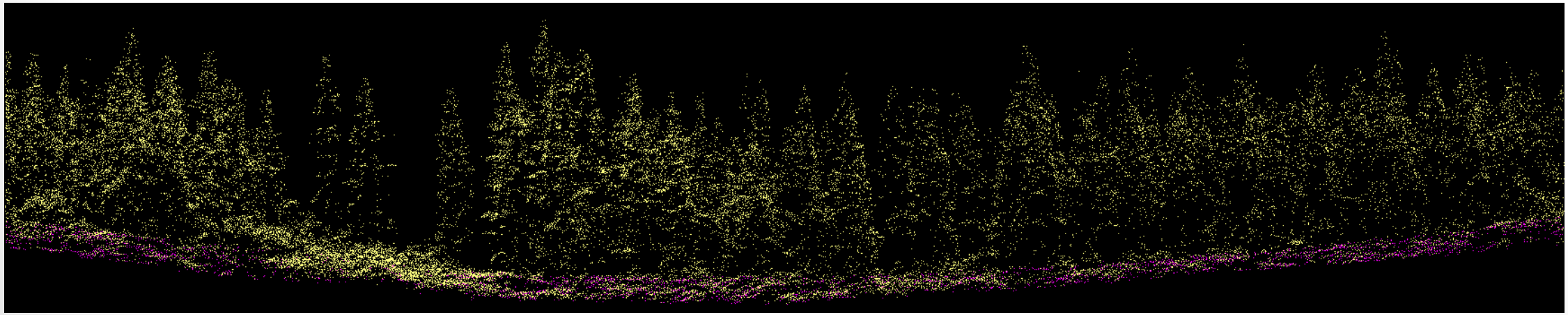
Practical Applications of LiDAR in the BC Forest Industry

February 2017

SISCO Winter Workshop



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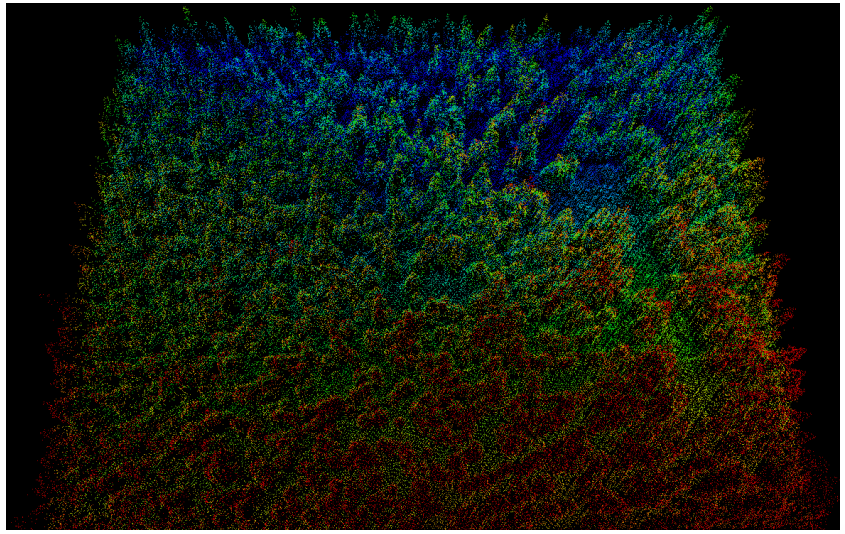
What is LiDAR – 'Refresher'

- **Li**ght **D**etection **A**nd **R**anging
- An active type of remote sensing where laser pulses are emitted from a sensor and returned to the sensor to determine highly accurate X, Y, Z coordinates of the target
- With modern aircraft-mounted sensors, > 500,000 pulses are emitted each second
- Typical point density is currently ~8-10 pulses/m^2; each pulse can have up to 5-7 returns in forested areas.



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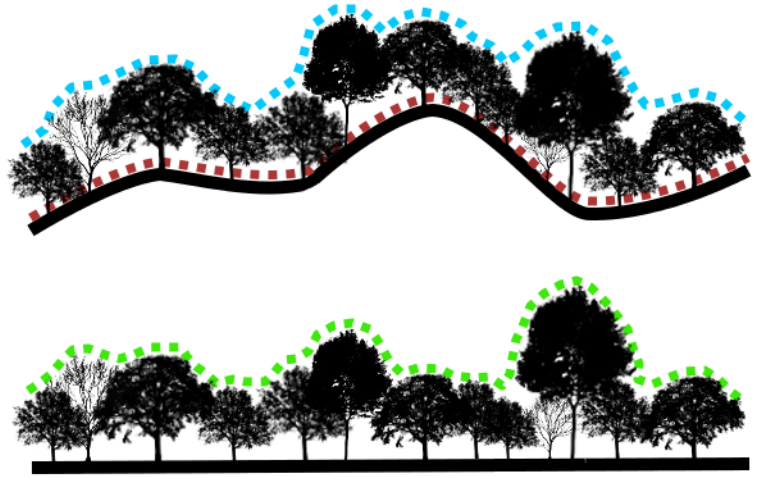
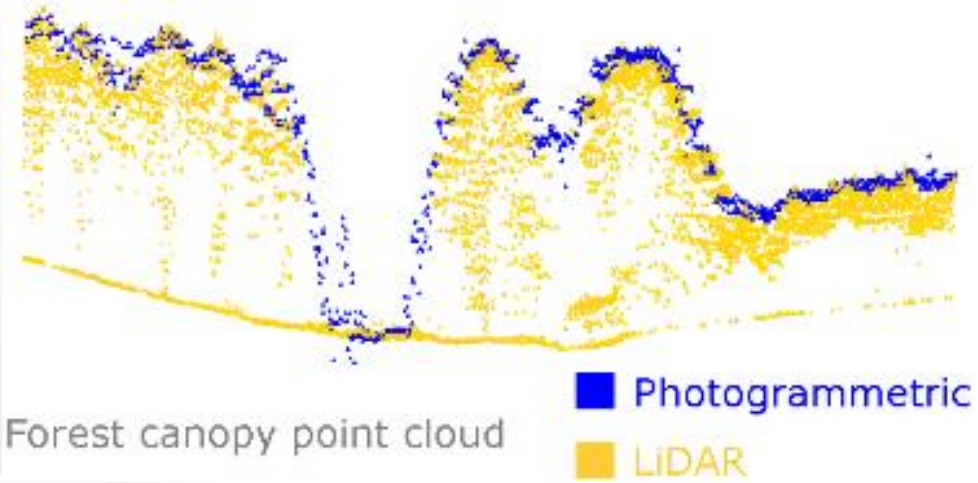
Difference of Point Clouds from Imagery (SGM)

LiDAR vs SGM

(SGM - Semi-Global Matching or 'Pho-DAR')



Point Cloud profile view (z values) – Digital Surface Model (DSM)



- LiDAR collects points from ground to top of canopy
- Pho-DAR collects 'points' (data) only along surface

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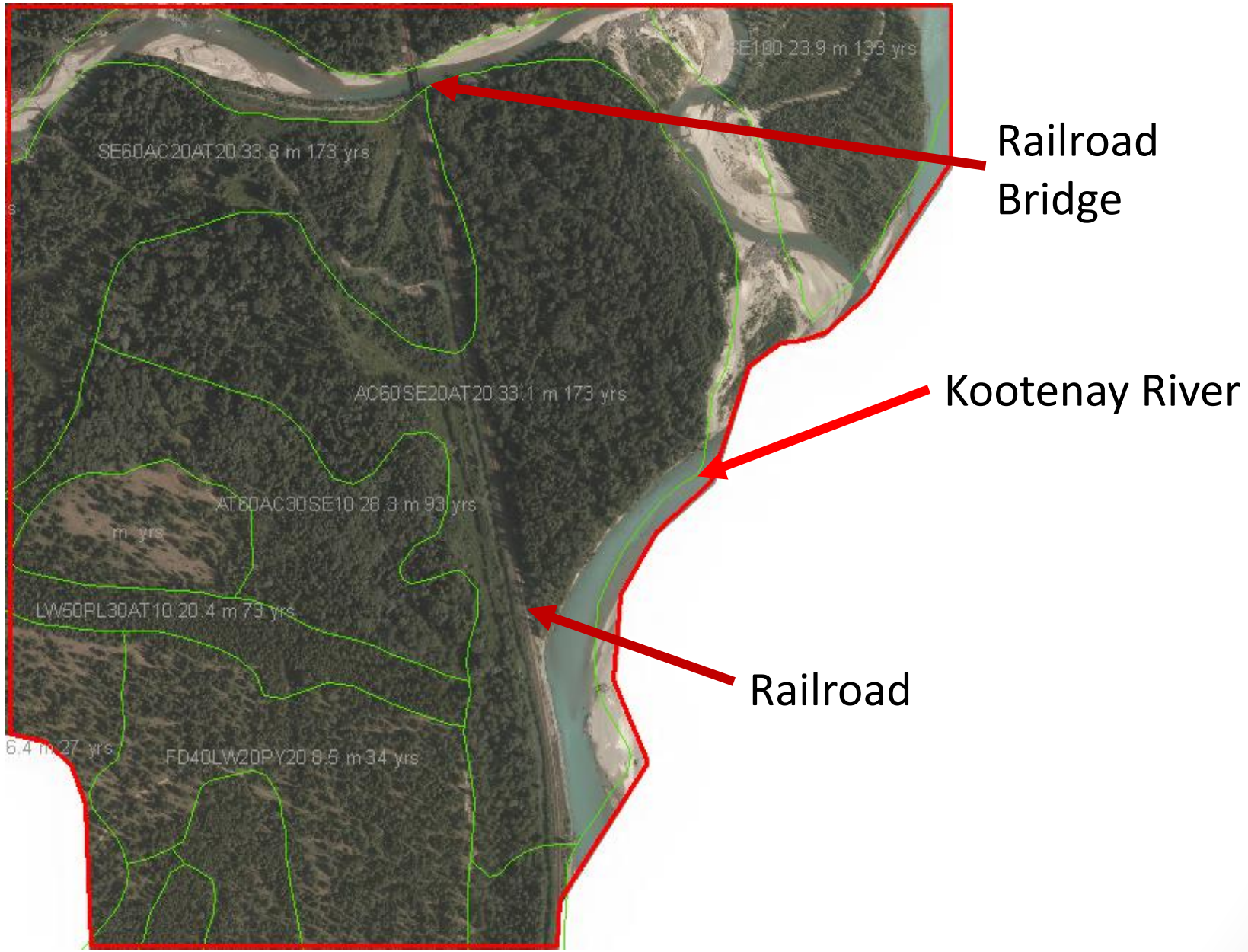
LiDAR Point Cloud Demo

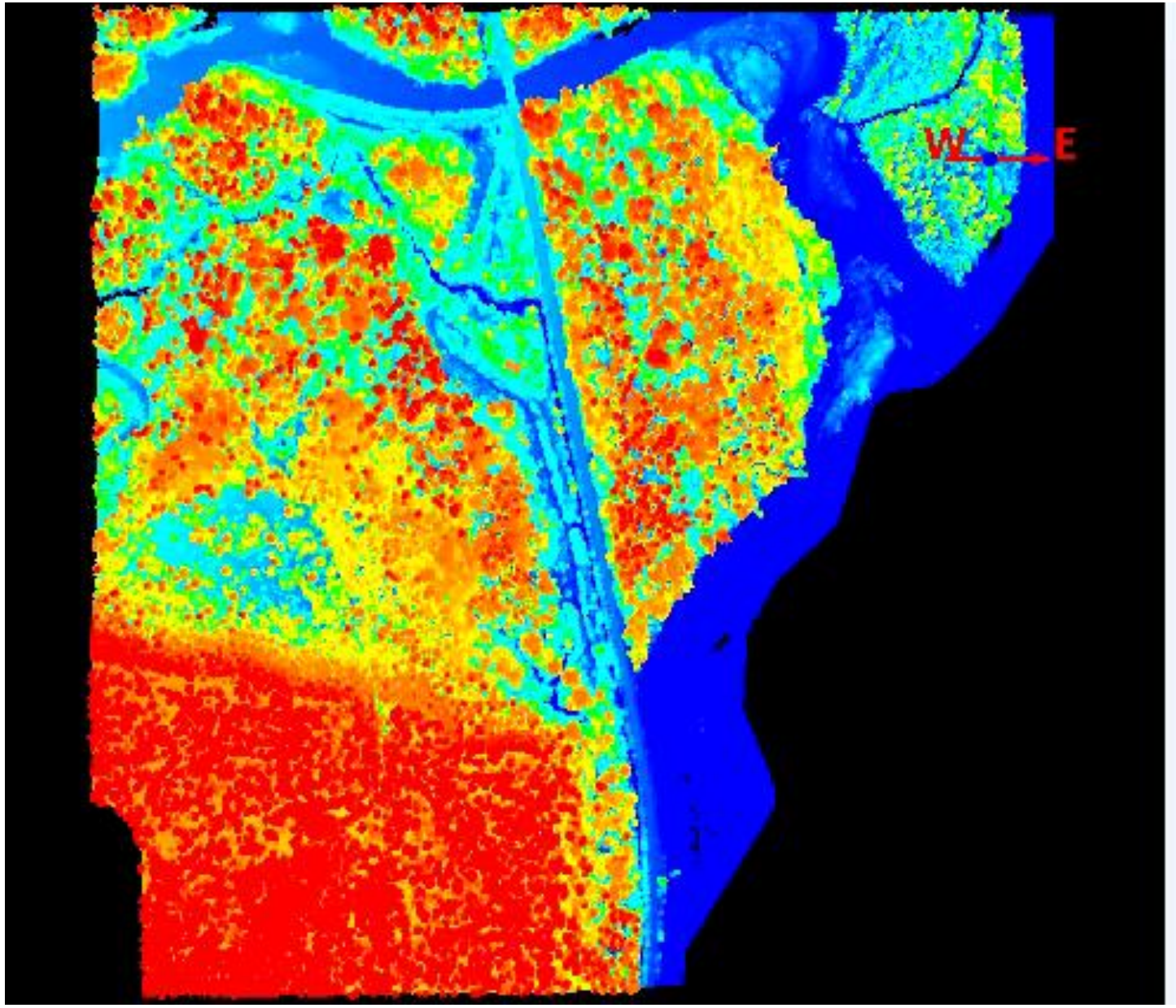
- Raw LiDAR point cloud
- East Kootenays
- IDFdm2



LiDAR Point Cloud Demo

- Raw LiDAR point cloud

- Blue – Ground / Water
- Yellow – 17m
- Orange – 25m
- Red – 30m



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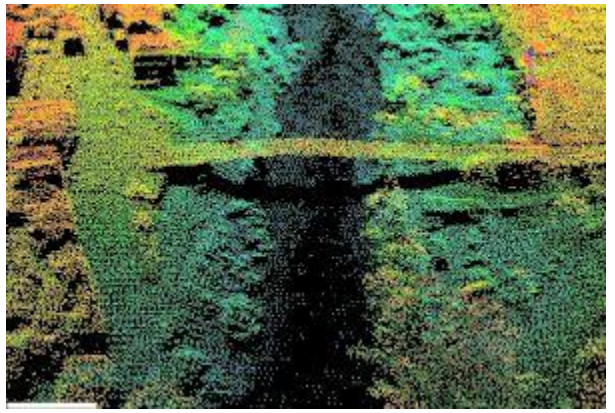
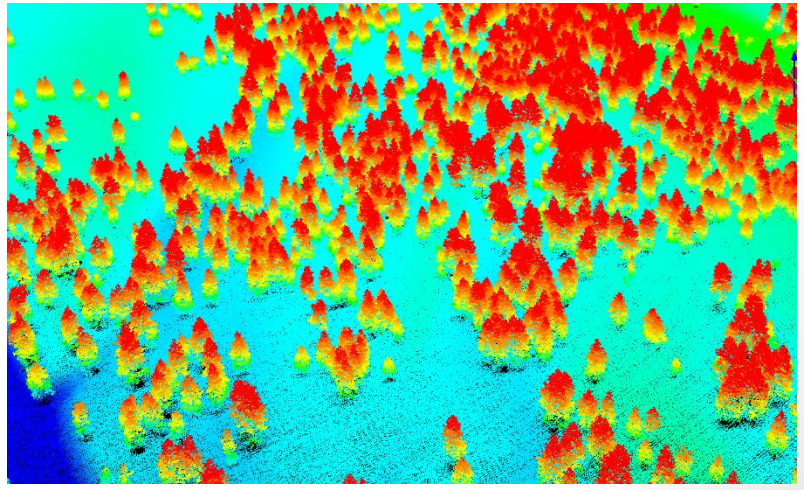
Overview of Applications



- Operational Planning (Blocks, Roads, Bridges)
- Watershed Management
- Terrain Assessments / Management
- Avalanche Assessments
- Stand Structure Assessments (wildlife habitat, selection cutting, understory detection)
- Visual Assessments
- Forest Inventory
  - Strategic: Improving VRI / Supply analysis / Stand and Stocking tables
  - Operational: Area based approach (low density lidar)
  - Operational: Single tree inventory (higher density lidar)
  - Operational: Economic Analysis



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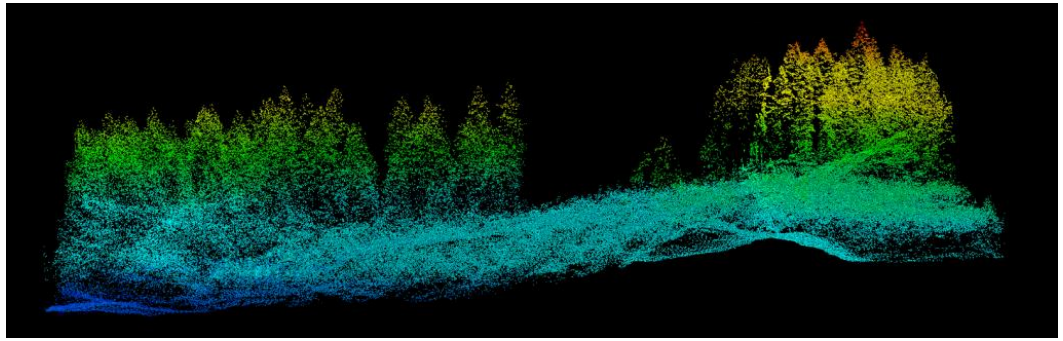
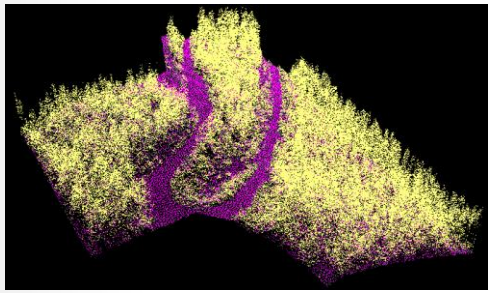
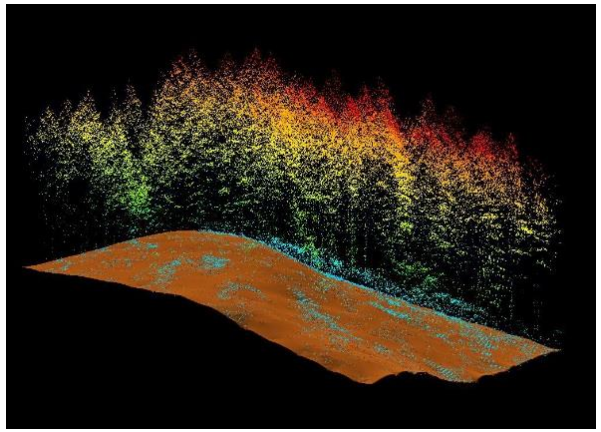
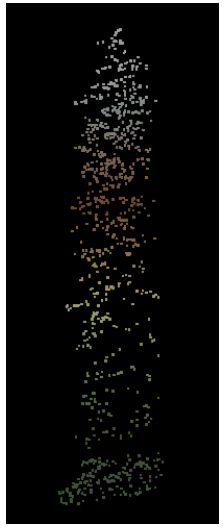
Operational Planning – '*The Blindfold Comes Off*'

