PHMSA R&D FORUM

Preventing and Mitigating Geo-Forces on Pipelines & Facilities

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February 19, 2020

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Geotechnical hazards pose the most significant geohazard threats to pipeline integrity and are responsible for more ruptures & pipeline damage

Geotechnical Hazards

Hydrotechnical Hazards

Geotechnical hazards cover a wide range of phenomena and movement mechanisms

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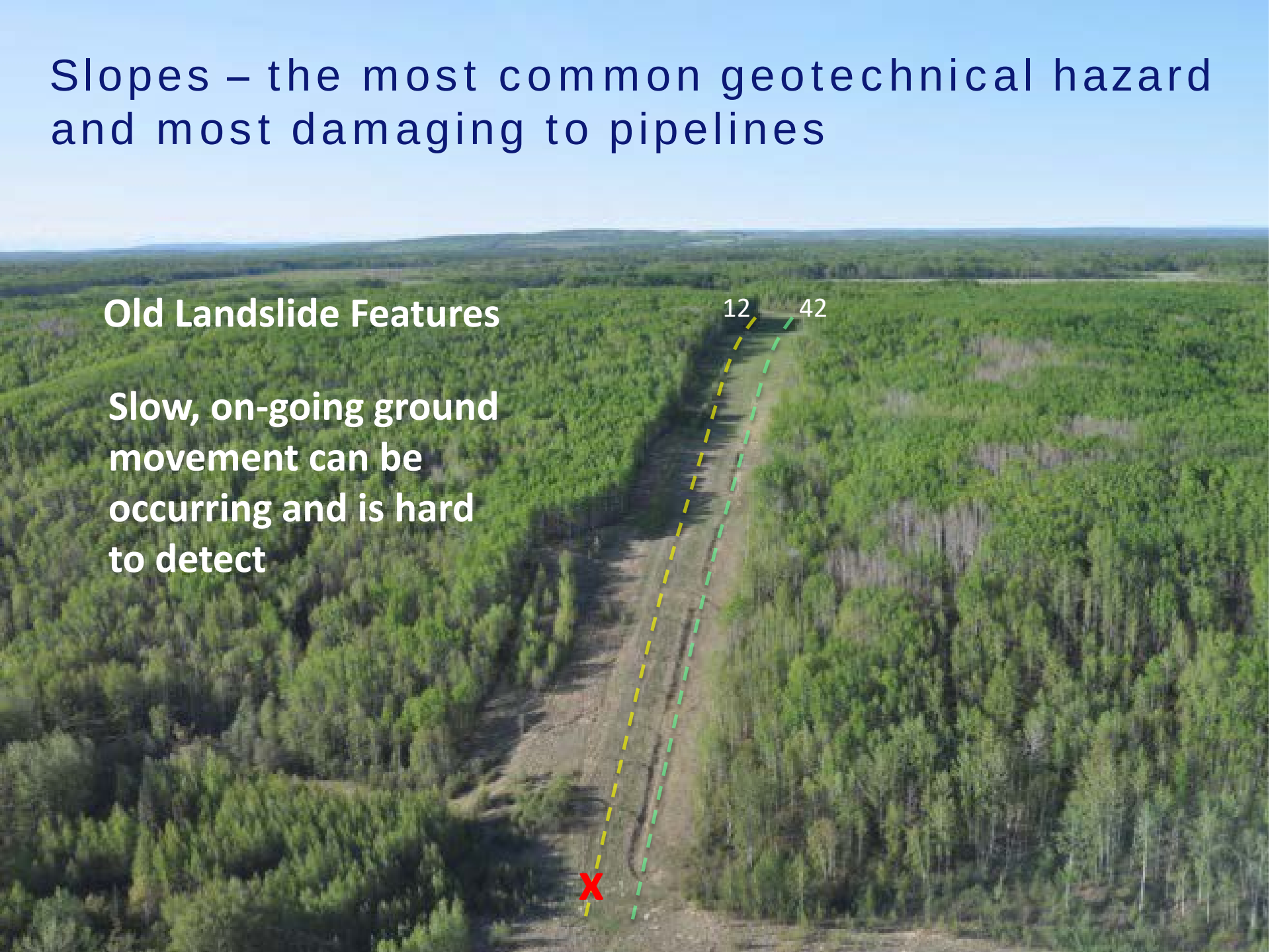
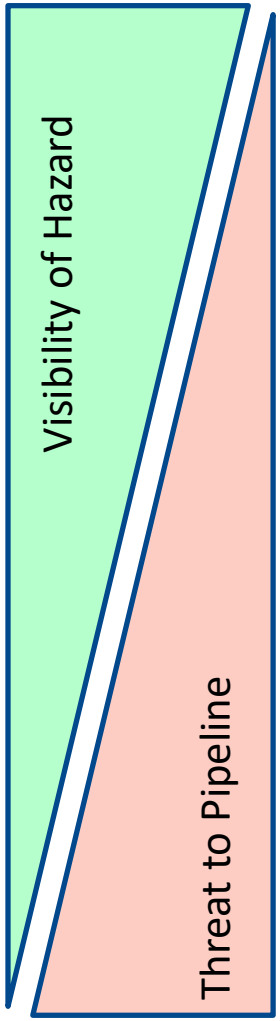
Slopes – the most common geotechnical hazard and most damaging to pipelines



