

Rockfall and Geohazard Site Characterization Using UAVs, Photogrammetry and LiDAR

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Outline

- State of Practice
- UAV technology
- Common Workflows
- Examples / Case Studies
 - Change Detection with Aerial LiDAR
 - Change Detection with Terrestrial LiDAR
 - Change Detection with Terrestrial Photogrammetry
 - UAV 3D model data for 3D numerical modelling
- Geotechnical Asset Management
- Emerging applications - Flying underground, BIM, and automation



State of Practice for Scanning with UAVs

- Presentations last year by Radford University and ATS International summarized the use of UAVs quite well
- Most work right now is done with Photogrammetry and almost all of that is using Structure From Motion
- As units get smaller and UAVs get better, LiDAR and RTK GPS being added
- Less common sensors include Thermal, Near Infrared and bathymetric LiDAR
- Scale is highly flexible from hand specimen to entire highway alignment



UAV Units

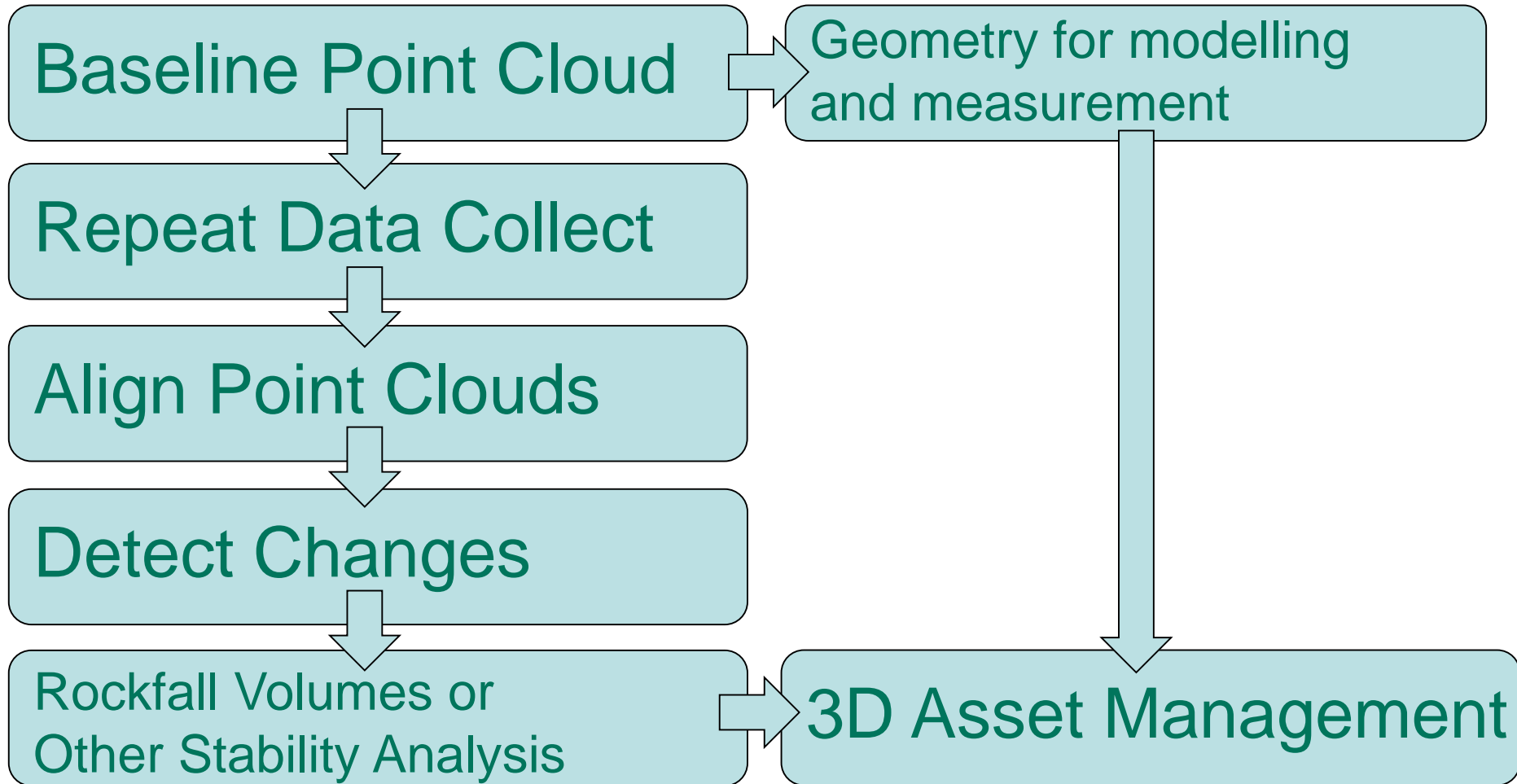


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eBee

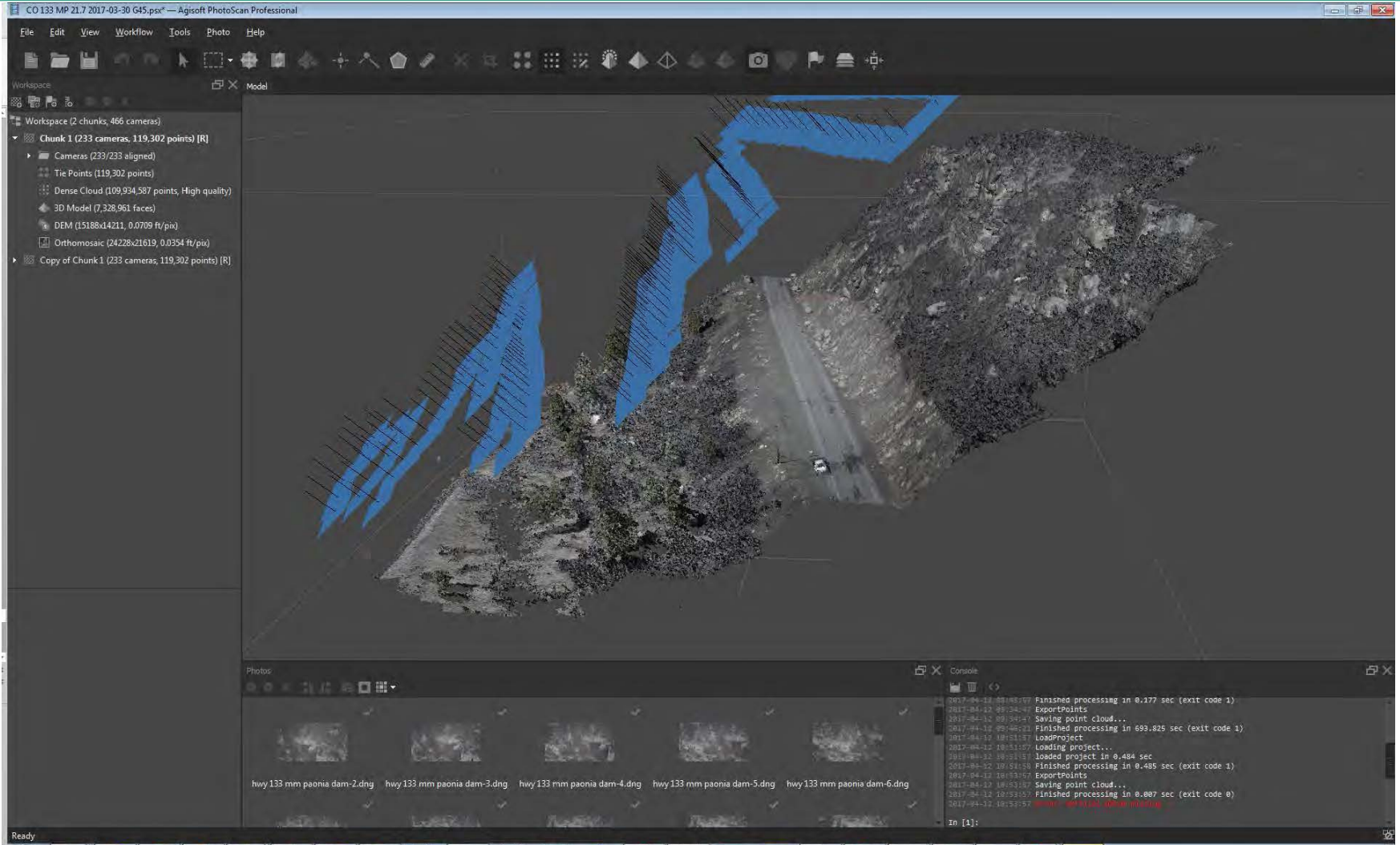




Common workflow



Baseline Point Cloud





Repeat Data Collect

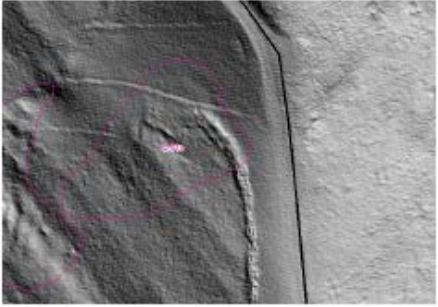
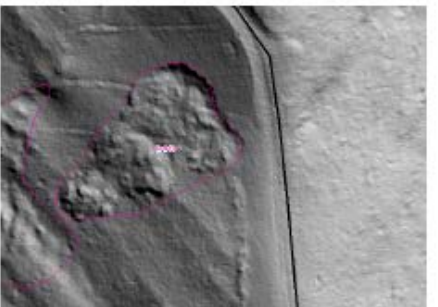
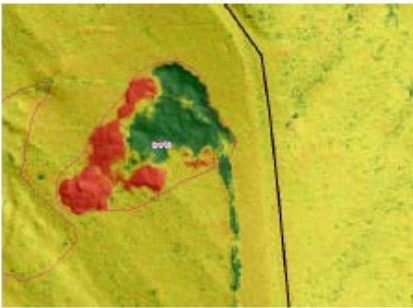


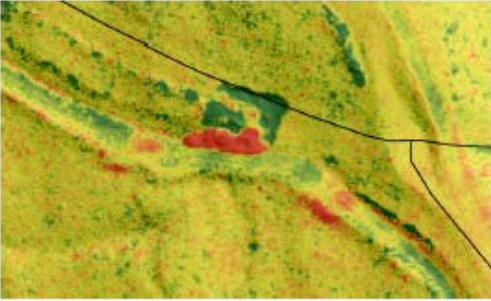
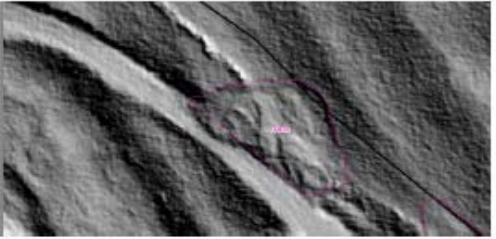
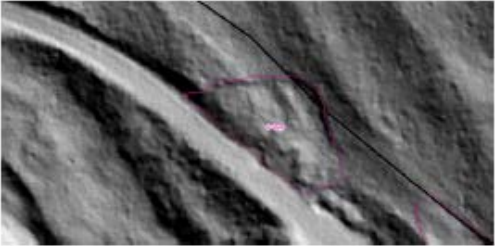
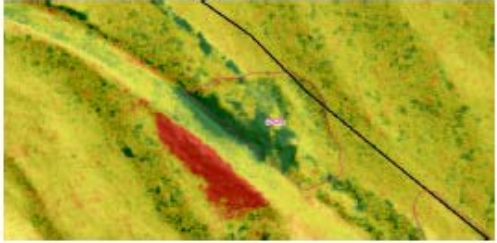