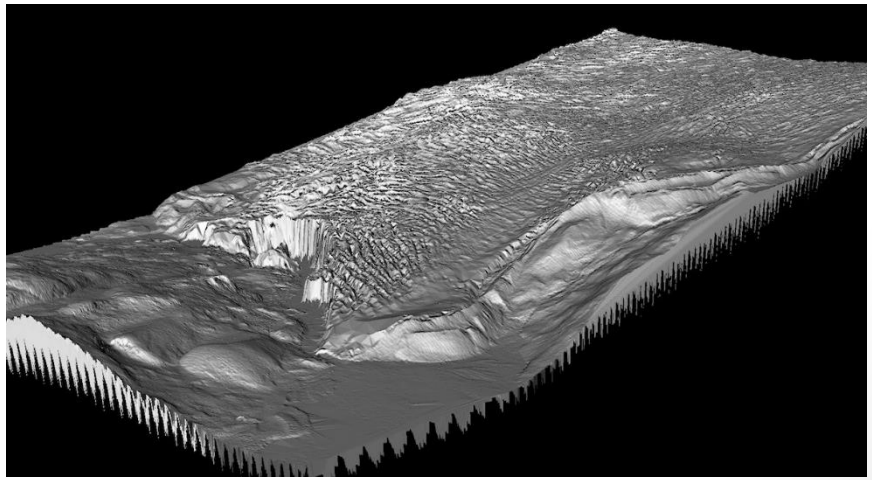
- Lidar allows detailed office based planning because of highly accurate spatial information:
  - Slope / Aspect / Elevation (terrain information)
  - Streams / Lakes / Wet areas
  - Tree height / density information











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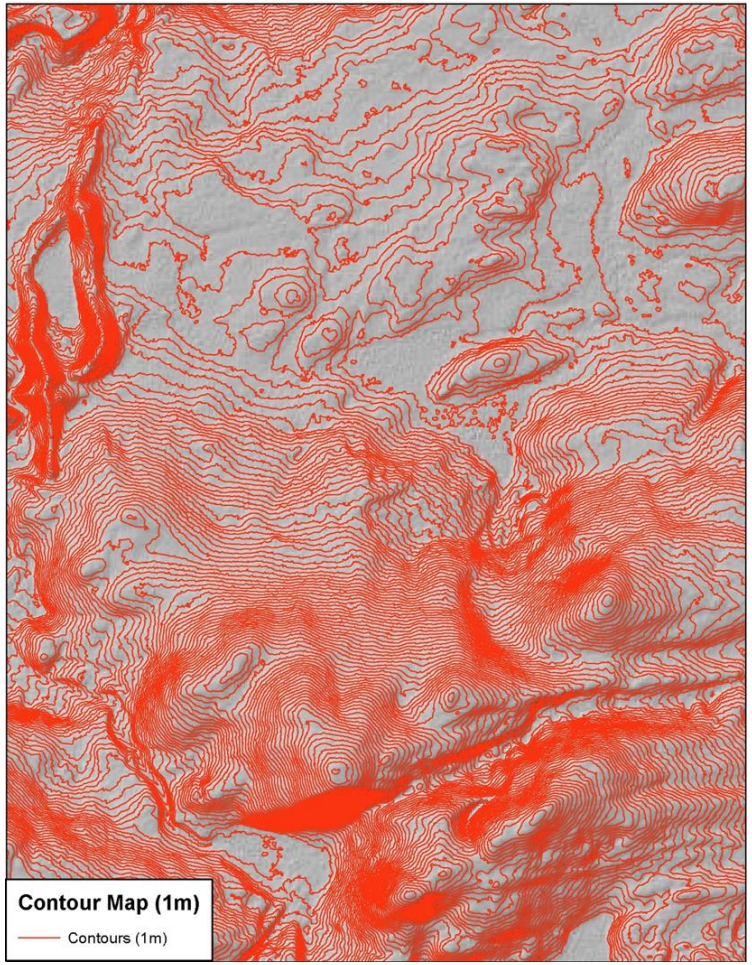
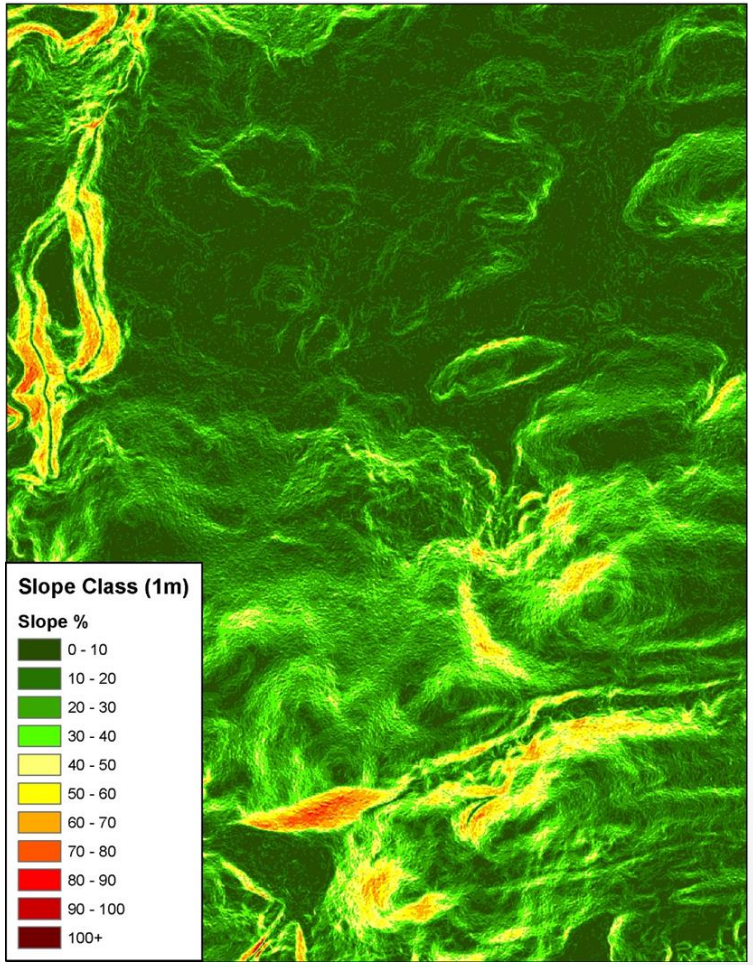
Standard Products to Support Planning