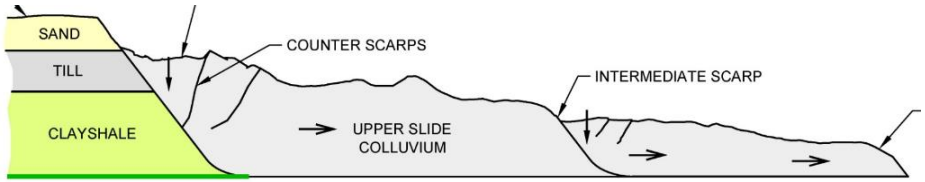
Perception of hazard and actual pipeline vulnerability to hazard can be very different



Flow Slide
Shallow & only upper portion involves loss of ground

Shallow Earth Slide
(Translational)

Deep Seated Landslide
(Translational)



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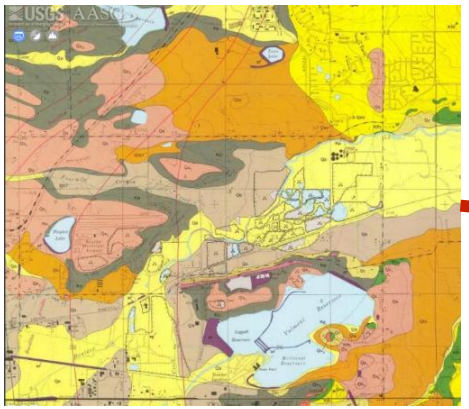
Many of the old landslide features on a route can be benign, but it can be challenging to tell

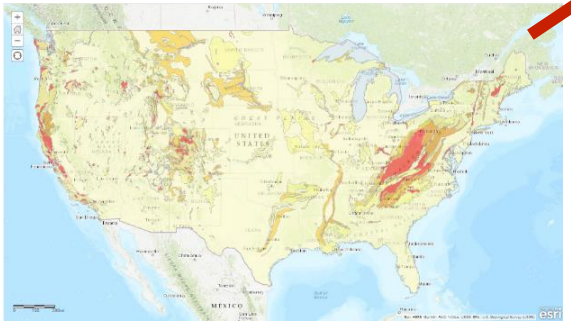
Common Characteristics of 7 Recent Pipeline Ruptures
Transmission Pipelines – mix of Oil and Gas
Very High Consequence Ruptures

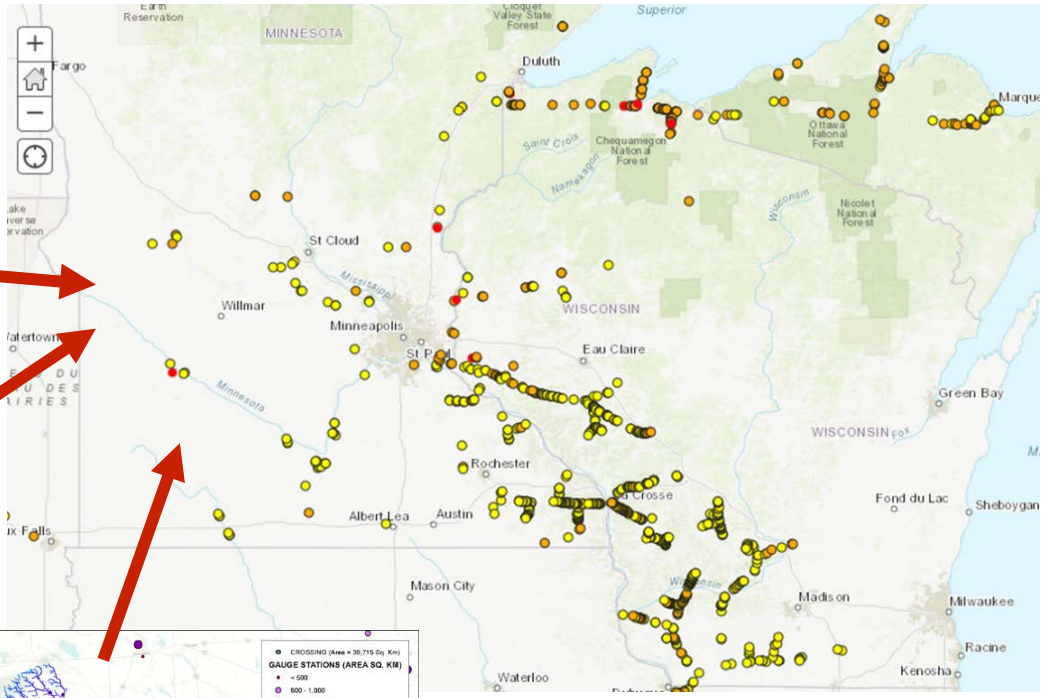
- All were caused by slope movement
- All were located within pre-existing landslide features
- All had a history of on-going slope movement prior to rupture that was recognized after the fact (one inferred)
- Average age of 29 years when rupture occurred
- 3 of 7 were after exceptionally wet periods
  - Acceleration added to accumulated strain
- 5 of 7 had subtle or no visible signs of activity that were recognized by operator – failures were a surprise
- Long term movement rates, where known or inferred generally 1 to 2 in/yr
- 3 of 7 had adjacent construction or 3rd party activity that played some contributing role

