Using Aerial Imagery over Cheyenne Bottoms Wildlife Area to Map the Extent of High Water Levels.

Michael E. Houts
GIS/Remote Sensing Specialist
Kansas Department of Wildlife and Parks
Kansas Applied Remote Sensing Program
Kansas Biological Survey

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Executive summary:

At the request of Kansas Department of Wildlife and Parks (KDWP), the Kansas Applied Remote Sensing (KARS) program at the Kansas Biological Survey used its aerial imaging system to acquire imagery over the Cheyenne Bottoms Wildlife Area to document the extreme high water levels that occurred in June of 2007. The individual images (127 of them) were geo-referenced, projected, and mosaiced to create a seamless image that followed the entire perimeter of the high-water line. Only the perimeter was processed because the high water covered all the features in the interior that could be used as reference points for geo-registering and rectifying the images. The high-water line was then digitized to create a digital data layer that could be overlaid on other data sets such as land cover, property lines, or roads for further analysis.

The Camera System and Image Acquisition:

The KARS Program owns and operates an aerial multispectral imaging system for acquiring data over research locations and other areas of interest as requested. The TerraHawk aerial imaging system was designed and built by TerraVerde Technologies and utilizes multispectral digital cameras from RedLake, a recognized leader in designing multispectral cameras. The system is mounted in a Cessna 182 airplane that is maintained and operated by the KU Aerospace Department. The camera (a DuncanTech MS3100) acquires data from the green, red and near infra-red portion of the spectrum. For this mission over CBWA, imagery was acquired on June 21, 2007 from 12,500 feet above mean sea level (about 11,000 feet above the ground) resulting in a pixel resolution of 1-meter and an image that is 1350 meters wide by 1012 meters tall. Data was acquired along 11 flight lines that were orientated in an east-west direction and spaced 1000 meters apart (Figure 1).

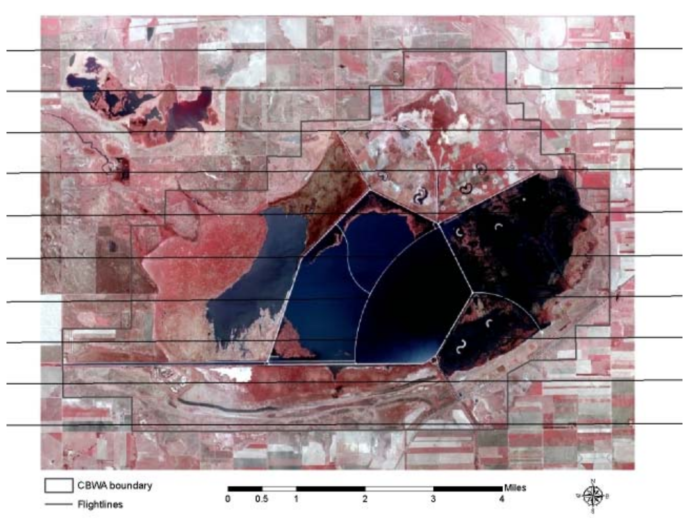


Figure 1. Flight lines used to acquire imagery shown over imagery from 2001. Due to the high water levels, an additional line was added on the southern edge to ensure complete coverage of the flooded area.

Data acquisition took place between 11:30 and 1:15 pm with clear skies dominating the horizon, during which time 443 pictures were acquired. A personal hand-held digital camera was used to acquire additional pictures out the plane window of the high-water conditions. These pictures ranged from zoomed in on specific locations to wide-angle images that attempted to show a large area (Figure 2, 3, 4).

Figure 2. A view looking south across the rest area/overlook on highway 156. The road is about 20 feet above surrounding CBWA ground levels and water would not normally be visible anywhere in this view.

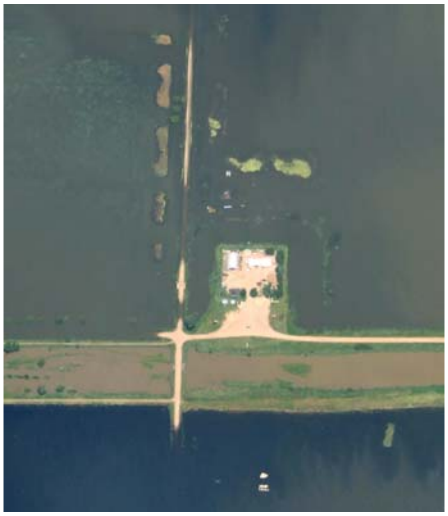


Figure 3. A picture of the main office surrounded by water and the access roads to the north, south, and west underwater.

Figure 4. Image looking north with highway 156 cutting across the lower left corner. The areas outside the irregular circle in the middle (water holding pools) are usually dry, as are significant portions within the pools themselves in recent years.