Hillshade

1m Contours

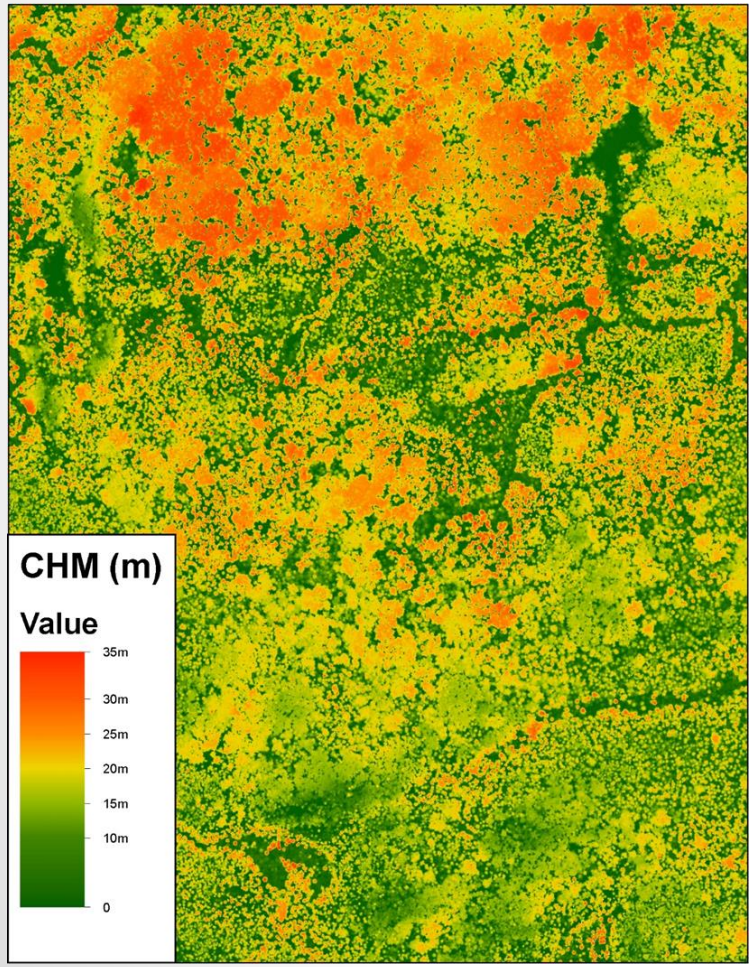


Slopes



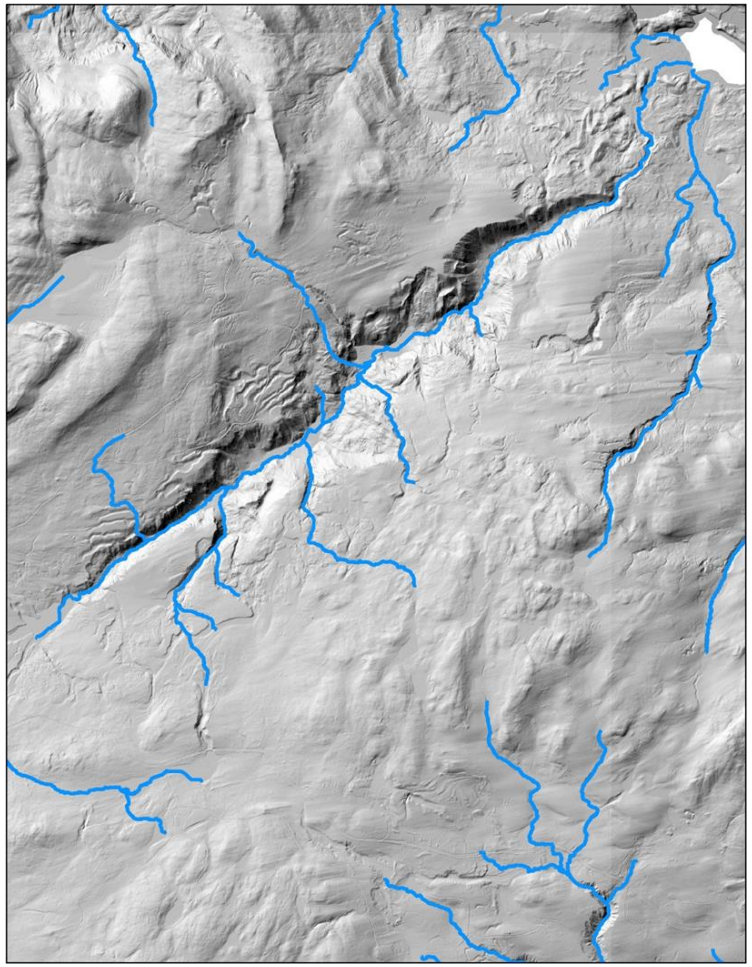
Standard Products to Support Planning

Canopy Height

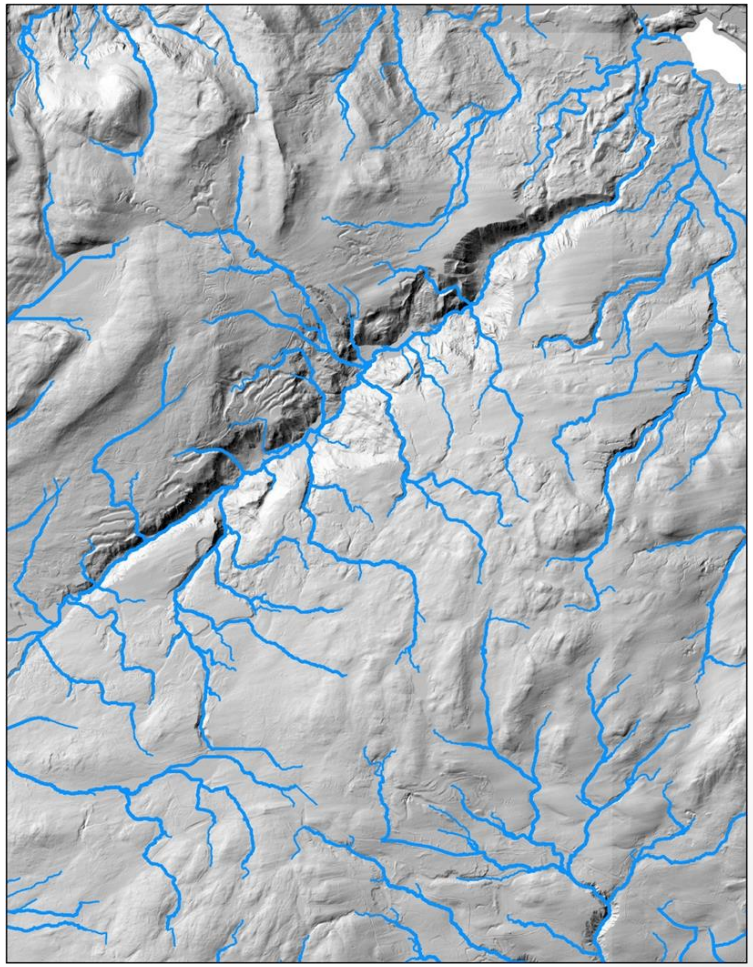


Major Streams

Flow Accumulation Models

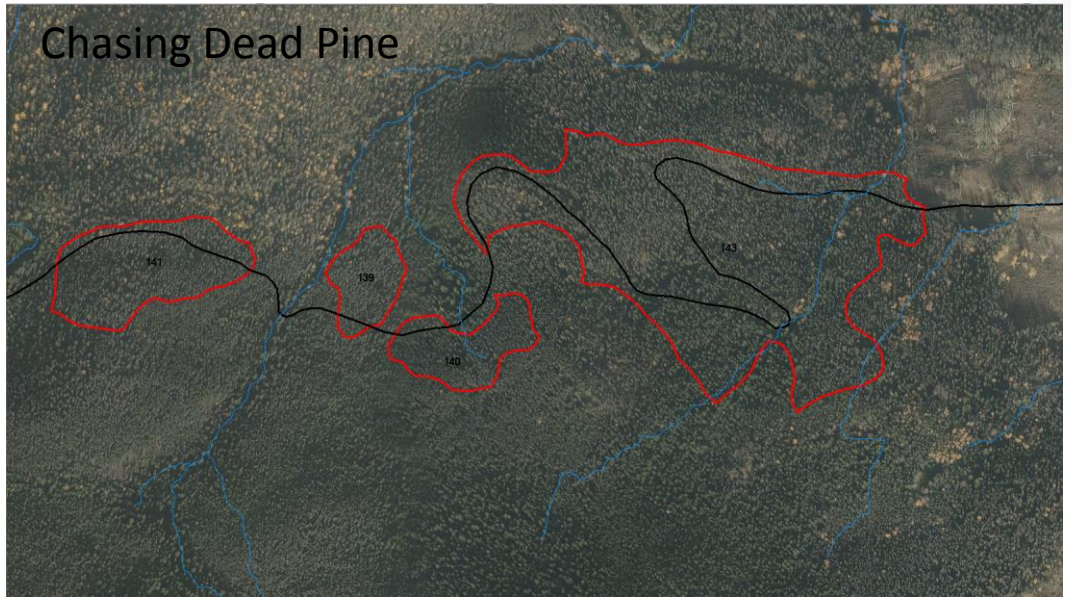


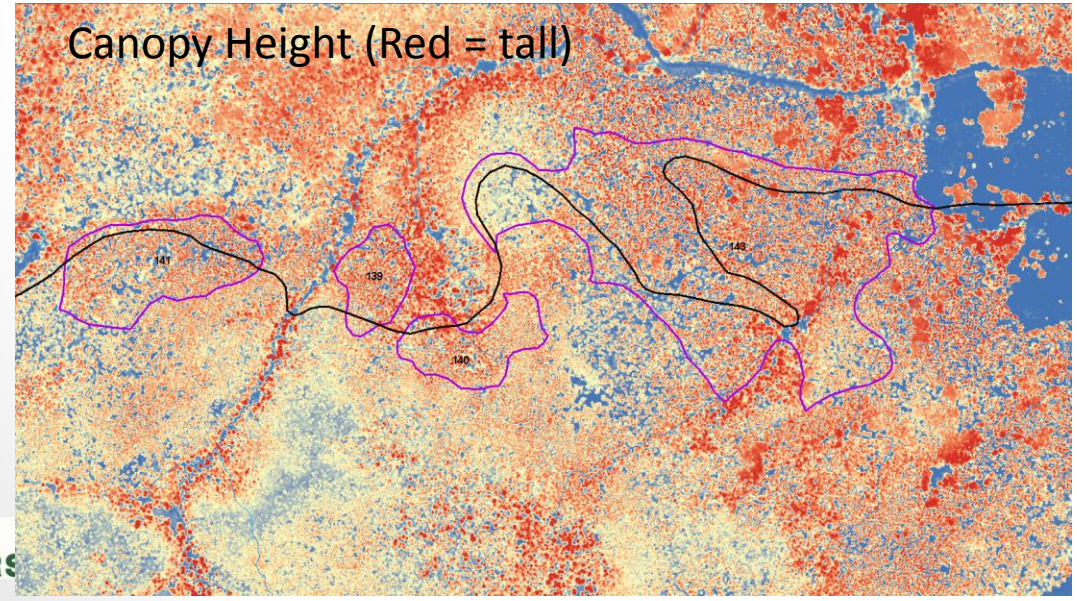
Detailed Streams

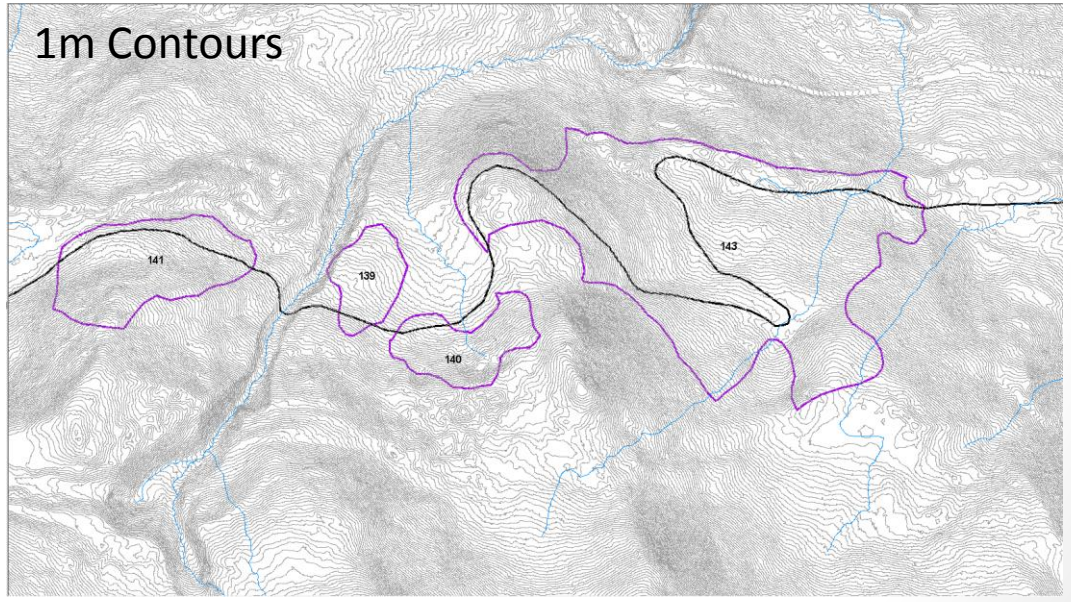


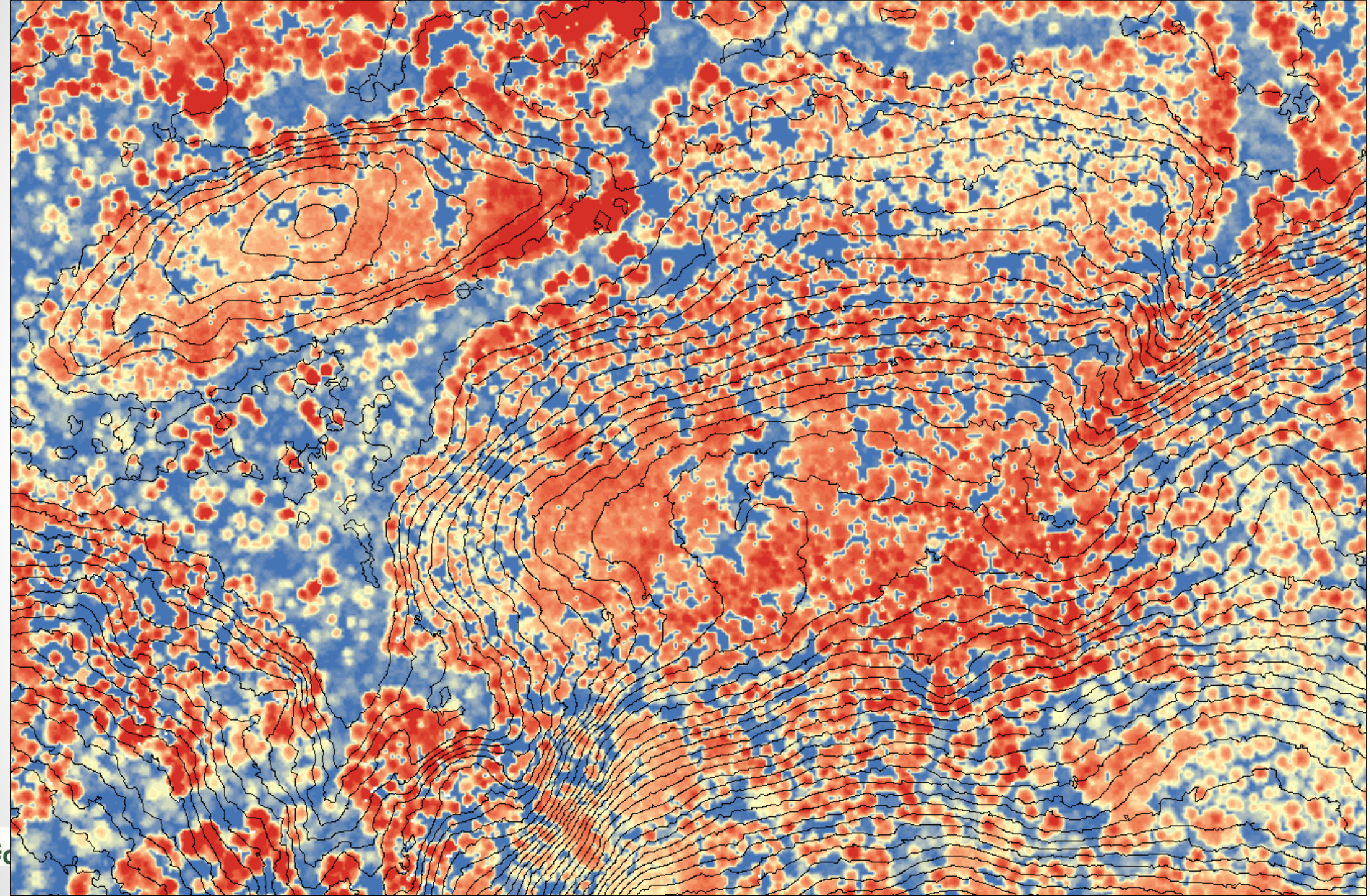
Office Planning of Blocks and Roads

- CHM: provides tree hts and stand density
- Ortho/VRI: provides species and age
- Contours: rd grades, landings, deflection
- Initial design in ARCMap
- Move to RoadEng to refine road design and/or assess deflection lines as needed.



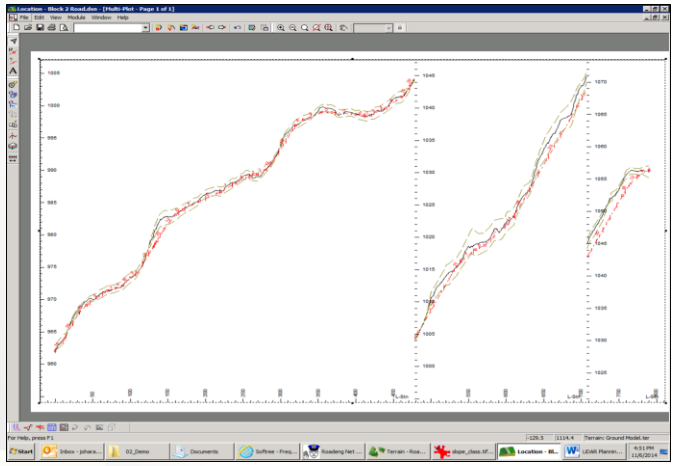


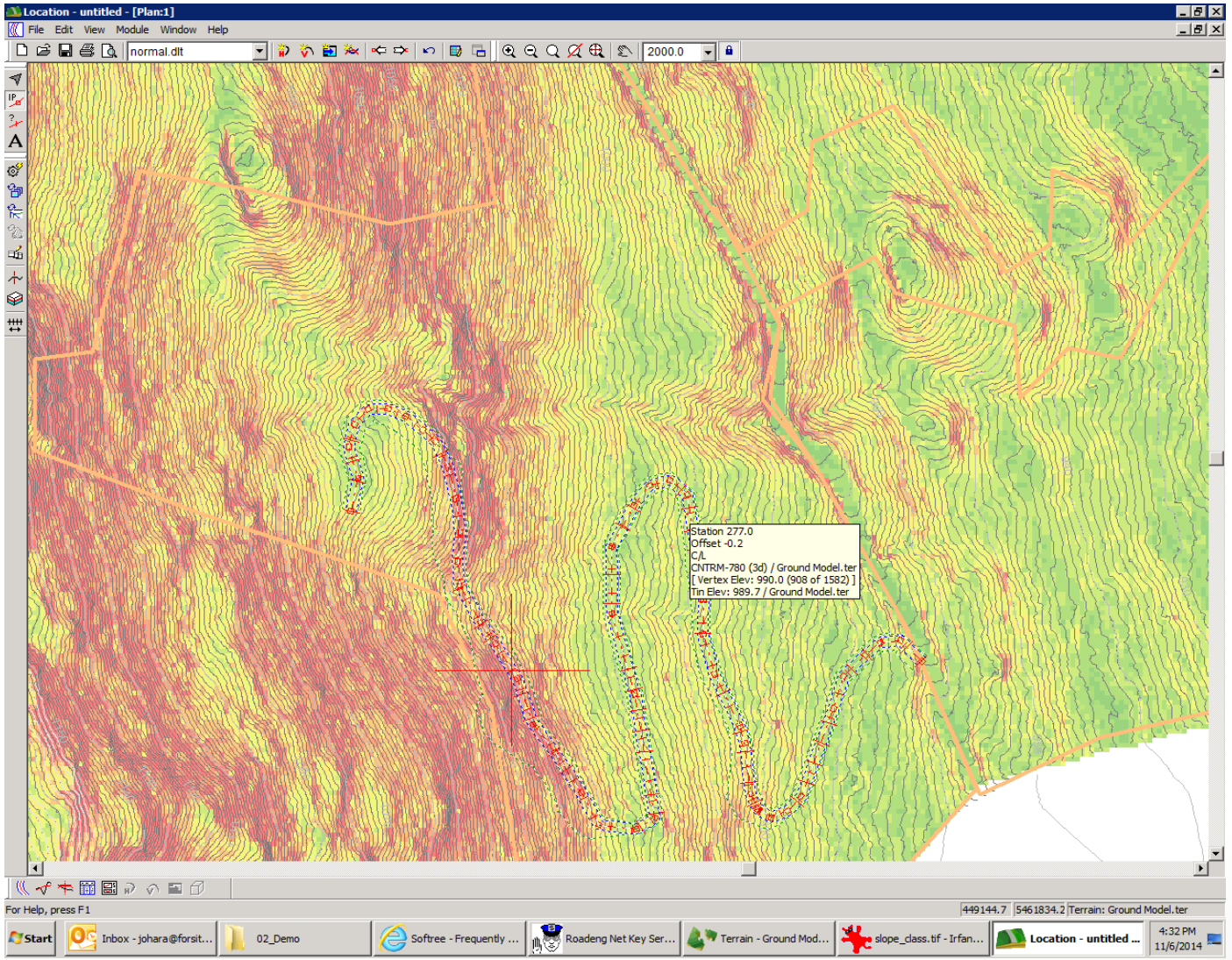




Refining Road and Landing Locations:

- Lidar data and shapefiles brought into RoadEng.
- Draft road locations can be profiled to ensure that the road can be constructed to the desired grade, and that associated side slopes are reasonable





Drawn road in RoadEng Location

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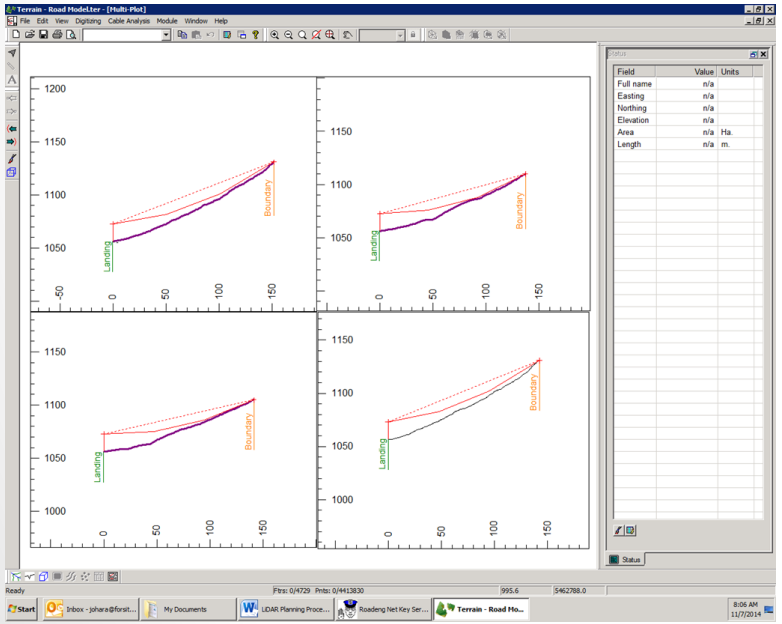
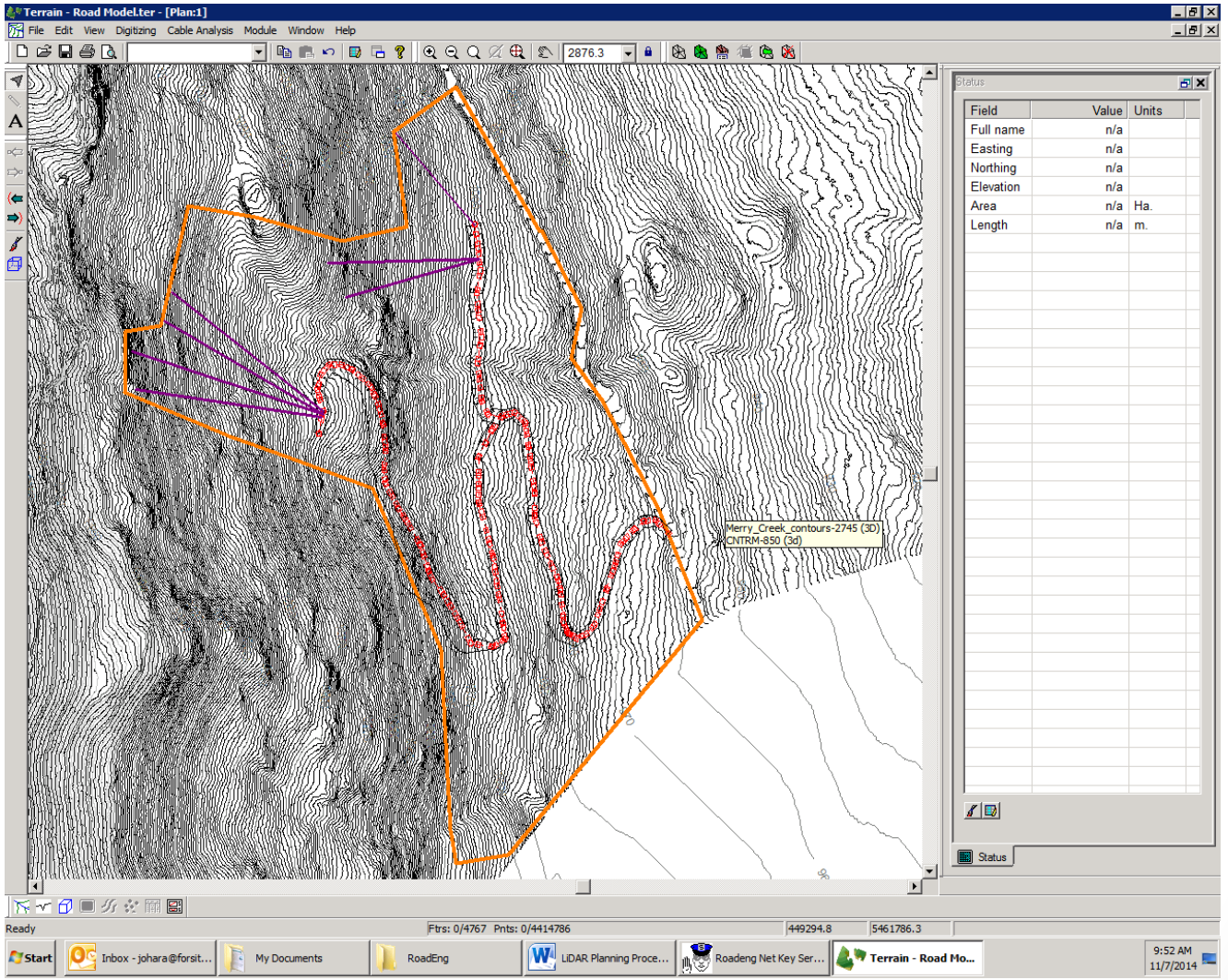
Refine Block Boundaries

- Once roads are in the right spot…
- Can refine block boundaries with deflection lines.





