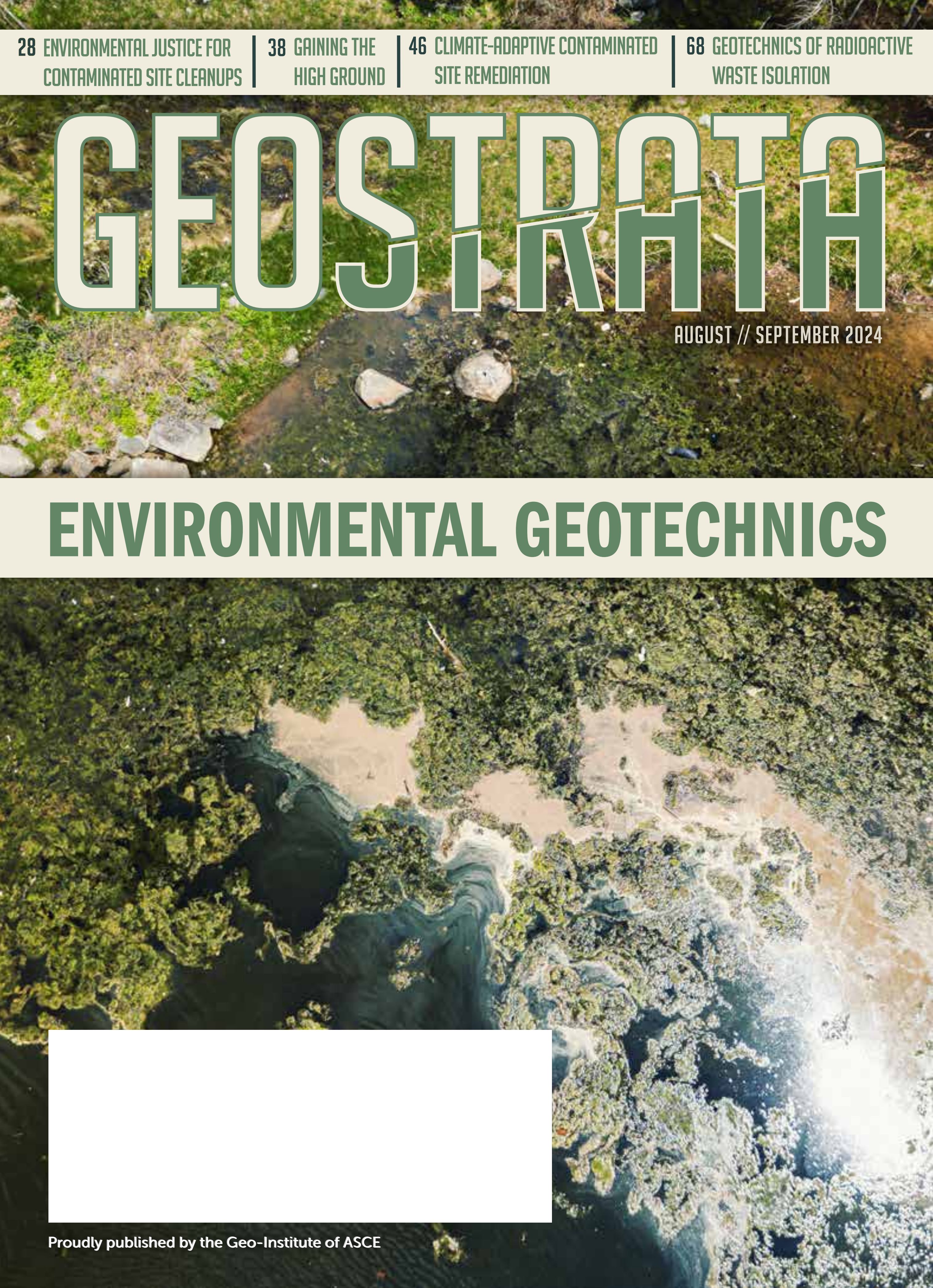
GEOSTRATA

AUGUST // SEPTEMBER 2024



ENVIRONMENTAL GEOTECHNICS

Proudly published by the Geo-Institute of ASCE

Playing Hide and Seek with Landslides

Cheating to Win with Lidar Change Detection

By Matt Lato, Ph.D., P.Eng., and Katie Burkell, P.Eng.

Lidar change detection can be used to track centimetre level movements over years and decades to help engineers understand slope processes and manage risks from landslides.

The earth is always changing, and landslide hazards cannot be eradicated; populations are expanding, public and private assets are deteriorating, and the public's tolerance to risk exposure from geohazards is reducing. Proactive landslide risk management is essential to manage the public's exposure and enable reliable and resilient infrastructure spending decisions. Landslide risk management is a process that starts with hazard identification, and then cycles through hazard assessment, risk assessment, risk prioritization, and risk management. It's a process that begins with landslide identification, but has no end point. Identifying and monitoring landslides at a regional scale (>10,000 sq km) has been elusive for a long time, but innovative approaches to lidar change detection are unlocking new potentials.