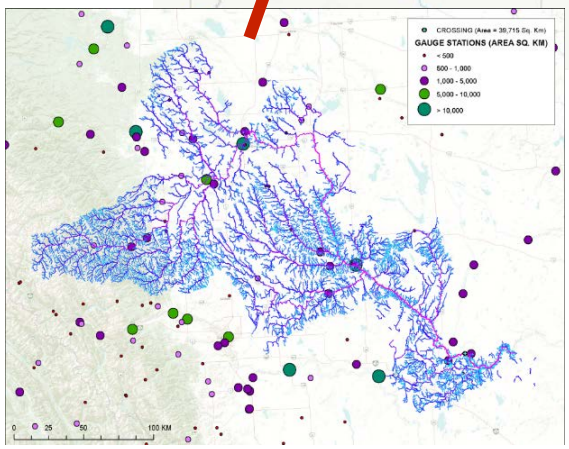
An inventory of all credible geohazard threats is critical to integrate data and reduce risk

4 of 7 were not identified as slide terrain or in an inventory



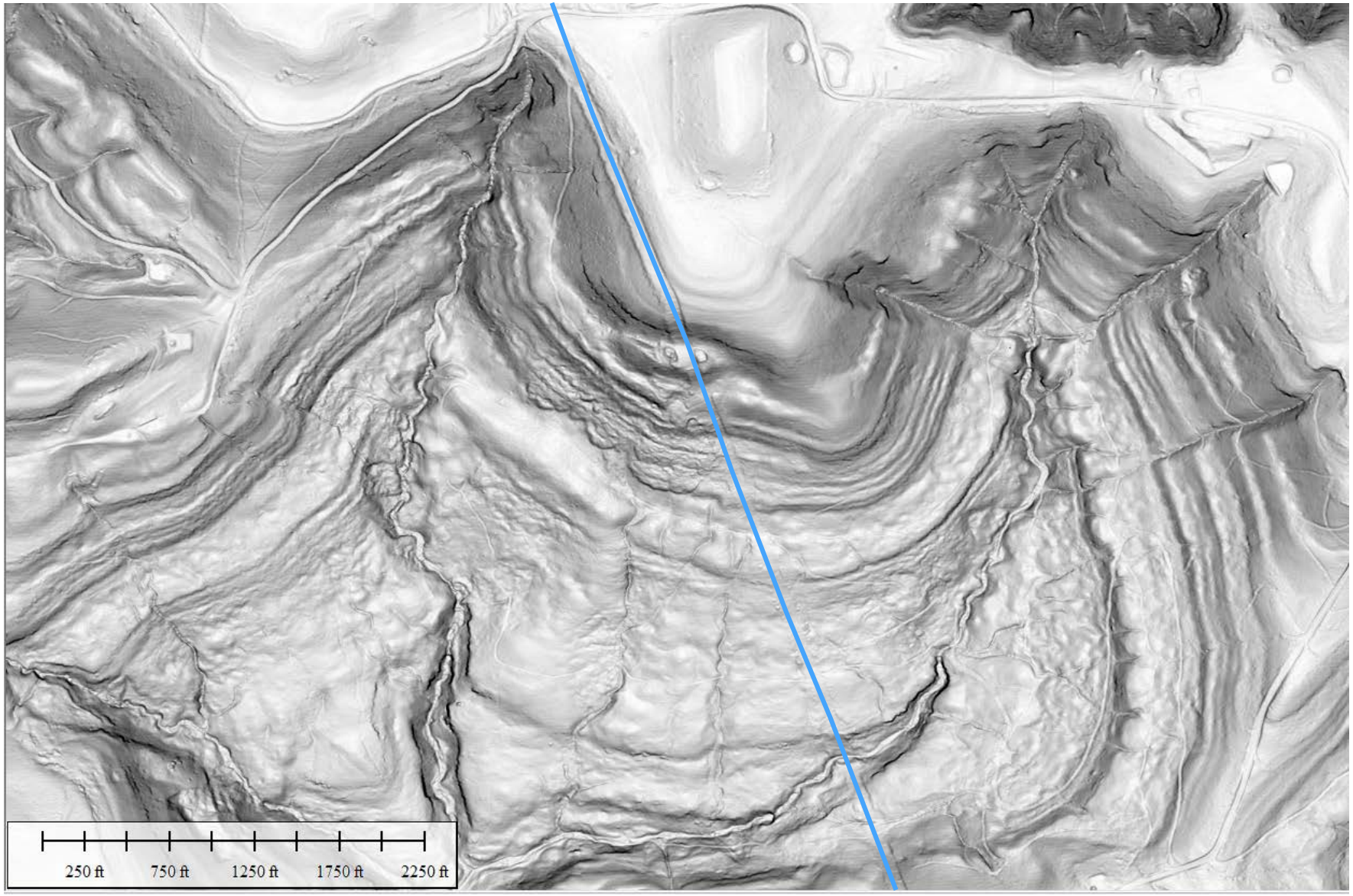