Complete block with deflection lines, roads and adjusted boundary

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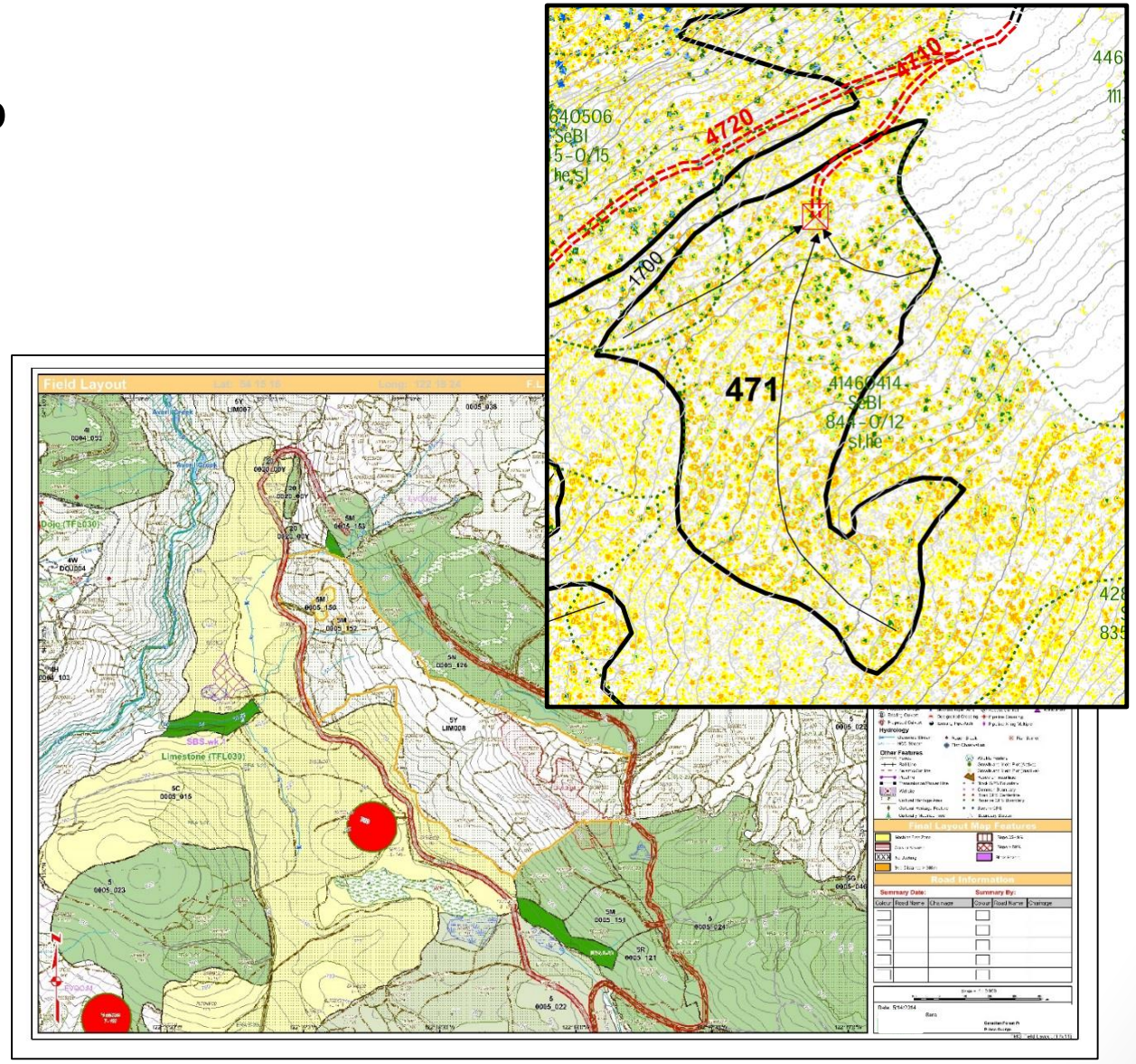
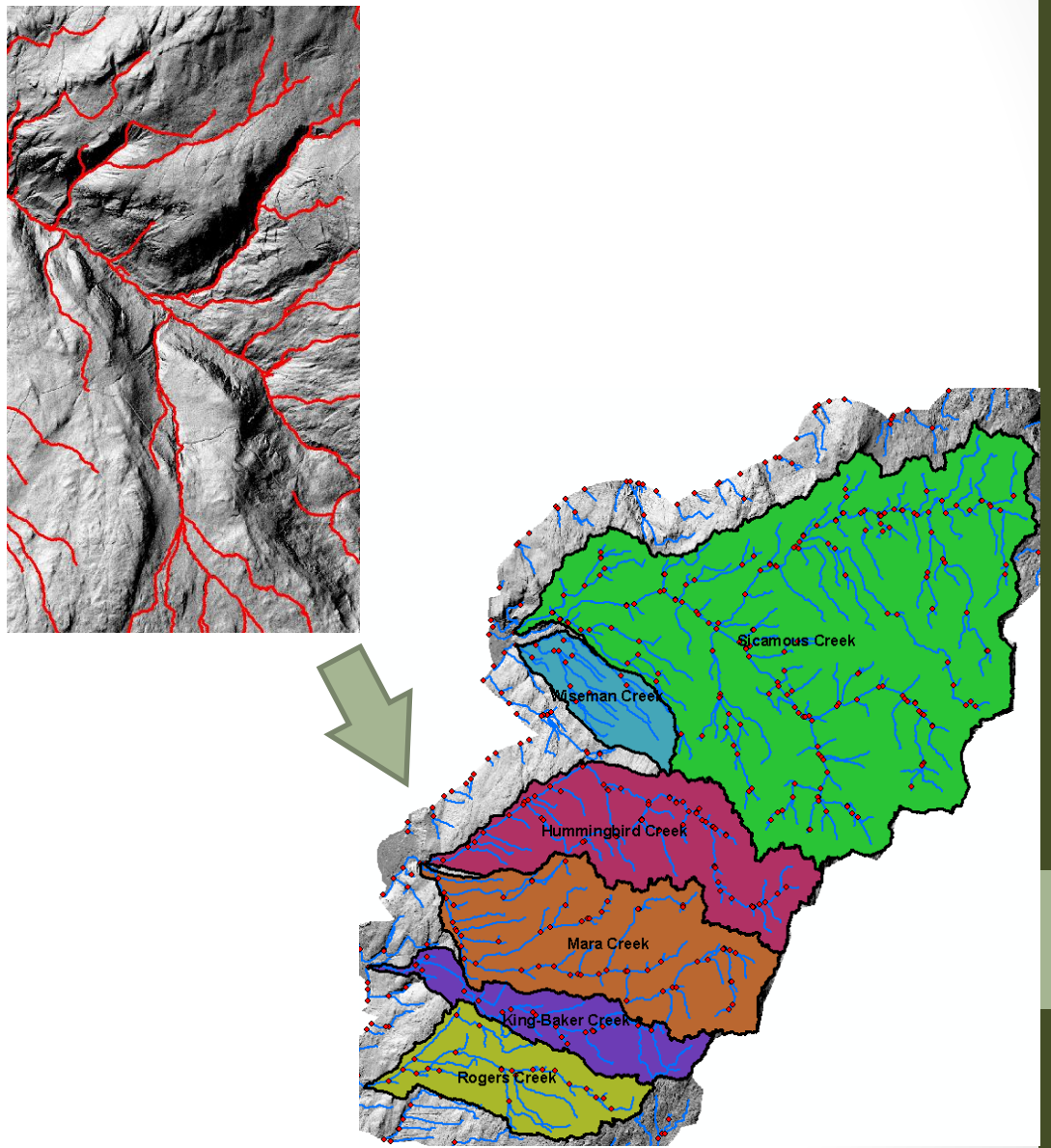
Confirming in the Field

- Geo-referenced maps loaded into tablets showing:
  - Roads (Location, creek crossings, gulley crossings)
  - Boundaries (Location, major reference points)
  - Streams (Location and LiDAR measured fish barriers)
  - Deflection Lines (only needed for one map in order to display important deflection points)
  - CHM
  - 5m Contours
- Field confirm / revise design as needed. Need to ‘go to know’.



Stream and Watershed Delineation

- LiDAR-derived DEM is used to generate flow accumulation models, which are used to map streams and drainage network.
- Each 1x1m cell has a flow direction assigned based on the elevation of its neighbours.
- Drainage points are then derived from the drainage network based on flow direction and elevation.
- Watershed units are defined and delineated as areas that drain to a common drainage point.



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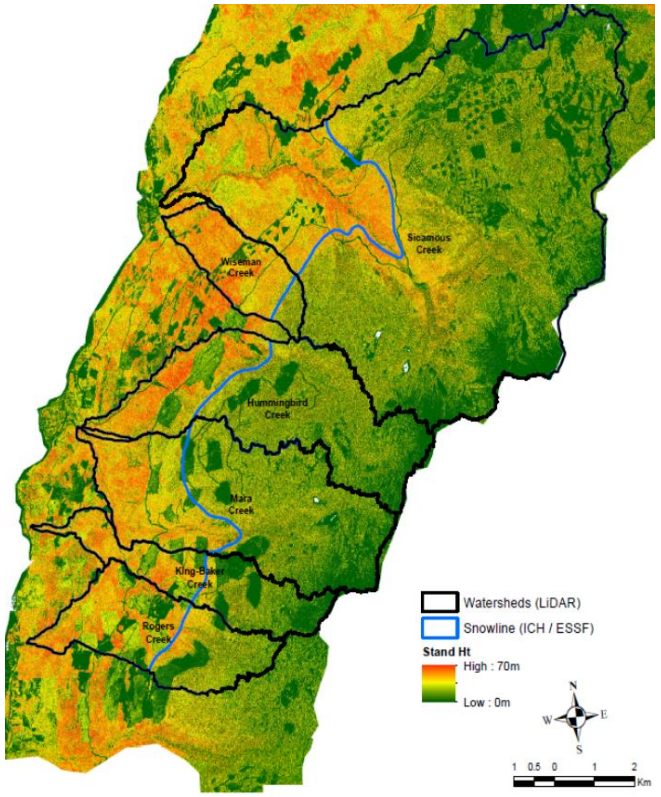
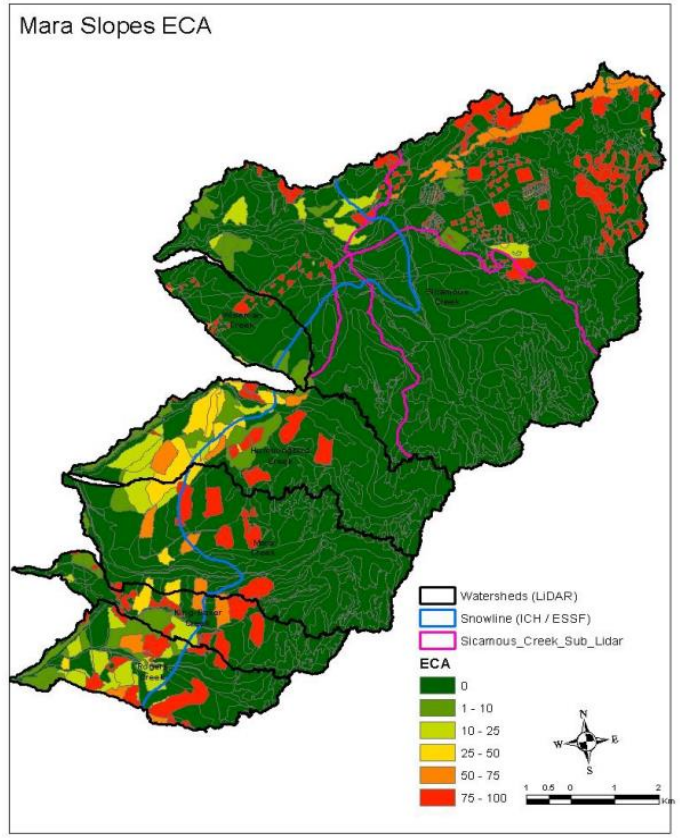
Assessing Hydrologic Recovery (ECA)



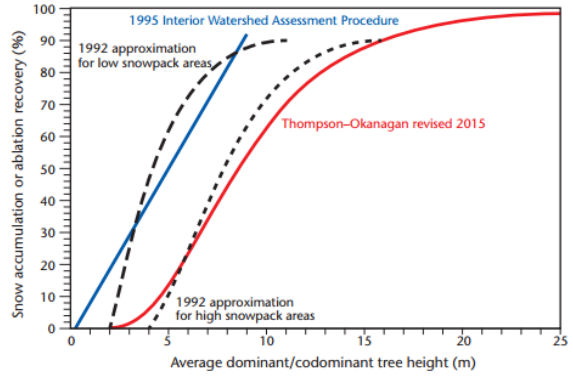
CHM



ECA

Lidar height data can provide accurate stand heights but must be spatially generalized for ECA purposes.

- 1m CHM too fine → Use 5m x 5m max height (ensures >400 sph at ht)
- Assign stand heights as the height where > 50% of 5x5 cells are taller than
- ECA only assessed on disturbed areas to avoid assigning ECA values to undisturbed mature stands.



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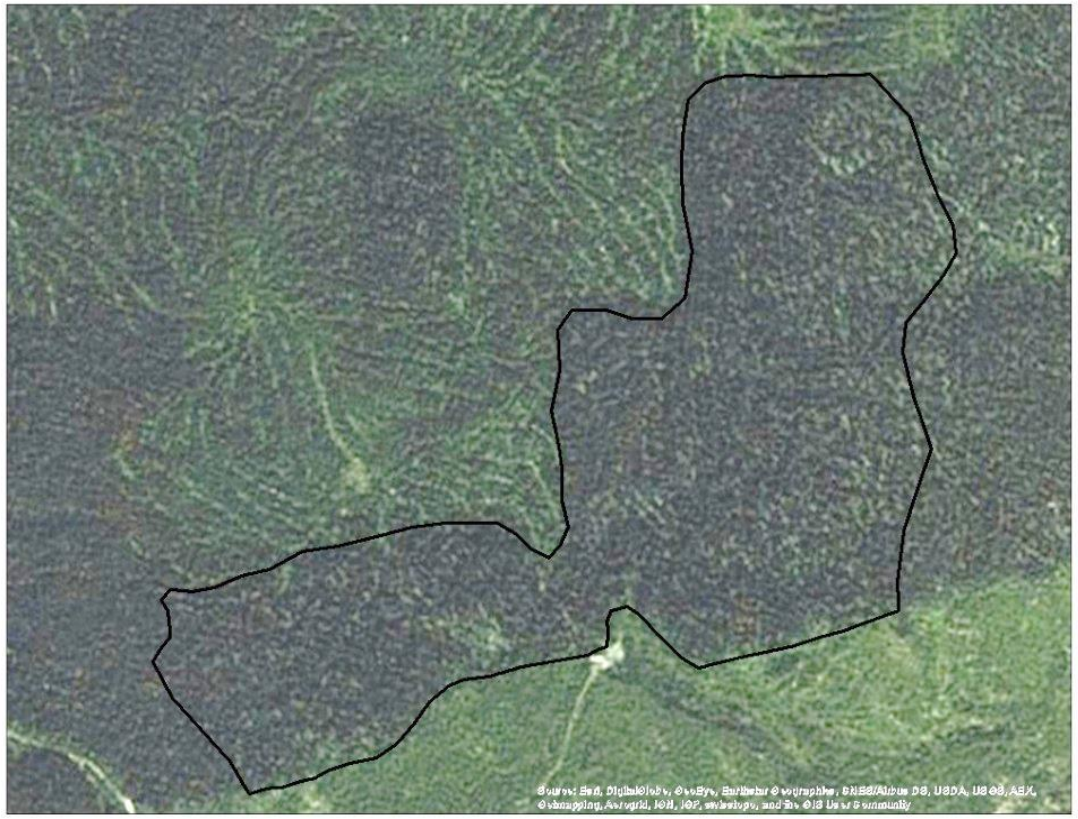
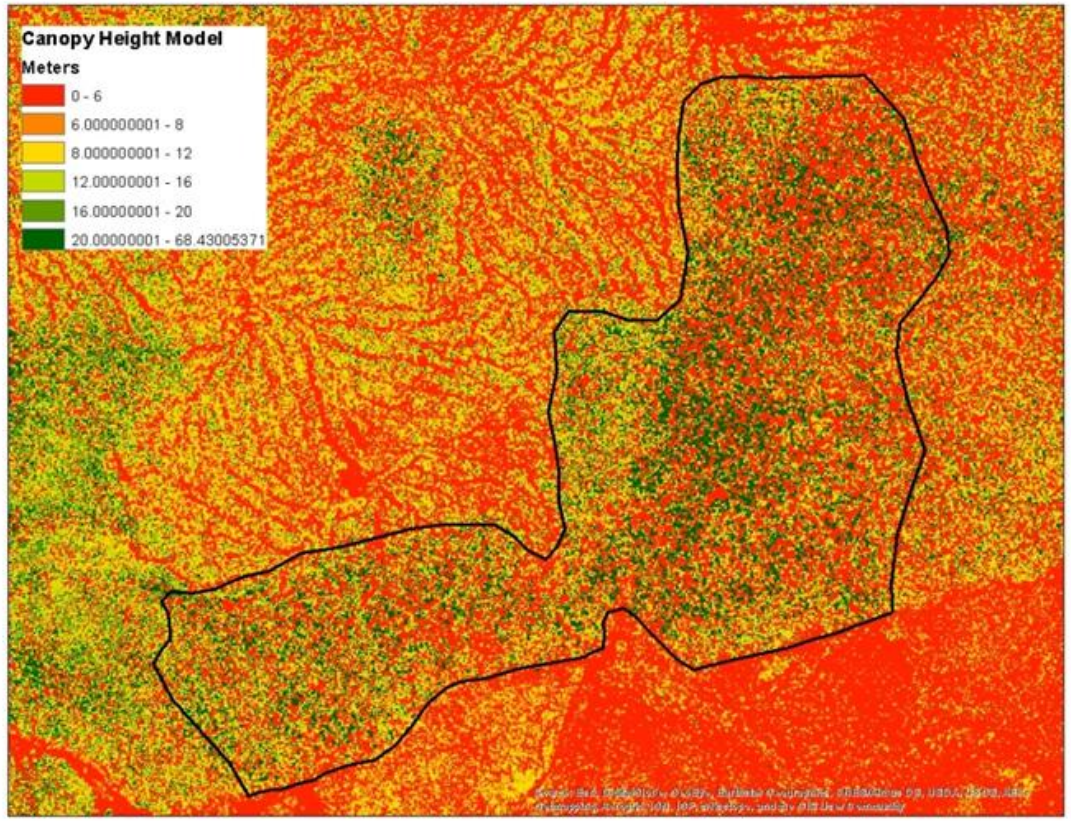
Assigning Stand Height to a Polygon



If ECA values assigned to each 1x1m cell, natural holes/gaps being recognized so need a single value for the polygon.

VRI: 163 yr old, 27.2 m tall

Lidar shows full range of heights (1x1m CHM)



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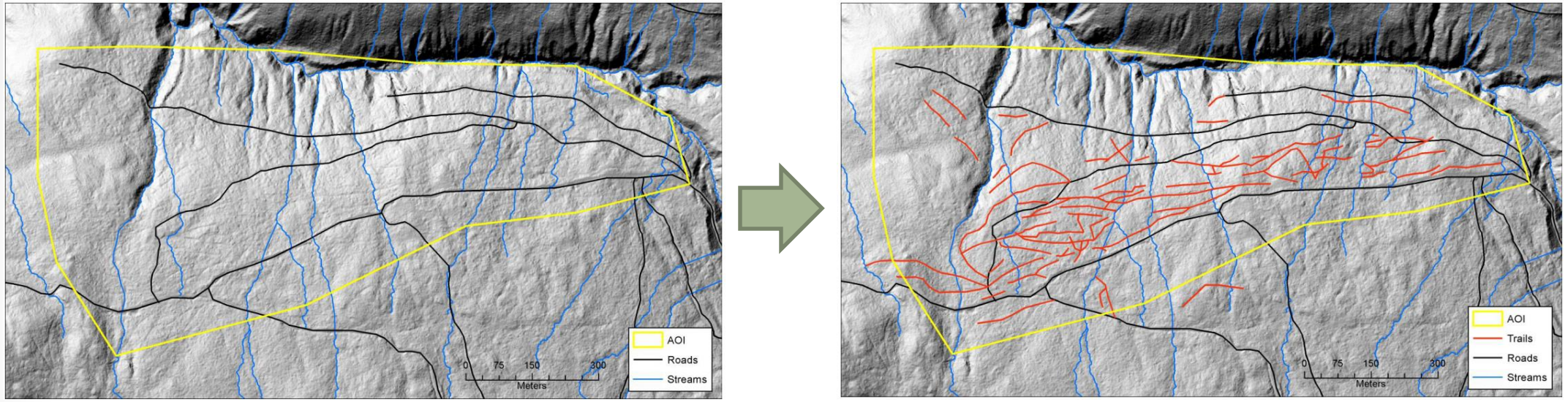
Mapping Of Legacy Roads/Trails - Diverting Drainage



- Legacy roads and trails are diverting runoff (hydrology concerns).
- LiDAR hillshade used to delineate legacy roads and trails manually; reduced field time to ID.
- Simpler, more efficient and accurate.

