

High Resolution Satellite Imagery for Mapping Invasive Aquatic Plants

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Figure 1 Invasive aquatic plants cover large areas as seen from a helicopter (left) but do not look very menacing in hand (right).

Introduction

Thousands of reservoirs and lakes are used for water supplies and recreation. The past several decades have seen an invasion of aquatic plants that can rapidly degrade a water body and the ability of people to use the resource. These plants include Hydrilla, Elodea, Eurasian water milfoil, water Hyacinth and many others. The economic impact of invasive aquatic plants on our water bodies is measured in the hundreds of millions of dollars.

Specialty companies have been established who work year-round to limit the impact of these invasive aquatic plants (Figure 1) on our reservoirs and lakes. This case history documents the efforts of a progressive company, Aquatic Nuisance

Plant Control, Inc. (ANPC) of Littleton, North Carolina, who wanted to determine if high-resolution satellite imagery could improve the effectiveness of its remediation service to property owners and agencies. The company acquired new imagery, had enhanced imagery and maps generated, and integrated the results with its new GIS and extensive field database. ANPC found that the focused application of satellite imagery does improve planning, productivity, and presentations.

Managing Invasive Aquatic Plants

ANPC provides remediation programs to federal, state and local agencies, lake associations and homeowners associations along the shoreline of Gaston Reservoir on the Virginia-North

Carolina border (**Figure 2**), to control the extent of invasive aquatic plants. Biological-, physical-, and chemical-remediation programs are applied to areas where invasive plants impede access to the reservoir, clog waterways, and impact water intake facilities. Timely and accurate knowledge of the location and acreage of invasive plants are required to properly and efficiently carry out the remediation programs.

Prior to implementing remote sensing, ANPC employees flew in a helicopter, collecting data and photographs, and noting the extent of aquatic plants on maps and in a notebook. This method was useful for providing a timely overview of vegetation in the reservoir, but the images and photographs were difficult to integrate with company maps and field operations. In addition, statistics were difficult to compile from the helicopter data and ANPC did not have a complete inventory of invasive plants across the reservoir to show potential clients and agencies.

The bulk of the company's database on extent, type, and depth of invasive aquatic plants has been collected during boat surveys to 500 sites located around the reservoir. This point data has been compiled into detailed tables that characterize the vegetation at each site. After inventorying the aquatic plants, ANPC works with the property owners and agencies to physically remove, chemically treat, or introduce biological solutions to mitigate the impact of these invasive plants. These remediation activities are documented in spreadsheets.

Can Remote Sensing Improve the Work Process and Productivity?

This past year ANPC implemented GIS technology to improve display and understanding of its field observations and remediation programs. However, current and complete digital maps of the shoreline, docks, and development are not available. It became apparent that having an up-to-date image of the reservoir in the GIS would improve planning for fieldwork and presentations to property owners and agencies. In addition, appropriate imagery would enable ANPC to map the spatial extent of aquatic plants directly into the GIS and to integrate its GPS-controlled field observations with the new imagery and maps. The imagery would also enable ANPC to establish a database for future use and comparison.

Acquiring the Imagery

ANPC contacted Ellis GeoSpatial through its business partner, Clean Lakes, Inc. of Martinez, California, to evaluate remote sensing alternatives. The requirements included:

- imagery collection in October 2003, coverage of 375 km²,
- derived maps within two weeks of acquisition,
- spatial accuracy equivalent to USGS 1:24,000 topographic maps,
- detection of docks,
- clear delineation of dense mats and growing vegetation, and
- some degree of water penetration.

DigitalGlobe's multispectral QuickBird satellite with its 2.6-meter (8-foot) spatial resolution was chosen as the

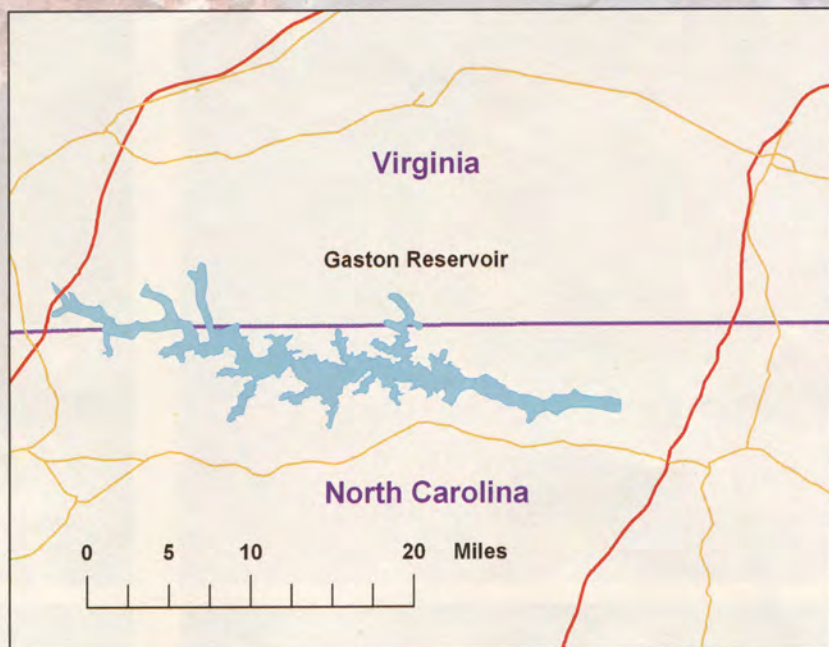


Figure 2 Location map

optimum data capture tool for this application. AeroMap U.S. (a DigitalGlobe Reseller) refined the acquisition parameters and prepared DigitalGlobe for the acquisition of three scenes during September. Approval to start the acquisition on a priority basis was given on September 26 and the first image was acquired on October 2.

