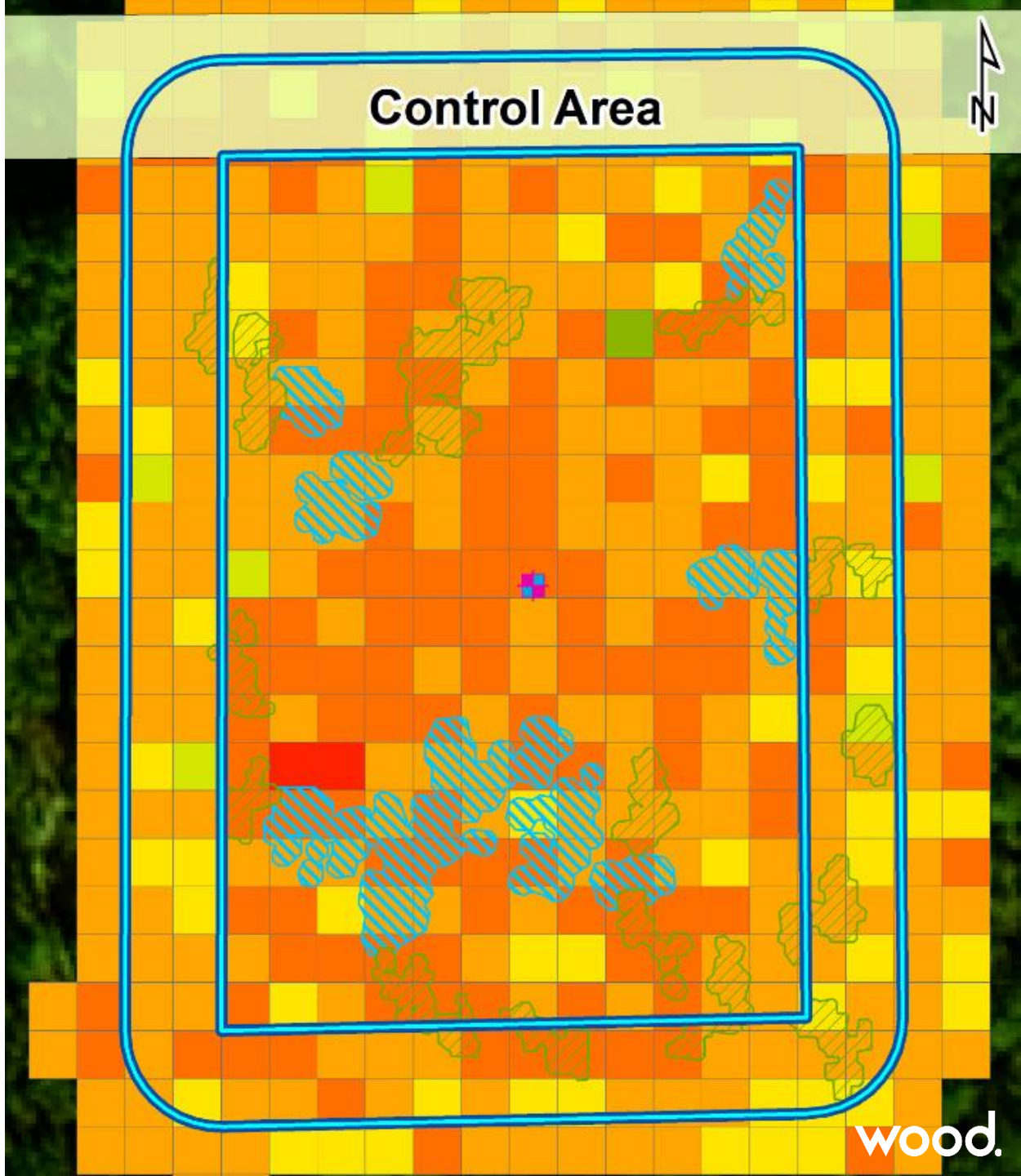


Species Diversity: Results

Above and beyond OSE criteria

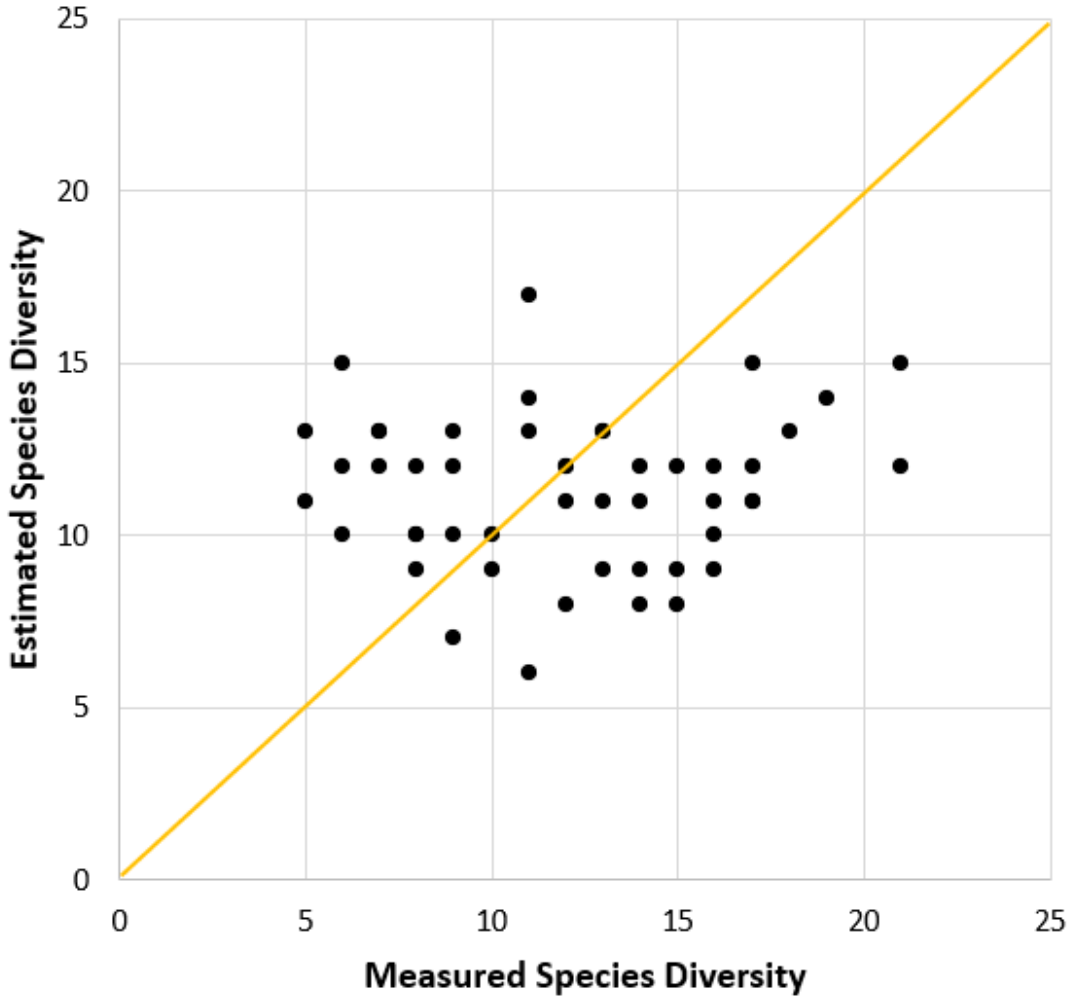
Peatland ground assessment guidelines for a Poor Fen is a minimum of 7 species per 40 x 40 m plot





