

Program for Monitoring Water Quality in the Coastal Zone of England and Wales

Borstad Associates Ltd., 1998

This paper describes a monitoring program recently undertaken by the NRA in which four surveys of the coastline are made annually using a combination of surface vessels and aerial remote sensing.

Under Section 84(2) of the British Water Resources Act 1991, the National Rivers Authority (NRA) is tasked with monitoring water quality and pollution in all of the inland and coastal waters of England and Wales, an area of some 13,000 sq km. Faced with the requirement of monitoring water quality around the entire coast of England and Wales several times each year, the National Rivers Authority came to the conclusion that in addition to automated continuous sampling, some sort of remote sensing would be required. Because there was lack of water quality data and information on the local pattern of surface circulation within the first few kilometers off the beach in the UK, it was hoped that the monitoring program could provide this in the form of detailed imagery.

Satellite imagery was the first type of remote sensing considered, because of the very large area to be covered. However, the current lack of water colour sensors and a consideration of the climate of the United Kingdom, especially in winter, quickly ruled this out. Aerial methods were next considered, especially the water colour techniques developed in Canada by Gower and Borstad (1981; Parsons et al, 1981; Borstad et al., 1985; Gower and Borstad, 1990) and the current generation of imaging spectrometers, the Compact Airborne Spectrographic Imager (CASI) which is manufactured by Itres Instruments Inc. of Calgary (Borstad and Hill, 1989). After a review of the airborne systems available and a pilot project in which a Daedalus scanner and a CASI were flown in 1991 (Boxall et al., 1992), a full scale project was begun in November 1992 using 4 surface vessels and a CASI mounted in a Cessna 402 twin engine aircraft. Borstad Associates Ltd. assisted the NRA to set up carry out the operation during the first three years of the project, transferring knowledge and software to British nationals. In 1996, the NRA [by that time the Environment Agency] moved to use British contractors for the work. The program continues in 1998.

SHIP-BASED SAMPLING

Four small ships were specially equipped for the task. They are based at intervals around the country and traverse the coast to make vertical and horizontal sampling using continuous profiling of dissolved oxygen, salinity, temperature and pH. Depth, transmission and fluorescence are also recorded on vertical profiles which are made at intervals of about 5 kilometers, and water samples are taken at these locations for calibration of continuous fluorescence measurements and the aircraft imagery.

AIRBORNE MONITORING

In order to supplement and extend sampling from slow moving surface ships, an airborne remote sensing program was implemented which involved a visual range imaging spectrometer, as well as thermal and Super VHS video. The survey aircraft is a chartered twin engine Cessna 402 with a crew of three, based in Coventry in the center of the country (Figure 1). Flying at

10,000' altitude and from 150 to 250 kph it could cover the entire coast in about 40 hours over 5 to 8 flight days under ideal weather conditions. Navigation is controlled and recorded via a computerized flight manager system based on a GPS system. Real-time monitoring of the infra-red, video and imaging spectrometer systems permits the operator to maintain data quality checks and to watch for water colour or temperature phenomena which may be of interest. Where potential pollution events are encountered (oil slicks from a vessel or harbour, visible plumes from coastal industry), these areas are flown a second or third time to optimize coverage.



Figure 1. Summary of the 188 survey flight lines, the location of the Coventry base of flight operations, and the Bridgwater NRA offices where data analysis occurs.

A Compact Airborne Spectrographic Imager (CASI) is used to provide up to 15 spectral bands chosen to provide several indices of water quality on 188 flight transects of 4.4 km width around the coasts of England and Wales (Figure 1). Instrument integration times and altitudes are chosen to obtain approximately 10 m square pixels. After each day's flying, the data tapes are couriered from the aircraft operating base in Coventry to Bridgwater where data processing occurs. Raw CASI tapes are immediately backed up and catalogued, then the image data are radiometrically calibrated and geometrically corrected for aircraft roll and pitch and temporarily stored on large hard disk. Thermal and video data tapes are also backed up and particular sections showing thermal variability in the region of industrial plants of river estuaries are copied and sent to area managers.

Within about 48 hours of data acquisition, radiometrically and geometrically corrected CASI image data becomes available for comparison with ship data and for distribution to local water quality managers, who are interested in spatial variability of river plumes, effluent discharges and tidal fronts as well as the mean and variation of chlorophyll and sediment concentration. Processing presently includes production of Fluorescence Line Height (FLH) images calculated according to the Gower and Borstad (1990) algorithms, and simple true-colour imagery enhanced to show patterns of water boundaries. The FLH calculation has the advantage that atmospheric corrections (which are significant over a wide angle field of view) are not required.

