USE OF AERIAL INFRARED THERMOGRAPHY TO MAP EMERGENT RIVERINE SANDBARS

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Abstract: The Big Bend, a 145-kilometer reach of the Platte River in central Nebraska, has been designated by the US Fish and Wildlife Service as critical habitat for the endangered interior least tern and threatened piping plover. In the past, high flows occurring during spring runoff were capable of building ephemeral sandbars, which provided nesting and foraging habitat for these species. During the last century, regulation of upstream water resources has altered the flow in the central Platte River, which has in turn affected the seasonal cycle of sandbar formation. Currently, management efforts are focused on creating and maintaining in-channel habitat areas (artificial islands) and off-channel habitat areas (gravel pits). Future releases from upstream dams may be used to generate pulse flows with the objective of creating in-channel sandbar habitats.

As a means to quantify and evaluate the effect of pulse flows and channel management practices on sandbar creation and maintenance along the central Platte River, six 1-kilometer stream segments were chosen for geomorphic analysis. Two of the segments are located at bridges, two segments are located where the channel carries the total flow in the river, and two segments are located where a braided channel carries a portion of the flow. The discharges at the upstream and downstream ends of the Big Bend study reach are determined at two U.S. Geological Survey streamflow-gaging stations, providing flow information for each site.

Identifying the spatial extent of emergent sandbars is an essential component of the geomorphic analysis. Resolving these boundaries with traditional aerial photographic imagery such as natural color, black and white, and even color-infrared photography can be extremely difficult, because sufficient contrast between water and land surfaces is required. Mapping the sandbar perimeters using ground-based survey techniques can provide the required accuracy, but is labor-intensive and provides limited coverage. Aerial infrared thermography provided both the necessary contrast and the adequate spatial coverage needed for this purpose. The contrast in temperature between subaerial and submerged areas in this imagery provided a means to detect and isolate the emergent sandbars. Digital still-frames along the six sites were captured from the video and georeferenced to digital orthophotographs. For each year, and in some cases on consecutive nights within a given year, the emergent sandbars in each of the six sections were digitized within a geographic information system. It is our intent to incorporate imagery collected following future streamflow management activities as a means to document and quantify the effects on the area and distribution of emergent sandbars in these reaches.

INTRODUCTION

The Platte River valley is a combination of open, shallow, braided river channels, grasslands, and low wet meadows. All of these features contribute to the areas designated as critical habitat for the interior least tern and the piping plover, both of which rely on emergent ephemeral sandbars for nesting and foraging (Faanes and Lingle 1995). High discharge, large bed-sediment load, and increased channel width are conditions responsible for channel instability, which in turn creates emergent sandbars (Karlinger et al. 1983, Lyons and Randle 1988). Historically, spring runoff was capable of producing such conditions; since then, river flow has been increasingly regulated so that seasonal in-channel sandbar development has been insufficient for the needs of the species (U.S. Department of the Interior 2003). The absence of high flows and the subsequent decrease in transport of sediment during these flows have prevented the creation of new sandbars, as well as the redistribution of existing sandbars (Crowley 1981, Lyons and Randle 1988). Without the regular redistribution of sandbars and natural scouring, vegetation has stabilized sandbars, and created vegetated islands (Williams 1978, Eschner et al. 1983, Currier 1997, Faanes and Lingle 1995). These changes in the channel morphology have prompted channel mitigation measures, and while these efforts may help in the recovery of the river, as well as the recovery of the endangered species, results are less effective if they cannot be quantified. For this reason, aerial infrared thermography was employed as a technique for measuring, mapping, and evaluating emergent sandbars.

There have been many attempts to document the changes in the channel, as well as assess the effectiveness of management techniques along the Platte River. Williams (1978) illustrated the nature of the narrowing channel by comparing photographs from the early 1900's to photographs from 1977. Low-level aerial photographs were used by Crowley (1981) to supplement ground observations of channel characteristics; while Karlinger et al. (1983) investigated channel width changes by comparing 1860 map information to aerial photographs taken between 1971 and 1979. Water depth was measured by topographic surveys, and channel slope was measured from U.S. Geological Survey 7.5-minute topographic quadrangles. For the purposes of displaying changes in river geometry, Zelt and Frenzel (1996) surveyed habitat characteristics near Grand Island in 1993 through 1995.