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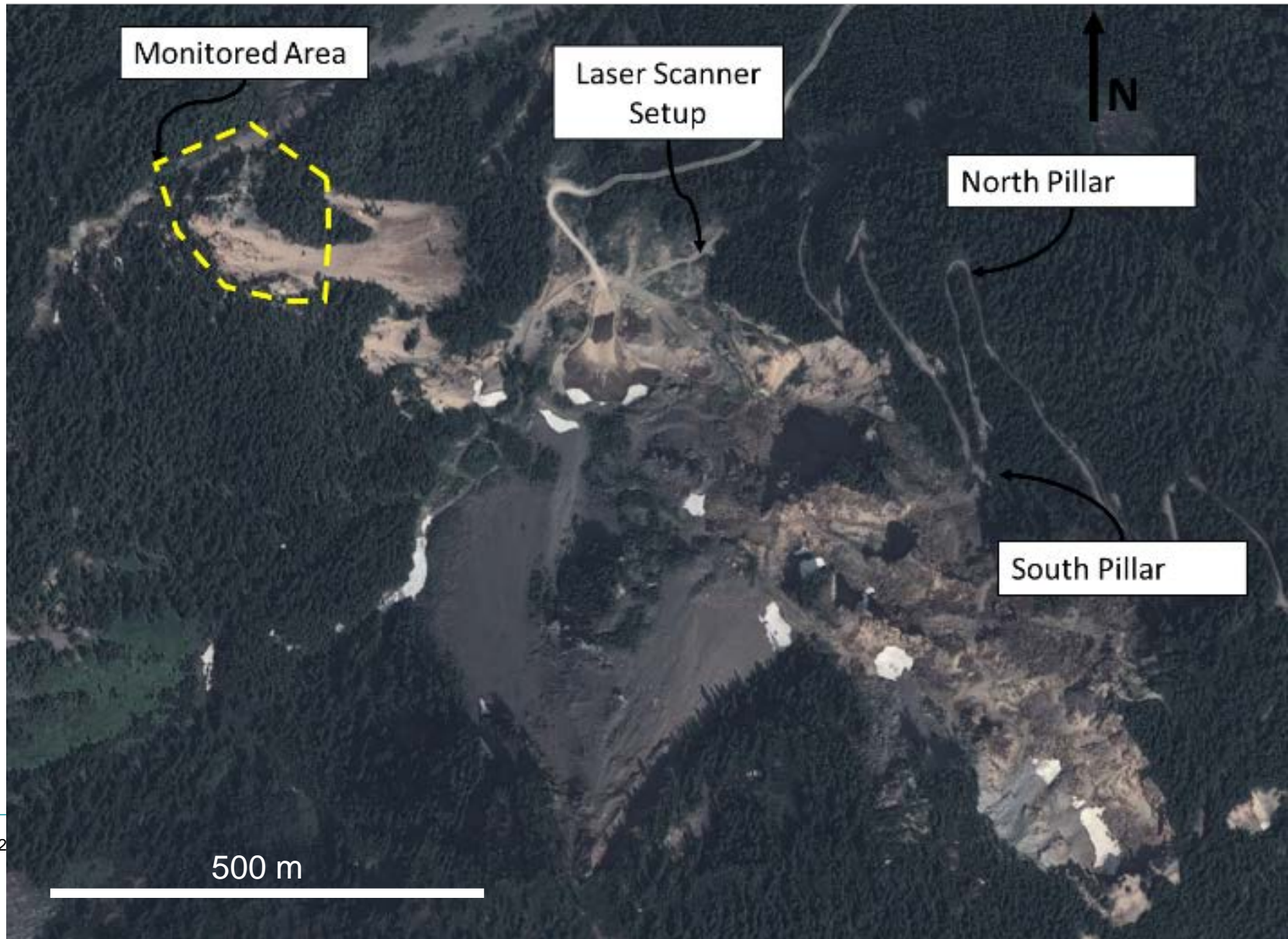


Change Detection Case Study – Aerial LiDAR

2013 LIDAR	2015 LIDAR	ELEVATION CHANGE
		
		
		



Change Detection Case Study – Terrestrial LiDAR



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Site flyover video

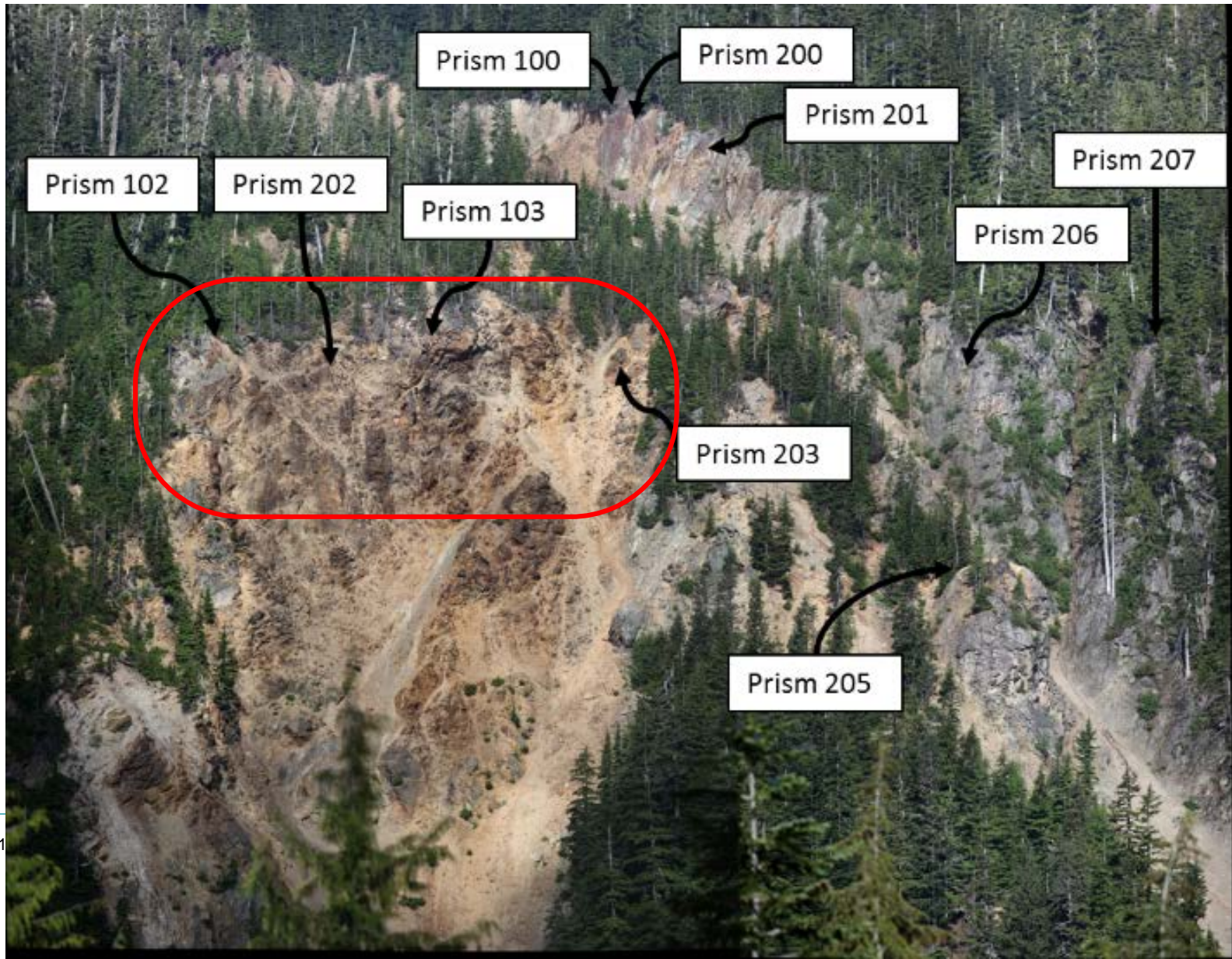


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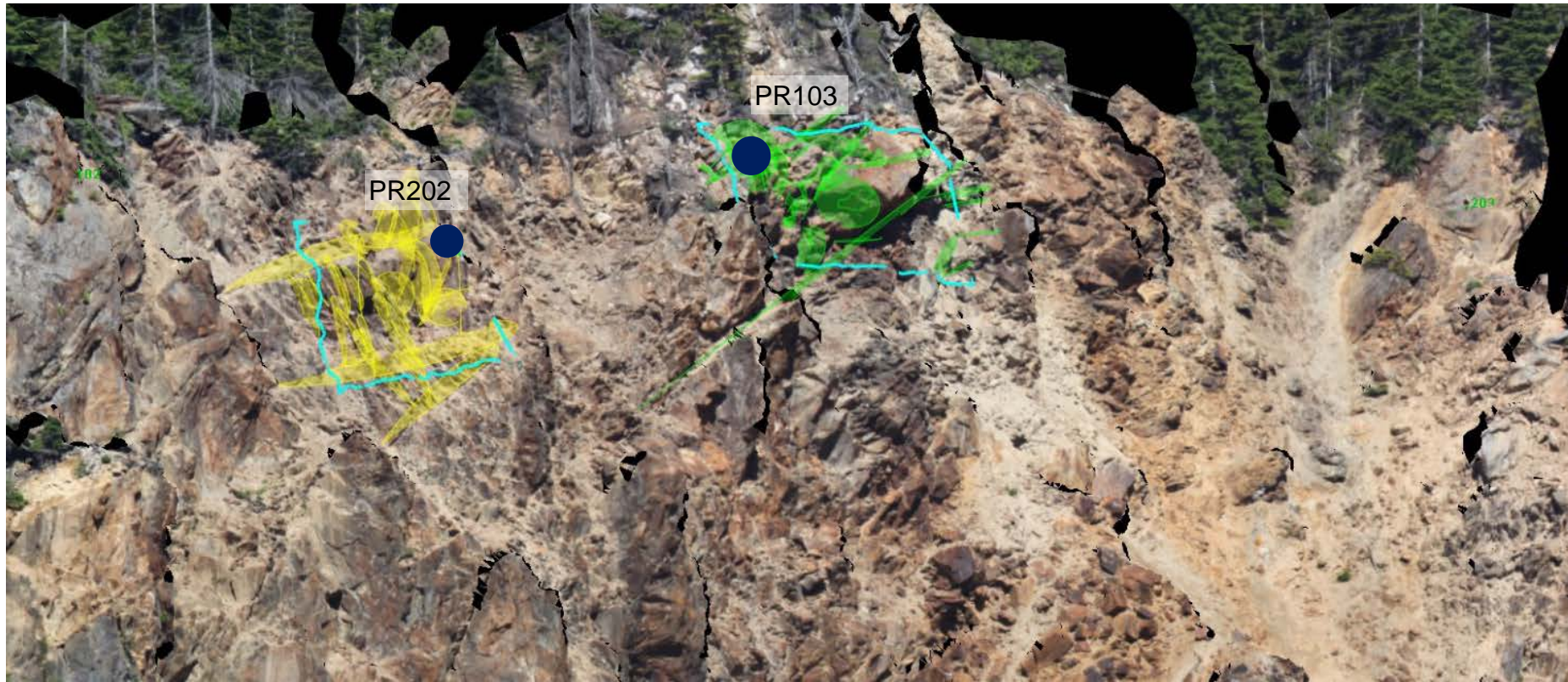