Species Diversity Mapping: Statistical Accuracy Level

Mean Absolute Error = 4



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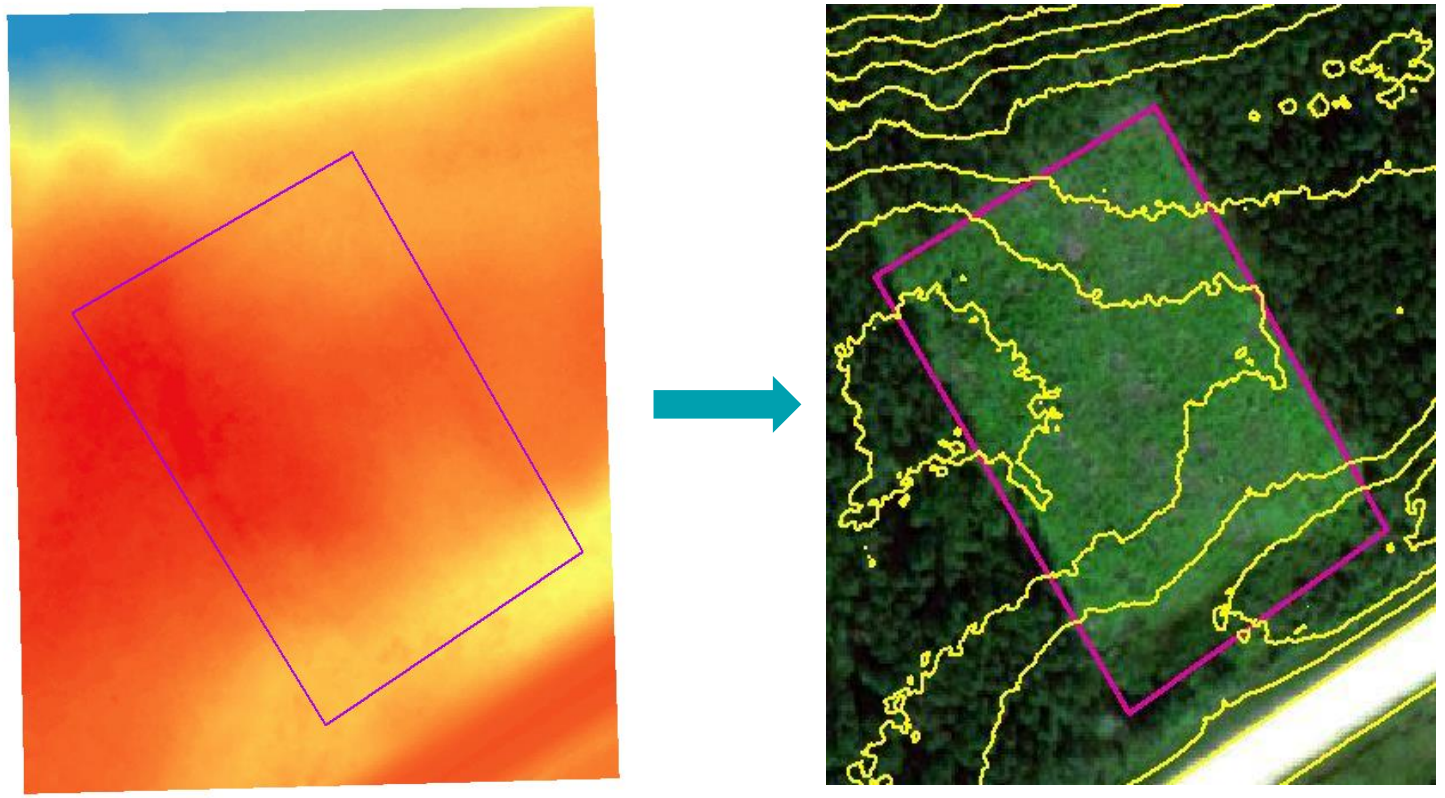
Landscape: Method

- Contours created based on LiDAR Digital Elevation Model products

- Intervals were 0.5, 1.0, 10.0, and 30.0 meters



Landscape: Results

Minimum requirement

Depressions (often at well centre)