More closely related to the work described in this paper, Sidle and Ziewitz (1990) described the use of an aerial videography system for quantifying habitat by determining total channel area, sandbar area, and permanent vegetation measured from video scenes that were selected and analyzed with image-processing tools. Currier (1997) used aerial videography collected between the years 1988 to 1994 to document both physical and biological changes in the Platte River. Furthermore, Tracy (2004) investigated the effects of river discharge on channel geometry by comparing the differences between two types of sandbars present in study sites on the Missouri River. Emergent sandbars were surveyed and mapped to measure their extent, and thus, determine available habitat for a variety of species.

SITE SELECTION

Six sections approximately 1-kilometer in length between Lexington and Grand Island were chosen for geomorphic analysis using aerial infrared thermography (figure 1). The sections were chosen for their proximity to river stage gages, and from west to east are: 1) Overton (at the bridge), 2) Kearney (also at the bridge), 3) Rowe Sanctuary (approx. 2 km west of the Gibbon bridge), 4) Prosser (approx. 5 km west of the Wood River bridge), 5) Doniphan (approx. 6 km east of the Alda bridge), and 6) Grand Island (approx. 0.5 km southwest from the U.S. 34 bridge). Of the six sites, two are located at bridges, (Overton and Kearney), two sites are located in areas where the channel carries the total flow of the river, (the Prosser and Grand Island reaches), and two sites are located in areas where a braided channel carries only a portion of the flow (the Rowe Sanctuary and the Doniphan reaches). The Overton and Kearney sites are located at bridges where the flow is constricted and the channels tend to be deeper. The Grand Island and Prosser sites are in reaches of river where the braided channels come together, and contain the total flow of the river. The Doniphan and Rowe sites are in reaches of the river where the flow is divided between multiple channels, and each only receives a fraction of the total flow.

