USE OF THERMAL INFRARED IMAGING TO INDENTIFY GROUNDWATER RESOURCES FOR COASTER BROOK TROUT ALONG THE MINNESOTA SHORELINE OF LAKE SUPERIOR

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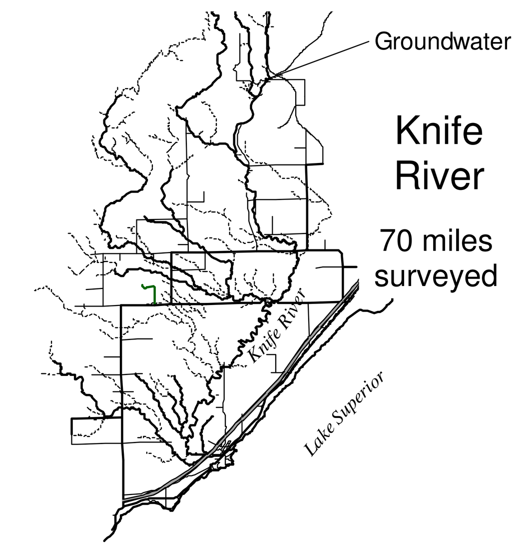


Abstract

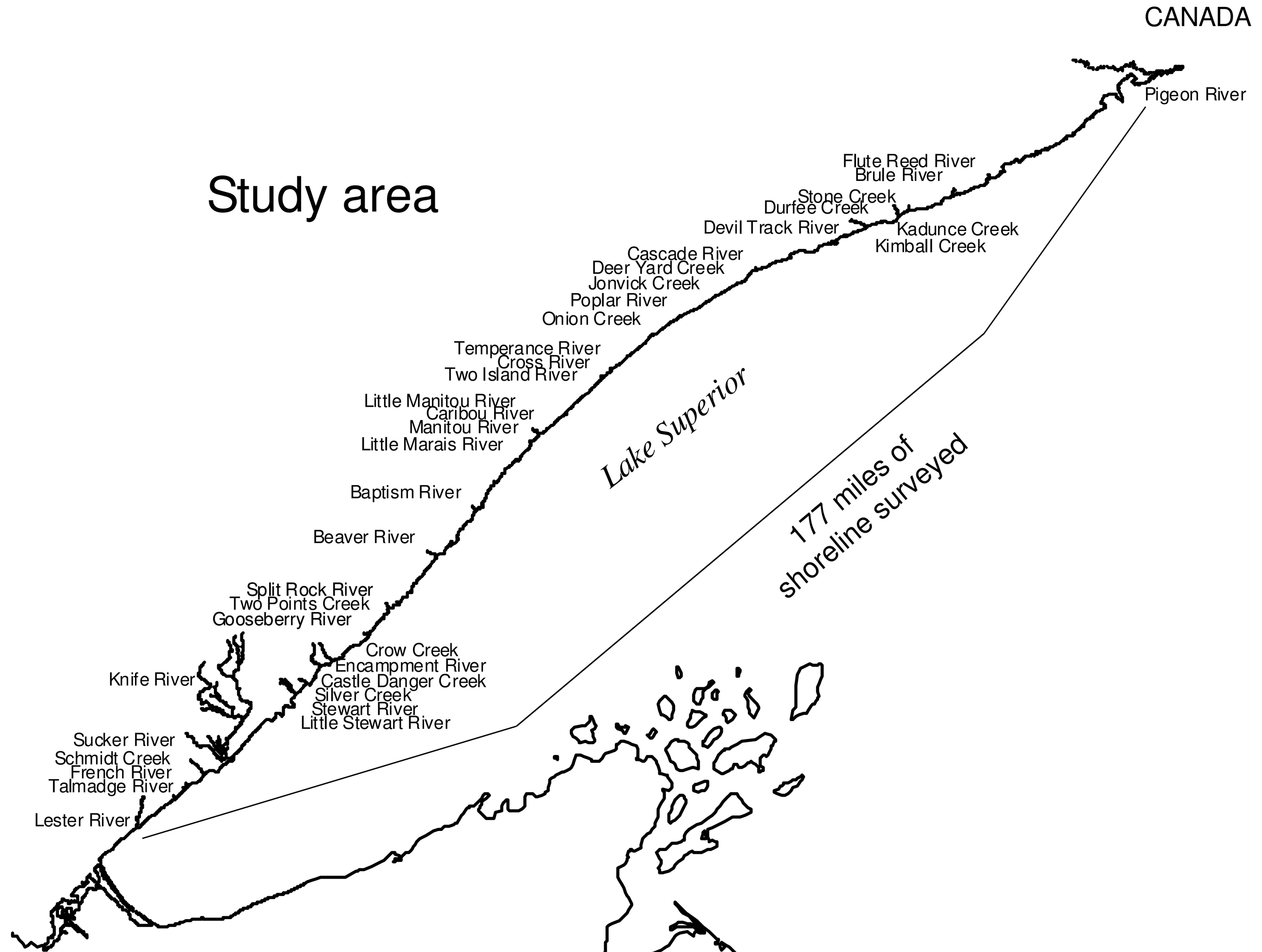
We conducted a regional groundwater survey on the Minnesota Lake Superior shore and below barrier tributaries using aerial thermal remote sensing. Groundwater intrusion areas provide essential spawning habitat for brook trout. Thermal infrared (TIR) video was shot from a fixed wing aircraft during the winter and spring seasons in 2003 and 2004. Timing and conditions were chosen to maximize temperature differences of groundwater with the surrounding environment and optimize groundwater detection by TIR. Areas with suspected groundwater intrusion indicated by TIR were further examined in the field. In the field temperature measurements confirmed the presence of minor groundwater intrusion areas in the Knife and Lester rivers. The success of TIR in detecting groundwater is sensitive to weather and environmental conditions. No groundwater resources were identified along the Lake Superior shoreline and tributaries that are likely to be important in the rehabilitation of coaster brook trout.