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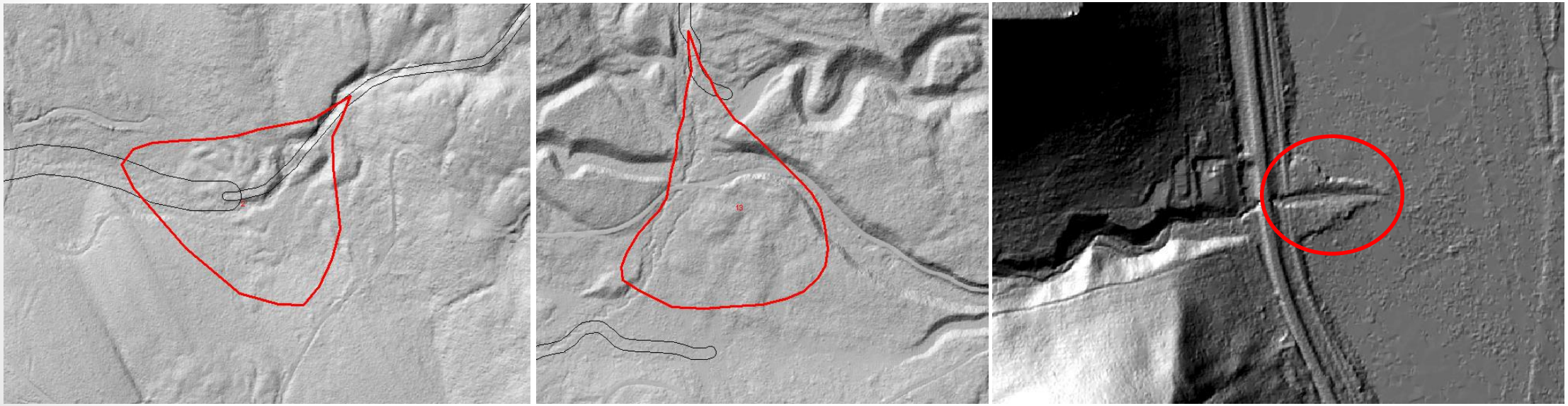
Mapping Of Active Fluvial Units (AFUs)

- Increasing requirements to identify and manage AFUs in the context of Fisheries Sensitive Watershed (FSW) regulations
- Detailed hillshade images can make the delineation of these features easier for hydrologists to delineate.
- LiDAR data make locating and mapping AFU's more efficient and accurate



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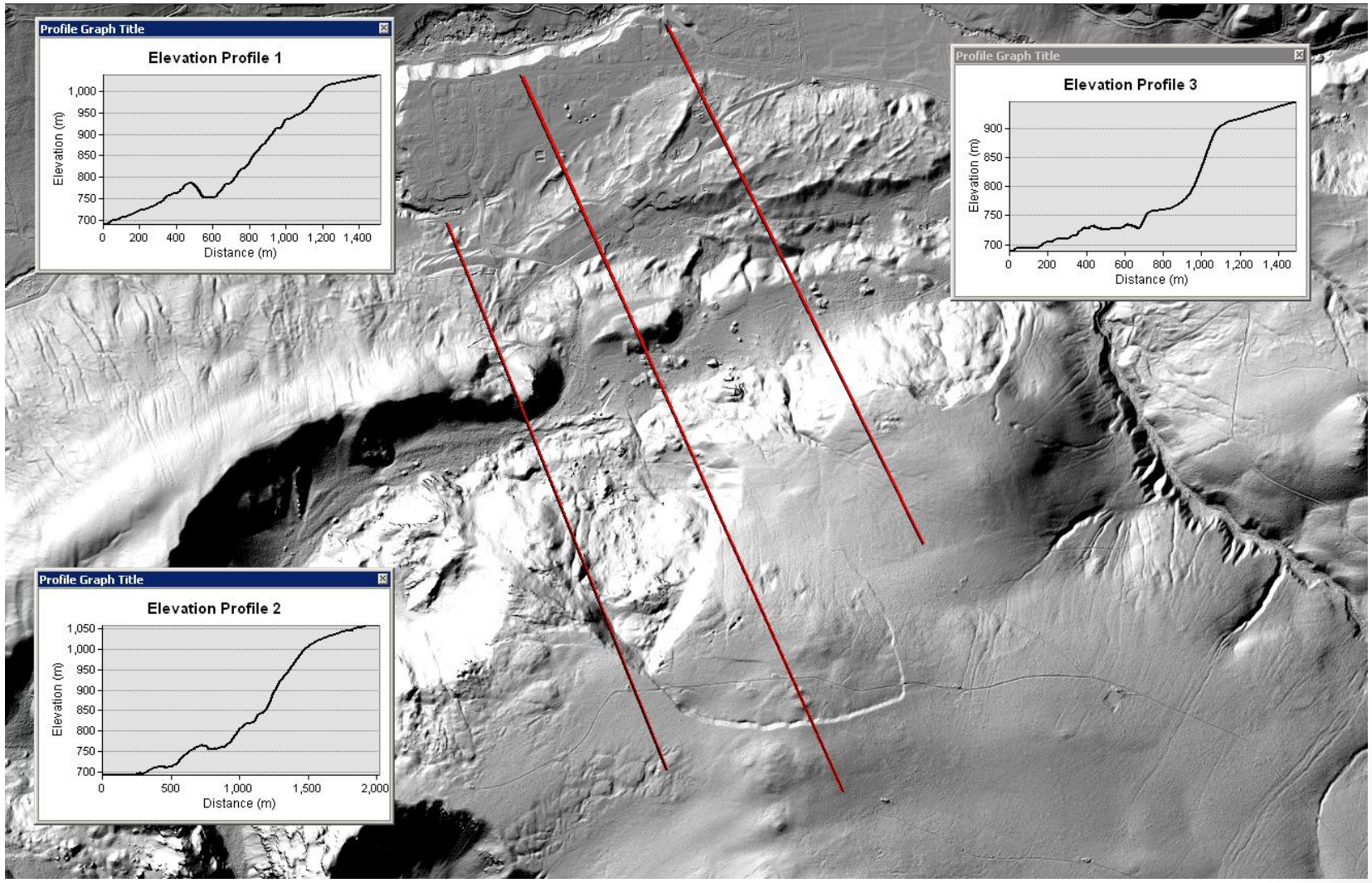
Terrain / Avalanche Assessments

- Identification of key land features is possible once the vegetation is removed (DEM/Hillshade)
- Possible to see old head scarps and failures.
- Supports refined mapping of hazardous terrain



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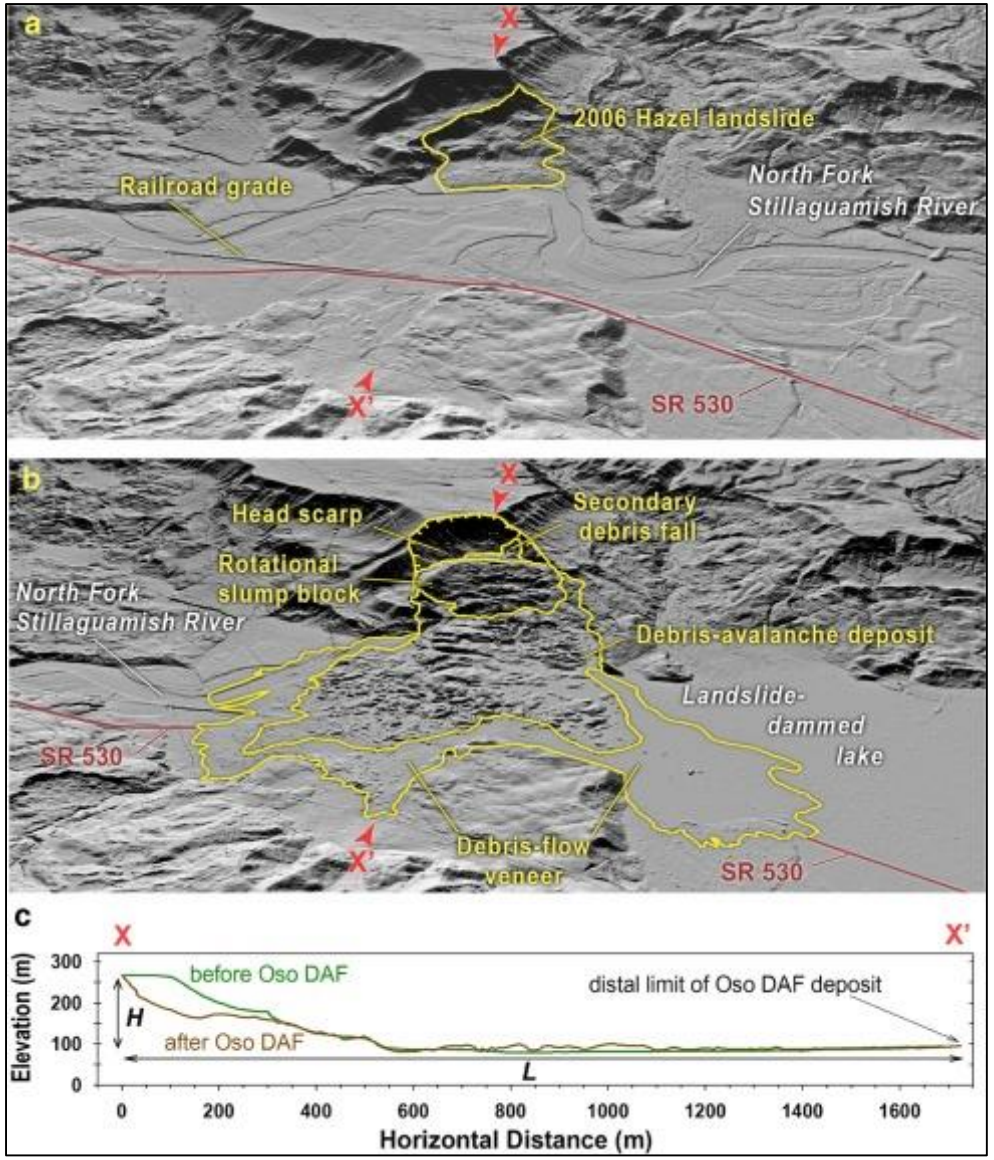
Terrain / Avalanche Assessments

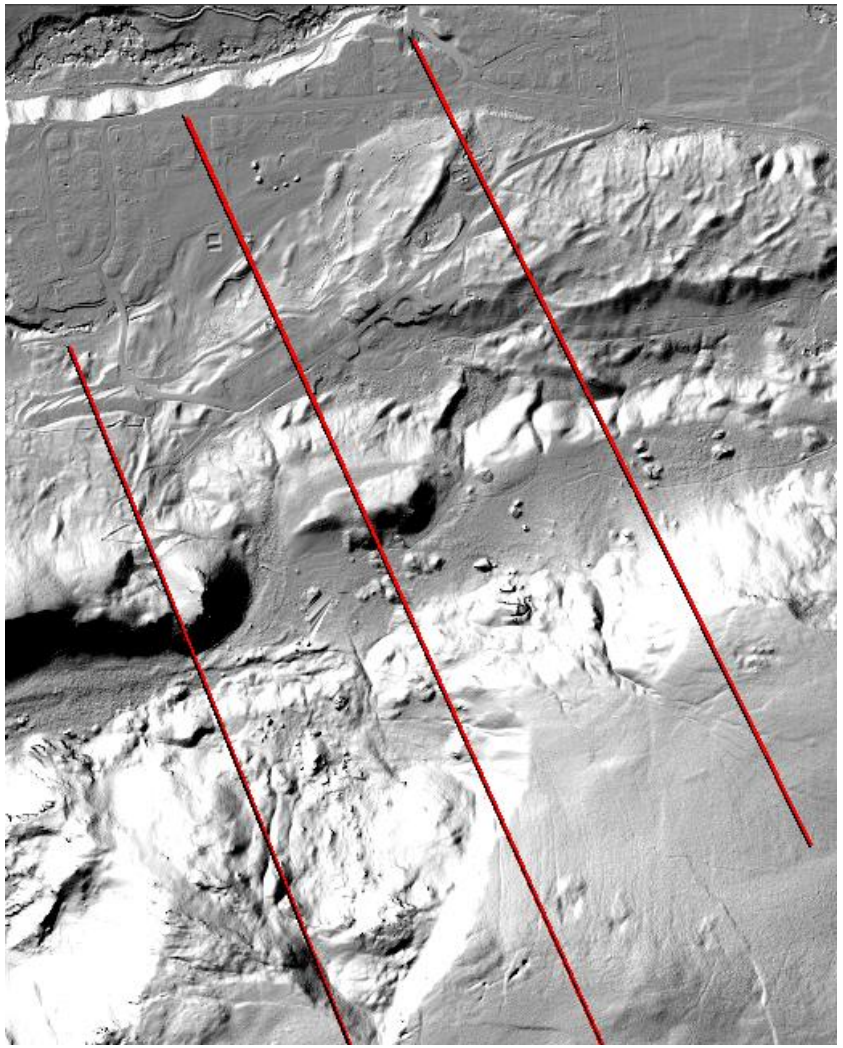
- Interesting use of Lidar to examine a large earth failure event in Washington State.



Slide near Oso, Washington

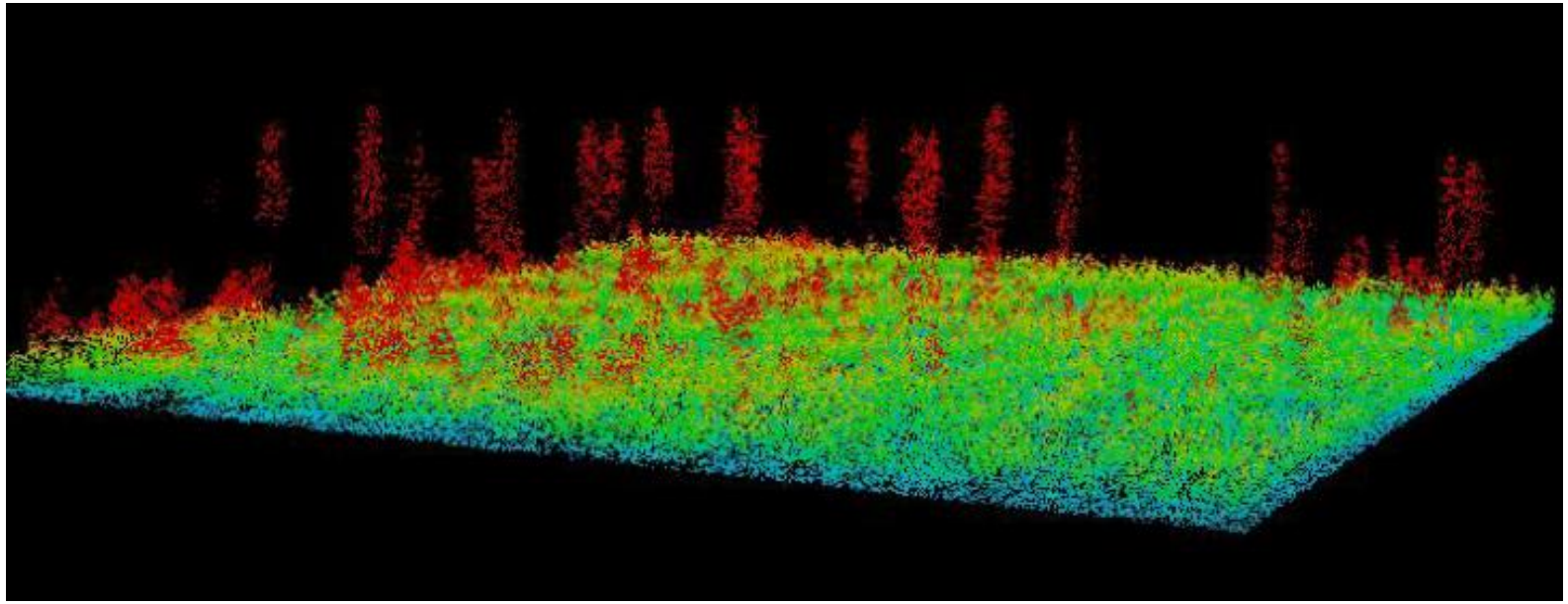
Cultural Features – Pit Houses

- Detailed hill shade information has been used to identify historical cultural features such as pit house locations



Stand Structure Assessments (Detailed Stand Descriptions)

- Indicators of Even Aged or Multi-storied Stands
- Crown Closure Calculations at selected heights
- Mapping of Residuals
- Used to Support Habitat Assessments (e.g. UWR Cover / Early Seral Conditions)



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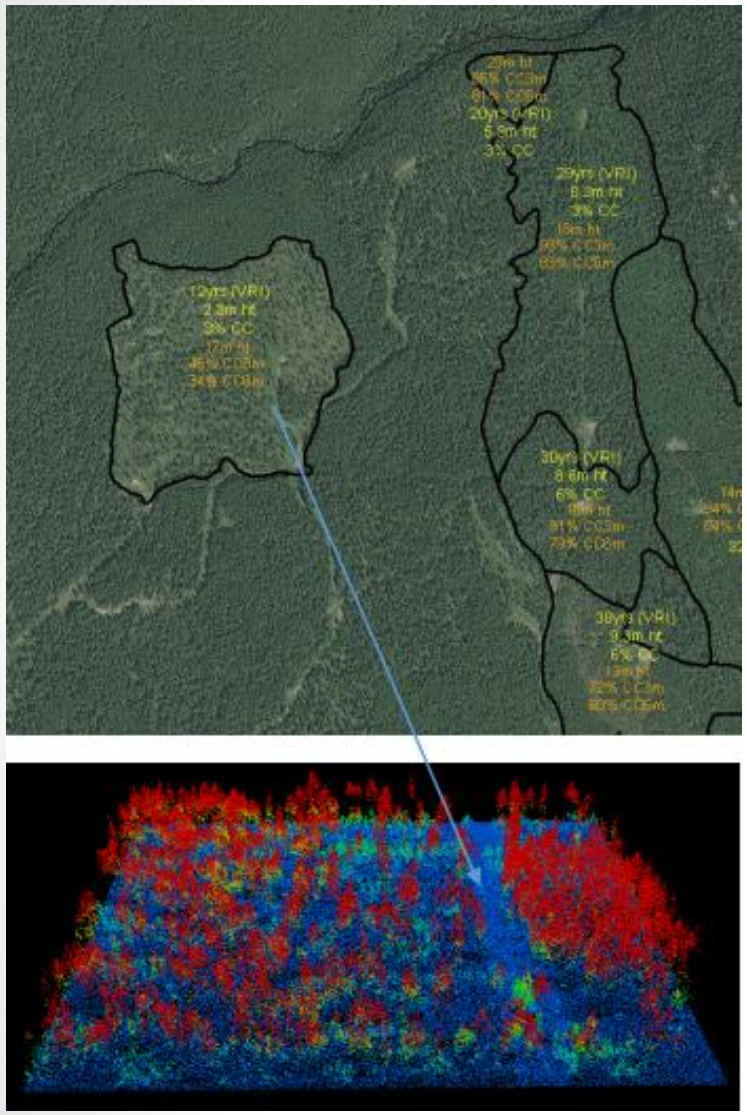
Stand Structure Assessments (2/2)



