Use of high-resolution airborne laser scanning for the analysis of archeological and natural landscapes on the northern Great Plains

By Jay T. Sturdevant, Stephen K. Wilson, and Jeff Bragg

Abstract

In 2012, an interdisciplinary team from the Midwest Archeological Center, the Northern Great Plains Inventory and Monitoring Network, and Knife River Indian Villages National Historic Site initiated a research project to produce a high-resolution laser scan of the landscape along the Knife River at its confluence with the Missouri River. Airborne laser scanning (ALS) is an airborne-based light-emitting sensor that produces a high-resolution three-dimensional model of the ground surface, vegetation, and other landscape features. Applied to archeological sites, this technique can reveal archeological features such as earthen lodge depressions, walled enclosures, trails, and linear earthen mounds. Natural features are also evident in the three-dimensional landscape models and include former river channels of the Knife River, eroded banks, vegetation, and infrastructure such as roads, buildings, and bridges. The three-dimensional landscape models provide detailed information on the location and extent of archeological resources, assist with the investigation of complex village landscapes, and enable the consideration of impacts from natural processes on archeological site preservation.

Key words

airborne laser scanning, alluvial geomorphology, archeological landscapes, archeology, Hidatsa, Knife River, Knife River Indian Villages National Historic Site, Missouri River

PEOPLE ARE CONTINUALLY MODIfying natural landscapes in ways that meet the needs of individuals and communities. Understanding how humans live within the natural environment and how we modify landscapes provides useful insight into human behavior and cultural practices. Archeological landscapes harbor details about past cultural practices at spatial scales that change over time and reveal community structures and patterning. The advancement of airborne technologies is creating new opportunities to explore archeological landscapes in ways not possible a decade ago (Chase et al. 2011; Crutchley and Crow 2009; Doneus and Briese 2011; Shaw and Corns 2011). The challenge for archeologists and other researchers is to produce data sets with sufficient resolution to identify and analyze individual archeological features such as earthen lodges, palisade walls, and earthen mounds. Earlier maps and aerial imagery have been effective at detailing topography, locating archeological sites, and illustrating archeological features. Current laser scanning technologies offer the potential to produce landscape models with incredibly detailed illustrations of archeological sites that can be used in geographic information systems, thereby harnessing the power of modern computing to generate new insights into past human interactions with natural landscapes. This multidisciplinary research project has produced a high-resolution three-dimensional data set that allows for detailed analysis of landscape features that clearly illustrate the archeological landscapes along the Knife River in North Dakota.

Hidatsa villages and communities

Knife River Indian Villages National Historic Site (NHS) preserves the ancestral home of the Hidatsa people. These villages exemplify the Missouri River cultural lifeways when people lived in compact earthen lodge villages, grew crops, negotiated trade, and hunted buffalo (fig. 1). Connections to the earth and the natural landscape are ever present and form meaningful foundations of Missouri River cultural systems. The earthen lodges are considered a living representation of Hidatsa culture and incorporated traditions central to the daily lives of village occupants. Representing the 16th to 19th centuries, the archeological landscapes at Knife River reflect a time of significant change for the Hidatsa people. Contact with Europeans and Americans introduced diseases that irrevocably altered Hidatsa communities even as many of their cultural traditions proved incredibly resistant to outside influence. Warfare with other Native American tribes also had profound impacts on the Hidatsa communities: defense against hostile raids is evident in the palisade walls that surround the villages. How did the Hidatsa people cope with the unprecedented forces of cultural contact, warfare, and multiple disease epidemics? Understanding how these pressures influenced the construction and accumulation of Hidatsa village landscapes provides insight into how these communities adapted to the pressures of a rapidly changing world. In order to investigate changes in village landscapes, archeologists need broad-scale data sets that complement the past archeological excavations within the villages.