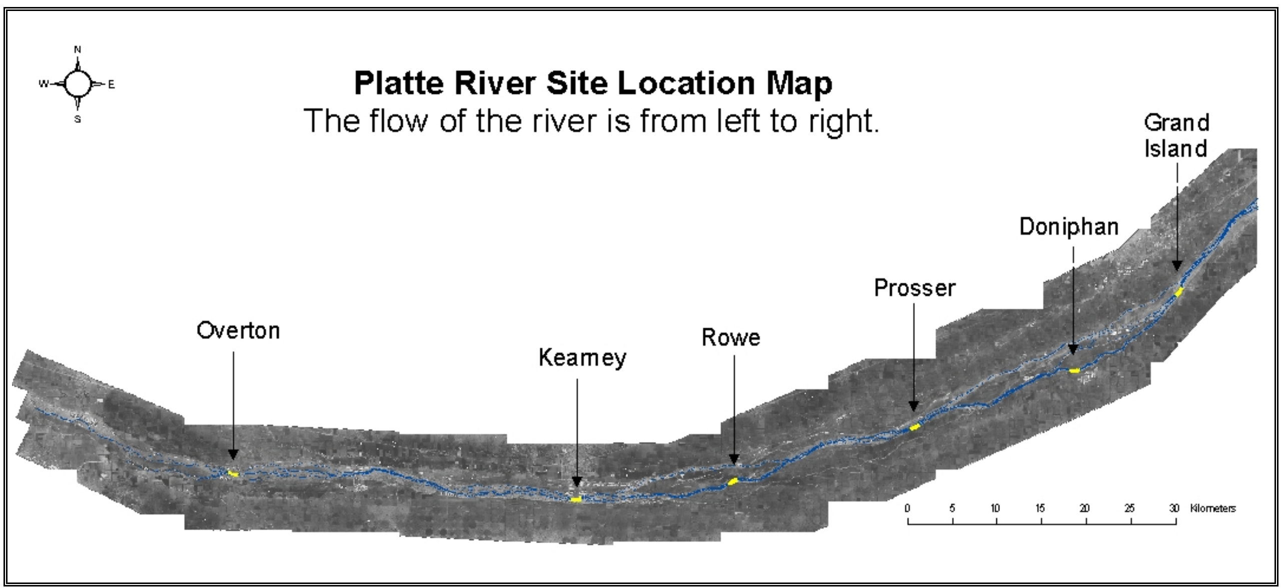

Figure 1 Map of the Big Bend reach of the Platte River. The selected sites for analysis are labeled and outlined in yellow. The USGS gaging stations are located at Overton and Grand Island.

METHODS

In shallow water depths such as those found in the Platte River, identifying the spatial extent of emergent sandbars requires sufficient contrast between water and land surfaces. Resolving these boundaries with traditional aerial imagery such as natural color, black and white, and even color infrared photography can be extremely difficult. Mapping the perimeters using ground-based survey techniques can provide the required accuracy, but the coverage can be spatially limited and the process is labor intensive. Aerial infrared thermography, however, provides both the necessary resolution of the land-water interface and the desired coverage with minimal labor.

Aerial thermal infrared video was collected from a Cessna 182 aircraft equipped with a 512 x 512 pixel camera mounted vertically in the underside of the aircraft. The camera had a Platinum Silicide Schottky_Barrier IRCSD detector with a detectable wavelength band of 3 to 5 microns and an infrared polarized f50 mm, F 1.2 lens with a field of view of 14 degrees horizontal by 11 degrees vertical. The image display was monochromatic with 256 gray levels. Images were displayed in a grayscale format where warm objects (such as water) appeared black to dark gray, while cold objects (such as land surrounding the river and wildlife) appeared white to very light gray.

The aerial thermal infrared video was collected in the third week of March each year from 2000 through 2003, and again in 2005. The aircraft was flown over the Big Bend, a 145-kilometer reach of the Platte River in central Nebraska, from Lexington to Grand Island throughout the night hours (figure 1). The pilot navigated over the river by noting his instantaneous position plotted on maps of the area. The pilot had control of the video output during the entire flight so that adjustments could be made to produce a clearer image at the pilot’s discretion. In some instances, the black and white representations of object temperatures were reversed if it appeared that a better image could be generated. The flight altitude was roughly 1200 meters above the ground and parallel to the ground whenever possible to prevent any unnecessary distortion to the images. Video was stored on digital videocassettes, which were then viewed on a desktop personal computer with video-editing software where the individual images were captured and stored. The date, time, UTM coordinates, altitude, and air speed were displayed within the video frame, so that each frame was ‘stamped’ with this information (figure 2). The date and time on the image was later used to obtain streamflow data from gaging records for that particular moment.

After the images were captured from the video, they were then registered to a 2001 Platte River black and white digital orthorectified mosaic using geographical information system software. Each video image was anchored to the mosaic at four to six select points that fell within each quadrant of the image. The root mean square (RMS) of each registered image was less than 2.0 pixels, ensuring the best possible fit. Each registered image overlapped the next image to create a seamless mosaic for digitization.

Once the black and white images were registered, for each year and site, the river segment channel margins, vegetated sandbars, and emergent sandbars were digitized. The digitization process first involved defining the area considered as active channel. Areas within the channel having permanent vegetation were defined as vegetated bars. The areas considered as permanently vegetated were chosen from the 1998 Bureau of Land Management color infrared orthophotographs (U.S. Department of the Interior 1999). The areas devoid of permanent vegetation, or the total channel area minus the area of permanently vegetated bars, were defined as the active channel. Sandbars were defined as emergent features within the active channel identifiable in the thermal images by their contrasting white color in the dark gray river (figure 2). The features (total channel area, vegetated bars and sandbars) were then digitized by defining their boundaries with a series of points that once connected, formed a solid polygon area. Once digitization of all features was completed, the areas of each sandbar, vegetated bar, and active channel area for each site were tabulated.