Forested Area by Stand Age and Lidar Height (Grave and Skook LU UWR Areas)

Sum of CFLB ha	Lidar Height																													
VRI Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	29	30	Grand Total
MANAGED FOREST DRY	17	138	77	189	95	39	49	33	22	91	119	42	30	8	9	24	7	13	1	10	9		3							1,025
0-4	17	138	23			6	2											12		0										197
5-9			54	189	15	21		6	1		2	1	2	1		12	3	1			8		1							317
10-14					80	11	36	27	1	9	8			4		5			1	10	0		2							194
15-19							12			13																				24
20-24									9	10	10																			30
25-29						1			10	34	61	1	20	3				0												130
30-34										23	19	23				6	4		1											77
35-40										2	19	17	8		9															55

Forested Area by Stand Age and Lidar Crown Closure at 6m (Grave and Skook LU UWR Areas)

Sum of CFLB ha	Lidar CC										
VRI Age	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1	Grand Total
MANAGED FOREST DRY	207	346	135	87	81	48	95	26			1,025
0-4	150	28	8	12							197
5-9	47	213	41	7	9						317
10-14	9	93	73	8	8		2				194
15-19		12		13							24
20-24			13	2	16						30
25-29		1		19	48	35	27	0			130
30-34				28		1	48	0			77
35-40				0	0	11	18	25			55

Determine stand structure for:

- Wildlife Habitat
- Selection cutting prescriptions (e.g. IDF)
- Understory identification post-MPB

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Visual Impact Assessments

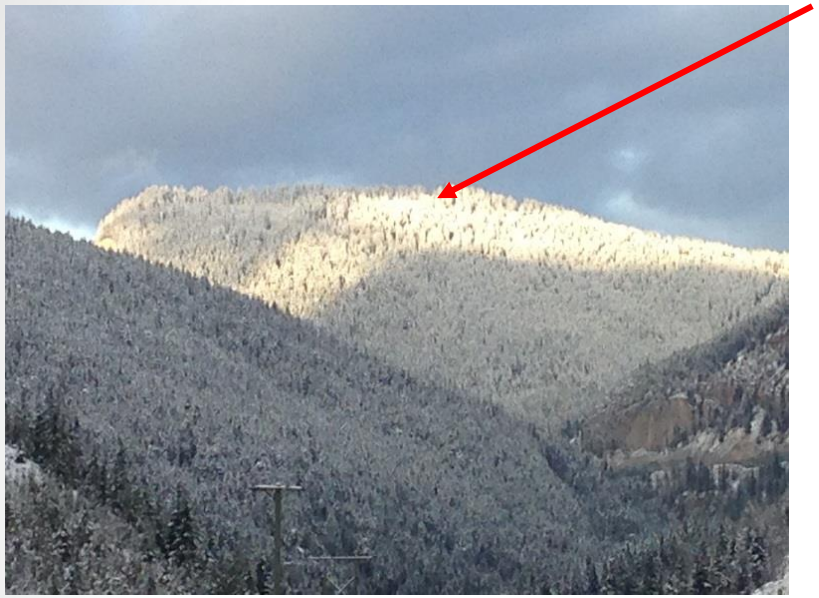
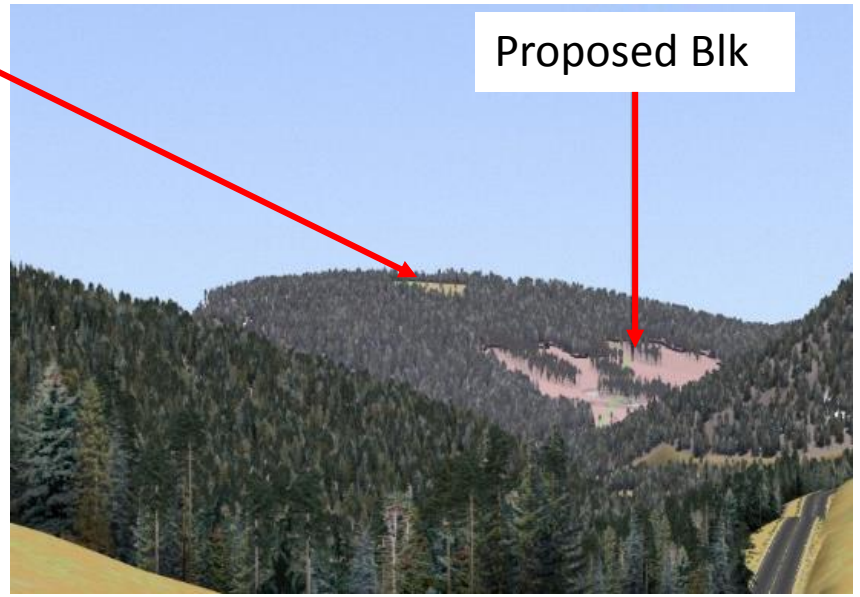


Photo from Viewpoint



Rendering from Viewpoint

- Use of LiDAR in visual models to improves rendering accuracy for visual assessments

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Enhanced Forest Inventories:

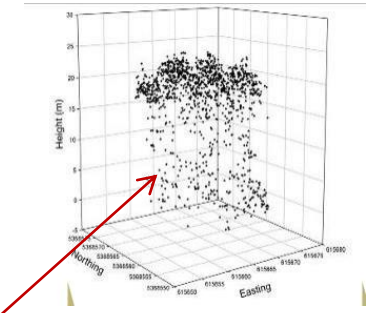
Area Based (Cell) vs Individual Tree

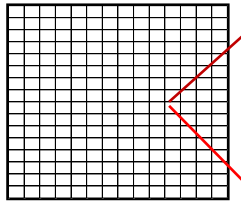
LiDAR metrics on 20x20m grid cells

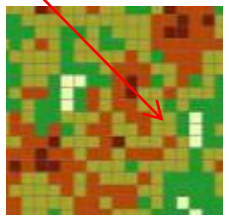
+ **Ground Plots** (spatially linked to cells)

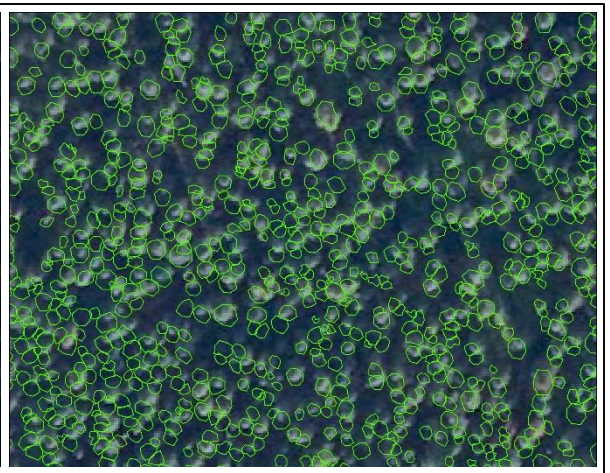
= **Models to Predict**

- Gross and Merch m^3/ha
- Products, Piece size
- Diameters
- Basal Area
- Biomass









- **"Bottom → Up"** inventory
- Individual trees segmented out (> 5-10m tall)
- Attributes assigned to each tree (species, height, diameter, volume, BA, etc)
- Provides operational scale inventory data

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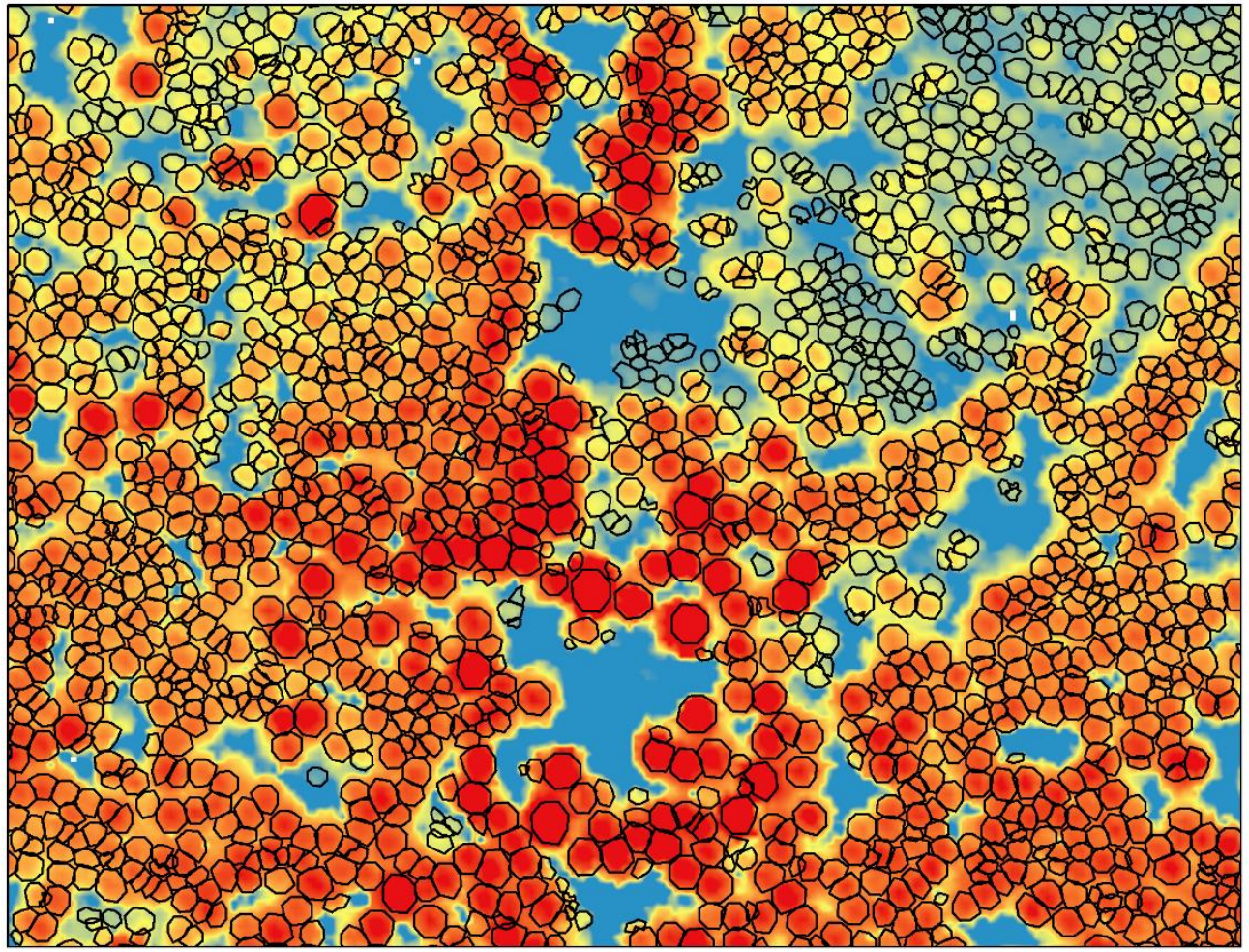
Individual Tree Inventory – Identification of Trees

Segmented stems overlayed on a CHM raster.

- Red = Tallest
- Blue = Ground level



Near Burns Lake, BC

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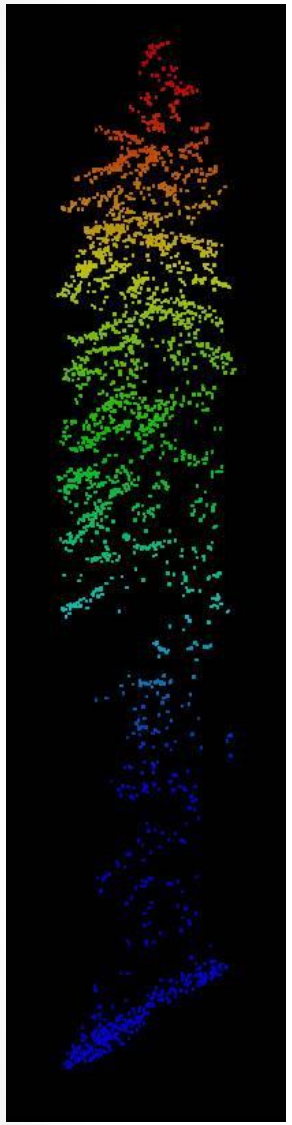
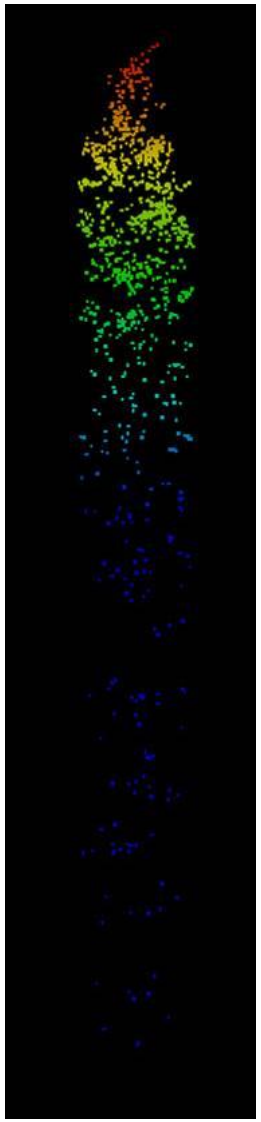
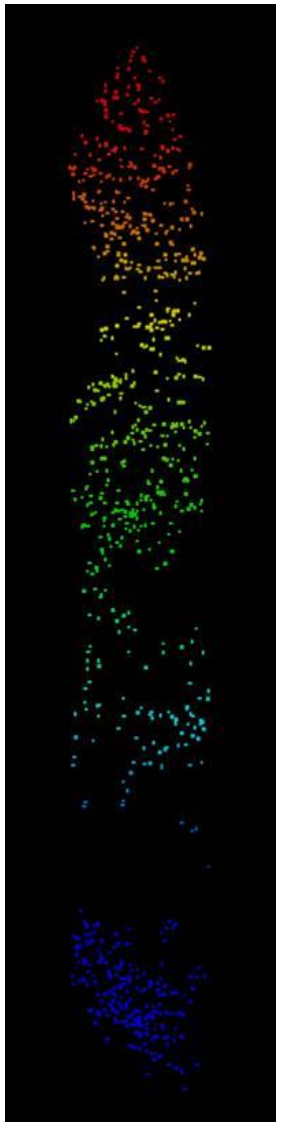
Individual Tree Inventory – Assigning Species



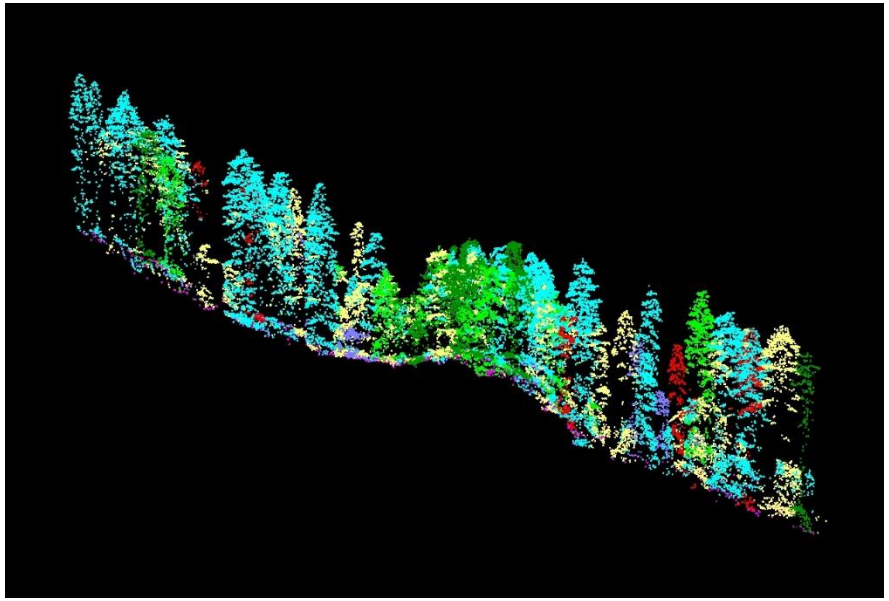
FD



HW



CW



Object Raku's TSI Software predicts species for each segmented stem based on the LiDAR metrics associated with its crown.