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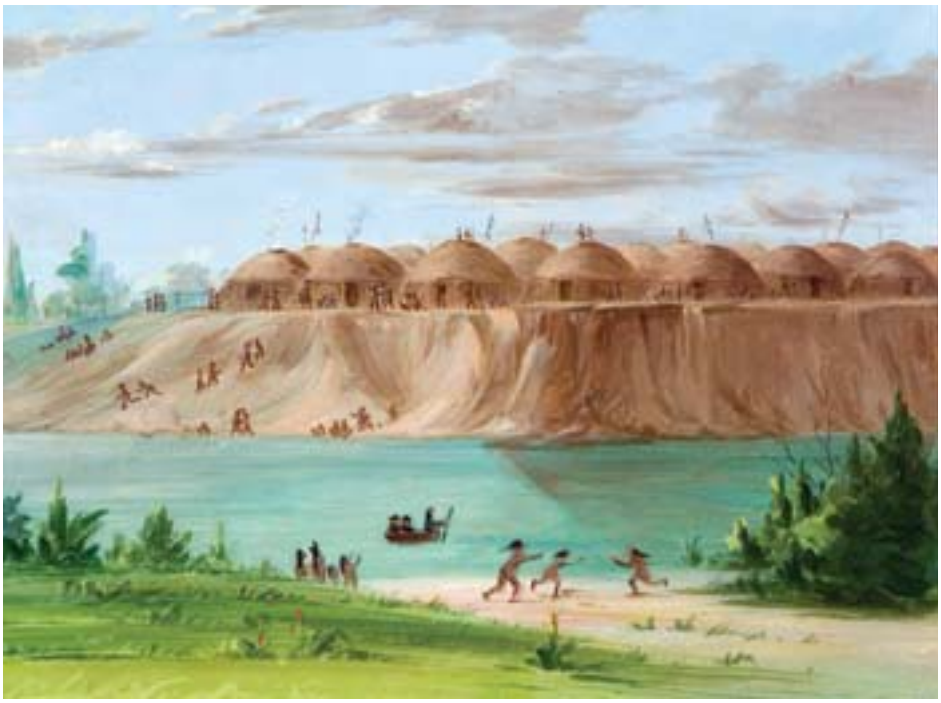

Figure 1. Renowned western artist George Catlin painted this scene of daily life at a Hidatsa village on the Knife River in 1832.

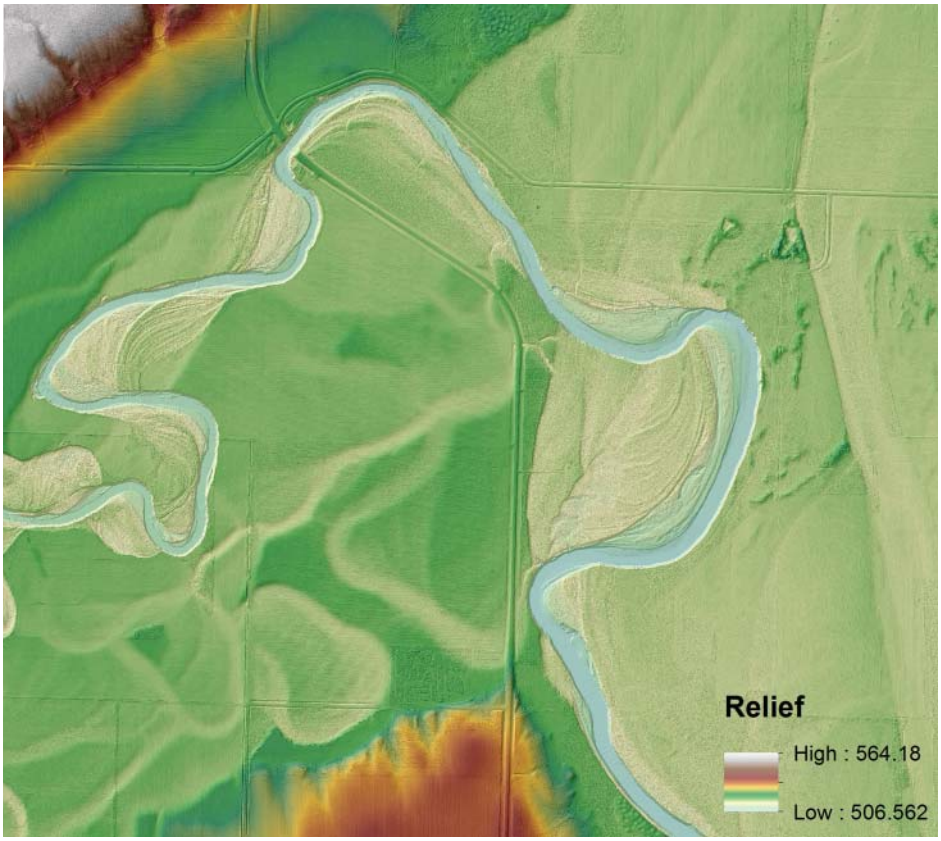

Figure 2. The digital terrain model was generated from the airborne laser scan of the Knife River area and shows the current river and old channel scars left behind during the river's migration within the confines of upland areas.