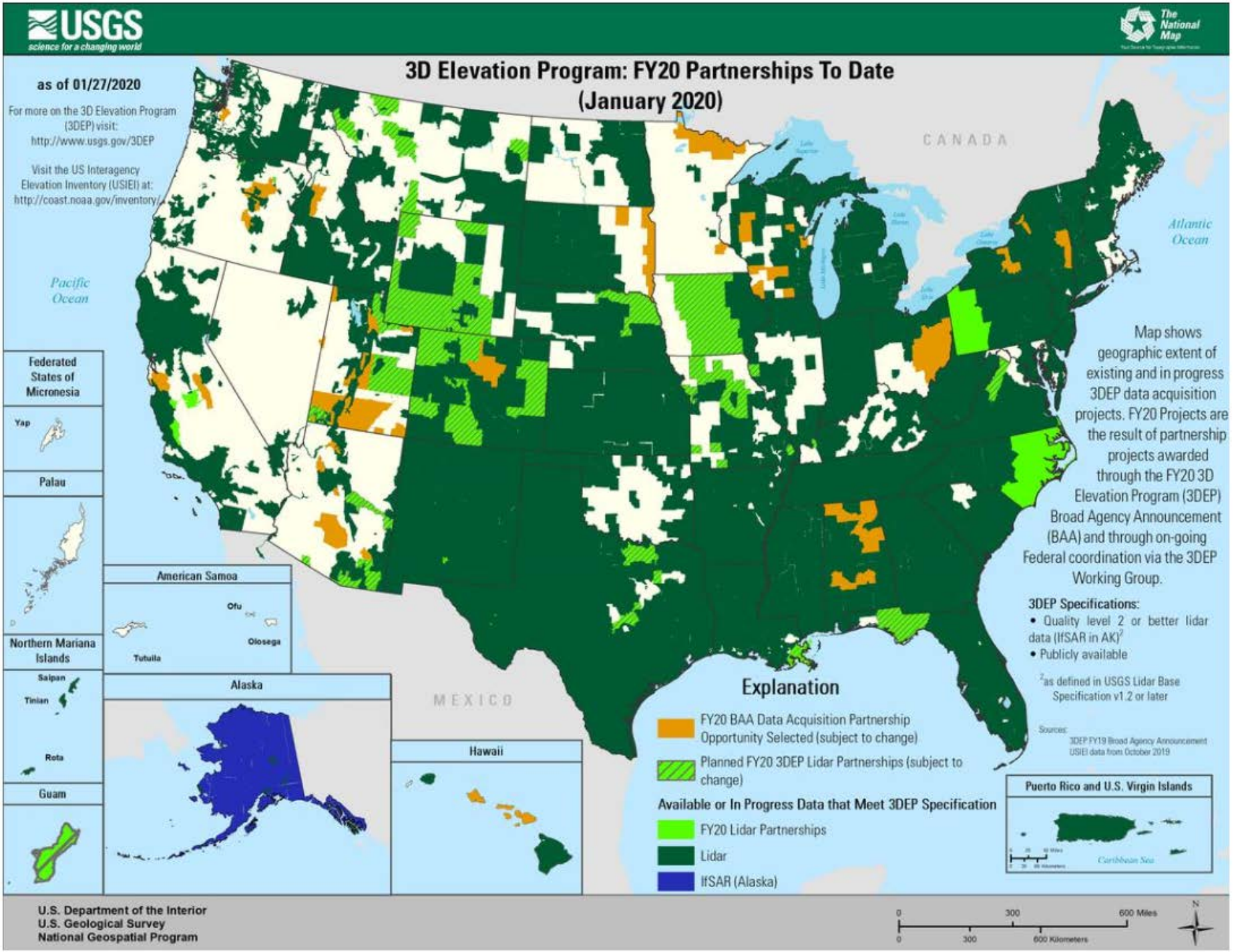




Publicly available aerial imagery

Publicly available LiDAR Imagery (same image as previous) can be a powerful and often under-utilized data source for hazard identification