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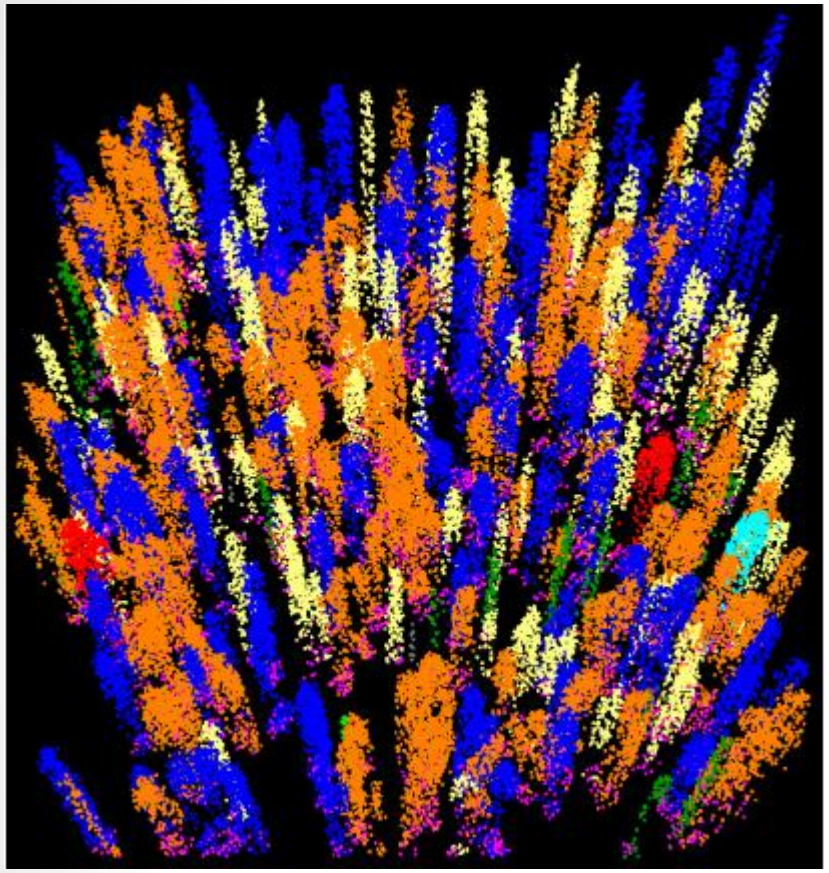
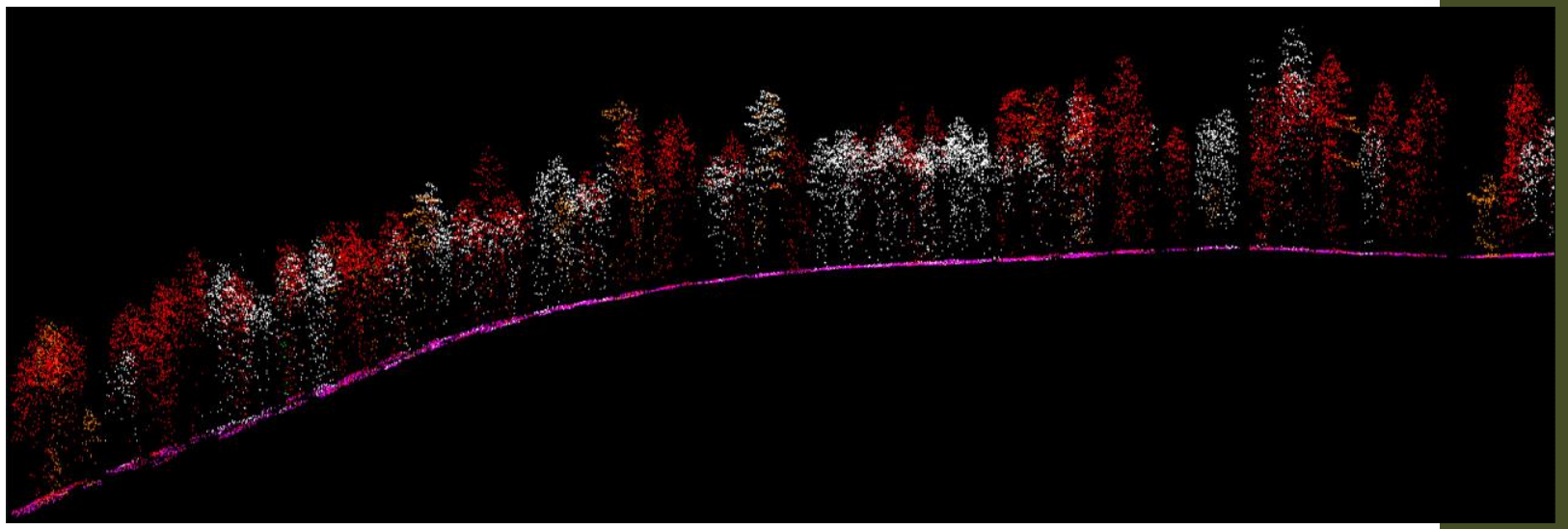
Individual Tree Inventory – Point Clouds with Species



Balsam Fir (yellow),
Spruce (blue)
Lodgepole Pine (orange)
Dead Lodgepole Pine (green)



Douglas-fir (red), Ponderosa Pine (white), Lodgepole Pine (orange)

Themed by Species using TSI – 'Timber Species Identifier' software. (Location: East Kootenays)

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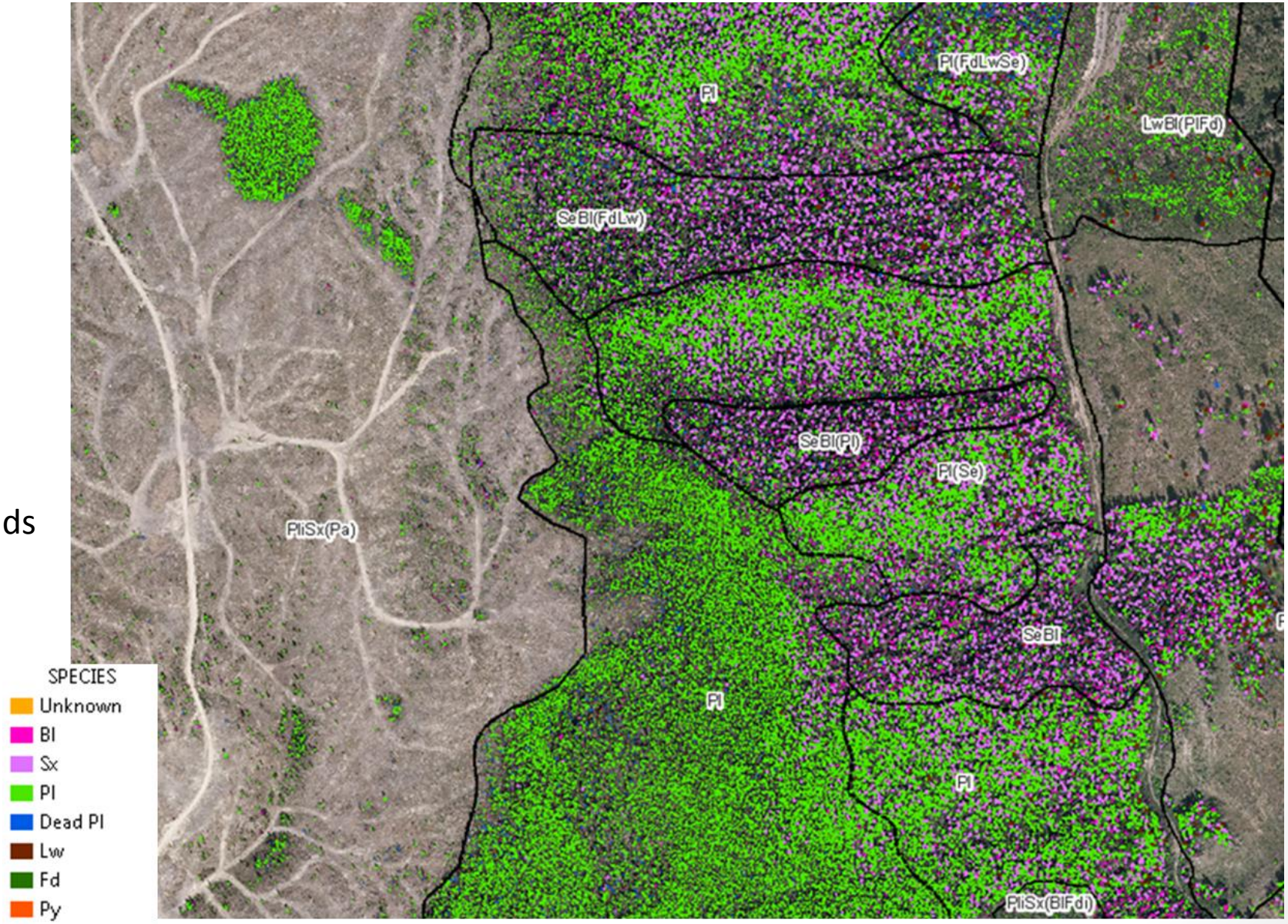
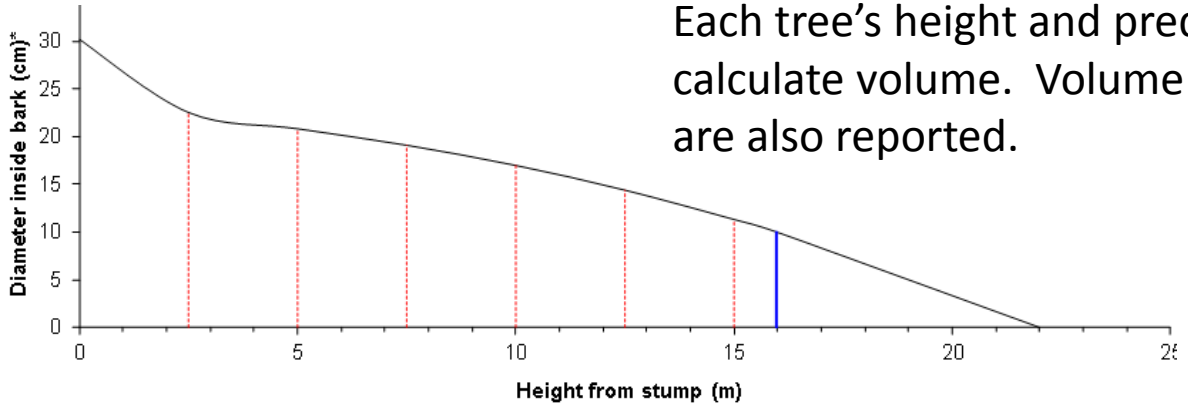
Operational vs. Strategic Inventory

ESSF/MS Stands with VRI polygons on top.

Individual tree inventory provides a more detailed view of where target stands are located.



Individual Tree Inventory
Predicting DBH,Calculating Volume



Each tree's height and predicted dbh used to calculate volume. Volume for custom log products are also reported.

Volumes / Log Products can be rolled up to analyze any area.

Species	FD	PL	BL	At	Sx	Totals
# Trees	2,884	2,375	1,243	97	2	6,601
Head Rig Vol	319.4	14.5	36.8	0	0	371
Lg Sawlog Vol	1,015.90	256.8	44.7	7.7	0	1,325
Md Sawlog Vol	230.9	157.2	12.4	7.6	0	408
Sm Sawlog Vol	65.5	33.4	5.1	2.2	0	106
Waste Vol	52.4	17.5	2.8	0.8	0	74
Net Merch Vol	**1,684.00**	**479.4**	**101.7**	**18.3**	**0**	**2,283**
Gross Vol	2,158.00	972.1	801.5	22.8	3.7	3,958

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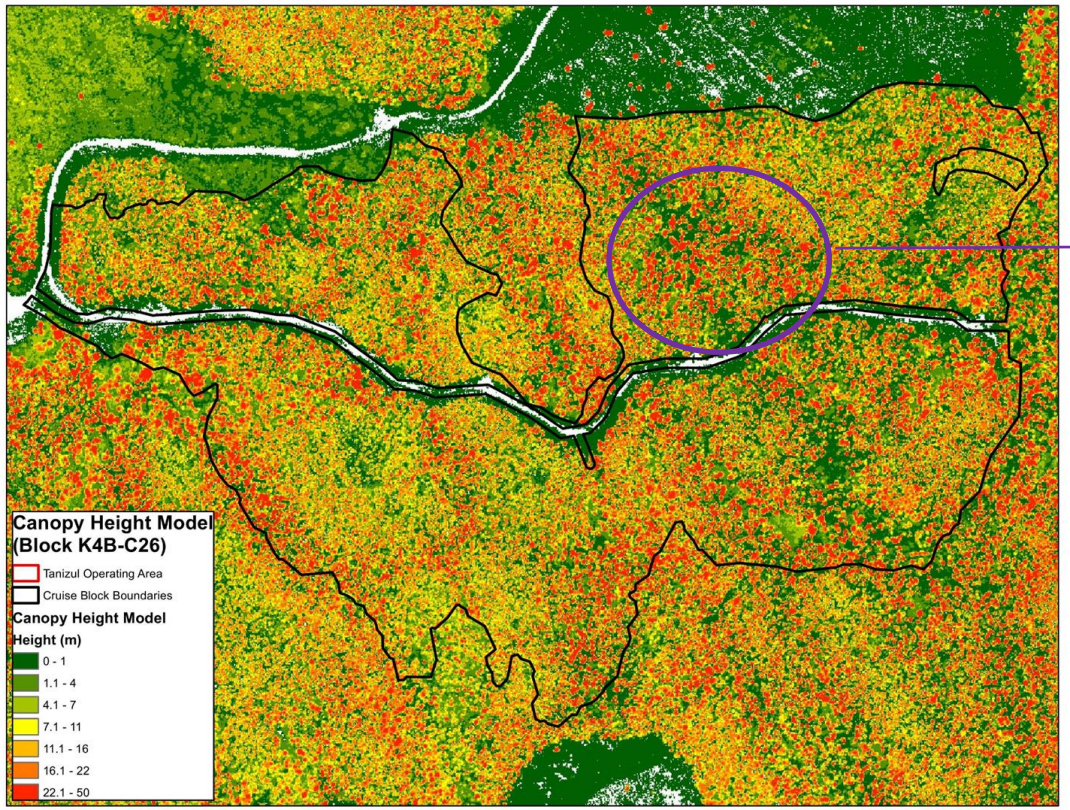
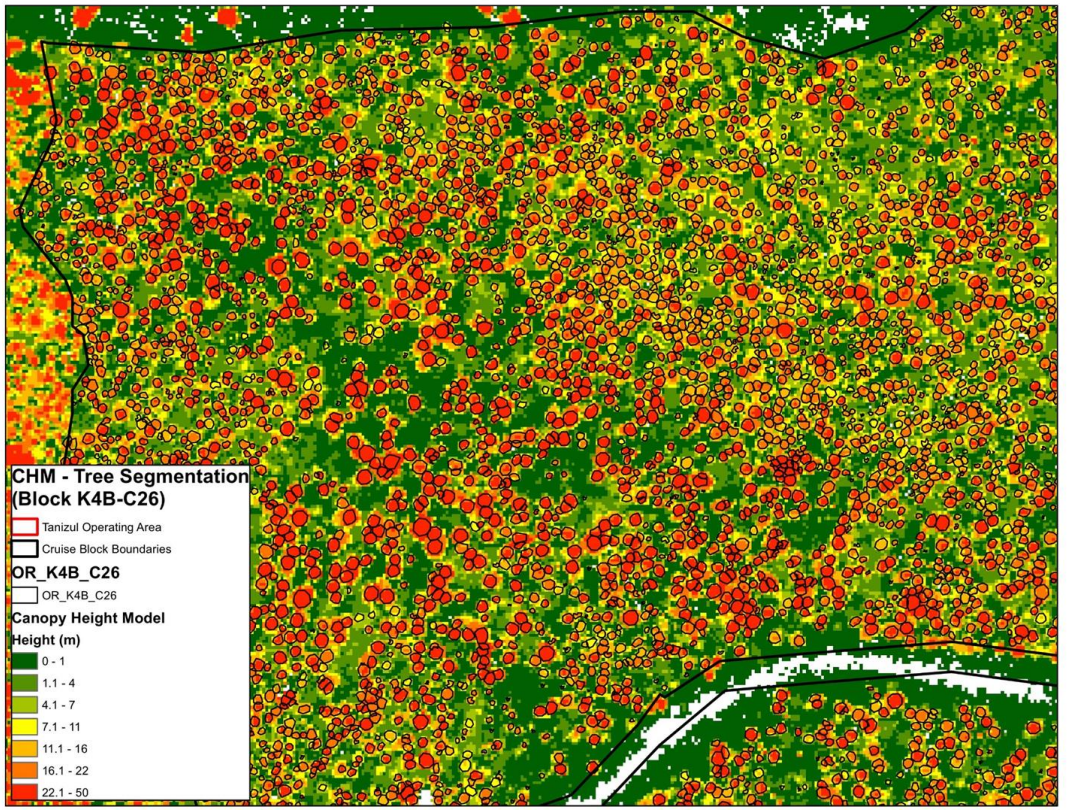
EXAMPLE USE – PROPOSED HARVEST BLOCK



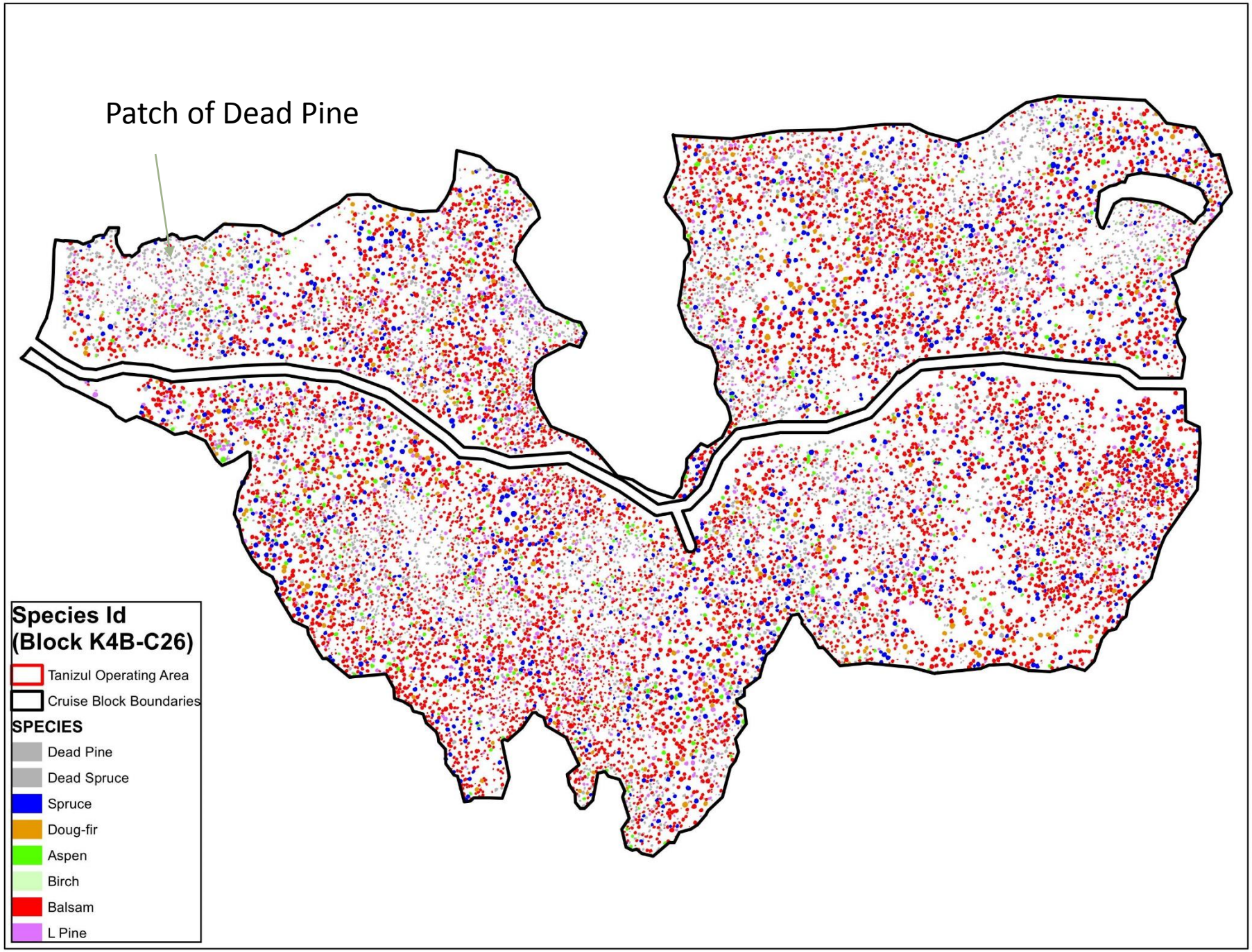
Full Block - Canopy Height Model (LiDAR)



Zoom in - Individual Trees Segmented Out

Individual trees with attributes.