Illumination of landscapes

In 2012, an interdisciplinary team from the Midwest Archeological Center, the Northern Great Plains Inventory and Monitoring Network, and Knife River Indian Villages NHS initiated a research project to produce a high-resolution laser scan of the landscape along the Knife River at its confluence with the Missouri River. Airborne laser scanning (ALS) is an airborne-based sensor that emits laser light, detects variations in the timing and strength of its reflection, and is processed into high-resolution three-dimensional models of the ground surface, vegetation, and other landscape features (fig. 2). The aerial survey at Knife River covered more than 5,300 acres (2,145 ha) and produced a six-points-per-meter (1.8 points per foot) point cloud coverage and a digital terrain model with a fine-grained vertical resolution of 25 cm (10 in) RMS (root-mean-square) error. The term *point cloud* describes the effect of covering the ground and aboveground features (vegetation, buildings, bridges, archeological features) with laser-emitted pulses that create clusters of data points from objects or surfaces that reflect the laser light (fig. 3, next page). These data reveal village features such as earthen lodge depressions, palisade wall enclosures, trails, and linear earthen mounds. Natural features are also evident in the data and include former channels of the Knife River, erosional banks, and vegetation. Local infrastructure such as roads, buildings, and bridges is also reflected in the data.

When combined with other data sets, the ALS findings provide researchers and managers with access to landscape models that show how natural and cultural resources are closely linked at Knife River Indian Villages. Understanding local conditions is a key component to the long-term preservation of archeological resources. This research will enable more effective management when park resources are subjected to changes in river flow or

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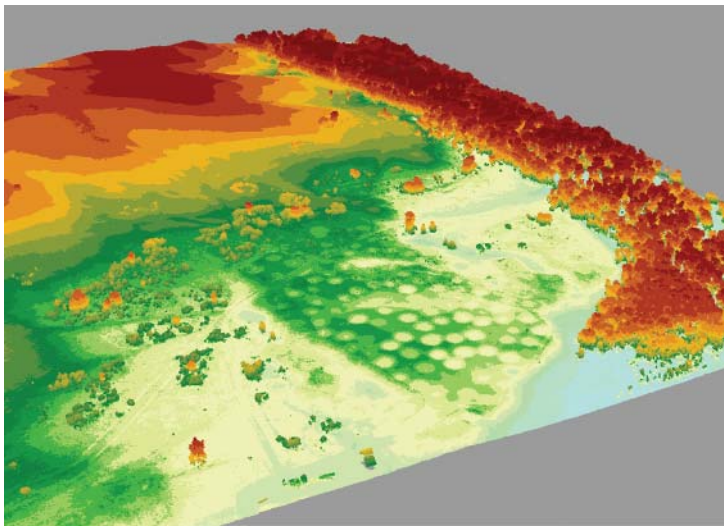

Figure 3. (Above right) Three-dimensional point cloud data overlay the terrain model for the Big Hidatsa Village area (left) and can be compared easily with the modern-day aerial image (above left). The point cloud gives definition to aboveground features while the terrain model defines the ground surface and landforms. The aerial photo shows earthen lodge depressions, trails, and areas that are interpreted for the public.

climate. Landscape models derived from airborne laser scanning complement other GIS data sources such as soils data, aerial photographs, topographic maps, and historical maps. Their combination with previous information is effective for evaluating floodplain dynamics and associated elevation characteristics at archeological sites.

Contact with Europeans and Americans introduced diseases that irrevocably altered Hidatsa communities even as many of their cultural traditions proved incredibly resistant to outside influence.

Understanding changes to archeological landscapes

Changes to Knife River village dynamics are revealed in the ALS data, particularly in village population size and site fortifications. These changes resulted from multiple waves of smallpox and disease epidemics that affected the villages in the 18th and 19th centuries (Trimble 1986, 1993). A local relief model of Big Hidatsa Village shows the contraction of the village and construction of a new fortification wall that occurred after the smallpox epidemics of the late 18th century (fig. 4). The reduction of village populations and corresponding smaller villages and fortification enclosures has also been observed at the Double Ditch Village just downstream on the Missouri River (Kvamme 2003; Kvamme and Ahler 2007). At Double Ditch, researchers have used multiple remote sensing techniques to identify contracting fortifications and village sizes that also correlate with the effects of disease and warfare. The contraction of villages on the upper Missouri River demonstrates the dramatic impacts that disease and warfare had on the Hidatsa people and how they used cultural traditions and practices to overcome severe hardships during the era of westward expansion.