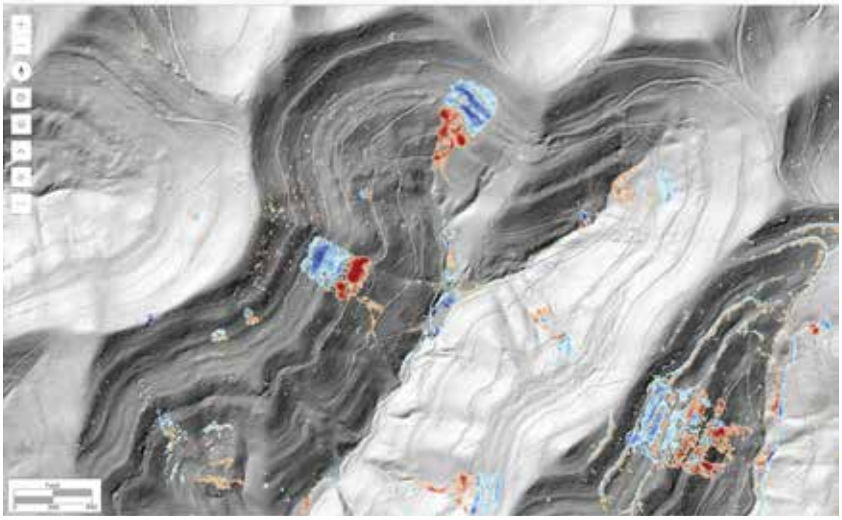
Making efficient funding allocation decisions that minimize the risk posed by landslides starts with a regional inventory of existing landslides, as well as information about recent velocity, geological setting, the type of landslide, and knowledge about elements at risk. The traditional means to generate regional inventories includes airphoto interpretation and terrain mapping, coupled with boots on the ground field work. However, recent advancements in the availability of multi-epoch airborne lidar datasets and automated processing workflows for 3D-point-based lidar change detection are creating new possibilities to develop highly accurate, spatially extensive, and detailed landslide inventories across all terrain and landslide types.

Airborne lidar scanning is uniquely capable of penetrating tree cover for the purpose of generating high-resolution, 3D bare-earth topographic models. Tree cover is effectively removed using systems that can detect multiple laser returns. The output of the last return, which represents the longest distance, is interpreted as the ground surface. Leveraging modern ALS hardware, billions of lidar points covering thousands of square kilometers of terrain can be captured in days to weeks from medium-altitude, fixed-wing aircraft.

When multiple ALS datasets with overlapping spatial extents, collected at different points in time, are available, lidar change detection can be conducted. Lidar change detection is the process of comparing ALS datasets to quantify changes in the Earth's surface. This process can reveal subtle or dramatic movements, deformations, or displacements caused by natural phenomena or human activities, including landslides.

Twenty years ago, the standard approach to lidar change detection was raster-based digital elevation model, or DEM, differencing (i.e., subtraction). At the same time, new technology was being developed that allowed for more advanced, computationally intensive methods for lidar change detection that involves spatial realignment utilizing iterative closest point, or ICP, algorithms and 3D point-cloud-based change-detection algorithms. These advanced approaches enabled higher accuracy change-detection results. Various publications have demonstrated their advantages in identifying and monitoring landslides in support of risk management at the local and regional scale.

In the past few years, ALS data collection has become increasingly better in terms of local accuracy and resolution (data density). It's common to capture bare earth point-cloud data with densities in excess of 10 pts/m^2 on the bare earth in forested terrain. Utilizing advanced lidar change-detection processing methodologies, these datasets are enabling the ability to confidently calculate changes less than 0.10 m between datasets. This sensitivity helps to identify slow-moving landslides and, in some cases, to confidently identify precursors to large-scale movements. However, until very recently, utilizing these high-resolution datasets to conduct ICP pre-aligned, point-cloud-based change-detection analyses was computationally expensive, slow, and therefore cost prohibitive to execute at a regional scale.



3D lidar change detection results overlain on a digital elevation using publicly available lidar data from 2017 and 2023 from the Commonwealth of Kentucky. Blue colors represent material loss (e.g., erosion or slumping) typical of a landslide headscarp; red colors illustrate material gain or bulging typical of a landslide deposit or toe bulge.

To unlock the opportunity that these methods offer to support regional landslide risk management, and address the computational and time challenges, we've developed a technique that's fully automated, graphics processing unit-enabled, and allows for lidar change-detection processing and digital data delivery.

Tools now exist for the broader adoption of ICP pre-aligned point-cloud-based change-detection analyses at the regional scale. The major attributes are:

- GPU-based algorithms that accelerate change calculations with a speed-up factor in excess of 50 times faster compared to a CPU-based algorithm.
- Point-cloud-based change-detection methods improve (reduce) the limit of detection, meaning that smaller changes can be reliably detected compared to difference of DEM across all terrain types.
- ICP pre-alignment reduces systematic georeferencing errors when applied at regional scales, while also preserving many types of large geomorphic and anthropogenic changes.
- With well-organized ALS datasets, thousands of square kilometers of LCD can be computed and delivered digitally in days.

It feels like cheating, but it isn't. Lidar change detection today can provide a completely new value for landslide risk management at different stages, including: identification, prevention, preparedness, response, and recovery.

By utilizing regional lidar change detection, decision makers can gain a more complete understanding of landslide hazards, better communicate risk to stakeholders, and more effectively plan boots on the ground field work. Lidar change detection can also support public awareness and education, as well as policy and decision making, regarding geohazard risks and risk management solutions. This is important for all levels of government, infrastructure owners, businesses, and the public. For many, it's just-in-time capability for building system resilience and for making tough, resource-constrained decisions. GS

▶ **MATTHEW LATO, PH.D., P.ENG.**, is a principal geotechnical engineer and the quality and innovation lead at BGC Engineering, Inc., based out of Ottawa, Ontario, Canada. His consulting work focuses on helping clients leverage advanced monitoring solutions and adopt new technologies. He can be reached at *MLato@bgcengineering.ca.*

▶ **KATIE BURKELL, P.ENG.**, is a civil engineer and senior product manager with Cambio Earth Systems in Calgary, Alberta, Canada, where she oversees software development and services for advanced earth science data management by creating powerful tools and solutions that enable efficient analysis and informed decisions. She can be reached at *Katie.Burkell@cambioearth.com.*