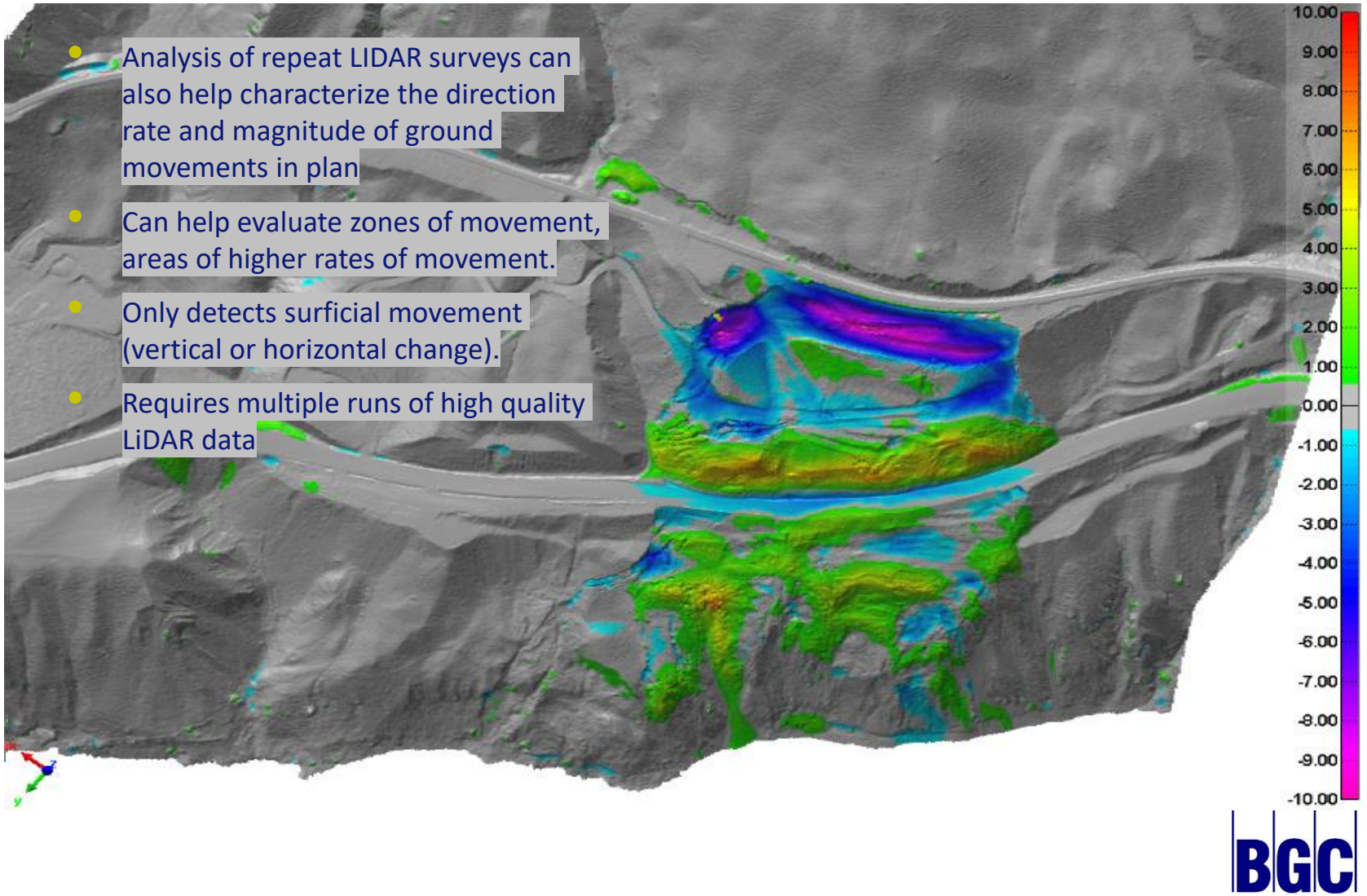

USGS
science for a changing world
The National Map
3D Elevation Program: FY20 Partnerships To Date
(January 2020)
as of 01/27/2020
For more on the 3D Elevation Program (3DEP) visit:
http://www.usgs.gov/3DEP
Visit the US Interagency Elevation Inventory (USIEI) at:
http://coast.noaa.gov/inventory/
CANADA
Pacific Ocean
Atlantic Ocean
MEXICO
Federated States of Micronesia
Yap
Palau
American Samoa
Ofu
Olosega
Tutuila
Northern Mariana Islands
Saipan
Tinian
Rota
Guam
Alaska
Hawaii
Puerto Rico and U.S. Virgin Islands
Caribbean Sea
Map shows geographic extent of existing and in progress 3DEP data acquisition projects. FY20 Projects are the result of partnership projects awarded through the FY20 3D Elevation Program (3DEP) Broad Agency Announcement (BAA) and through on-going Federal coordination via the 3DEP Working Group.
3DEP Specifications:
• Quality level 2 or better lidar data (IfSAR in AK)[2]
• Publicly available
[2]as defined in USGS Lidar Base Specification v1.2 or later
Sources:
3DEP FY19 Broad Agency Announcement
USIEI data from October 2019
Explanation
FY20 BAA Data Acquisition Partnership Opportunity Selected (subject to change)
Planned FY20 3DEP Lidar Partnerships (subject to change)
Available or In Progress Data that Meet 3DEP Specification
FY20 Lidar Partnerships
Lidar
IfSAR (Alaska)
U.S. Department of the Interior
U.S. Geological Survey
National Geospatial Program
0 300 600 Miles
0 300 600 Kilometers
N

How could precursor movements have been detected early with remote or existing data sets?