Clay pads left in place

Hill cuts

Legend

Well Centre

Contour Noted*

30 m Contour

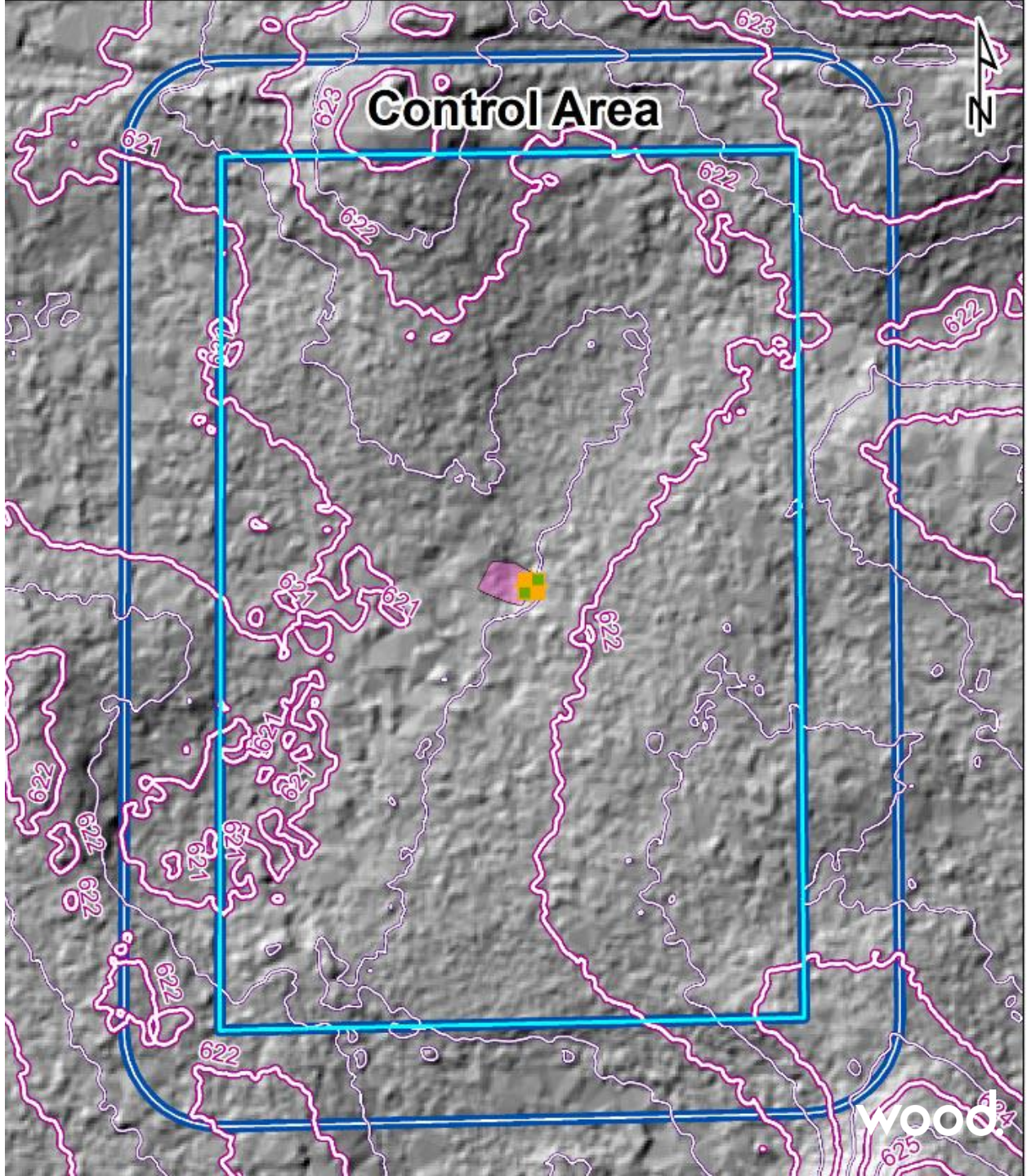
10 m Contour

1 m Contour

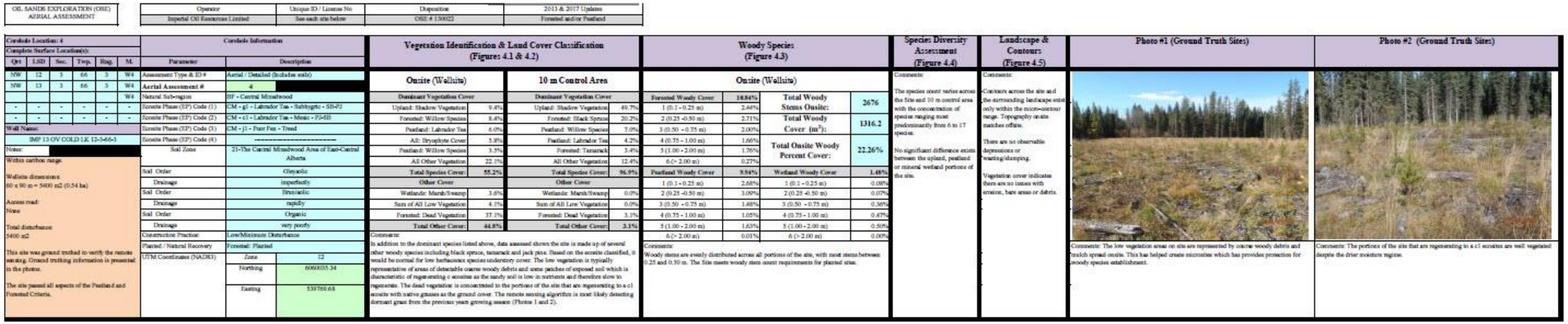
0.5 m Contour

* 6 x 4 metres

20 - 30 cm lower elevation at well center.



Final Product



OIL SANDS EXPLORATION (OSE) AERIAL ASSESSMENT

Operator	Unique ID / License No	Disposition	2013 & 2017 Updates
Imperial Oil Resources Limited	See each site below	OSE # 130022	Forested and/or Peatland

Corvids Location: 4 Complete Surface Location(s): Qtr	LSD	Sec.	Twp.	Rng.	M.
NW	12	3	66	3	W4
NW	13	3	66	3	W4
					W4
-	-	-	-	-	-
-	-	-	-	-	-
Well Name: IMP 13-3W COLD LK 12-3-66-3					
Notes: [redacted] Within carbon range. Wellsite dimensions: 60 x 90 m = 5400 m2 (0.54 ha) Access road: None Total disturbance: 5400 m2. This site was ground truthed to verify the remote sensing. Ground truthing information is presented in the photos. The site passed all aspects of the Peatland and Forested Criteria.					

Corvids Information	
Parameter	Description
Assessment Type & ID #	Aerial / Detailed (Includes soils)
Aerial Assessment #	4
Natural Sub-region	BF - Central Mixedwood
Ecosite Phase (EP) Code (1)	CM - g1 - Labrador Tea - Subhygric - SH-PJ
Ecosite Phase (EP) Code (2)	CM - c1 - Labrador Tea - Mesic - PJ-SH