Geo-Registering, Rectifying and Mosaicing

After acquiring the imagery, the point locations of individual images were calculated from a GPS log created at the time of image acquisition, then plotted over a base map for reference. Images that occurred along the perimeter of the high-water line were selected for geo-referencing (Figure 5).

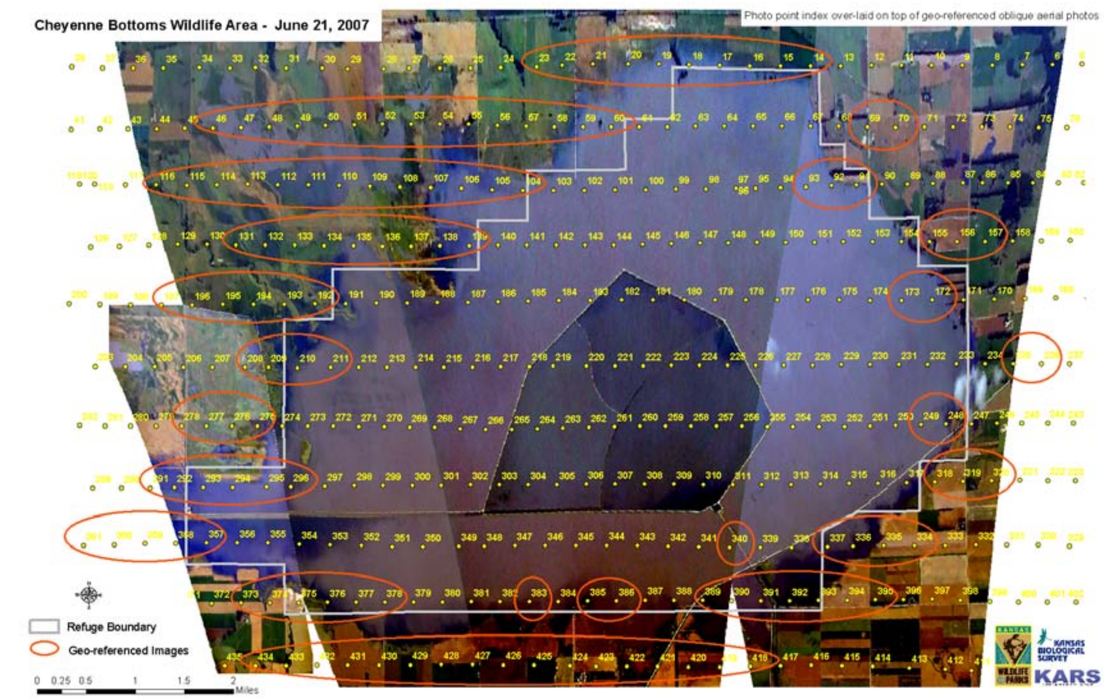


Figure 5. A map of all image points and images that were georeferenced shown over a mosaic of geo-registered oblique photos taken out of the airplane window.

Geo-referencing was done using the AutoSync module in Erdas Imagine 9.0. Raw multispectral images were referenced against a 2006 natural color NAIP image of the area that had a 1-meter spatial resolution. Ground control points were placed on trees, road intersections, features protruding from the water, and other features visible in both the new imagery and the 2006 NAIP photo. Only images around the perimeter were geo-referenced because the high water prevented the identification of enough ground control points within the interior of the refuge. Many images acquired contained nothing but water within the field of view. A total of 127 images were processed around the perimeter, with images extending as far to the interior as possible and a little further inland to provide some location context. Rectification resampling was performed using bilinear interpolation to a one-meter pixel to create an output image in the UTM zone 14, NAD 83 projection.

Once all the images were rectified, they were processed using the mosaic tool in Erdas Imagine to create a seamless image showing the extent of the high water. All 127 images were entered into the module with the option to calculate active area activated and the option to crop the images set to 7%. This was done to remove some rows and columns of bad data that occurred along the edges. The options to delete cut-lines and feather the edges were also activated to help blend the images together and create a more seamless final image. Since the mosaic only covered a relatively narrow ring around the perimeter and did not show the interior at all, It seemed important to also show the extent of the waters impact on the interior roads and levees. To show this, a series of four oblique photographs from the airplane window that covered all of the refuge were geo-referenced and mosaiced together. While this image shows some distortion towards the north horizon, the refuge area itself is rectified to a reasonable degree of accuracy (+/- 5 meters in most areas) and is useful for examining the entirety of the area and the interior.

