REMOTE SENSING IN SEDIMENT RESEARCH[1/]

by

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INTRODUCTION

The deposition of sediment in channels, reservoirs, lakes and estuaries is a major problem (Robinson, 1971). Sediments restrict water movement, occupy space, and restrict the usefulness of the water body for flood control, power production, water supply, and navigation. Sediments frequently adversely affect the chemical quality of the water and indirectly the aquatic organisms and the recreational potential of the water body. The location and amount of sediment deposition is of major concern, yet there are no "quick and easy" techniques for estimating the amount of suspended sediment in a water body which is available for future deposition.

Present techniques for estimating the concentration of suspended sediments in reservoirs involve the collection of discrete samples for laboratory analysis or the in situ measurement of turbidity at discrete locations in the water body. Most of the in situ techniques have been seriously questioned (National Oceanographic Instrument Center, 1974). These techniques are accurate for the discrete site measured but are too expensive to give the synoptic view of the water body that is needed for an accurate assessment of the patterns of suspended sediment distribution in a water body.

A new technique for assessing the concentration of suspended sediment in large bodies of water is to use remotely sensed data in the form of aerial photography or aerial imagery. Since 1970, there has been a large increase in the production and availability of aerial photographs and images. LANDSAT 1 and LANDSAT 2 satellites are providing repeated imagery that are available from several governmental agencies. There are many studies on the use of remotely sensed data to evaluate environmental problems. This paper reviews some of the recent studies on the use of remotely sensed data to evaluate the suspended sediment concentration in water bodies.

Looking at a water body, one preceives different colors depending on the type and the amount of material either dissolved or suspended in the water. The peak of the color spectrum in natural water shifts according to the material dissolved or suspended in it. The red portion of the spectrum is roughly proportional to sediment concentration, if all other parameters are held constant (McCluney, 1975).

Studies were undertaken at the Sedimentation Laboratory, Oxford, Mississippi to evaluate the spectral response of natural water bodies with different concentrations of suspended sediment to determine if a

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quantitative relationship existed between concentration of surface suspended sediment and spectral reflectance and to determine what wave length could best be used to determine surface suspended sediment (Ritchie et al., 1974; Ritchie et al., 1975; Schiebe and Ritchie, 1975). These studies were conducted from a small boat using a portable spectroradiometer to measure the reflected solar radiation from the surface water of four, large, flood control reservoirs (Arkabutla, Sardis, Enid, and Grenada) and two small agricultural reservoirs in north Mississippi. Measurements were made from July 1973 to July 1975, during which time a wide range of suspended sediment concentrations (28 to 340 mg/l) was encountered. Reflected solar radiation was measured from 400 to 750 nm at 25-nm intervals and from 750 to 1550 nm at 50-nm intervals. Measurements were made about 50 cm above the surface of the water and within 2 hr of solar noon. Statistical analyses showed a simple linear relationship between surface suspended sediment and reflected solar radiation.

The best linear relationship between surface suspended sediment and reflected solar radiation was between 700 and 800 nm (Figure 1). The r value of about 0.90 indicated that the observed linear relationship accounted for about 81% of the variation in the concentration of suspended sediment in the surface water. This highly significant relationship indicated that surface suspended sediments in the four north Mississippi reservoirs could be reliably estimated from measurements of reflected solar radiation.

Further studies have shown that the sun angle contributes significantly to the relationship. Using the Fresnel formula, List (1971) showed that the reflectivity of water is less than 2.5%, when the solar zenith angle is less than 40°, but the reflectivity increases rapidly above 40° to 100% at near 90°. By considering the effect of sun angle in the relationship between surface suspended sediment and reflected solar radiation an additional 5 to 10% of the variability in the data could be explained. Other data (Kal'ko, 1972; Blanchard and Leamer, 1973) collected with portable spectroradiometer showed essentially the same results.

If there is a quantifiable relationship between surface suspended sediment and reflected solar radiation measured near the water surface, will this relationship hold for data collected from airplanes or satellites?