Ecosite Phase (EP) Code (3)	CM - j1 - Poor Fen - Treed
Ecosite Phase (EP) Code (4)	----------
Soil Zone	21-The Central Mixedwood Area of East-Central Alberta
Soil Order	Gleysolic
Drainage	imperfectly
Soil Order	Brunisolic
Drainage	rapidly
Soil Order	Organic
Drainage	very poorly
Construction Practice:	Low/Minimum Disturbance
Planted / Natural Recovery	Forested: Planted
UTM Coordinates (NAD83)	Zone: 12; Northing: 6060035.34; Easting: 539769.68

Vegetation Identification & Land Cover Classification (Figures 4.1 & 4.2)			
Onsite (Wellsite)		10 m Control Area	
Dominant Vegetation Cover		Dominant Vegetation Cover	
Upland: Shadow Vegetation	9.4%	Upland: Shadow Vegetation	49.7%
Forested: Willow Species	8.4%	Forested: Black Spruce	20.2%
Peatland: Labrador Tea	6.0%	Peatland: Willow Species	7.0%
All: Bryophyte Cover	5.8%	Peatland: Labrador Tea	4.2%
Peatland: Willow Species	3.5%	Forested: Tamarack	3.4%
All Other Vegetation	22.1%	All Other Vegetation	12.4%
Total Species Cover:	55.2%	Total Species Cover:	96.9%
Other Cover		Other Cover	
Wetlands: Marsh/Swamp	3.6%	Wetlands: Marsh/Swamp	0.0%
Sum of All Low Vegetation	4.1%	Sum of All Low Vegetation	0.0%
Forested: Dead Vegetation	37.1%	Forested: Dead Vegetation	3.1%
Total Other Cover:	44.8%	Total Other Cover:	3.1%

