

# Monitoring Water Quality in Falls Lake Reservoir Using High Spatial Resolution Satellite Imagery

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## Abstract

An important resource for any city is a reliable source of clean drinking water. Falls Lake Reservoir provides a drinking water reservoir for Raleigh and flood control and recreational opportunities for communities surrounding the lake. Despite these vital functions, the water quality of Falls Lake Reservoir has been problematic for some time with the upper reaches of the lake listed as 303(d) impaired waters. Phytoplankton blooms, high suspended sediment loads and other impairments are potential hazards to both the drinking water supply and human health. Rapid population growth in the communities surrounding the lake make the monitoring of water quality in Falls Lake Reservoir increasingly difficult and important.

A water body the size of Falls Lake Reservoir is difficult to adequately monitor using traditional boat or mooring based sampling strategies. One solution is to use high spatial resolution satellite imagery. In collaboration with the Center for Applied Aquatic Ecology at NC State, Global Earth Observation and Data Analysis Center at National Cheng Kung University and the National Space Program Office of Taiwan a program was instituted to integrate remotely sensed images and a suite of water quality measurements taken from small boats. The goal of this joint effort is to produce maps of important water quality parameters for the entirety of Falls Lake Reservoir at a given time. These synoptic snapshots of the health of Falls Lake Reservoir can provide a valuable tool for managers at both the state and local levels. The preliminary results of this work are presented here.