Sandbar lengths and segment lengths were also tabulated for each night in order to compute the braiding index for each segment using a modification of Williams’ (1978) definition for braiding index. William’s definition sums the length of islands within the given reach divided by the length of the reach measured midway between the banks. The modified definition includes sandbars as well as vegetated bars (or islands) in the calculation because both contribute to the braiding. Consequently, the braiding indices appear to be quite high in recent years. The modified braiding index could be misleading in 2005, because as the sandbars integrate, fewer larger bars are created, replacing the numerous smaller bars. For this reason, only the relative degree of braiding between sites is considered here.

Figure 2 Aerial thermal infrared image from the Rowe Sanctuary site in 2003. The dark areas are wetted channel and the white areas are sandbar or vegetated bar.

RESULTS

By creating a series of time-lapse maps illustrating the progression of braiding and sandbar development, a geomorphic view of the river emerges over time. Because the video is able to capture a snapshot of the river over one night, the entire section of channel can be evaluated at that exact moment. Furthermore, the nighttime discharge into and out of the study reach is known at the Overton and Grand Island stream-gages, and when paired with the video images, allows evaluation of the sandbar morphology associated with a specific discharge through the study reach. The discharges into and out of the reach are presented in table 1.

Table 1 Instantaneous discharges reported at the upstream and downstream ends of the Big Bend study reach, Platte River, Nebraska.

Date (m/dd/yyyy)	**Discharge at Overton (in cms)**	**Discharge at Grand Island (in cms)**
3/27/2000	79.85	85.23
3/26/2001	25.63	41.63
3/27/2002	48.99	19.00
3/25/2003	11.07	18.49
3/27/2005	28.32	22.23

For the Rowe Sanctuary site, the channel morphology was captured by the video on more than one night for each year, displaying emergent sandbar development and braided channel behavior for multiple discharges (figure 3). Qualitatively, what was once a wide, single-thread channel has progressively narrowed and become braided with numerous smaller channels. Sandbars have emerged and begun to close off the channel in some areas. Quantifying attributes such as total sandbar area, sandbar area as a percent of the total area, and braiding index from the digitized features provides a numerical depiction of the changes occurring in the channel.