Introduction

- The purpose of this project was to identify ground water sources that if present will be critical to "coaster" brook trout rehabilitation efforts.
- Thermal infrared imaging has proven useful in discerning temperature differences over broad spatial scales (Cherkauer et al. 2003, Kay et al. 2001) and in identifying spring locations (Campbell and Singer 2001).
- Specific locations of groundwater intrusions should be detectible if surveys are conducted under conditions that maximize the differences between ground water temperature and the local surface environment.

Groundwater detection, the "old-school" method

Study area



Methods

Selection of the study area and below barrier tributaries was based on potential as coaster brook trout habitat. Thermal infrared (TIR) data were gathered in the winter and spring in 2003 and 2004 when there was no canopy and thermal differences between groundwater and the surrounding environment were thought to be maximized. Aerial surveys were conducted by A.W. Research Laboratories, Inc. of Brainerd, Minnesota. Cameras recorded video in the thermal infrared frequency and in the visible spectrum. Still 35 mm slide images were also taken. Video tape running time was indexed with GPS location. Video data were transferred to DVD format. Temperature gradients appeared on the thermal footage as areas of contrast with warm areas appearing light and cold areas appearing dark. Since most of the surveys were conducted at temperatures below groundwater temperature, potential groundwater should appear as white. Regions of interest were crosschecked with visible images to ascertain the nature of the source of the signal captured by the thermal camera. Areas of suspected groundwater intrusion were assigned a GPS waypoint and reconnoitered for signs of groundwater. Water temperatures and conductivity readings were taken in the field.

Photo: A.W. Research Labs, Inc.