Block is mostly Bl Pl Sx with some Aspen mixed in.



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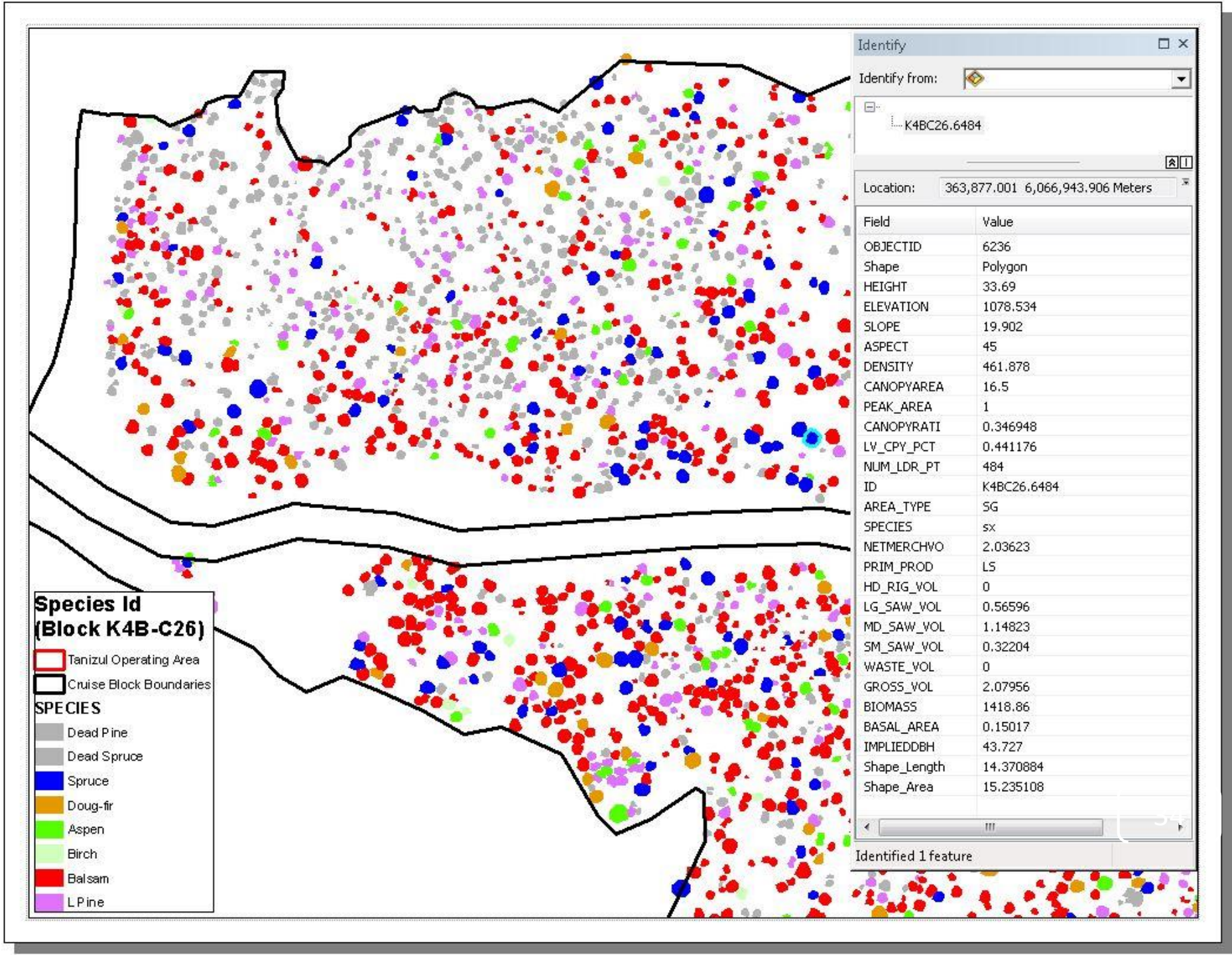
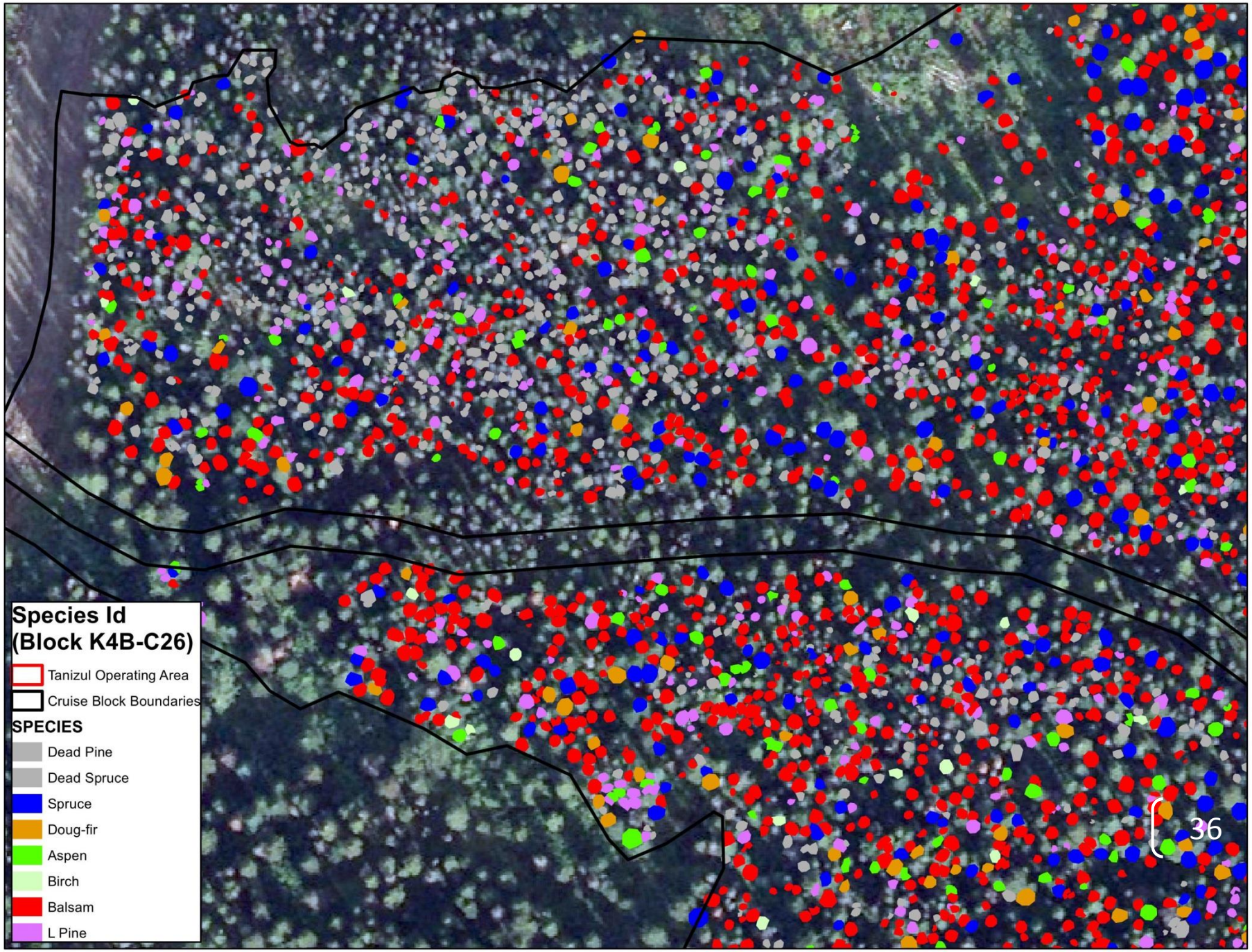
Zoom in on patch of dead pine



Dead Pine – Grey coloured stems on Ortho.

Overlay of segmented stems on Orthophoto

(road was logged when Lidar flown)



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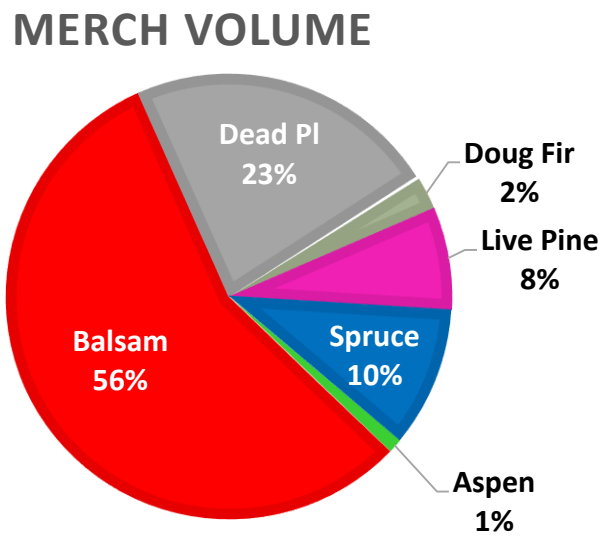
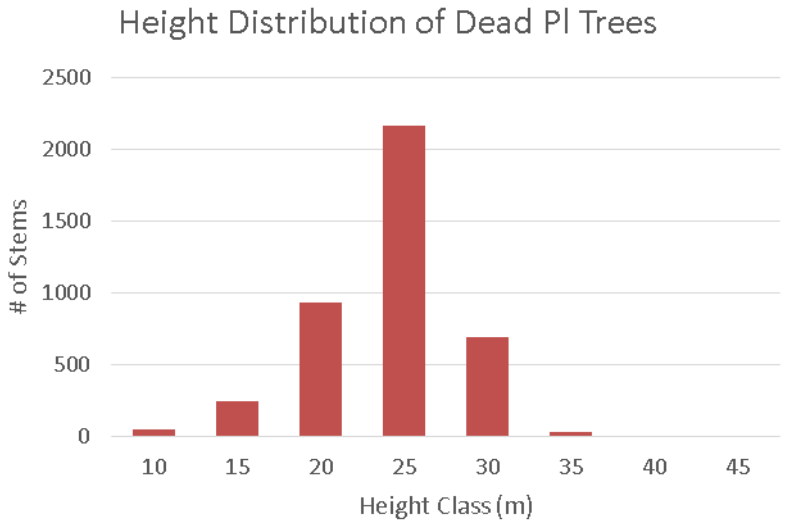
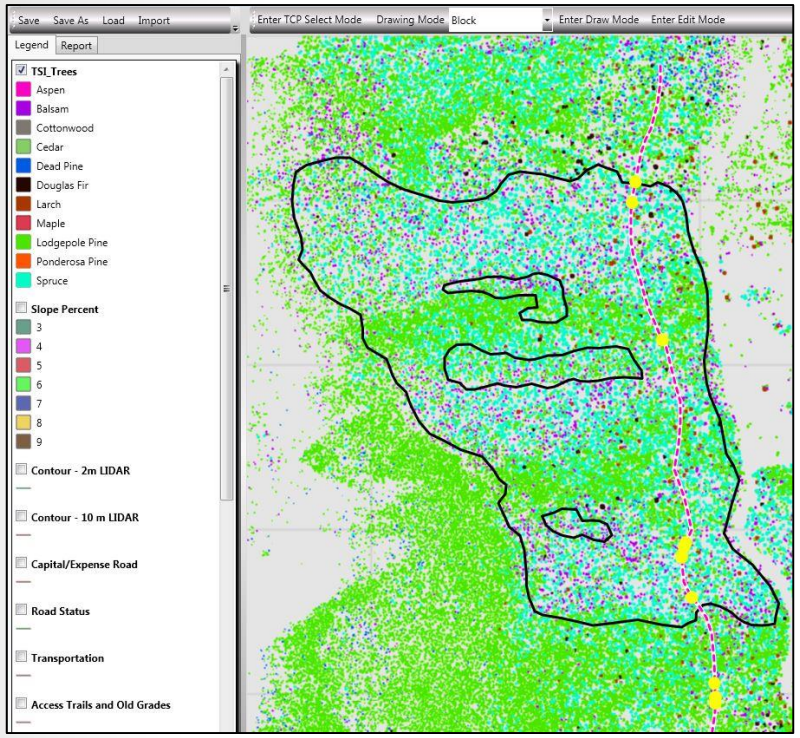
Block Summary Report (100% Census – not sampling)

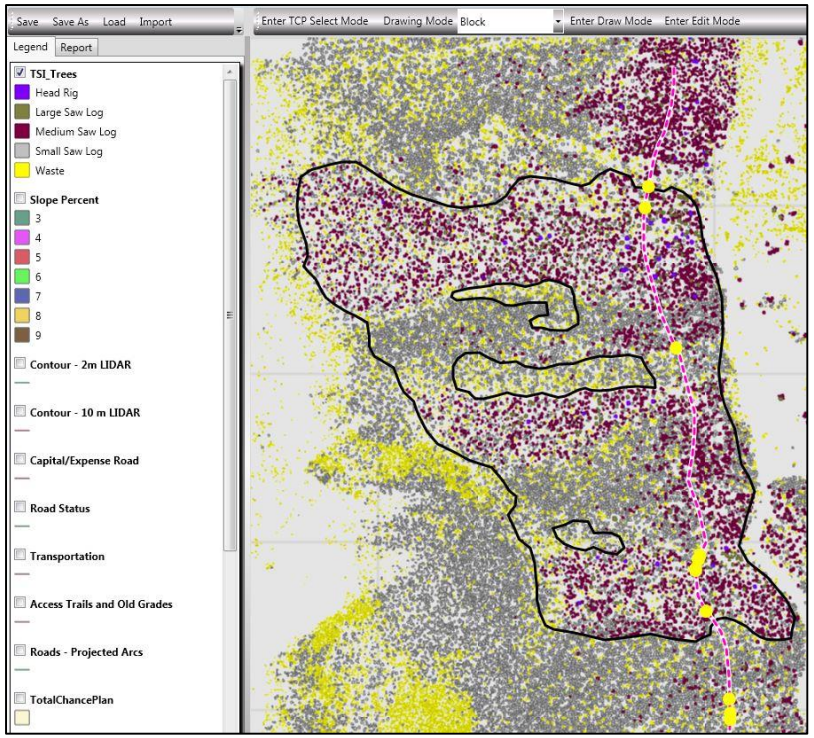
SPECIES	# of Stems	MERCH VOLUME	HEAD RIG VOL	LG SAWLOG VOL	MED SAWLOG VOL	SM SAWLOG VOL
Aspen (At)	610	154	-	-	55	99
Balsam Fir (Bl)	9,326	8,135	30	839	4,550	2,716
Dead Pine (DP)	4,091	3,271	-	37	1,943	1,291
Dead Spruce (DS)	21	24	-	2	17	6
Birch (Ep)	77	12	-	-	3	9
Douglas-fir (Fd)	413	345	3	41	199	101
Live Pine (Pl)	1,725	1,078	-	45	563	471
Spruce (Sx)	1,547	1,468	1	118	960	389
Grand Total	**18,238**	**14,488**	**33**	**1,082**	**8,291**	**5,081**

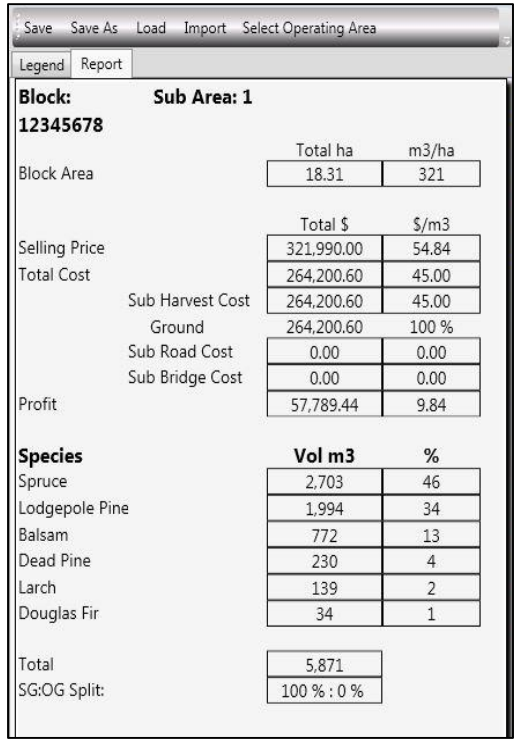




Tree Level Inventory → Stand Level Economics







Individual tree inventories help planners locate and analyze harvest opportunities based on:

- Species,
- Log products,
- Volumes,
- Slope Class (Grd vs Cable vs Heli),
- Custom logging and road costs,
- Current species specific rates ($/m)

Allows economics to be analyzed at the block level almost instantly.

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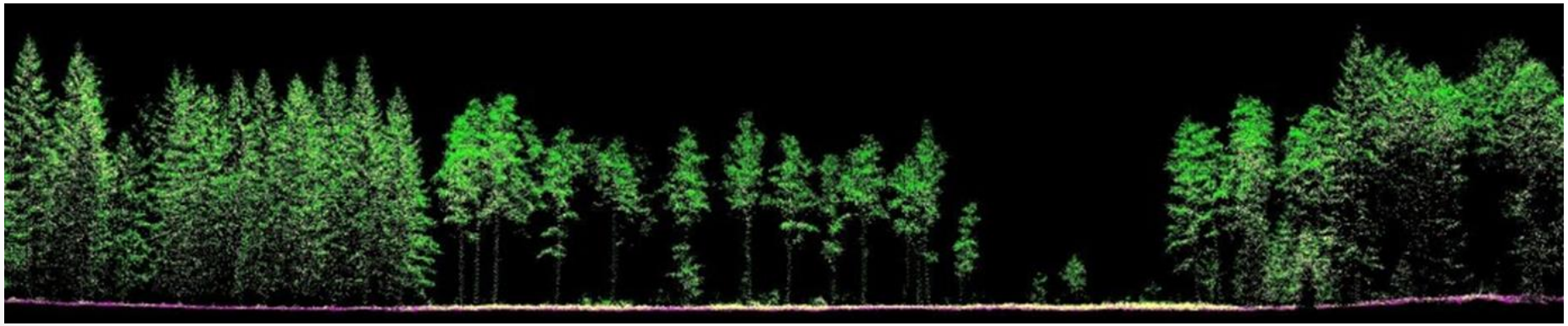
Summary

3D point clouds generated from LiDAR present a wide range of opportunities for enhancing forest management decisions and improving efficiency. Applications in the forest industry are becoming increasingly widespread and diverse.

- Watershed Hydrology
- Terrain / Avalanche Assessments
- Stand Structure Assessments
- Visual Assessments
- Forest Inventories / Growth and Yield



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Questions?

For more information:

Cam Brown, MF, RPF cbrown@forsite.ca

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