Change Detection Case Study – Terrestrial LiDAR



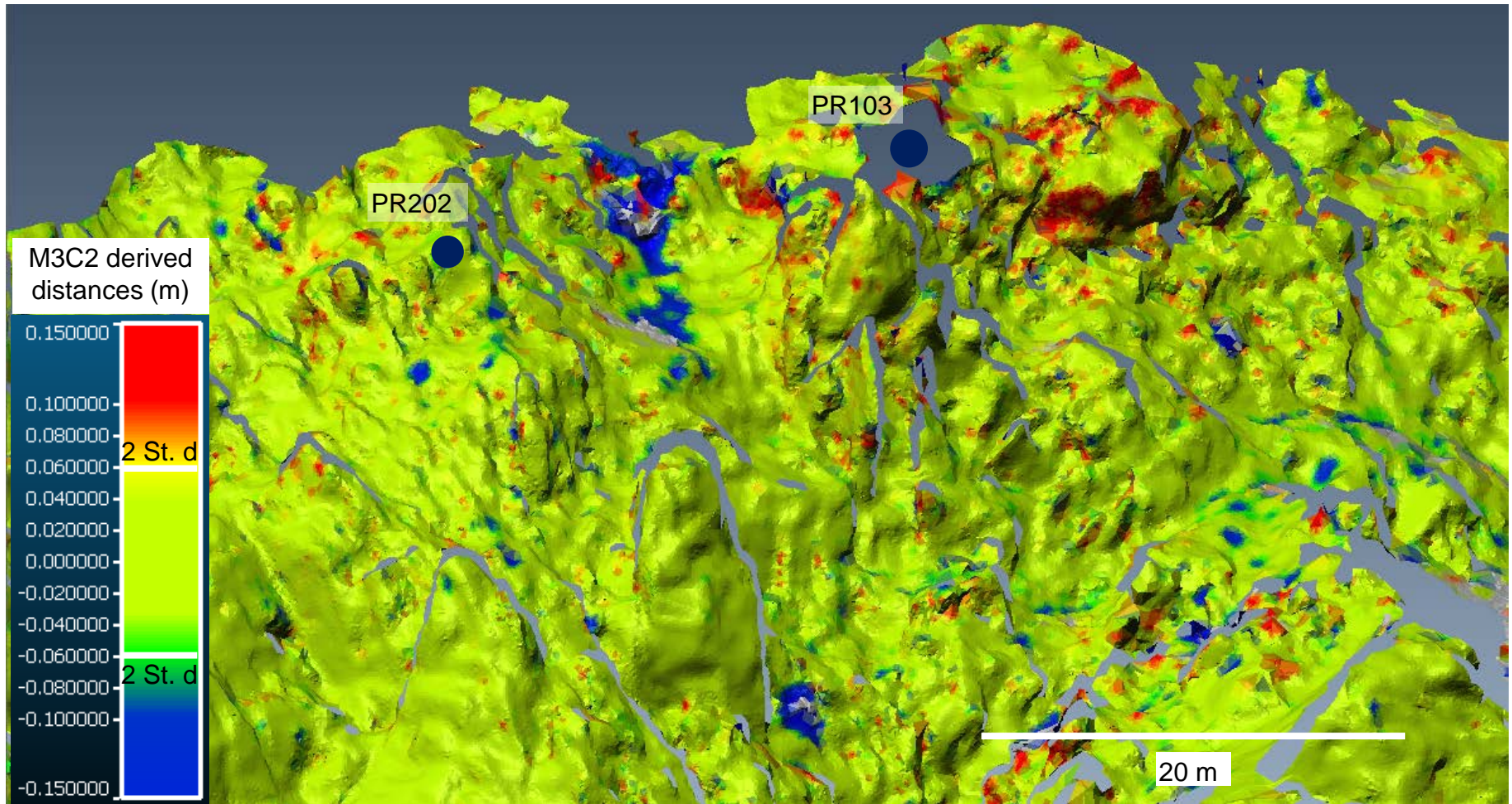


Change Detection Case Study – Terrestrial LiDAR



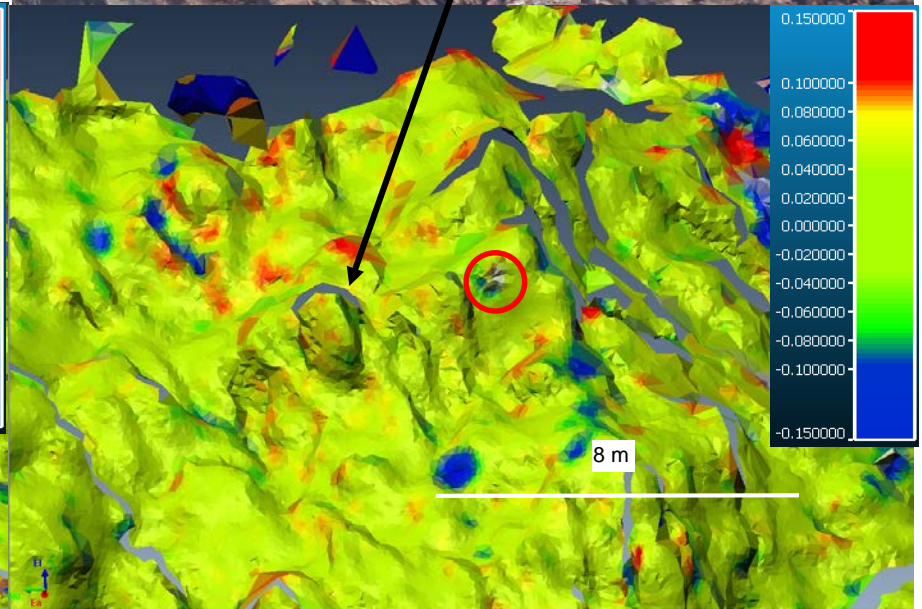
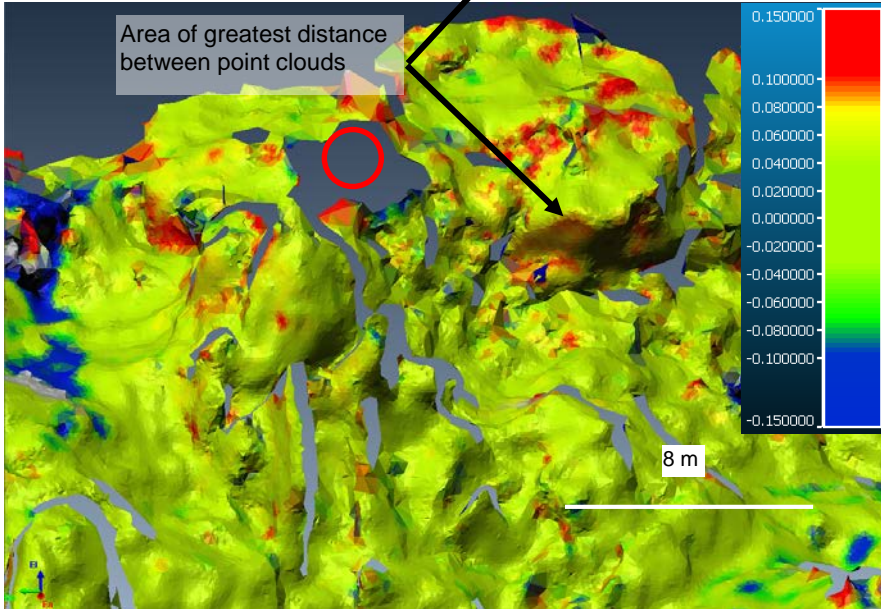