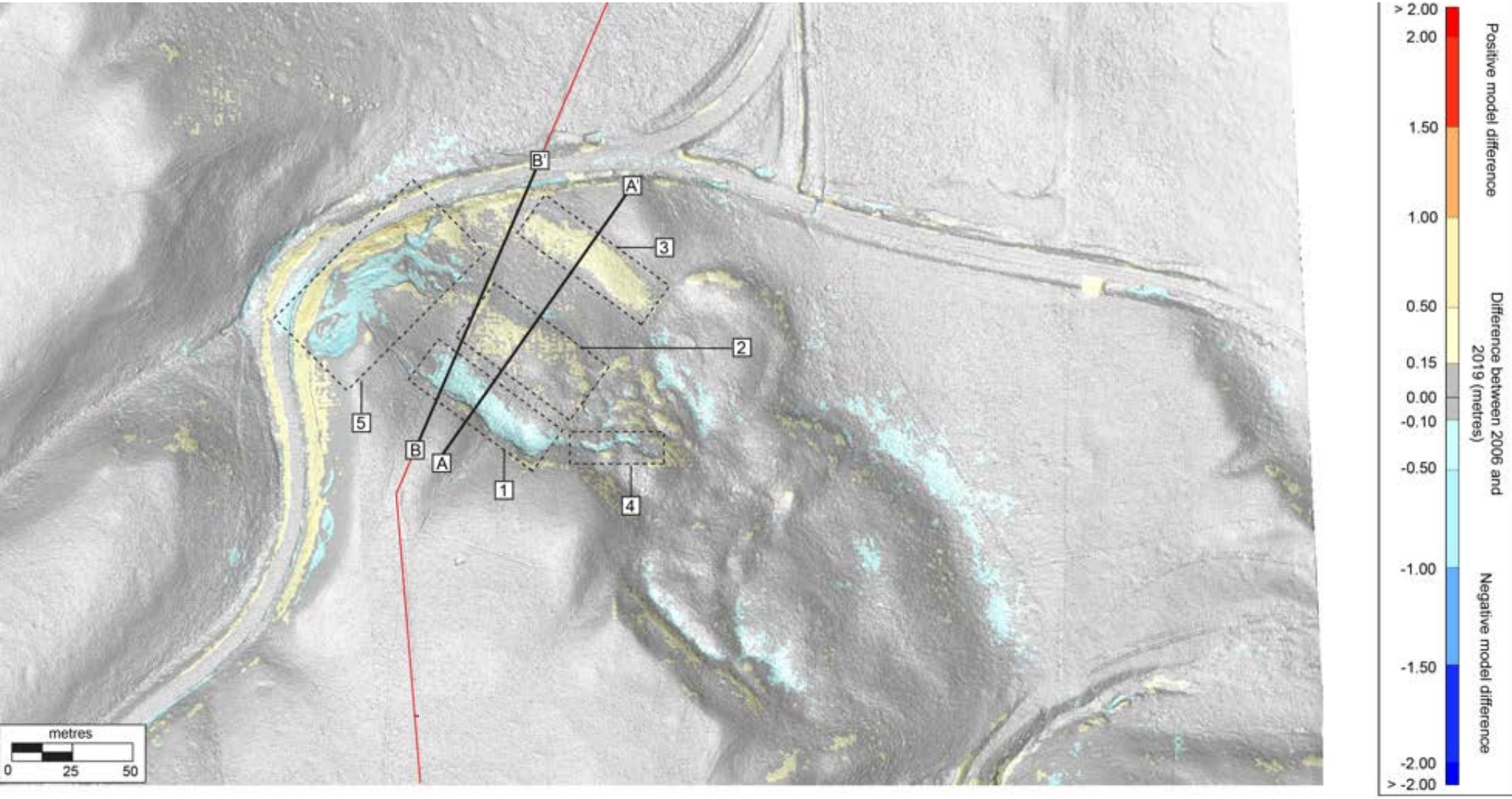
- LiDAR
- inSAR
- In-line Inspection IMU tool

- Key issue is dealing with false negatives and false positives
  - all of the above can be dominated by both
  - Challenge is finding movements of real concern vs data errors or non-critical movements