Digitizing the High-Water Line

With the mosaic complete and providing a spatially accurate and detailed delineation of the waters edge, the next task was to digitize the water line for use in additional analysis. Soon after starting to digitize though it was discovered that the water line was not as clear-cut as initially thought. There were many instances where it was hard to tell where to draw the line because of issues regarding where the water ended and saturated soil began, where the current water level was versus where it appeared to have been recently, or where it went when crossing through trees. It was an exercise in judgment calls and trying to remain consistent. It was decided to map the extent of the high water, that meant sometimes going further inland than the current water line to a "line" where the vegetation looked less damaged (Figure 6). Still, there were occasions like along the west edge of pool 2 where, due to the lack of any real elevation changes, saturated soils extended further inland but there was no clear line of where the water was. In this instance, the line was drawn further towards the interior of the basin because it was thought that while the soil moisture increased dramatically and there may have been shallow pockets of water, there probably was not any real flooding. Some interior features that protruded from the water like roads and small islands were not excluded from the high water perimeter. Once finished, the area of the high water polygon was

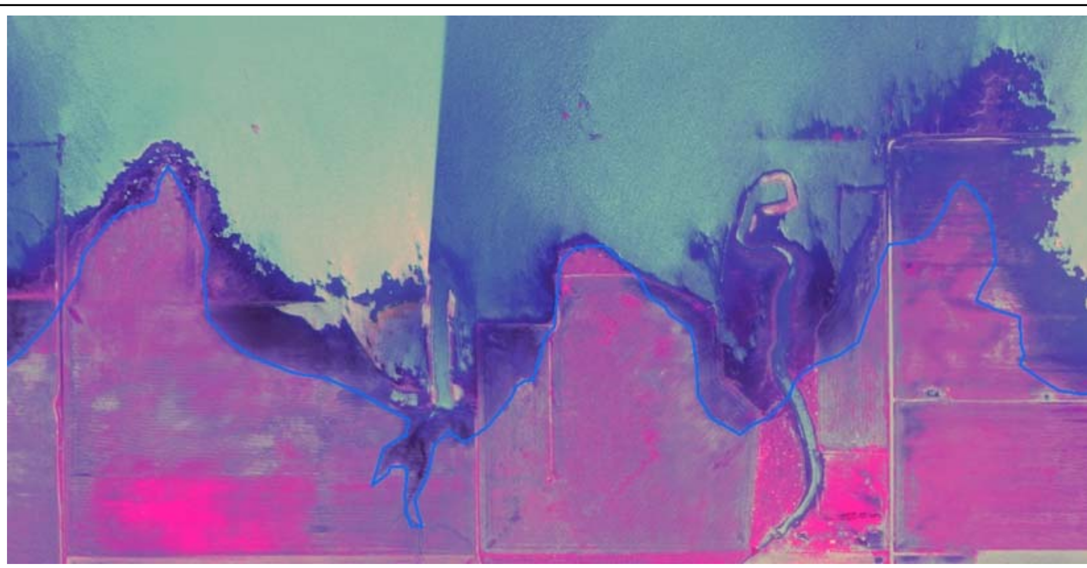


Figure 6. A detailed view of a portion of the waterline delineation along the southern edge of CBWA.

calculated to be 18,774 acres. The Cheyenne Bottoms wildlife Refuge is 19,857 acres, and when the high water line and the refuge boundary were intersected, it was found that 92% (18,276 acres) of the refuge was underwater (excluding some roads and levees). Additionally, it was found that 498 acres outside the refuge was underwater.

Discussion

Realizing that the CBWA sits within a natural basin of approximately 41,000 acres, it seems natural that this area would occasionally flood. Zimmerman (1990) reported that the area has flooded nine times since 1885, with these events likely turning the shallow basin into a 20,000 acre shallow lake. The most recent flood was in August of 1927 when over 14 inches of rain fell in two days and flooded the basin. Recently, the region has been dry, with barely enough water to partially fill the three internal storage basins. The wet spring and summer of 2007 changed this however, when after an already wet early spring, over 20 inches of rain in May and June. It became impossible to keep all the water contained within the levee system and water spilled out onto the surrounding landscape. Despite their infrequency, the areas history of flooding became very evident as the aerial images were examined in detail while looking for GCP's to rectify the images. Parallel to the current high water line, there were scars in the dryer uplands that, once in the context of this water line, immediately became recognizable as old water line scars. Some were just a few meters higher, while others were considerably higher indicating that water levels had been much higher in the past. While this event has surely had unpleasant consequences for many, it will provide a fresh dose of nutrients to the flooded cropland and a unique opportunity to examine how the wetland vegetation responds and regenerates.