The new image was delivered via ftp to Ellis GeoSpatial for processing and mapping. By October 8, ANPC was receiving enhanced color-infrared and natural color plots of the first scene for its GIS. Derived maps of shoreline and floating vegetation began to be delivered to ANPC on schedule. The final image was acquired on October 16.

Enhanced Imagery

The QuickBird imagery was initially processed to provide presentation materials of developed areas and the nearshore. Unfortunately, turbidity in the Gaston Reservoir was higher than normal due to the massive run-off associated with Hurricane Isabel in late September. The turbidity significantly degraded water penetration with band 1 (blue light—the shortest wavelength band). Natural color composites of Quickbird bands 1, 2, 3 as blue, green, red contained minimal information on submerged vegetation. In addition, grayscale images of the individual bands had little value for mapping aquatic vegetation.

Color-infrared composites displayed the onshore vegetation as shades of bright red, while the offshore floating vegetation was displayed as shades of gray. To maximize the visual appearance of the aquatic vegetation on the imagery, a mask was created over the land area, and a color-infrared composite made of only the water in the Gaston Reservoir. This was a highly informative image as the floating vegetation was displayed as shades of pink and was clearly differentiated from the water (**Figure 3**).

Roads, developments, and docks can be seen in the enhanced imagery. GPS-controlled field sites located along the

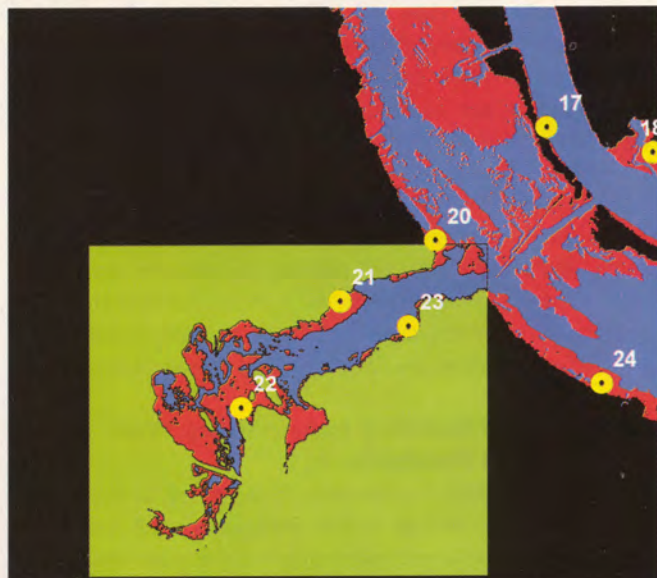


Figure 3 Western portion of Gaston Reservoir, showing color-infrared image (top left), natural color image (top right), aquatic vegetation (pink, bottom left) highlighted with land mask, and subarea with classification map of land (black), water (blue), masses of Hydrilla (red), and field sites (yellow dots) (bottom right)

shoreline were superimposed on the “ortho-ready” Quickbird imagery in the GIS. The fit between the field sites and imagery was good. Large masses of growing and topped out mixed vegetation were immediately recognized on the enhanced imagery.

Maps Derived from Imagery

Generating maps that provided location and acreage of heavily infested invasive vegetation was a primary objective. The maps were developed with the same map projection/datum as the imagery—North Carolina State Plane, NAD-83 (meters)—to enable area (acres and hectares) to be calculated by the GIS.

In areas where the turbidity and aquatic plant conditions were appropriate, classification of the imagery could be based on spectral characteristics of the pixels. In areas where the signal from the vegetation was minimal due to water, atmospheric, or plant conditions, the enhanced imagery was interpreted using

GIS digitizing tools. Field observations made on the same day as the satellite acquisitions confirmed that the masses of vegetation were largely Hydrilla mixed with Elodea and milfoil. Knowledge about the spatial extent of Hydrilla at a few sites visited on the day of image acquisition provided the “ground truth” or training sites for interpreting the plants on the imagery.

The spectral classification evaluated both supervised and unsupervised methods. It was found that unsupervised classification with 15 classes and three iterations provided good results. The 15 classes were grouped into three—land, water, and aquatic vegetation. These three classes were converted to vector polygons (shapefiles). Statistics were derived from these three classes, including acreage of Hydrilla (**Figure 4**).