Monitoring Slope Conditions – LiDAR Change Detection



Deep seated landslide movements picked up by LiDAR change detection



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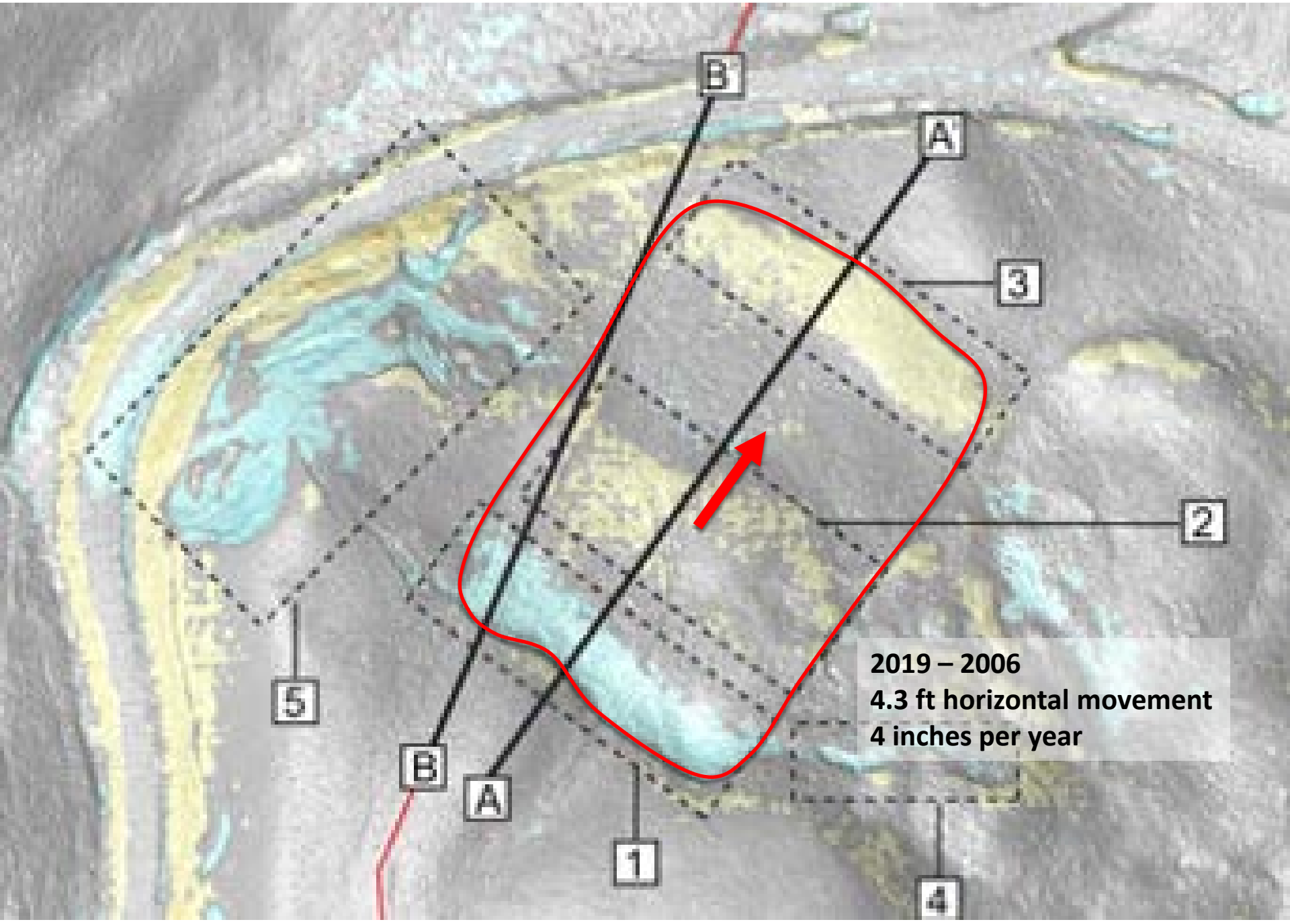
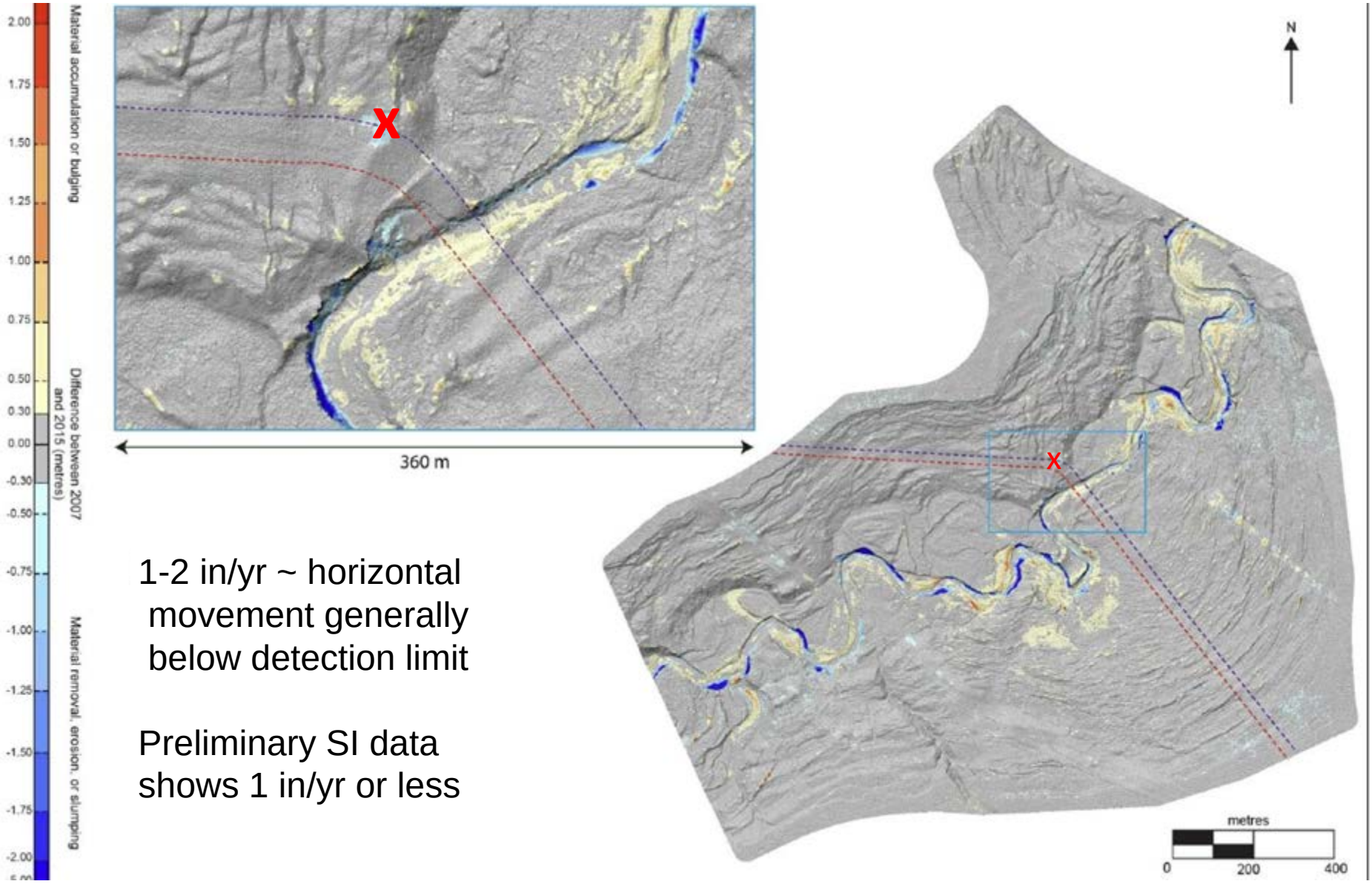