Change Detection Case Study – Terrestrial LiDAR





Change Detection Case Study – Terrestrial LiDAR



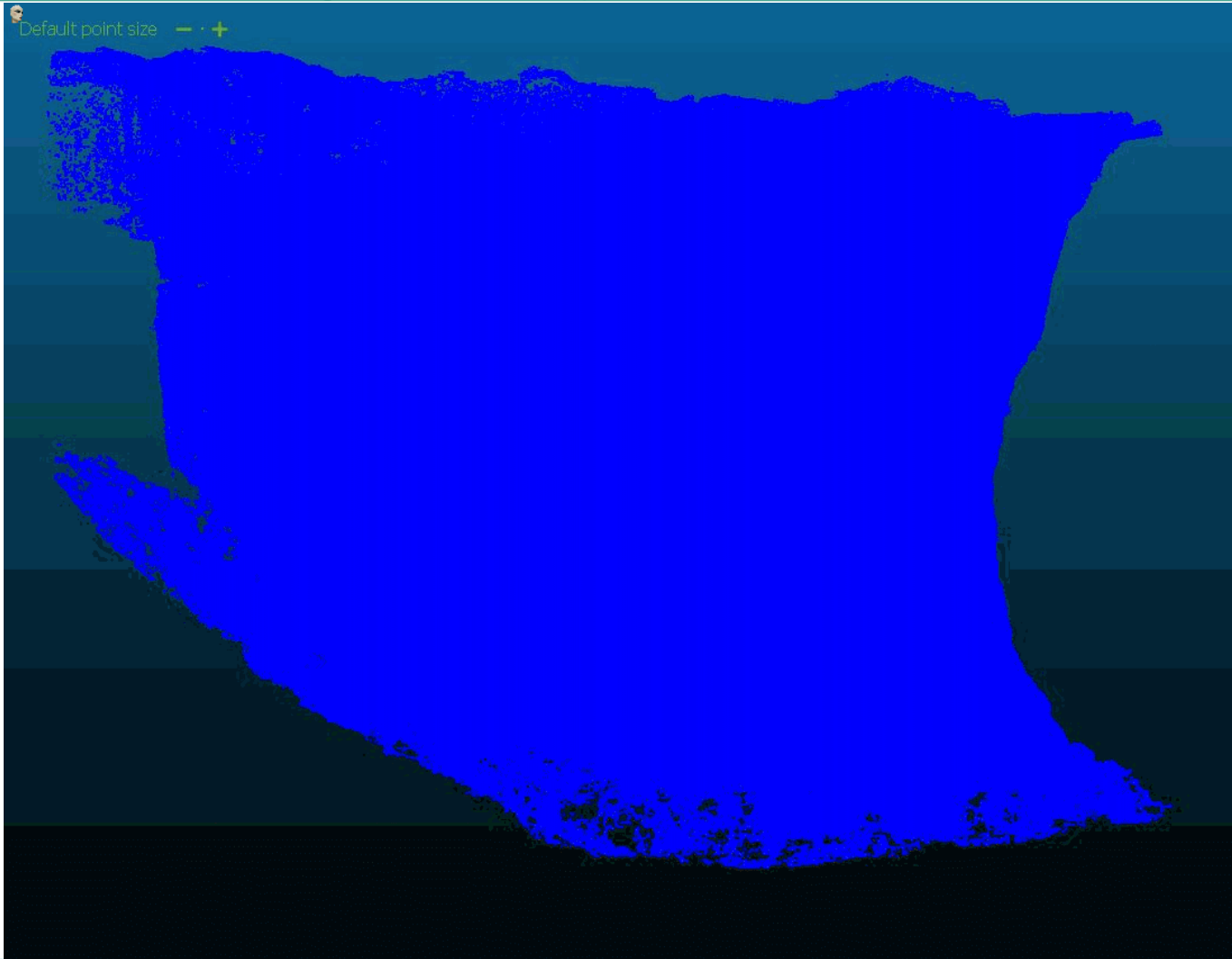


Change Detection Case Study – Terrestrial Photogrammetry





Change Detection Case Study – Terrestrial Photogrammetry





I-70 – Debeque Canyon MP 53 Test Site





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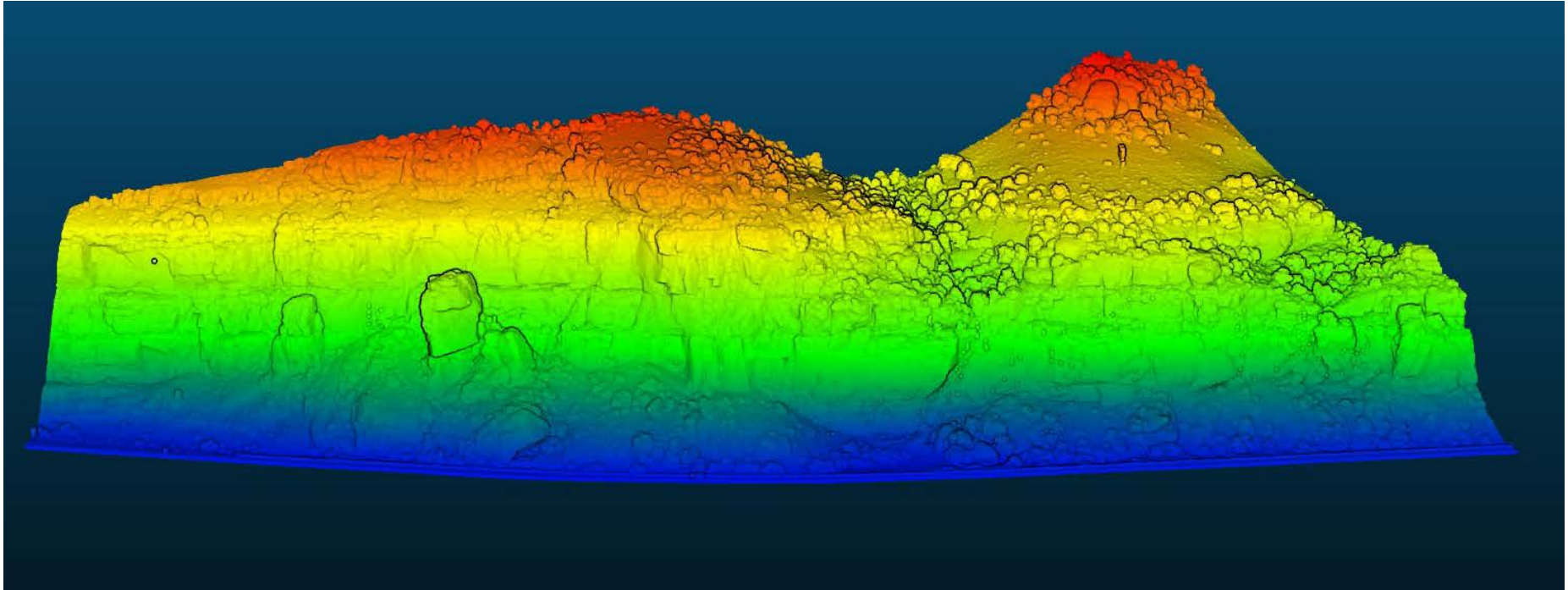
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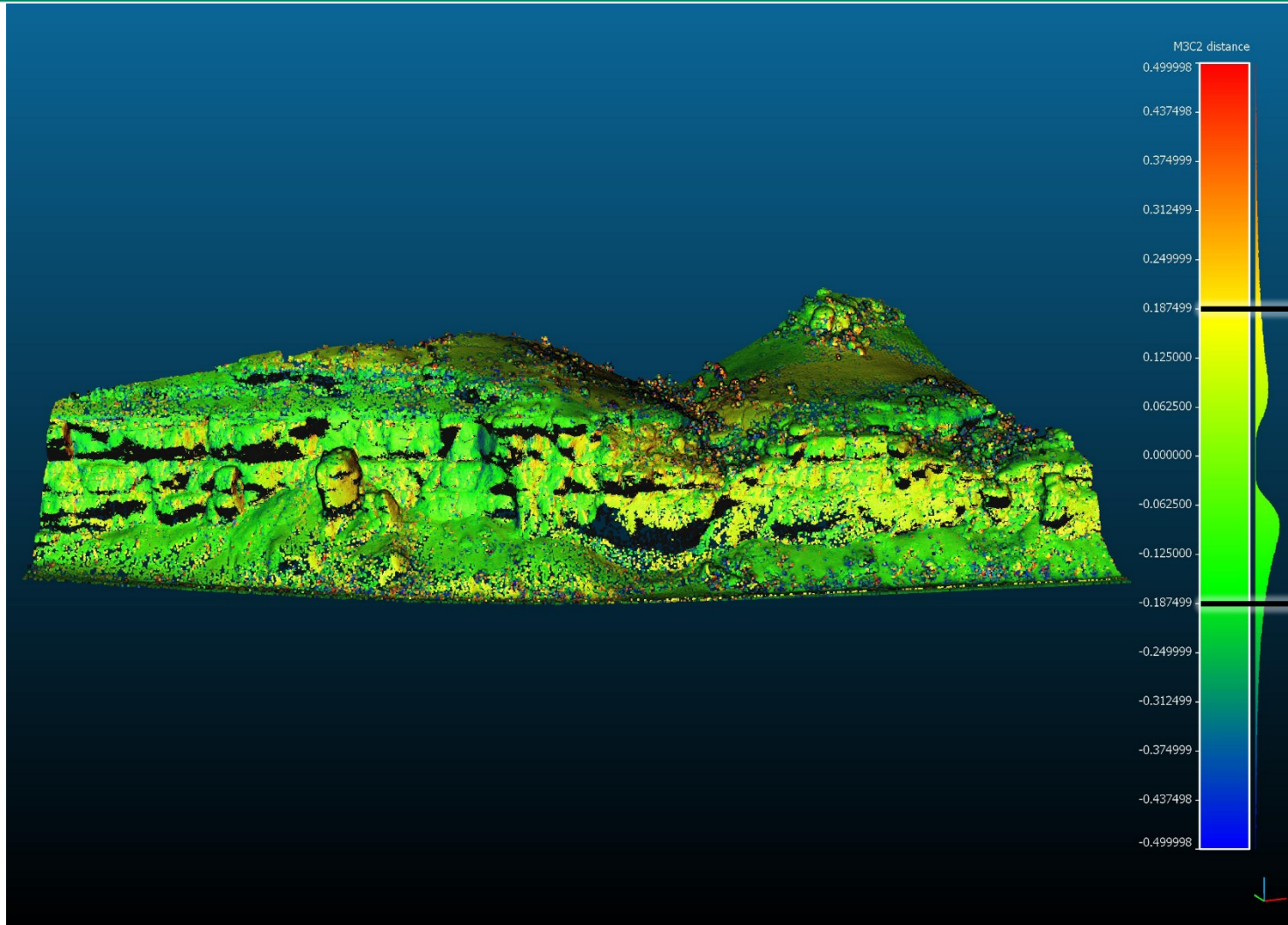


UAV LiDAR Data Set – I-70 Debeque Canyon





UAV LiDAR Data Set – Limits of Detection







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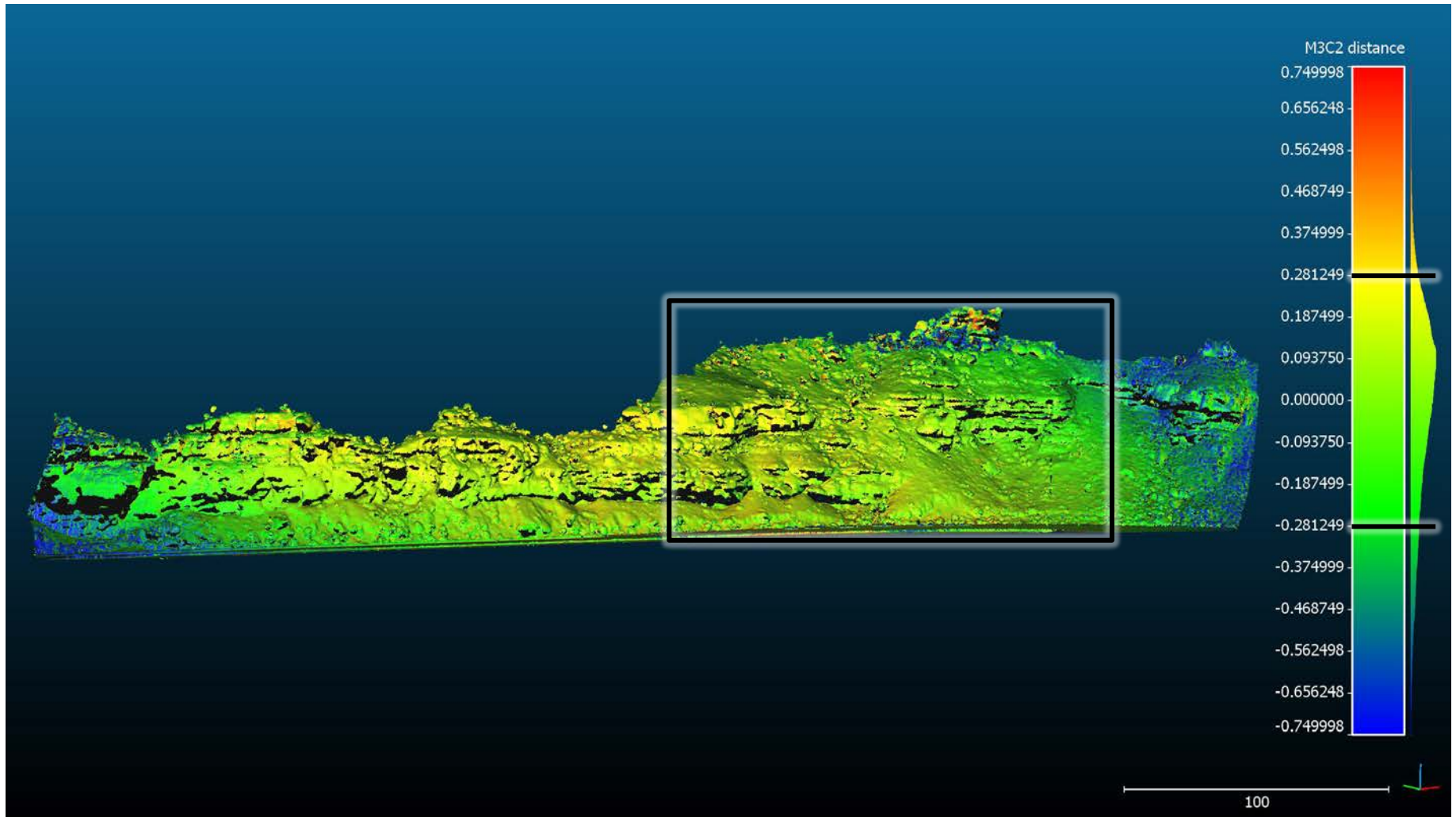