Thermal infrared remote sensing

Ground truthing

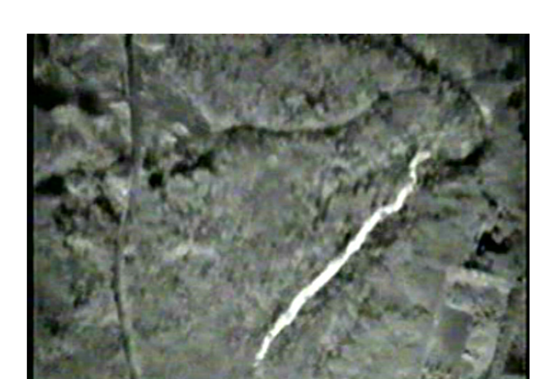
Temperature differences

Summer

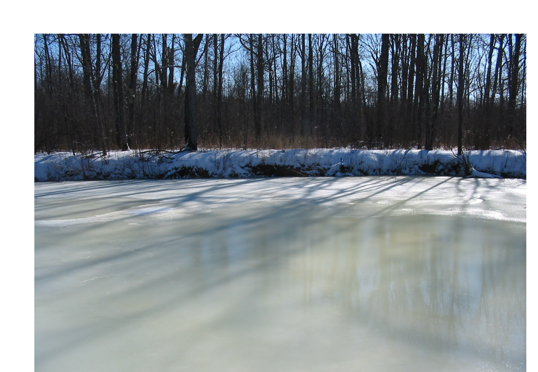
Winter

Results

Weather and local environmental ground conditions were highly variable over the time that the aerial surveys were conducted, confounding interpretation of the TIR data. Two areas of groundwater intrusion were located among many potential sites that were indicated from the TIR data. No groundwater sources were found along the Lake Superior shore. The following images illustrate the sensitivity of the technology to various conditions.



TIR image showing a "false positive", water flowing on top of the ice, Knife River, January 29, 2003. Warm areas are white on TIR images.

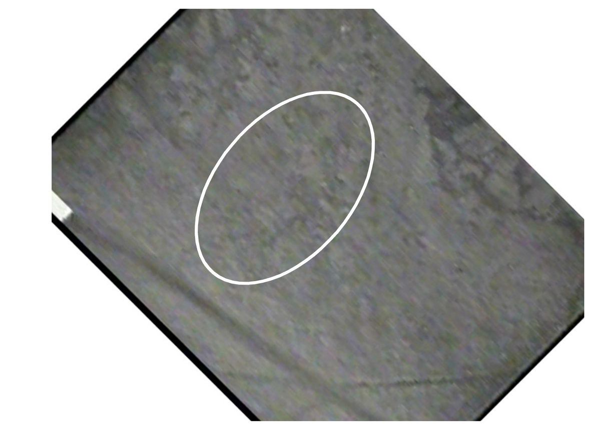


Water flowing on top of the Knife River, February 19, 2003. The extreme winter of 2002-2003 froze many tributaries to the bottom, caused cracks in the ice, and resulted in water flow over the ice.

Groundwater located within the Knife River watershed

Groundwater detection is dependent on environmental conditions

TIR image showing a groundwater intrusion area on the Knife River, January 29, 2003.

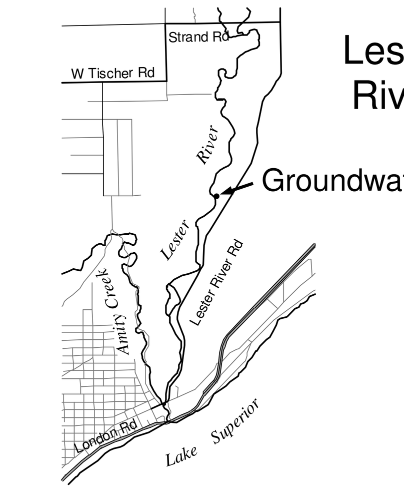


TIR image of groundwater intrusion area on the Knife River, December 4, 2003. No groundwater indicated, possibly because of warm air between the ground and the TIR sensor.

The groundwater intrusion area on the Knife River, February 19, 2003. Water appeared on top of the ice.

Groundwater intrusion area on the Knife River, December 10, 2003. Open water and vegetation are evidence of groundwater.

Groundwater located in the Lester River



Groundwater intrusion on the Lester River, July 9, 2004.

TIR image showing ground-water seeping into the Lester River, December 4, 2003.

Simultaneous visible spectrum image of groundwater intrusion on the Lester River, December 4, 2003.

No groundwater found along the Lake Superior shore

The TIR sensor produced a "shadow" where sun-warmed rock, cobble and sand met the lake shore. Mouth of the Split Rock River, April 13, 2004.

Simultaneous visible spectrum image of the mouth of the Split Rock River, April 13, 2004.

Cold surficial flow of spring runoff was well highlighted against sun-warmed substrate on the Lake Superior shore in the April 29, 2003 data, shot under clear sky conditions. TIR image near Sugarloaf Cove.

Surficial flow of spring run off is shown cascading into the lake near Sugarloaf Cove, April 24, 2004.

Conclusions

- TIR can successfully identify groundwater
- Groundtruthing TIR sites is critical to proper interpretation
- TIR may be effective within a narrow range of environmental conditions
- Minnesota's Lake Superior shore and tributaries lack significant groundwater resources
- Coaster brook trout rehabilitation along Minnesota's north shore will be difficult given limited groundwater habitat

References

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Funding Sources