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Measuring and modeling high-resolution topographic change at archaeological sites in Grand Canyon National Park, Arizona, U.S.A.

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Erosion of archaeological sites within Grand Canyon National Park (GCNP) Arizona, located in the southwestern United States is a subject of continuing interest to land and resource managers. This is partly fueled by an ongoing debate about whether and to what degree controlled releases from Glen Canyon Dam, located immediately upstream of GCNP, are affecting the physical integrity of archaeological sites. Long-term topographic change due to natural sources is typical in the desert southwest region. However, continuing erosion, which may be related in-part to anthropogenic factors, threatens both the preservation of archaeological sites as well as our ability to study evidence of past human habitation in GCNP that dates back at least 8,000 years before present.

To quantitatively identify changes to archaeological sites in this region, and with the broader intention of developing numerical models to predict how and under what circumstances dam-controlled flows influence archaeological sites, we undertook a detailed terrestrial-lidar based monitoring program at thirteen sites between 2006 and 2010. Our studies looked specifically at sites located along the Colorado River that are potentially subject to changes related to dam operations. This could occur, for example, by limited sediment supply to sand bars which in turn contribute aeolian sediment to archaeologic sites. Each site was several hundred to several thousand square meters in size and was surveyed multiple times during the 5-year period.

Our monitoring program shows how various data registration and georeferencing techniques result in varying degrees of topographic surface model accuracy. For example, surveys performed between 2006 and 2007 used point cloud registration methods and resulted in estimated change detection thresholds of 8 cm between repeat surveys. In 2010, surveys at the same sites used control point registration methods and resulted in estimated change detection thresholds of 3 cm. Error thresholds were determined using two types of change detection error analyses. The first used the absolute errors inherent in each step of the lidar data collection process (i.e. directly combining laser, survey, and registration errors) and provides a conservative estimate of potential errors. The second used an empirical metric based on the closest point-to-point match between known fixed objects (e.g., large boulders) and results in a more realistic error bound.

Our data indicate that some sites changed significantly during the monitored time period. These measurements provide much of the essential data required for developing an in-house, physically-based, numerical sediment transport model that can provide estimates on the likelihood for future archaeological site change in GCNP. Thus far, we are finding that the data provided by typical terrestrial lidar surveys is likely overly-dense for numerical model requirements with respect to computational efficiency. Despite this, we also find that high-resolution data is necessary to perform change detection at the accuracy required for model calibration and to document changes before they have progressed beyond the point when site integrity is compromised. The results of the study will provide land and resource managers with the pertinent information needed to oversee these archaeological resources in the best way possible.