UAV Photogrammetry Data Set – I-70 Debeque Canyon





UAV Photogrammetry Data Set – Limits of Detection





April 26, 2017

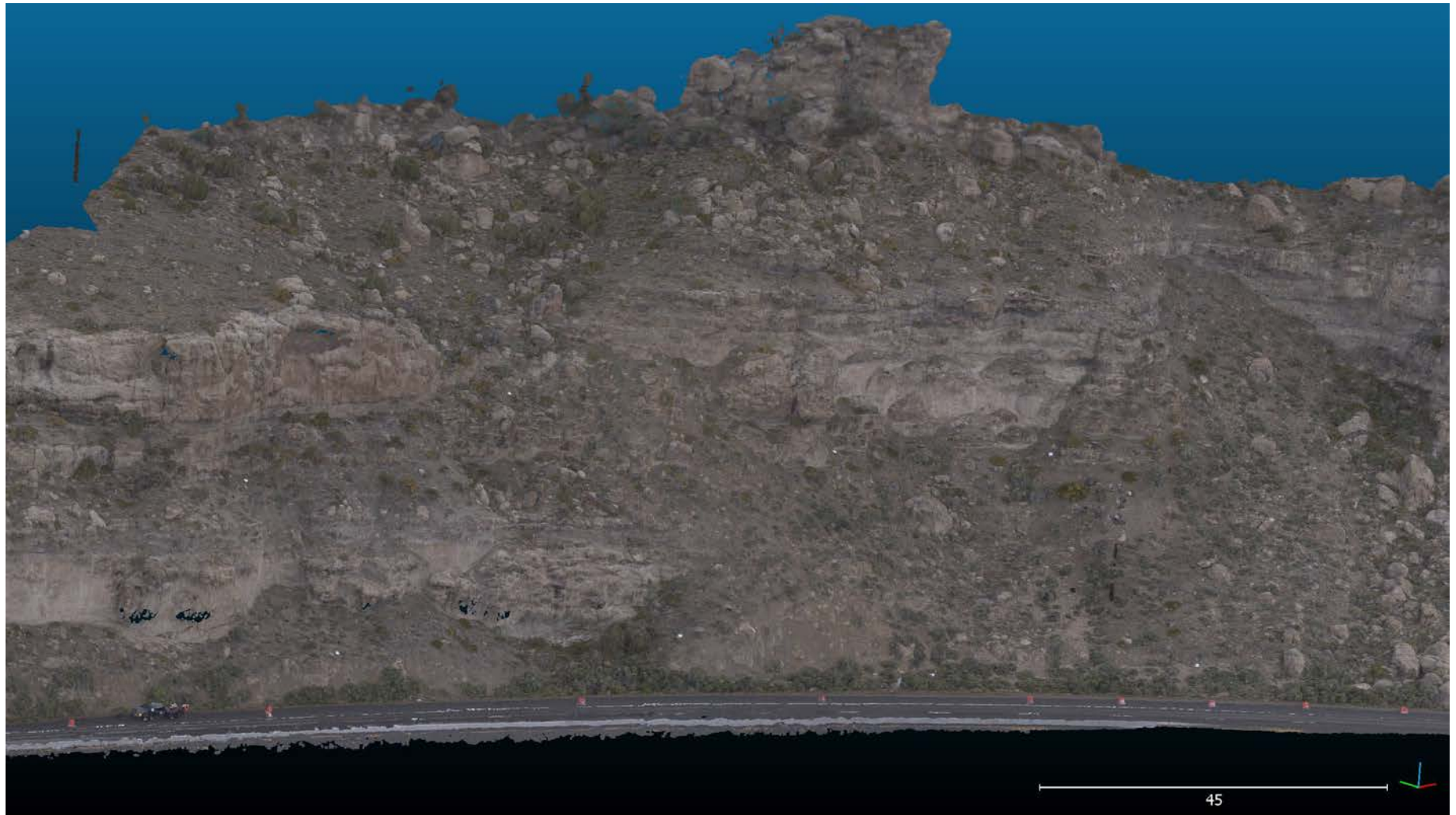


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April 27, 2017

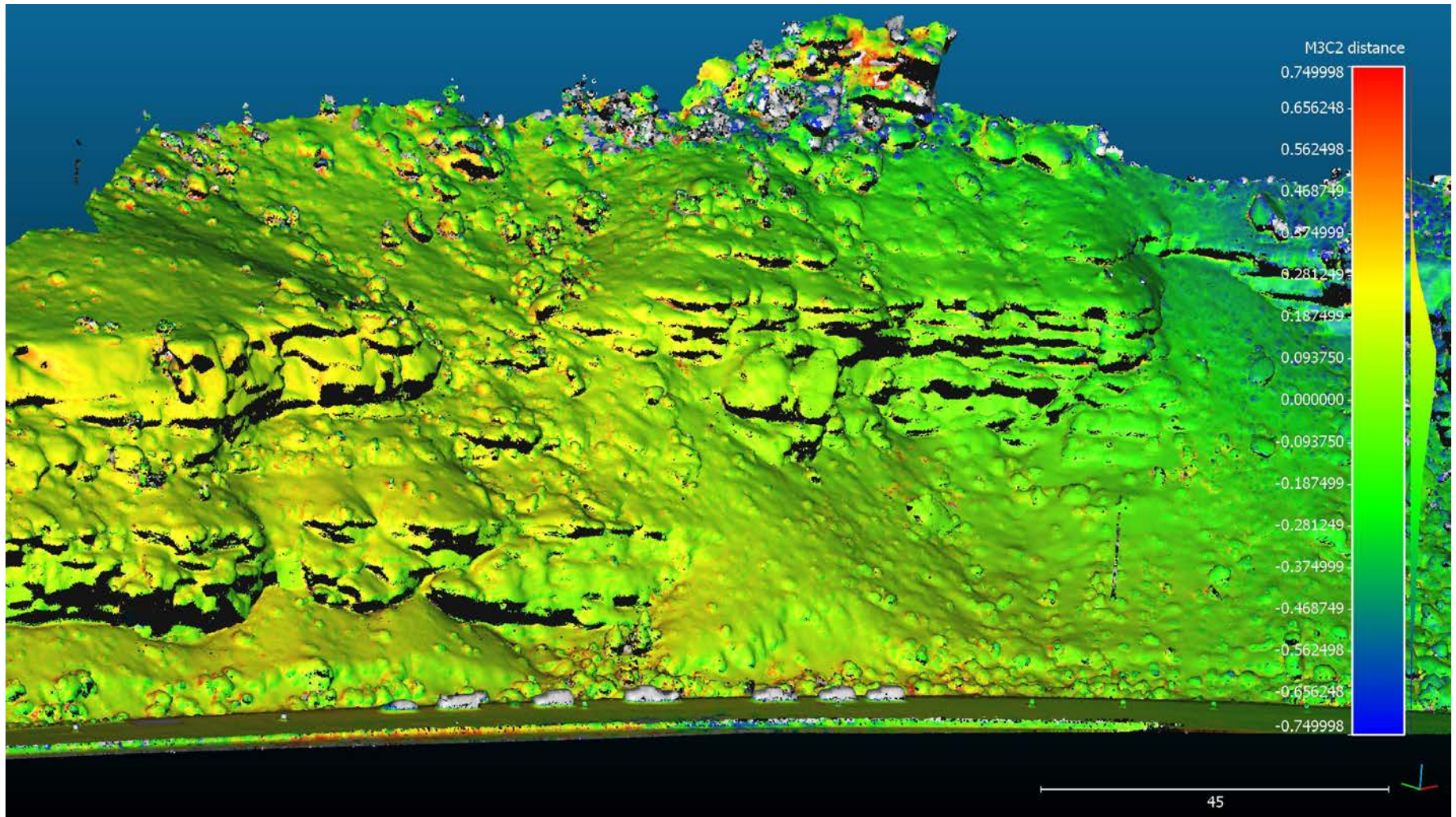


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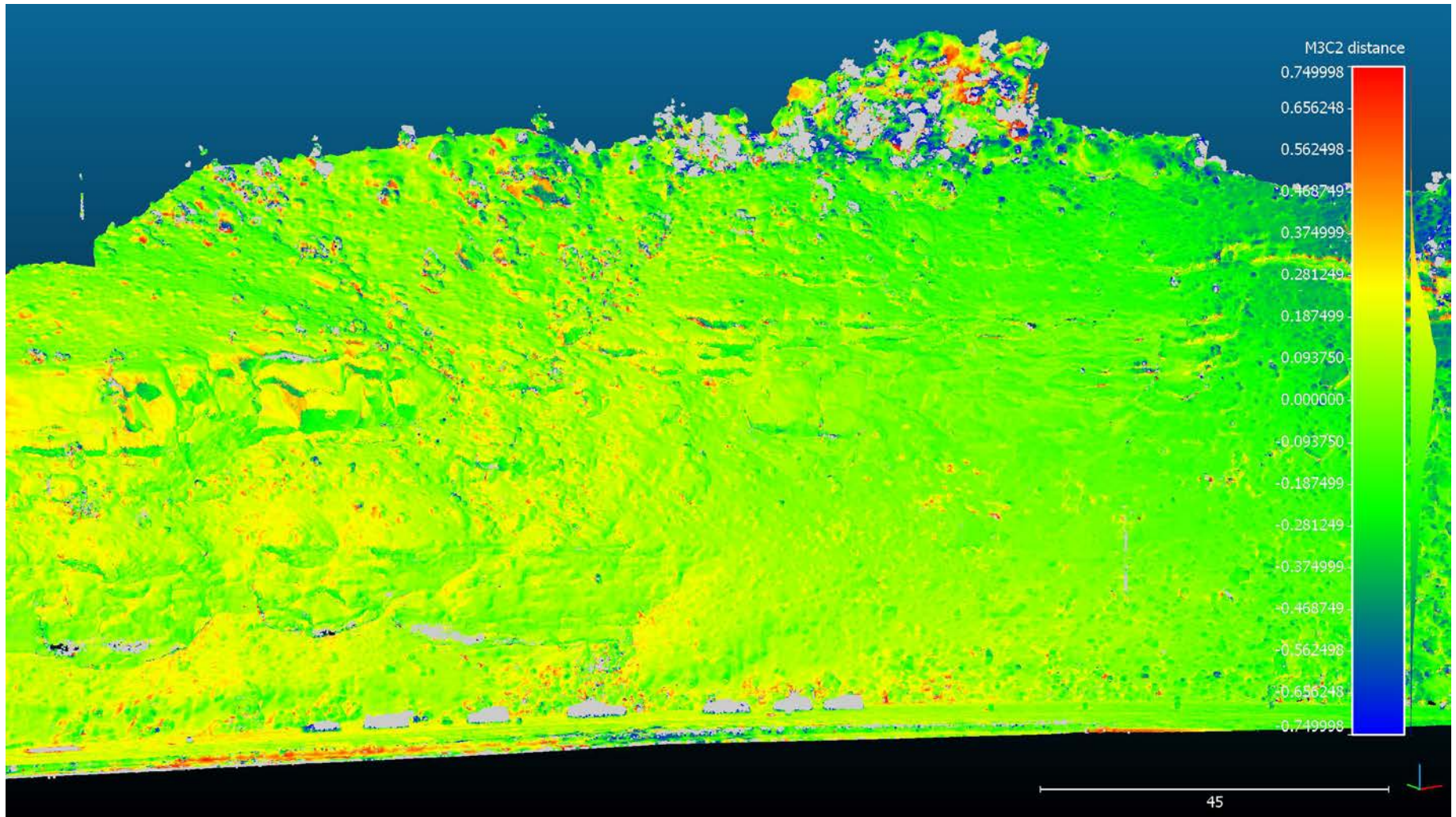


Difference – April 26 to April 27, 2017





Difference – April 26 to April 27, 2017





Preliminary Findings – Limits of Detection

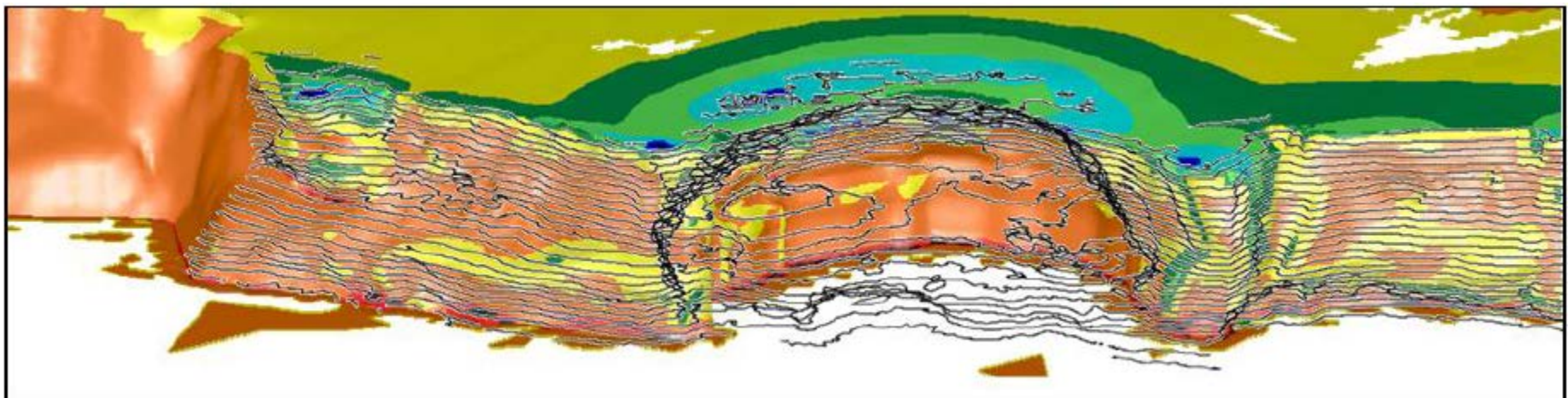
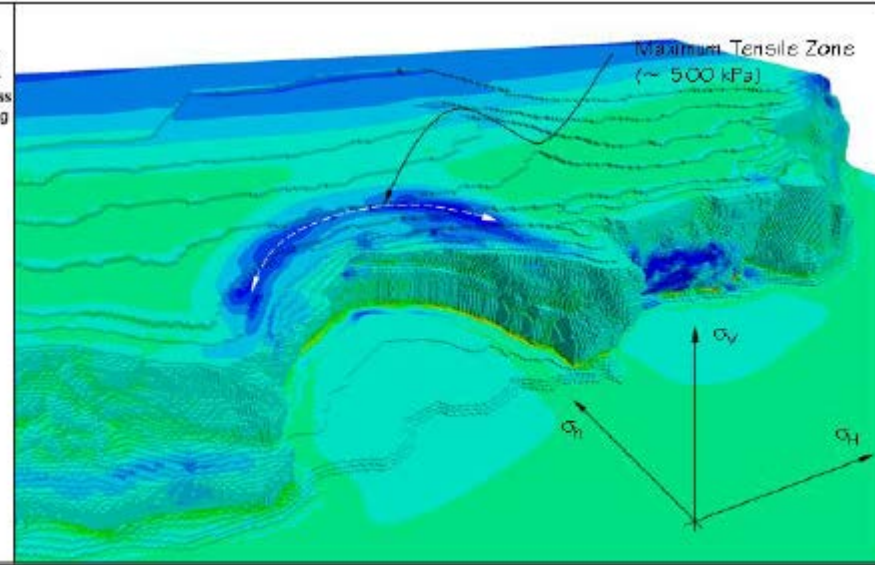
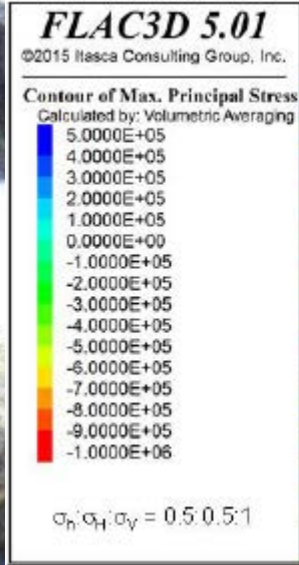
- Resolution
 - UAV LiDAR ~10 cm/point (~4 in/point)
 - UAV Photogrammetry ~2 cm/pixel (~3/4 in/point)
- Approximate Limits of Detection / Registration Error
 - UAV LiDAR ± 6 cm (2.5 in)
 - UAV Photogrammetry ± 30 cm (12 in)
 - Photogrammetry – Registration is Key