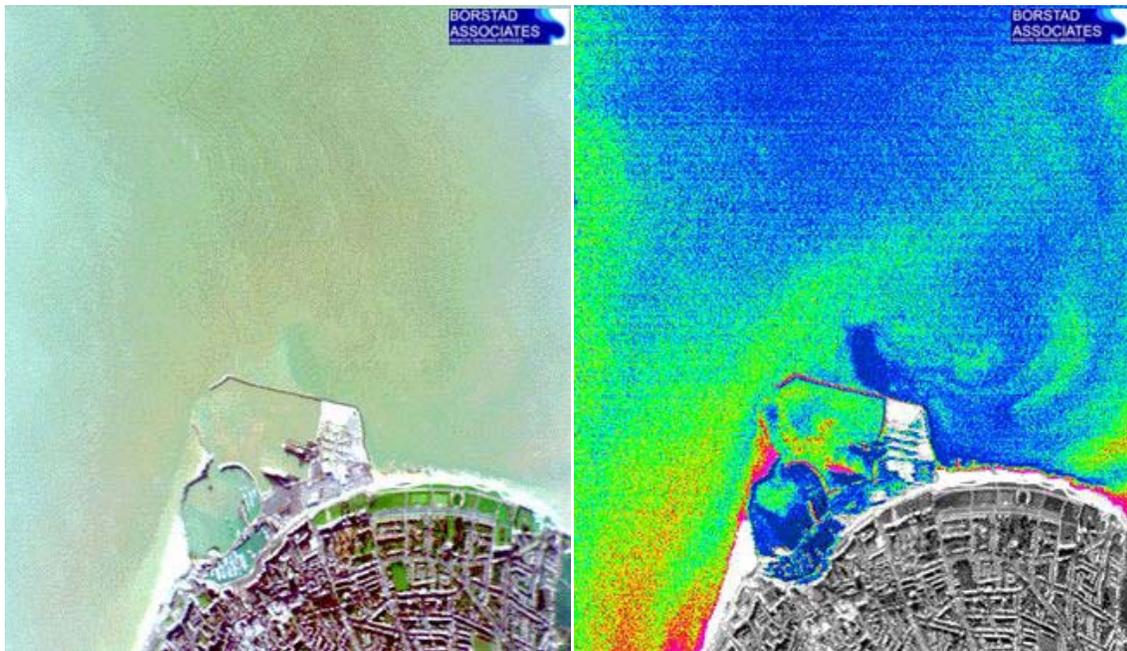


Figure 2. A section of the coast at Ramsgate imaged on November 16, 1992. Left: a near true colour composite of 3 bands. Right: a calculated Fluorescence Line Height image.

DEVELOPMENT OF OPERATIONAL PROCEDURES

As of 1992, the ship and aircraft methodologies and instrumentation had been well worked out in a research mode, but an operational program places rather different demands on resources than do research programs. During the first year of operation, procedures and protocols were worked out to permit effective communication between the managers, ship based survey officers and the aerial survey crew, and rapid turn around of the data. Since there was a requirement for nearly simultaneous ship and aircraft observations, and the ships can move only relatively slowly, the ships were held back until the aircraft was able to fly their survey area. The aircraft was in turn held back until relatively good weather was available. Where possible, the survey crew flew under clear skies at 10,000' altitude. However, during the English winter this is not always possible. Many flights were made under completely overcast skies, but with CASI integration times lengthened to increase signal levels. High overcast is an acceptable operating condition for qualitative mapping water colour boundaries and temperature features, but more than about 2 eighths patchy cumulus cloud either above or below the operating altitude is not. The combination of cloud itself and shadow doubles the masking effect of the cloud, and even with continuous data from an illumination sensor mounted on top of the aircraft it will not be possible to correct for the cloud shadowing.

In spite of very heavy air traffic, especially in the vicinity of London and Manchester, we experienced very little operational difficulties with British civilian air traffic control. However, military air traffic controllers sometimes delayed or directed us around active military zones. Some parts of the coastline were not covered for this reason. Weather was the most significant operational constraint to the aerial surveys in winter months. In these months, the east coast lines were acquired first and many repeat attempts were required in order to obtain reasonable data for western lines. Not all western lines were acquired during winter surveys. This was not unexpected, since the English weather patterns move from the west to the east and the west coast receives fully 2 to 3 times as much rain as eastern shore in these months. During summer, weather did not pose a significant constraint.

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