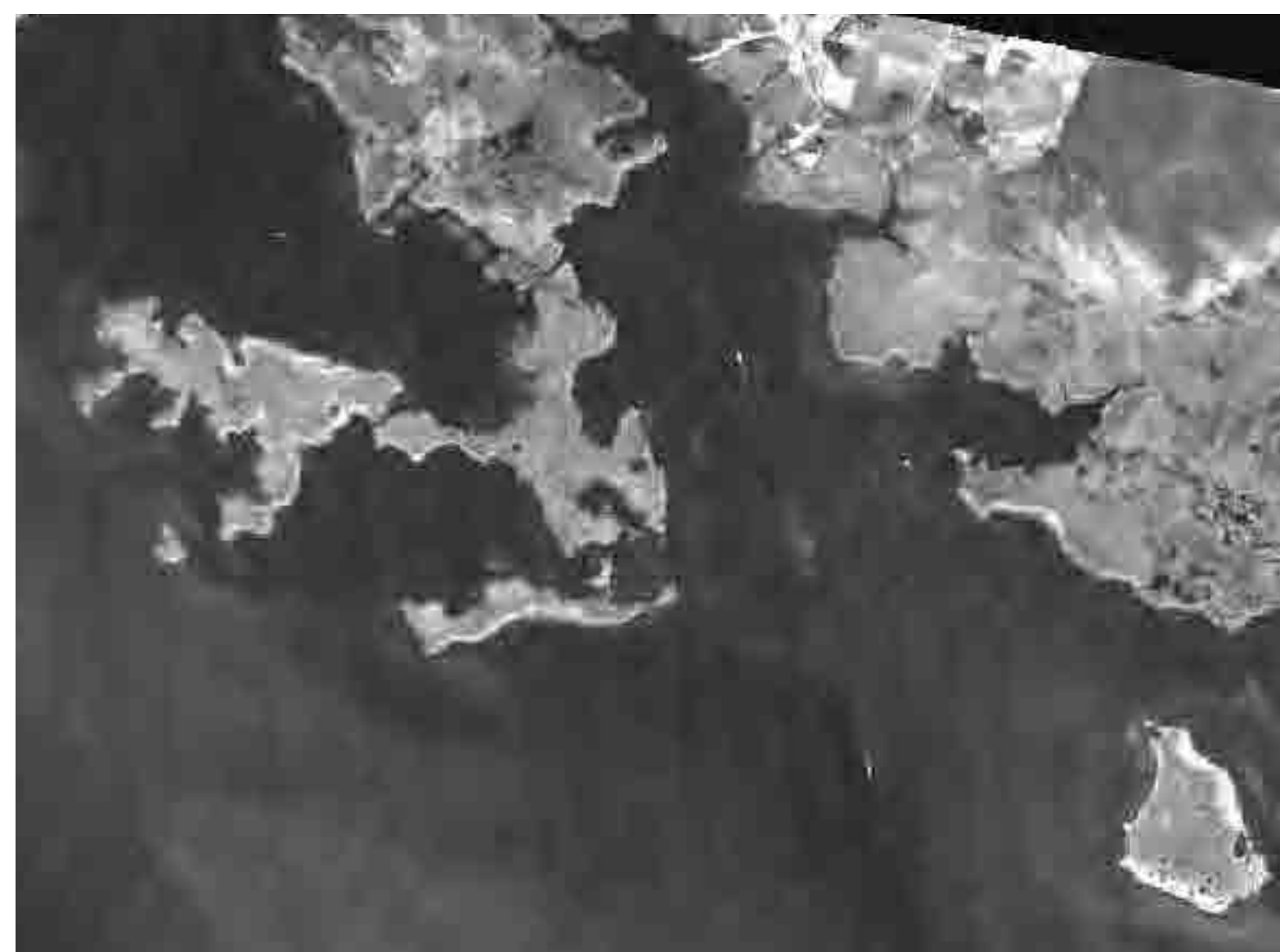


Figure 1: Formosat-2 (top) and Landsat 7 (bottom) images of Pamlico Sound, NC on 8 November 2010. Landsat 7 (30m) has a lower spatial resolution than Formosat-2 (8m) resulting in decreased detail and feature discrimination.