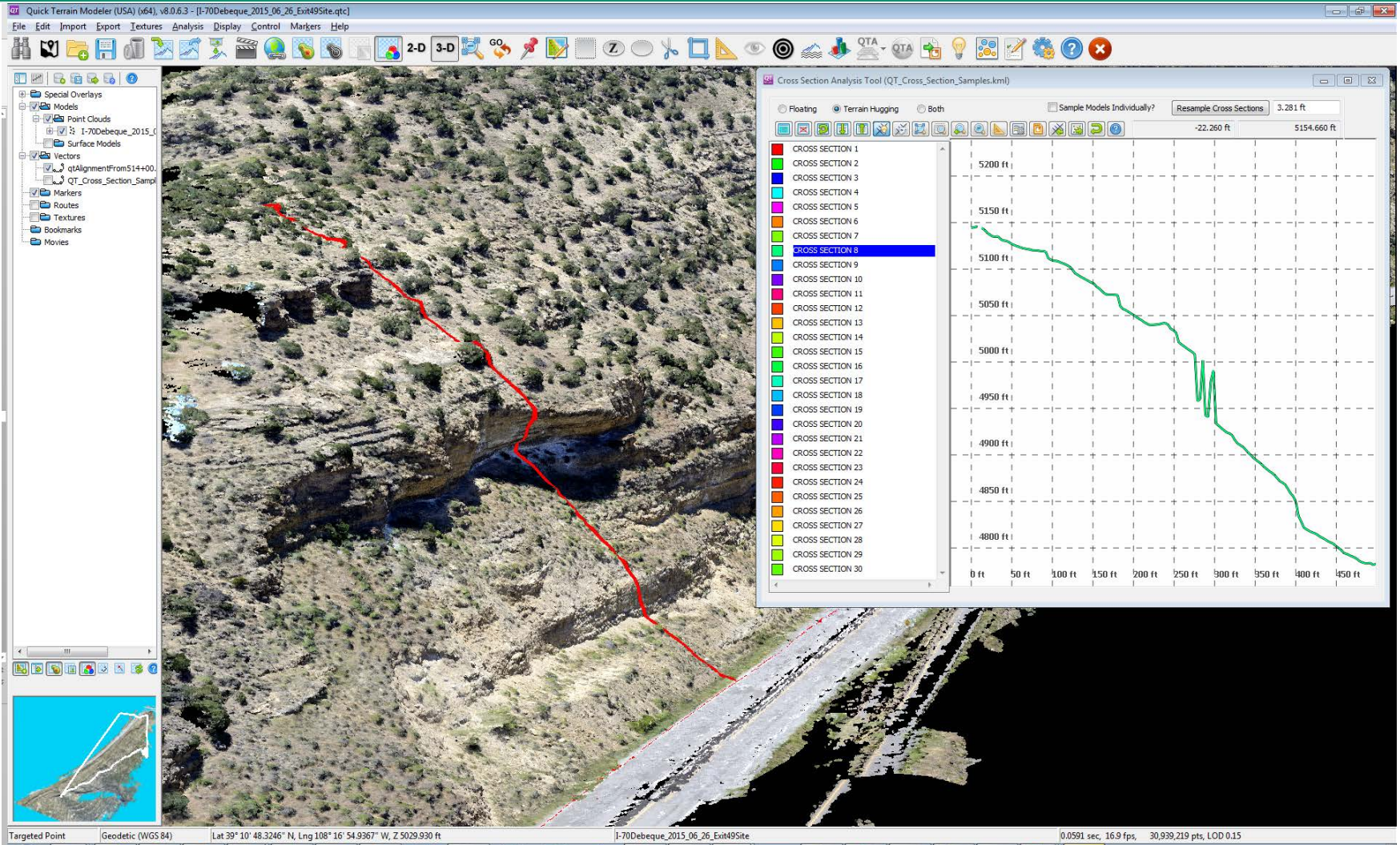
Case Study – UAV Data for Numerical Modelling



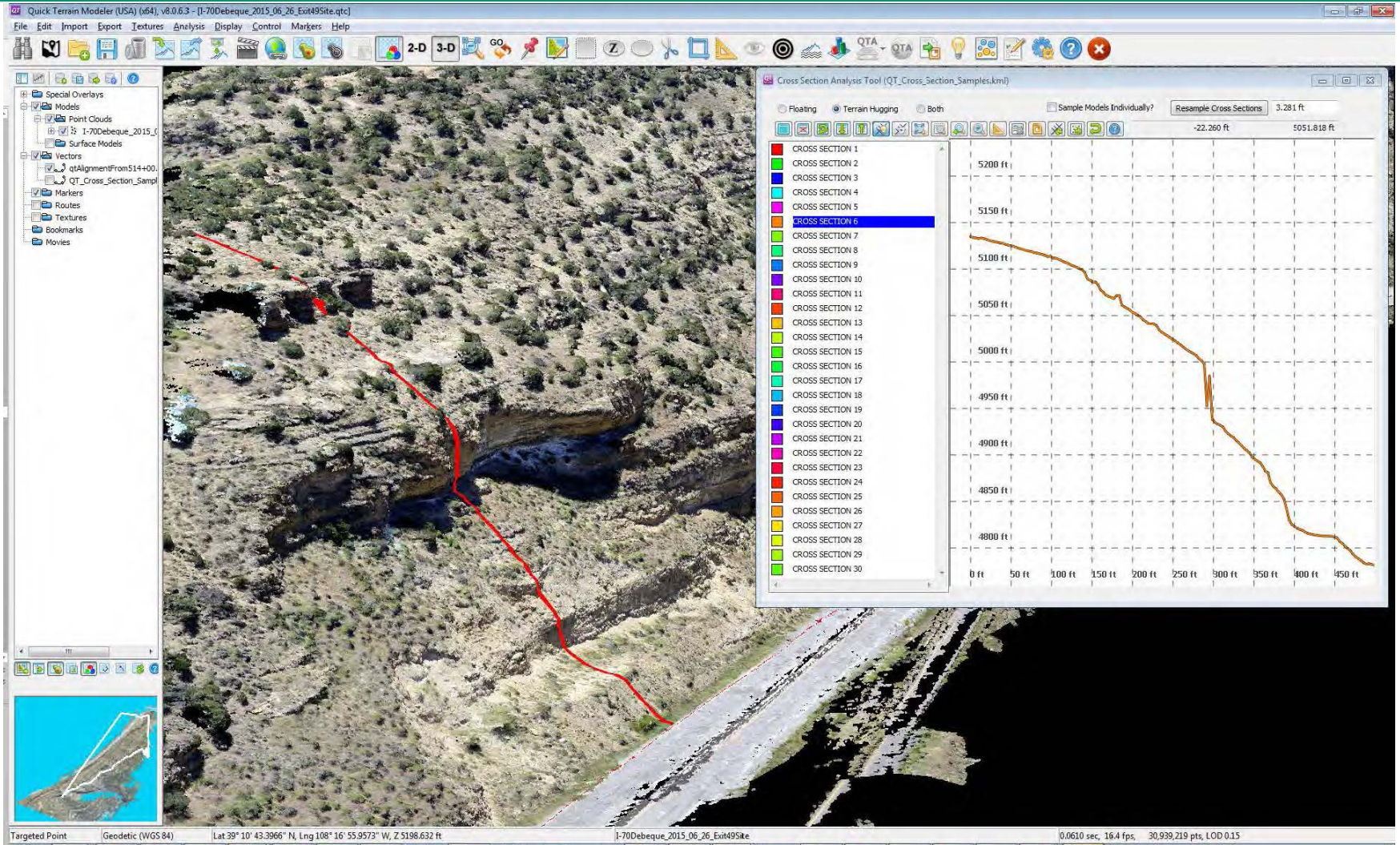
Drone Generated DEM



Rapid Generation of Rockfall Simulation Runs



Rapid Generation of Rockfall Simulation Runs

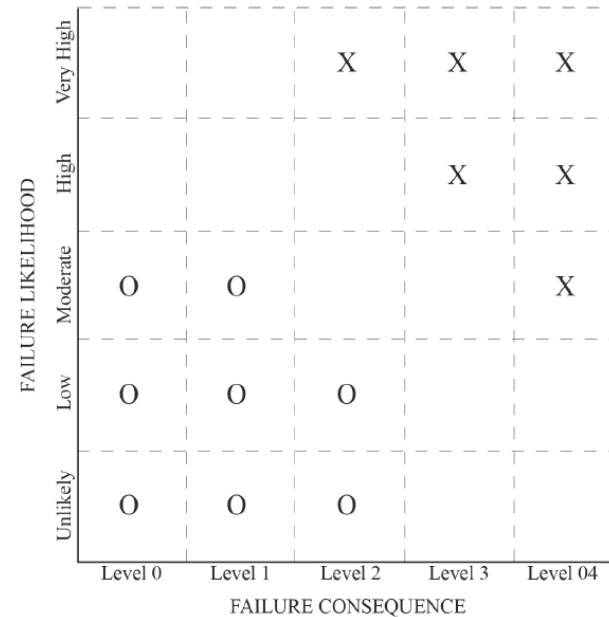




Geotechnical Asset Management

- GAM Still in Development Stages
- Currently – Inventory of Features (Hazard Identification)
- Score/Rating – Not a Probability

	Unlikely	Likely	Very Likely
Major	Medium	High	Extreme
Moderate	Low	Medium	High
Minor	Low	Low	Medium



LEGEND
 X - Geotechnical features that present greatest risk to corridor performance and require further assessment.
 O - Low priority features based on risk screening