The heads-up interpretation of the enhanced imagery used the color infrared images (masked and unmasked). The 500

field sites were displayed in the GIS and the attributes posted on the screen during interpretation. As the polygons were being mapped, they were assigned to specific field sites. This correlation has significant advantages as acreage of Hydrilla and other vegetation was immediately assigned to each field site. The new attribute table being developed with heads-up interpretation was joined in the GIS to the extensive attributes documented in the field for each site.

Products for Presentations, Reports, and Marketing

Color plots and maps are easily generated from the Quickbird images and derived maps using GIS. Enlargements to 1:10,000 could be plotted, enabling ANPC to show property owners and agencies their areas of interest. The color polygons of vegetation were made transparent and superimposed over the imagery to facilitate communication and understanding of the new interpretation and acreage.

The GIS attribute tables derived from the imagery were exported to Microsoft Excel for easier summation of acreage and integration into reports. For each of the 500 field sites, acreage of dense mats of growing vegetation as of October 2003 is now known.



Figure 4 Masses of Hydrilla interpreted from imagery (polygons along the shoreline) with acreage and location of each plant mass associated with field site

Priorities can now be more efficiently established using the October 2003 vegetation maps. Marketing of remediation services can first target those areas with extensive growth and a large number of impacted property owners. Impacted docks are now documented with the imagery and maps, providing a convincing story to property owners of the need to manage the invasive vegetation (**Figure 5**). Agencies responsible for the watershed and reservoir may find the imagery and maps of interest, opening opportunities for partnering and cost sharing. Areas that were remediated in the past by ANPC can be clearly seen as having little or no invasive vegetation. These successful examples are proving to be very effective for presentations and reports.

Managing Remediation

The enhanced imagery and derived maps enable ANPC to more accurately model the level of effort needed to clean up an impacted site. The spatial extent and shape of the invasive vegetation patches improves the company's knowledge base for making decisions about the optimum remediation method to employ. GPS receivers are being evaluated that would enable the remote sensing-based maps to be downloaded and deployed on the company's boats to directly support fieldwork.

The methods of remediation and level of effort are being documented in the GIS for the 500 field sites. This growing database will enable ANPC to easily review and summarize its efforts for different parts of the reservoir.

Issues and Future Work

High turbidity limited water penetration by the shorter wavelength bands (visible blue and green light) at Lake Gaston during early October 2003. Most of the invasive aquatic plant biomass is submerged, so having the ability to detect and map the outlines of submerged plants is important for ANPC's remote sensing business model.

Differentiation of invasive species using Quickbird imagery was not done with this project. The differences may be too subtle for Quickbird's limited spectral depth. For high value assets, airborne hyperspectral imagery may be required to identify the different aquatic plants. Correlation of the spatial extent of invasive plants with bathymetry was also not done, but it seems reasonable that with further experience such correlation would improve the accuracy of derived maps.

ANPC has ordered new imagery acquisition in late 2004 to document changes of Hydrilla acreage as well as other invasive plants across the large reservoir. Areas under remediation

ACREAGE OF HYDRILLA ASSIGNED TO EACH FIELD SITE

Id	Acres	Hectares	X	Y
157	1.2	0.5	698075.073	309018.179
158	3.4	1.4	697968.431	308720.281
159	3.2	1.3	698021.552	308455.62
160	5.7	2.3	698013.334	308235.438
161	9.1	3.7	697984.648	307945.884
162	9.5	3.8	698233.978	307756.52

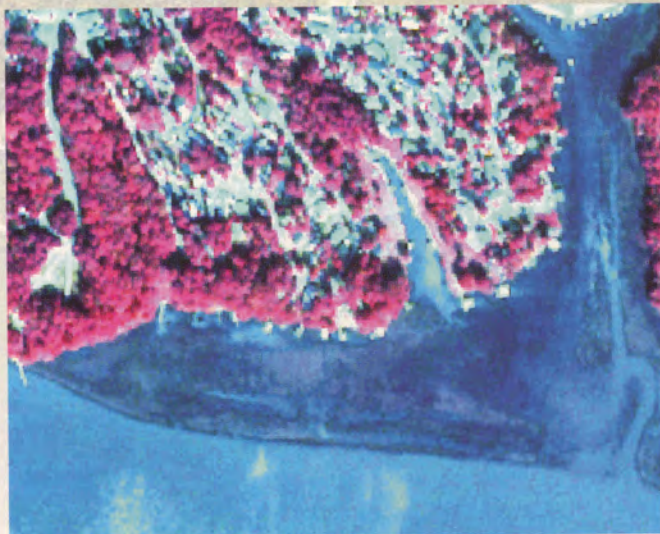


Figure 5 Close-up of developed area with docks built into water shown as white and masses of Hydrilla (red in classification map)

should show significant decrease in invasive vegetation, while those areas that are being neglected could show significant increase in invasive vegetation. Using imagery to document the difference in invasive plant acreage over time will reveal the effectiveness of treatments, show how different lake environments affect treatment success, and provide excellent marketing material. 🌐

About the Authors

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