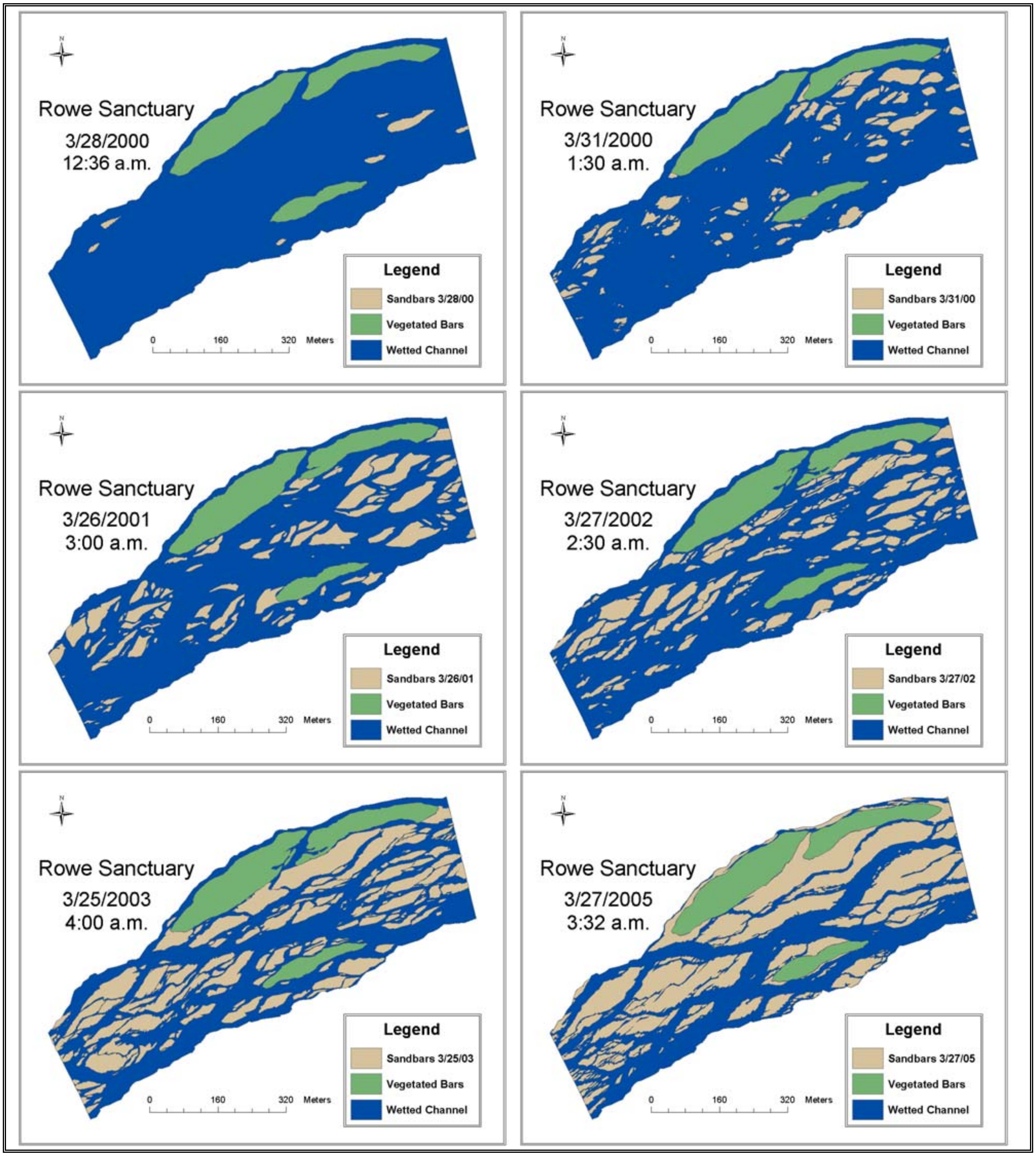

Figure 3 Changes in channel morphology of the Rowe Sanctuary site from 2000 through 2003, and 2005.

The total sandbar area was tabulated for each of the sites and then calculated as a percent of the total channel area. The results show that Rowe and Doniphan, both sites containing only part of the total flow, had a higher sandbar percent of total area than the other sites. Prosser and Grand Island, sites containing the total flow of the river, had a generally lower percentage of sandbars (figure 4). All but two sites (Overton and Prosser) had a progressive increase in sandbar area from 2000 to 2005.