Source: Vessely, 2013



Modified Colorado RHRS and UAV Data

Colorado Rockfall Hazard Rating Field Worksheet

Sight Information							
ROUTE NO		SEGMENT ID NUMBER		ENGINEERING REGION	MAINTENANCE SECTION	DATE	
COUNTY		BEGIN MILE POST		END MILE POST	R / L OF CENTERLINE	RATER	
Actual Values			Remarks				
Slope Height	Ditch Depth		Major rockslide potential:				
Slope Angle	Sight Distance		Dominating rockfall mode: Block-in-matrix / Sedimentary rock / Crystalline rock				
Ditch Slope	Speed Limit		Dominating sight distance: Horizontal / Vertical				
Ditch Width	ADT		Mitigation effectiveness: A B C D F				
Rating							
Cut Slope / Total Slope (Circle one)							
		3 Points	9 Points	27 Points	81 Points		
Slope	Slope Height	25 to 50 ft	50 to 75 ft	75 to 100 ft	>100 ft		
	Rockfall Frequency	> 2 years	1 to 2 years	Yearly, seasonal	Year round / severe events		
	Average Slope Angle Score	0 to 2	2 to 4	4 to 8	> 8		
	Launching Features	None (smooth slope)	Minor (< 2 ft. surface variation)	Many (2 to 6 ft. surface variation)	Major (> 6 ft. surface variation)		
	Ditch Catchment	95% to 100% / Class 1	65% to 94% / Class 2	30% to 64% / Class 3	< 30% / Class 4 / ≥ Major launching features		
Climate	Annual Precipitation	< 10 inches	10 to 20 inches	20 to 35 inches	> 35 inches		
	Annual Freeze Thaw Cycles	1 to 5	6 to 10	11 to 15	16 or more		
	Seepage / Water	Dry	Damp / wet	Dripping	Running water		
	Slope Aspect	N	E, W, NE, NW	SE, SW	S		
Geology	Sed. Rock	Degree of Under-Cutting	0 to 1 ft	1 to 2 ft	2 to 4 ft	> 4 ft	
		Jar Slake	6	5	3 to 4	1 to 2	
		Degree of Interbedding	1 to 2 weak interbeds, < 6 in.	1 to 2 weak interbeds, > 6 in.	> 2 weak interbeds, < 6 in.	> 2 weak interbeds, > 6 in.	
	Crys. Rock	Rock Character	Homogenous / massive	Small faults / strong veins	Schist / shear zones < 6 in.	Weak pegmatite / micas / shear zones > 6 in.	
		Degree of Overhang	0 to 1 ft	1 to 2 ft	2 to 4 ft	> 4 ft	
		Weathering Grade	Fresh	Surface staining	Slightly altered / softened	Core stones	
	Discontinuities	Block Size / Volume	< 1 ft / < 1 cy	1 to 2 ft / 1 to 3 cy	2 to 5 ft / 3 to 10 cy	> 5 ft / > 10 cy	
		Number of Sets	1	1 plus random	2	> 2	
		Persistence, Orientation	< 10 ft and dips into slope	> 10 ft and dips into slope	< 10 ft and daylight out of slope	> 10 ft and daylight out of slope	
		Aperture	Closed	0.1 to 1 mm	1 to 5 mm	> 5 mm	
	Block in Mat.	Weathering Condition	Fresh	Surface staining	Granular infilling	Clay infilling	
		Friction	Rough	Undulating	Planar	Slickensided	
		Block Size (x3)	< 1 ft	1 to 2 ft	2 to 5 ft	> 5 ft	
Block Shape (x3)	Block Shape (x3)	Tabular	Blocky	Blocky to angular	Rounded and smooth		
	Vegetation (x3)	Fully vegetated	Patchy vegetation	Isolated plants	None		
Total Hazard Score:							
Traffic	Sight Distance	> 80 %	60 % to 80 %	40 % to 60 %	< 40 %		
	Avg. Vehicle Risk	0 to 24%	25 to 49%	50 to 74%	75% or more		
	No. of Accidents	0 to 2	3 to 5	6 to 8	9 and over		
Total Risk Score:							

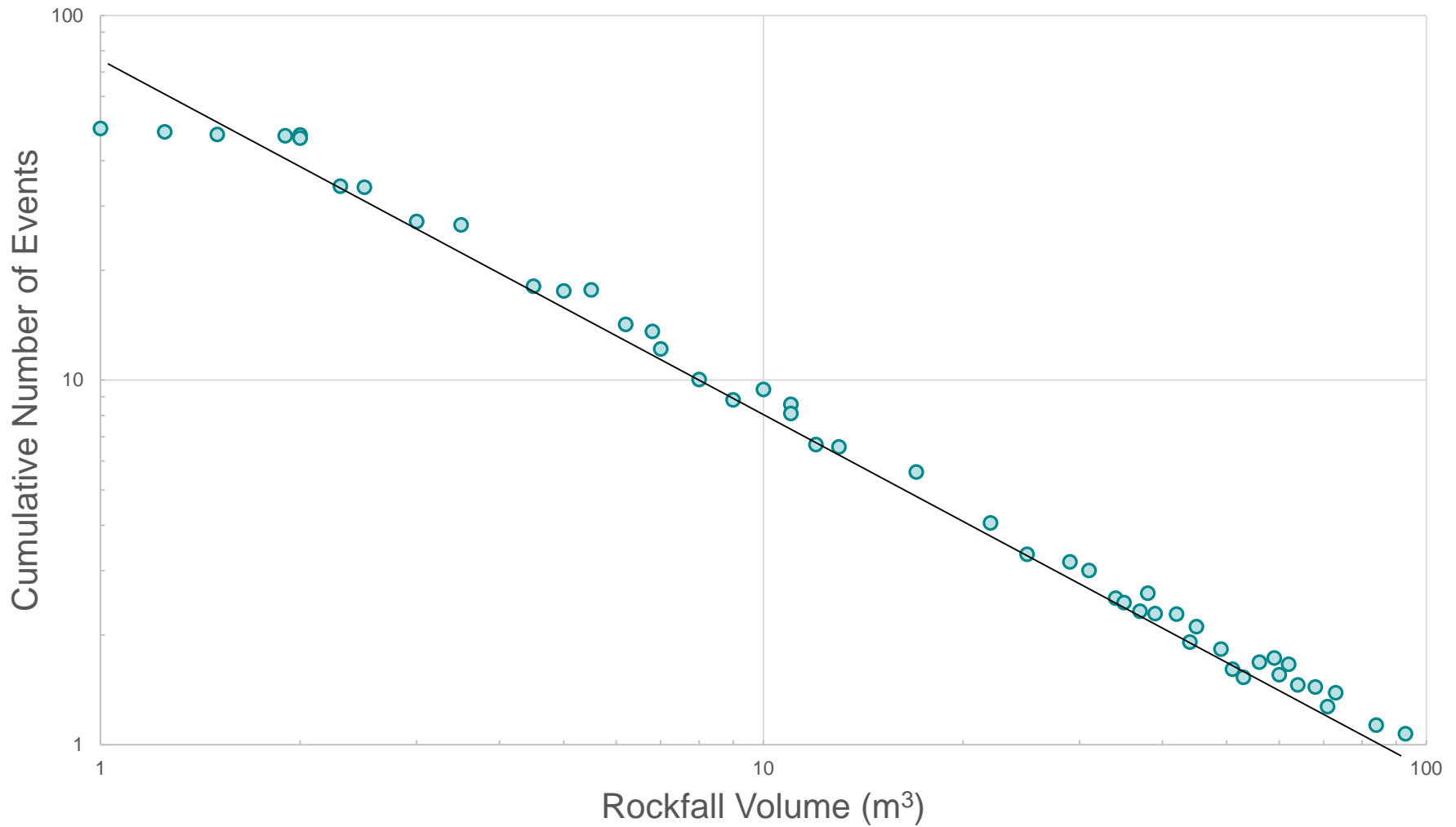
Additional Rater's Comments:

- Measurable
- Quantifiable

- May be Quantifiable
- Potential to Visually Assess



Rockfall Magnitude-Cumulative Frequency





Difficult / Limited Access





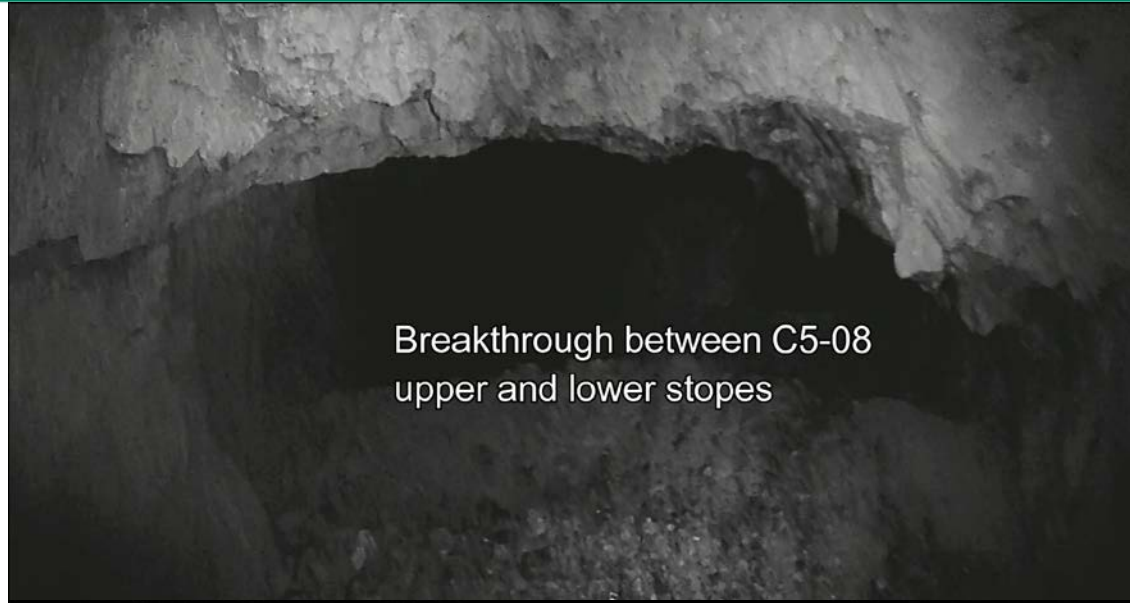
Emerging Applications – Drones Underground