The intersection of Hidatsa cultural traditions, active river processes, and European contact defines the human experience at Knife River. Moreover, the Hidatsa villages at Knife River are critical for understanding the human experience in North America. Understanding past human modifications to the natural landscapes is indispensable for effective management and preservation of these places for future generations. The recent use of nondestructive technologies to produce high-resolution landscape models has enhanced our understanding of this complex cultural setting. More generally this method provides information for multidisciplinary research and site conservation that can address questions for which traditional archeological excavation techniques are poorly suited or not feasible. Employing advanced digital technologies to investigate the past places Knife River Indian Villages at the forefront of the ongoing dialogue relating to tradition and change.

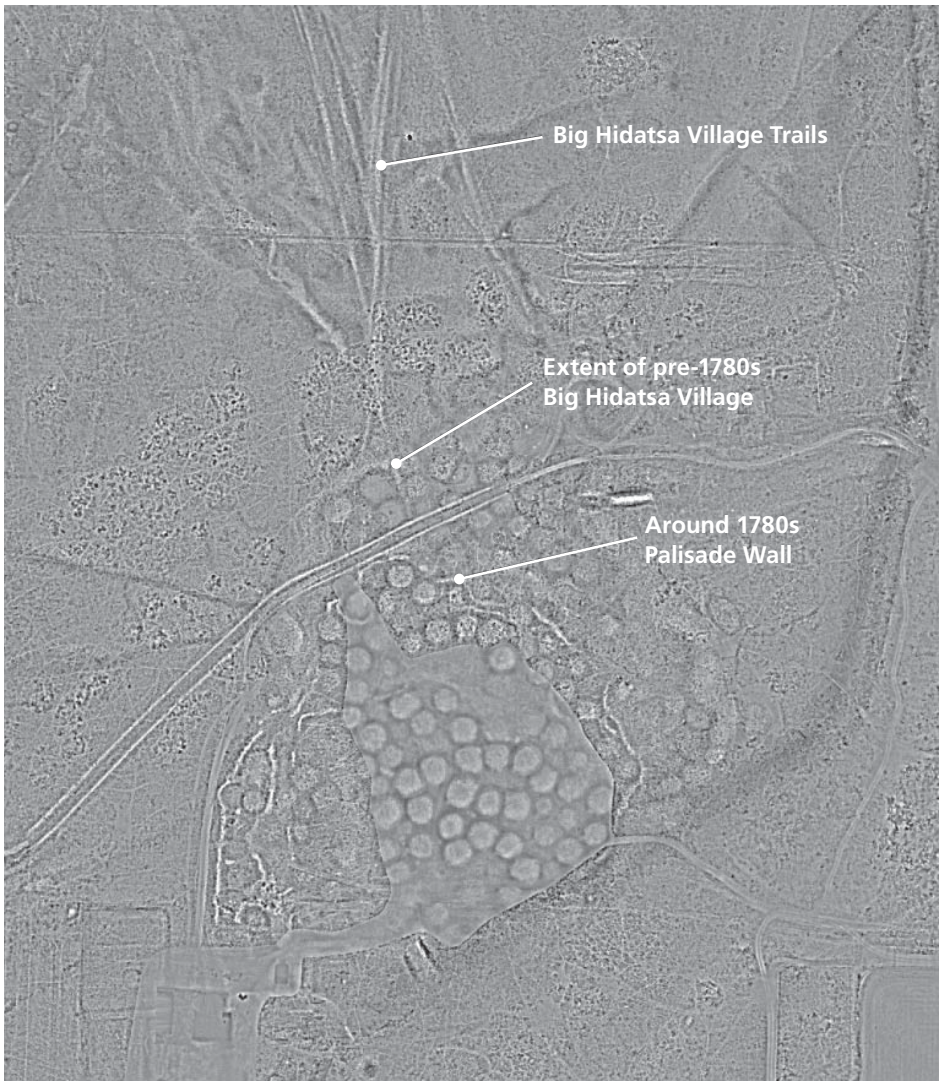

Figure 4. This ground surface model was generated from the airborne laser scan and illustrates archeological features associated with the Big Hidatsa Village and the changing dynamics of village life.

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