Comments: In addition to the dominant species listed above, data assessed shows the site is made up of several other woody species including black spruce, tamarack and jack pine. Based on the ecosite classified, it would be normal for low herbaceous species understory cover. The low vegetation is typically representative of areas of detectable coarse woody debris and some patches of exposed soil which is characteristic of regenerating c ecosites as the sandy soil is low in nutrients and therefore slow to regenerate. The dead vegetation is concentrated to the portions of the site that are regenerating to a c1 ecosite with native grasses as the ground cover. The remote sensing algorithm is most likely detecting dormant grass from the previous years growing season (Photos 1 and 2).

Woody Species (Figure 4.3)			
Onsite (Wellsite)			
Forested Woody Cover	10.84%	Total Woody Stems Onsite:	2676
1 (0.1 - 0.25 m)	2.44%		
2 (0.25 -0.50 m)	2.71%	Total Woody Cover (m^2):	1316.2
3 (0.50 - 0.75 m)	2.00%		
4 (0.75 - 1.00 m)	1.66%	Total Onsite Woody Percent Cover:	22.26%
5 (1.00 - 2.00 m)	1.76%		
6 (> 2.00 m)	0.27%		
Peatland Woody Cover	9.94%	Wetland Woody Cover	1.48%
1 (0.1 - 0.25 m)	2.68%	1 (0.1 - 0.25 m)	0.08%
2 (0.25 -0.50 m)	3.09%	2 (0.25 -0.50 m)	0.07%
3 (0.50 - 0.75 m)	1.48%	3 (0.50 - 0.75 m)	0.36%
4 (0.75 - 1.00 m)	1.05%	4 (0.75 - 1.00 m)	0.47%
5 (1.00 - 2.00 m)	1.63%	5 (1.00 - 2.00 m)	0.50%
6 (> 2.00 m)	0.01%	6 (> 2.00 m)	0.00%

Comments: Woody stems are evenly distributed across all portions of the site, with most stems between 0.25 and 0.50 m. The Site meets woody stem count requirements for planted sites.

Species Diversity Assessment (Figure 4.4)
Comments: The species count varies across the Site and 10 m control area with the concentration of species ranging most predominantly from 6 to 17 species. No significant difference exists between the upland, peatland or mineral wetland portions of the site.

Landscape & Contours (Figure 4.5)
Comments: Contours across the site and the surrounding landscape exist only within the micro-contour range. Topography on site matches offsite. There are no observable depressions or ponding/slumping. Vegetation cover indicates there are no issues with erosion, bare areas or debris.

Photo #1 (Ground Truth Site)	Photo #2 (Ground Truth Site)
[image]	[image]
Comments: The low vegetation areas on site are represented by coarse woody debris and mulch spread onsite. This has helped create microsites which has provides protection for woody species establishment.	Comments: The portions of the site that are regenerating to a c1 ecosites are well vegetated despite the drier moisture regime.

- Example of a the modified ‘Tool & Record of Observation’
- Plus additional four figures attached for each site:
    1. Land Cover Classification and Vegetation Identification
    2. Wood Species Heights
    3. Species Diversity
    4. Landscape Assessment

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Final Results

AER Submission (Dec 2020)

- Assessments
- Methods report with statistical accuracies assessment

AER Decision (Jan 2021)

- DSA considered complete
- Reclamation Certificates issued
- Better data (quantitative vs. educated guess)

Wood's Global Inspire Award Winner for Impactful Innovation

'First Reclamation Certificate issued by AER using Remote Sensing Technology'