B
A
3
2
5
B
A
1
4
2019 – 2006
4.3 ft horizontal movement
4 inches per year

LiDAR change detection is a valuable and low cost means to identify movement over large area but can miss slow, creeping slide activity

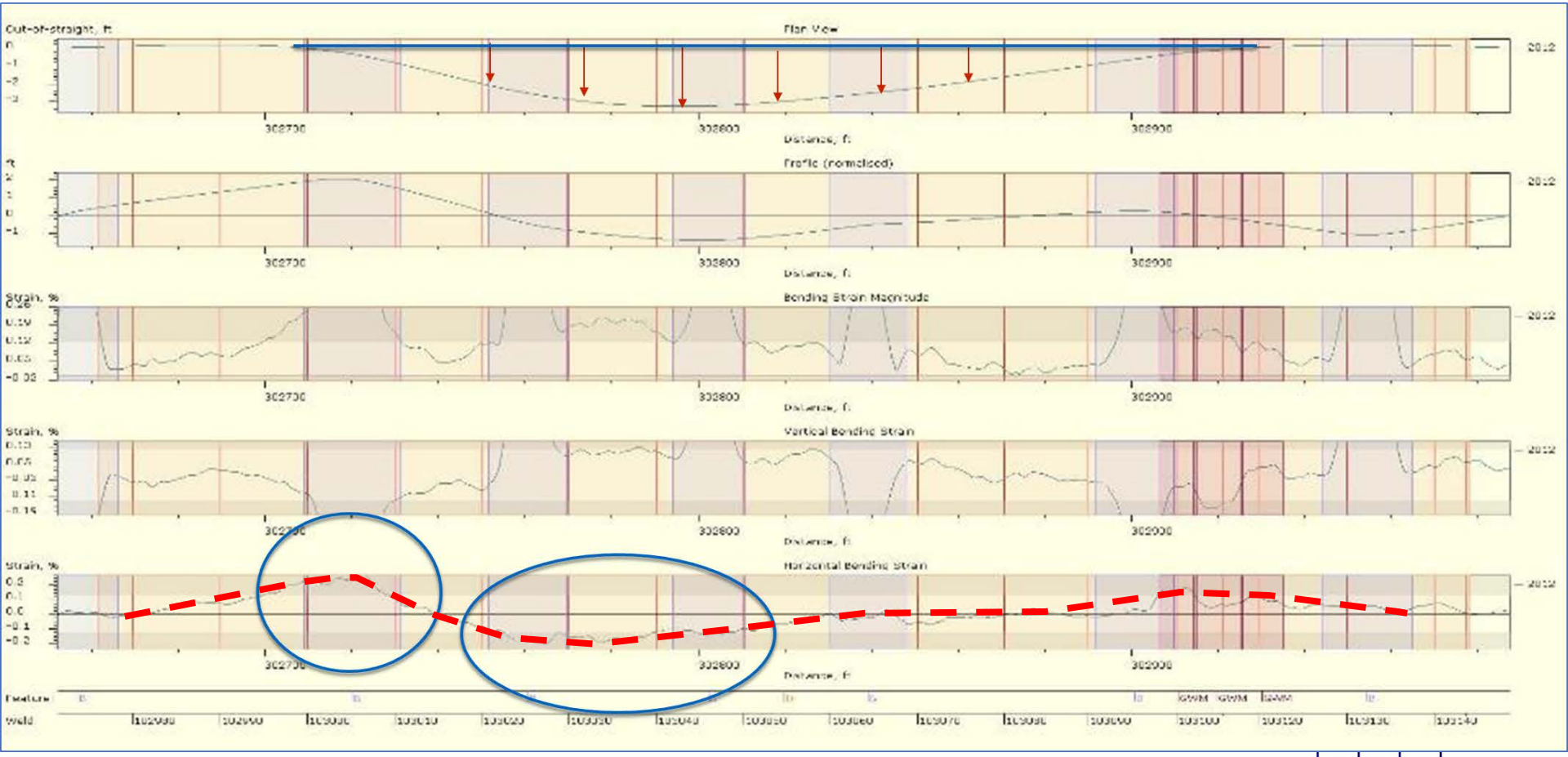


1-2 in/yr ~ horizontal movement generally below detection limit

Preliminary SI data shows 1 in/yr or less

IMU data from In-Line Inspection can be an effective tool at revealing sites where on-going slow ground movement is deforming the pipeline

Slope movements that are engaging the pipeline can be detected by the irregular bending strain signatures they cause



IMU is particularly suited to environments like the Appalachian Plateau

- **Transverse movements common**
- **On-going creep common but often difficult to discern**
- **High number of slopes**

IMU data is can accurately and with precision identify irregular bending strains – “false positive” issue is distinguishing strains from on-going post construction ground movement from strains caused by initial construction that are not a current threat