Emerging Applications– Drones Underground

Applicable to
tunnel
inspections



Breakthrough between C5-08
upper and lower stopes



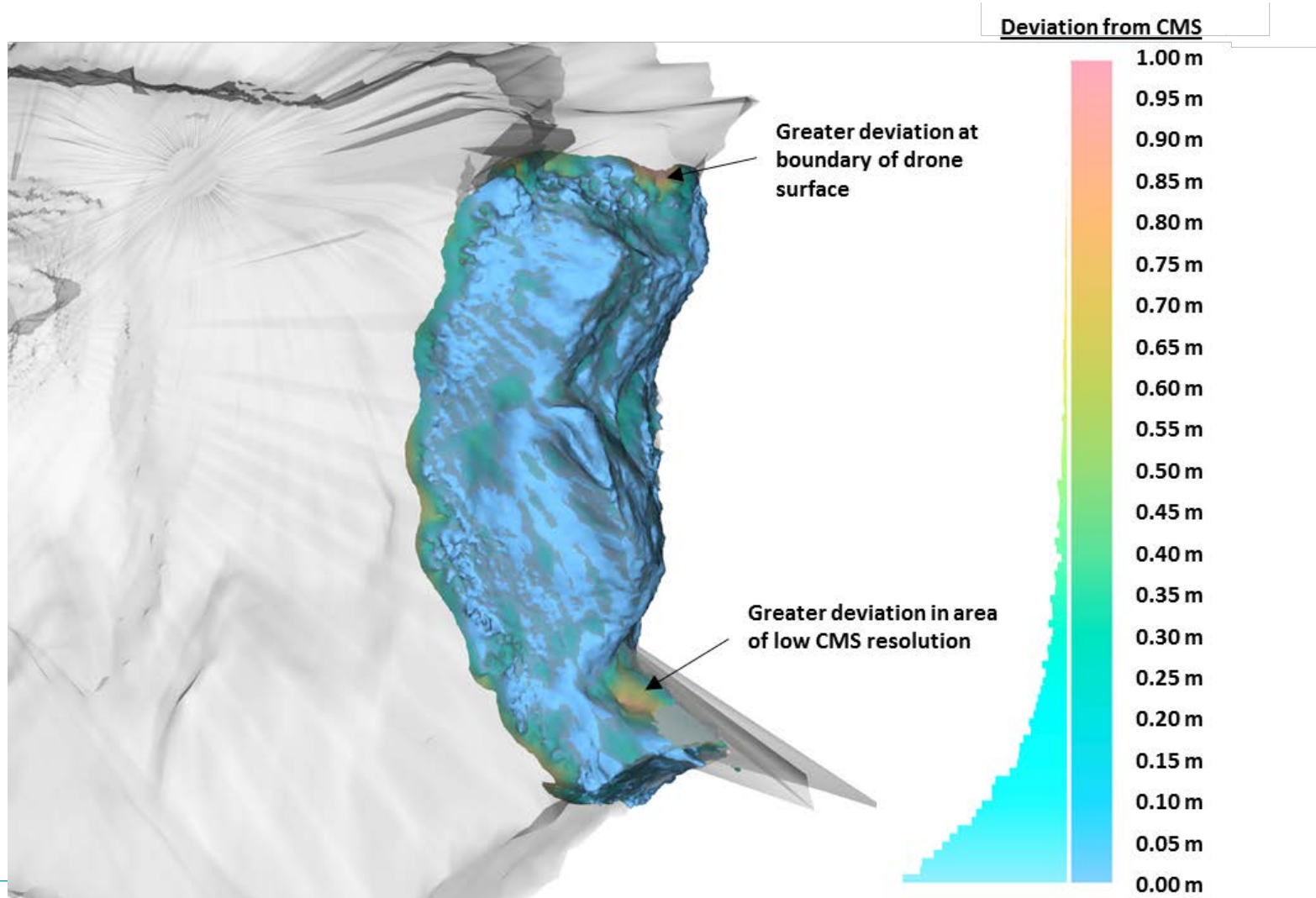


Emerging Applications– Drones Underground



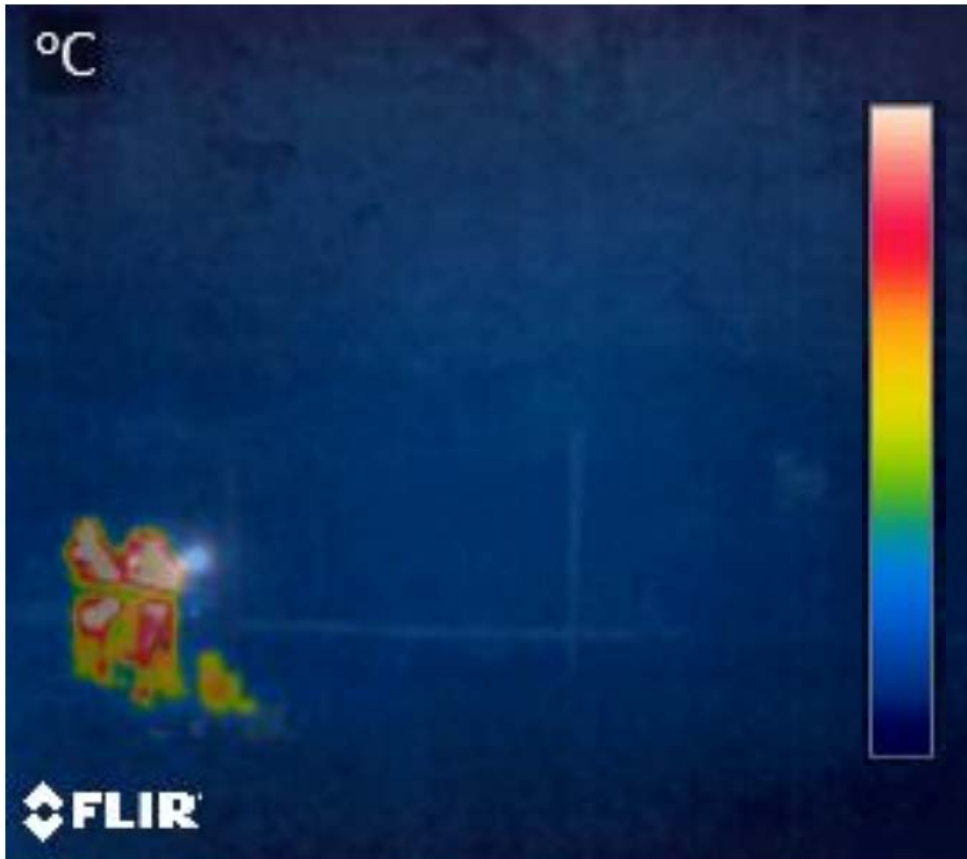


Emerging Applications— Drones Underground

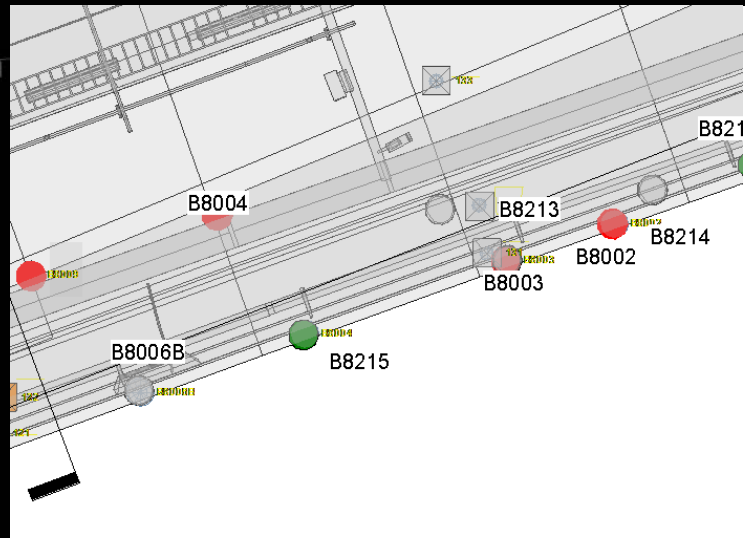
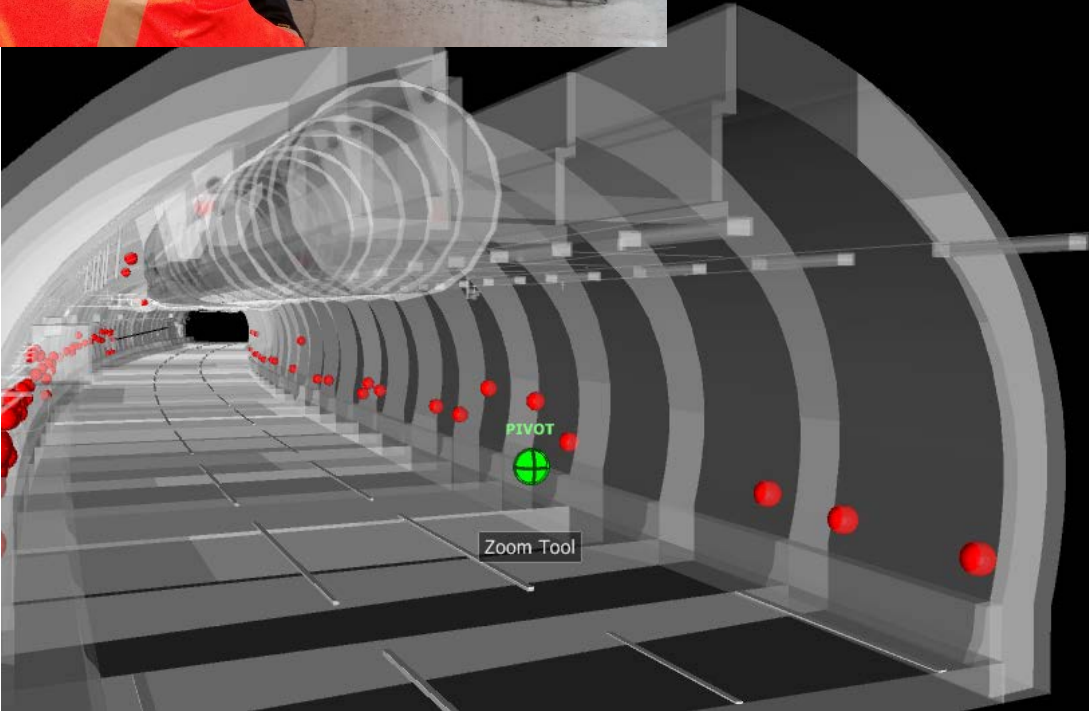
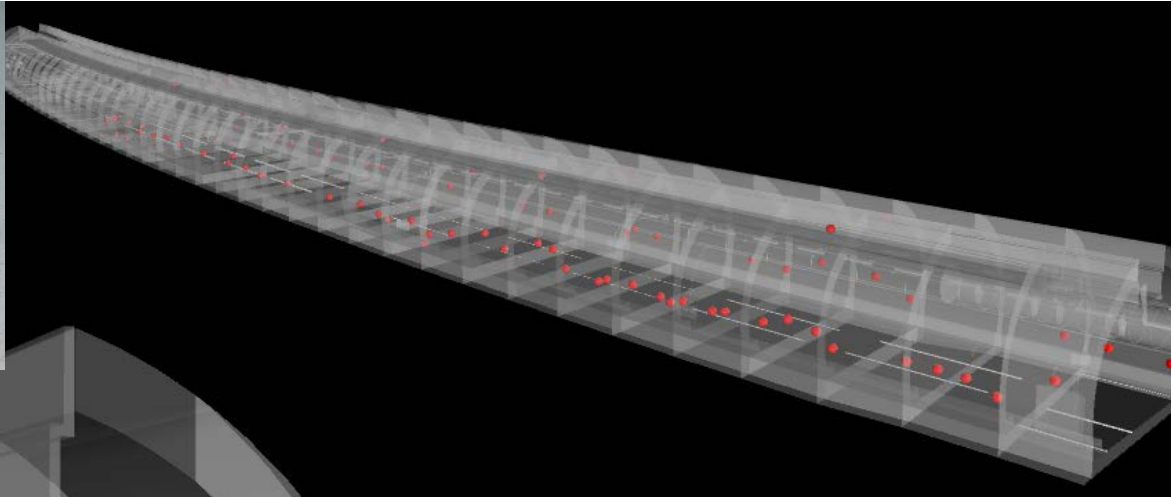




Emerging Applications– Drones Underground – Looking for Seepage with Thermal Imager



Emerging Applications— Input into BIM Systems





Emerging Applications - Automation

Mission Planner 1.3.19 build 1.1.5508.10848

Distance: 1.1136 km
Alt: 124.65 m A2: 264
Home: 88.55 m

Survey (Grid)

Simple | Grid Options | Camera Config

Simple Options: New OR Update 15min

Altitude (ft): 100
Angle (deg): 120
 Camera top facing forward
Flying Speed (m/s): 5
 Use speed for this mission
 Add Takeoff and Land WP's
 Use RTL

Display:
 Boundary
 Markers
 Grid
 Interim
 Footprints
 Advanced Options

Action

Geo: 45.171147, 4.314495, 607.30m
Grid: View XML, GoogleSatellite, Status: Loaded File, Load WP File, Save WP File, Saved version formations, Read WP's, Write WP's

Home Location:
Lat: 45.1727212
Long: 5.81773936
Alt (obj): 670.1300048

State:
Area: 15064 m² Pictures: 42 Flight Time (est): 3:55 Minutes
Distance: 0.54 km No. of Steps: 72 Photo every (est): 3.45 Seconds
Distance between images: 17 m Footprint: 86.2 x 57.5 m
Ground Resolution: 1.76 cm Dist. between lines: 17.24 m

Waypoints

WP	Radius	Loiter Radius	Data A	B	Alt	Verify Height	Add Option	Alt Warn	Spline	Delete	Up	Down	Grid %	Dist	A2
1	TAKEOFF	0	0	0	0	0	0	30	X	7	0	0	0	0	0
2	DO_CHANGE_SPEED	0	5	0	0	0	0	0	X	6	0	0	0	0	0



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Questions?

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