Closing Thoughts

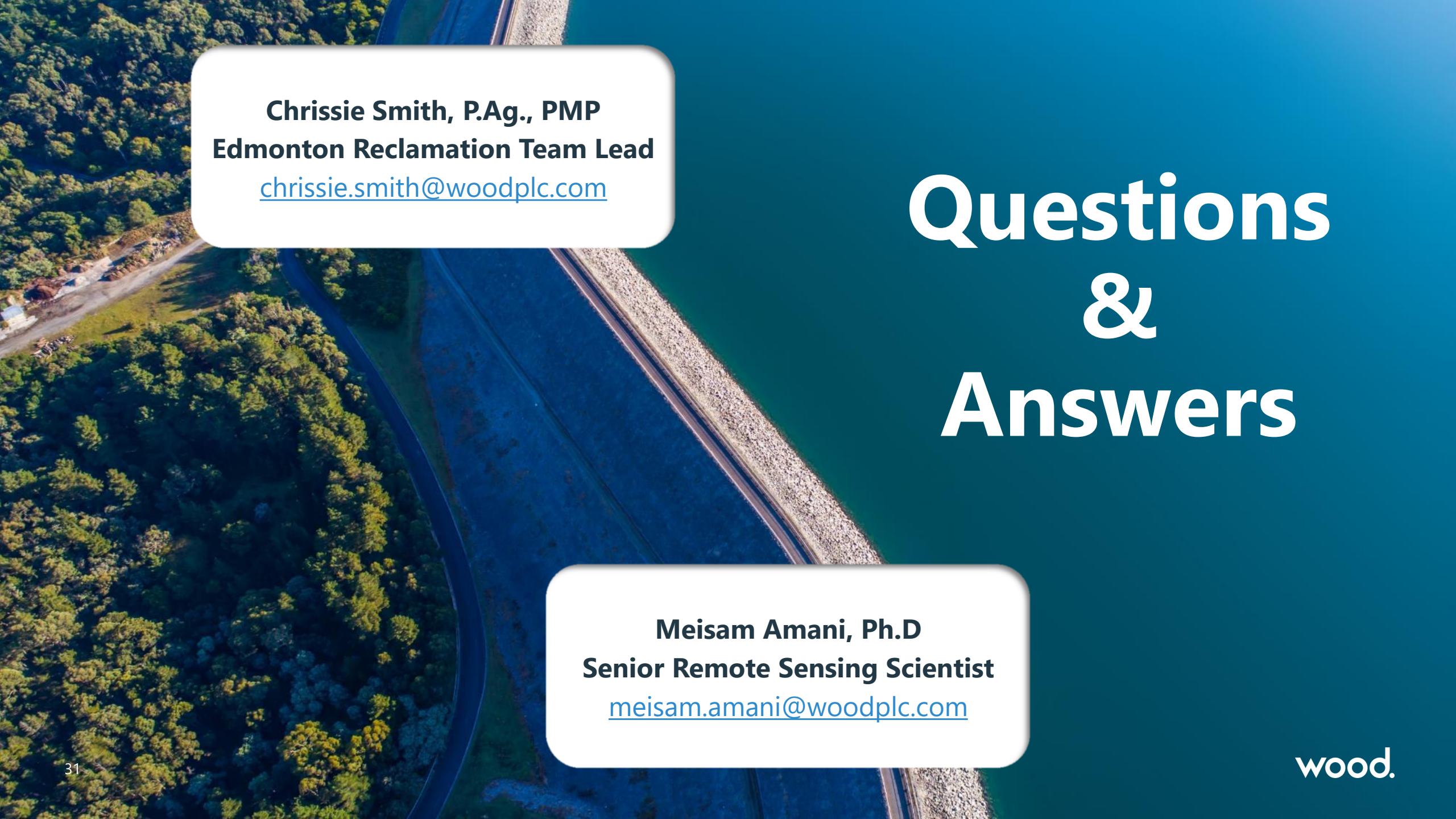
Upsides of remote sensing for OSE management

- Reduced safety exposure and costs through reduced helicopter flight times
- Improved data quality, and the data is usable later for other applications.
- Capacity to close large OSE portfolios with simultaneous assessments.
- Little field time and automates almost the entire process of mapping.

Considerations for future execution

- Efficient imagery capture strategies required to make it viable

Models like this can be used to address other regulatory or execution needs



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Questions & Answers

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