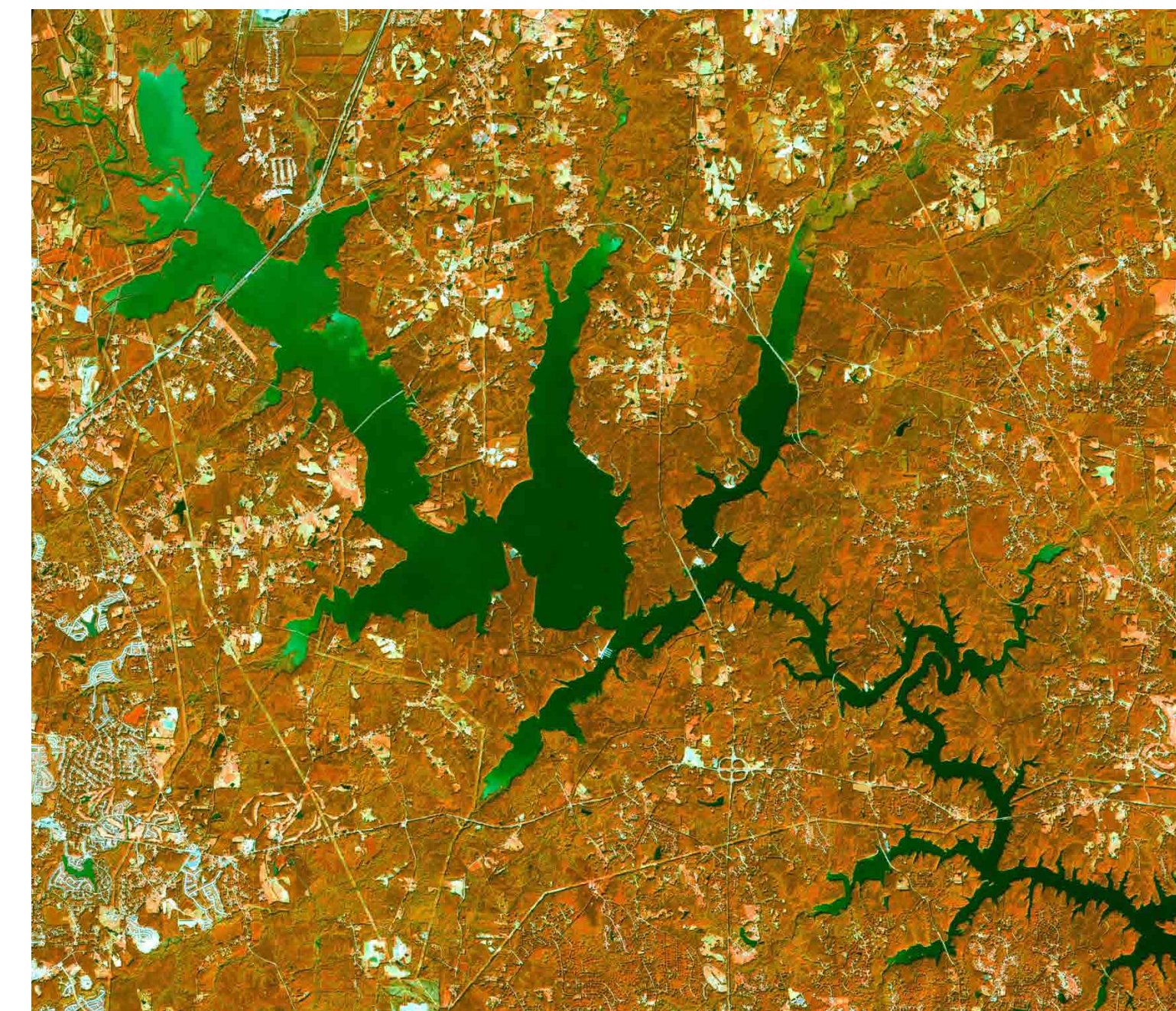


Figure 2: False color Formosat-2 images (Bands 4,2,1) of Falls Lake Reservoir on 12 September 2012 (top left panel) and 22 October 2012 (top right panel) showing suspended sediment concentrations. Note the higher sediment concentration in the zoomed image on 12 September 2012 (bottom left panel) and lower concentration on 22 October 2012 (bottom right panel).

## Falls Lake Reservoir

Falls Lake Reservoir was created in 1981 to provide a source of water for Raleigh, NC and the surrounding communities. Falls Lake Reservoir has a surface area of over 50 km<sup>2</sup> and extends 28 miles upriver from the earthen dam. Falls Lake Reservoir has experienced eutrophic conditions and water quality issues since shortly after it was impounded. The primary impairments are high sediment loads, algal blooms due to nutrient enrichment, and high fecal coliform concentrations. These issues have led to the listing of Falls Lake Reservoir on North Carolina's 303(d) list of impaired waters. In an effort to reduce these issues, new rules on nutrient inputs to Falls Lake Reservoir came into force in 2011. These rules seek to limit algal blooms throughout the lake and to ensure the lake remains a suitable reservoir for drinking water and recreation. The monitoring of water quality in Falls Lake Reservoir is increasingly important as rapid population growth in the area increases both the utilization and pollution of the lake.

## Remote Sensing

Due to its sheer size and configuration, adequately sampling the entirety of Falls Lake Reservoir by boat is quite difficult. One practical solution is to use high spatial resolution satellite imagery (Figure 1). Satellite imagery provides a large-scale synoptic view of an area (Figure 2). These images can be used to map the surface concentration of water quality parameters, such as chlorophyll *a* and suspended sediment.

Formosat-2, operated by the National Space Program Office of Taiwan, was chosen for this study for its imaging flexibility and spatial and spectral characteristics. Formosat-2 has a band configuration that is very similar to the Landsat series of satellites. However, Formosat-2 is a targeting system with a daily revisit capability. This allowed for images to be acquired whenever appropriate (e.g. clear sky) conditions were present. Images were acquired on several clear days when samples were also collected in the reservoir from small boats.

## Field Sampling

A key component of this project was a field sampling program, undertaken in collaboration with the Center for Applied Aquatic Ecology at NC State University. This effort collected a suite of water quality measurements, including chlorophyll *a* and suspended sediment concentrations, from small boats throughout Falls Lake Reservoir (Figure 3). These samples were then processed in the Center for Applied Aquatic Ecology laboratory according to standard water quality methods. By providing laboratory data using proven methodology, the field program provides a reliable database of measurements for algorithm development. Field samples are vital to developing accurate and robust algorithms for the Falls Lake Reservoir; these ground-based algorithms will be used to develop large-scale spatial maps of various water quality parameters for the Falls Lake system.