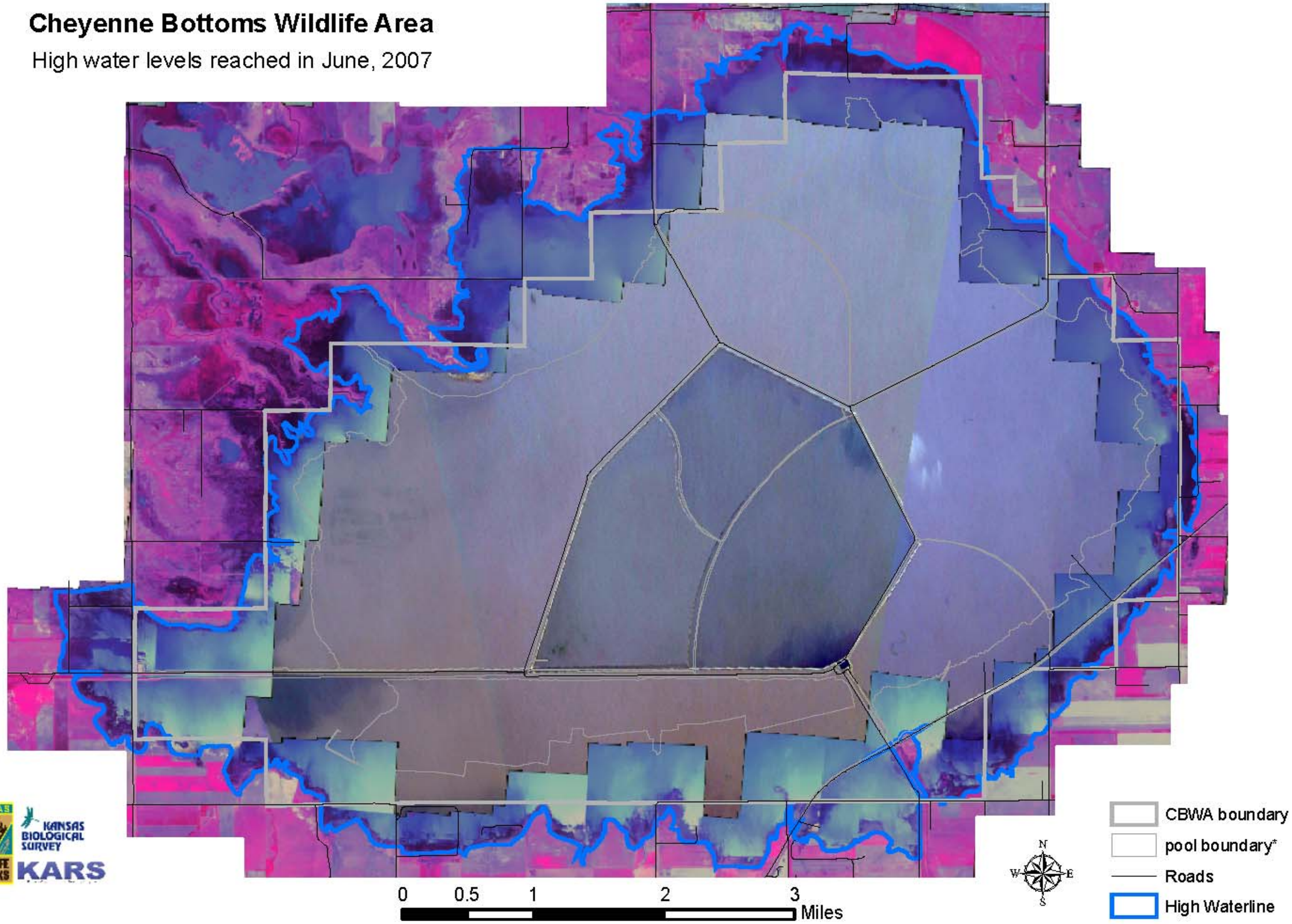
Citations

Zimmerman, J.L. 1990. *Cheyenne Bottoms: Wetland in jeopardy.* University Press of Kansas, Lawrence, Kansas, 197 p.

KANSAS WILDLIFE & PARKS
KANSAS BIOLOGICAL SURVEY
KARS
Kansas Applied Remote Sensing Program

Cheyenne Bottoms Wildlife Area

High water levels reached in June, 2007



Near infer-red (NIR) aerial imagery was acquired on June 21, 2007 to map the extent of the water levels at Cheyenne Bottoms Wildlife Area (CBWA). The individual images that occured along the "shore" were geo-referenced and mosaiced to create a single image. Images of the interior of CBWA were not geo-referenced and included in the mosaic due to the lack of features to reference. The interior of the wildlife area is displayed by a series of oblique digital photographs taken out the plane window, then geo-referenced and mosaiced. Once the extent of the high water was identified, the perimeter was delineated to create a digital boundary that could be overlaid on other data sets. Having a map like this to document the extent of the water will be useful for assessing damges and planning for future events.

* pool boundaries are from 2005 imagery