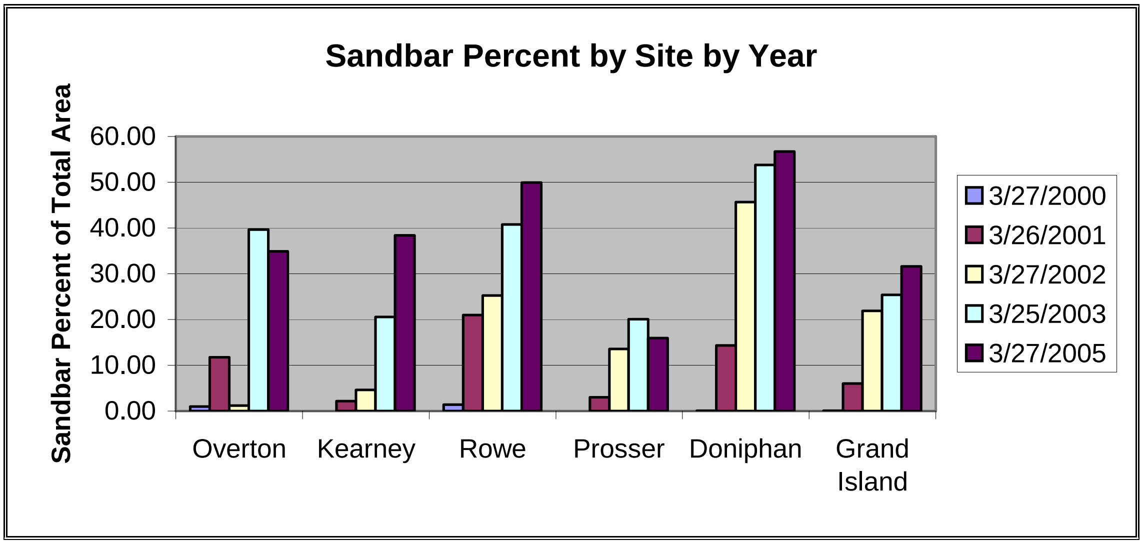

Figure 4 Chart displaying the percent of total area occupied by sandbars at each site by year.

The braiding index was also calculated for each year at each site using Williams' (1978) definition of total sandbar and vegetated bar lengths divided by stream segment length. These results showed that the channel morphology at both the Rowe and Doniphan sites was more braided than at the other sites, while the channel at Overton and Kearney, both at bridge segments, was less braided (figure 5). Most sites show a progressive increase in braiding index, at least through 2003.

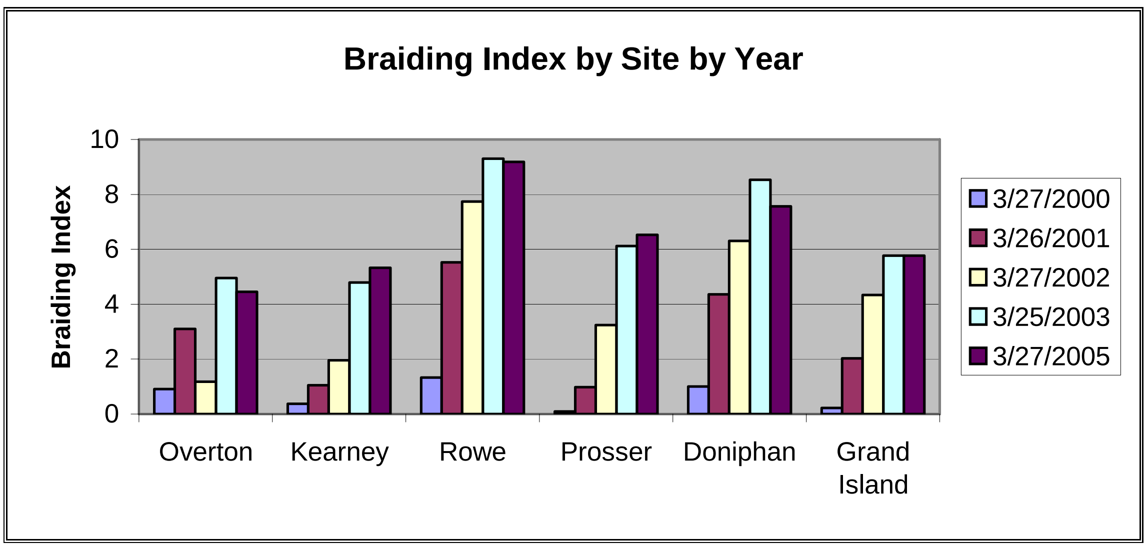

Figure 5 Chart displaying the braiding index at each site by year.

CONCLUSIONS

The use of aerial infrared thermography can be quite effective for mapping the spatial extent of emergent sandbars and consequently, the available habitat for endangered species. It is also a process by which a large amount of data can be collected and analyzed with a small amount of labor. When paired with other surveying techniques or other forms of aerial photography, it can be a very powerful tool.

The amount of subaerial sandbar area changes regularly as water-management practices in the Central Platte River change each year. This paper proposes a method of measuring that area for the purposes of habitat mapping and evaluation. In the event of one or more scheduled pulse flows along the Platte River, aerial infrared thermography could be utilized as a means to detect changes in the geomorphology of the channel. By pairing this information with discharge and stage information, conclusions may be drawn about the effects of hydrology on channel morphology.

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