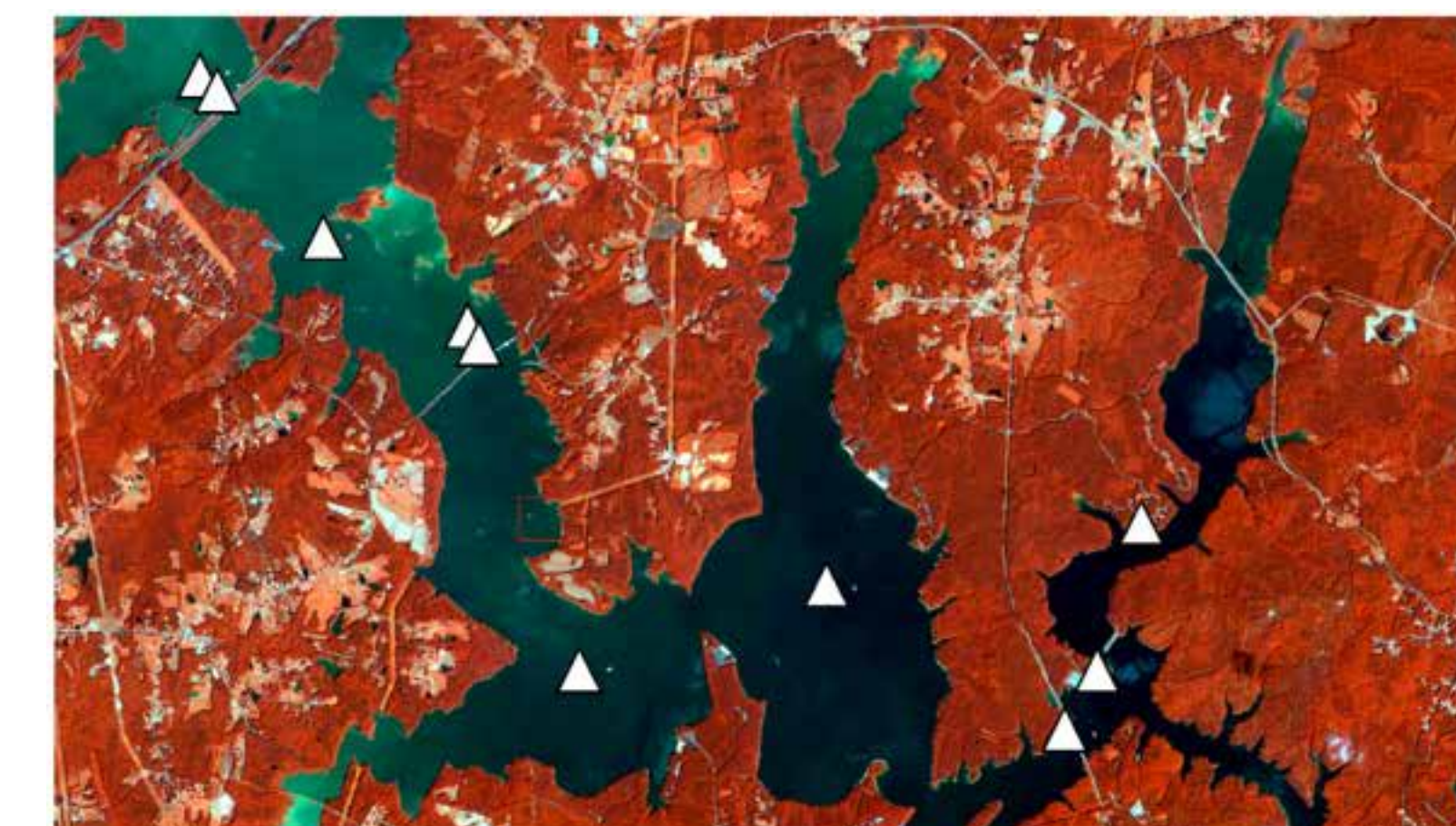


Figure 3: Formosat-2 image of Falls Lake Reservoir showing a subset of field stations for water quality sampled by small boat (triangles).

## Future Work

The work presented here is based on preliminary results from a subset of the data collected. The main goal of our project is to map chlorophyll *a* and suspended sediment concentrations throughout the Falls Lake Reservoir using remotely sensed data. These maps of water quality parameters will hopefully be useful to managers at all levels of government concerned with the Falls Lake system.

The similar spectral characteristics of Formosat-2 and the Landsat series of sensors should allow for a direct transition of these results to the recently launched Landsat 8 OLI (Operational Land Imager) instrument. Landsat 8 data is regularly acquired for the entire United States and is freely available to any user online. While having a lower spatial resolution (30m) than the Formosat-2 satellite (8m), the regular (16 day revisit time) collection of data and free distribution will ultimately allow for the potential creation of a long term record of water quality in the Falls Lake Reservoir.

## Acknowledgements

We would like to thank the National Space Program Office of Taiwan for imagery and the Public Utilities Department for the City of Raleigh for funding the field program.