Several studies have shown that remotely sensed data can be used to determine sediment flow patterns. Harris (1972) found that aerial color infrared photography could be used to detect suspended sediment patterns in the Mississippi River. Carlson and McCulloch (1974) concluded that light aircraft are effective observation platforms for synoptic views of suspended sediment patterns useful as indicators of circulation of coastal and estuarine surface water in a study of San Francisco Bay. They observed and photographed turbid water plumes to estimate flow rates. Pluhowski (1974), who used aerial photography to detect and follow sediment plumes entering Lake Ontario, concluded that high altitude photography was an effective tool for studying the dynamics of turbidity plume of large- and medium-sized rivers entering Lake Ontario.

LANDSAT 1 satellite images have been used to study ocean currents by observing color differences due to suspended materials in the water (Maul and Gordon, 1975). Welby (1975) used LANDSAT 1 images to study the Cape Fear River turbidity plume off the North Carolina coast to determine water movement patterns. Studies of Delaware Bay (Klemas, Borchardt and Treasure, 1973) showed LANDSAT 1 images were a suitable platform for observing suspended sediment patterns in water masses synoptically over large areas.

These and other studies have shown that aerial and satellite imagery can be used to synoptically view the flow patterns of suspended sediment. This type of information can be interpreted to determine many of the dynamic properties of large water bodies. This type of information would also be useful in determining where sediment deposition is likely. However, such information would not give quantifiable information on suspended sediment concentration.

Studies at the University of Wisconsin (Scherz, 1971) showed that aerial color infrared photographs could be used to monitor the quantity of suspended waste effluent discharged from paper mills. These studies suggested the possibility of estimating quantities of other suspended materials in water masses. A study of Ross Barnet Reservoir, using aerial photography (Wertz et al., 1974), showed that estimates of total suspended sediment were possible, although the estimates were preliminary.

In a study of 14 small agricultural impoundments in Oklahoma, Pionke and Blanchard (1975), using aerial multiscanner data, found that they could estimate surface suspended sediment. They concluded that the relationship between suspended sediment and reflectance developed specifically for a single area could be expanded to larger areas, if the sediment characteristics controlling reflectance were similar. They also concluded that textural differences among sediment contributing soils located on the watershed did not significantly affect this relationship.

While there have been few studies using low-level, aerial imagery to estimate suspended sediment, there has been a great interest in the use of LANDSAT data to estimate suspended sediment (Yarger et al., 1972; Klemas et al., 1974; Williamson, 1974; Weishlatt et al., 1973; Johnson, 1975; Kritikos et al., 1974). All these studies have shown, with varying degrees of success, that surface suspended sediment could be estimated using LANDSAT imagery, after proper calibration of the system. Best results were obtained when imagery between 600 and 800 nm (Band 6 and 7) was used.

All these studies have shown that with proper care, calibration and selection of the correct wavelength, we can make reliable estimates of the suspended sediment in surface water. Further studies are needed to determine the regional extent of reliable estimates for a given calibration of a system. Also, studies are needed, using photographs taken from airplanes, to determine what film stock and filter combinations give the best results.

Our studies have shown that concentration of suspended sediments in surface waters can be estimated from remotely sensed data to give the needed synoptic view of the water body. Recent research at the Sedimentation Laboratory (McHenry et al., 1975) have shown that the total suspended sediment load can be accurately estimated from the concentration of suspended sediments in surface waters.

If the relationship between the surface suspended sediments and the total suspended sediment loads proves useful in other reservoir systems, then estimating the total load of suspended sediments from remotely sensed data should be possible with reasonable accuracy. This also would provide a synoptic view of the total suspended sediment load in a water body. Since most of the coarse material (sand, heavier silts) will be deposited in the delta, these remotely sensed data will represent the fine particles, which are most important in the biological and chemical dynamics of the water body. Remotely sensed data of the surface suspended sediment will give us information on the total amount of sediment in a reservoir and should make it easier to understand the chemical and biological cycle in water bodies, as they are affected by suspended sediments.

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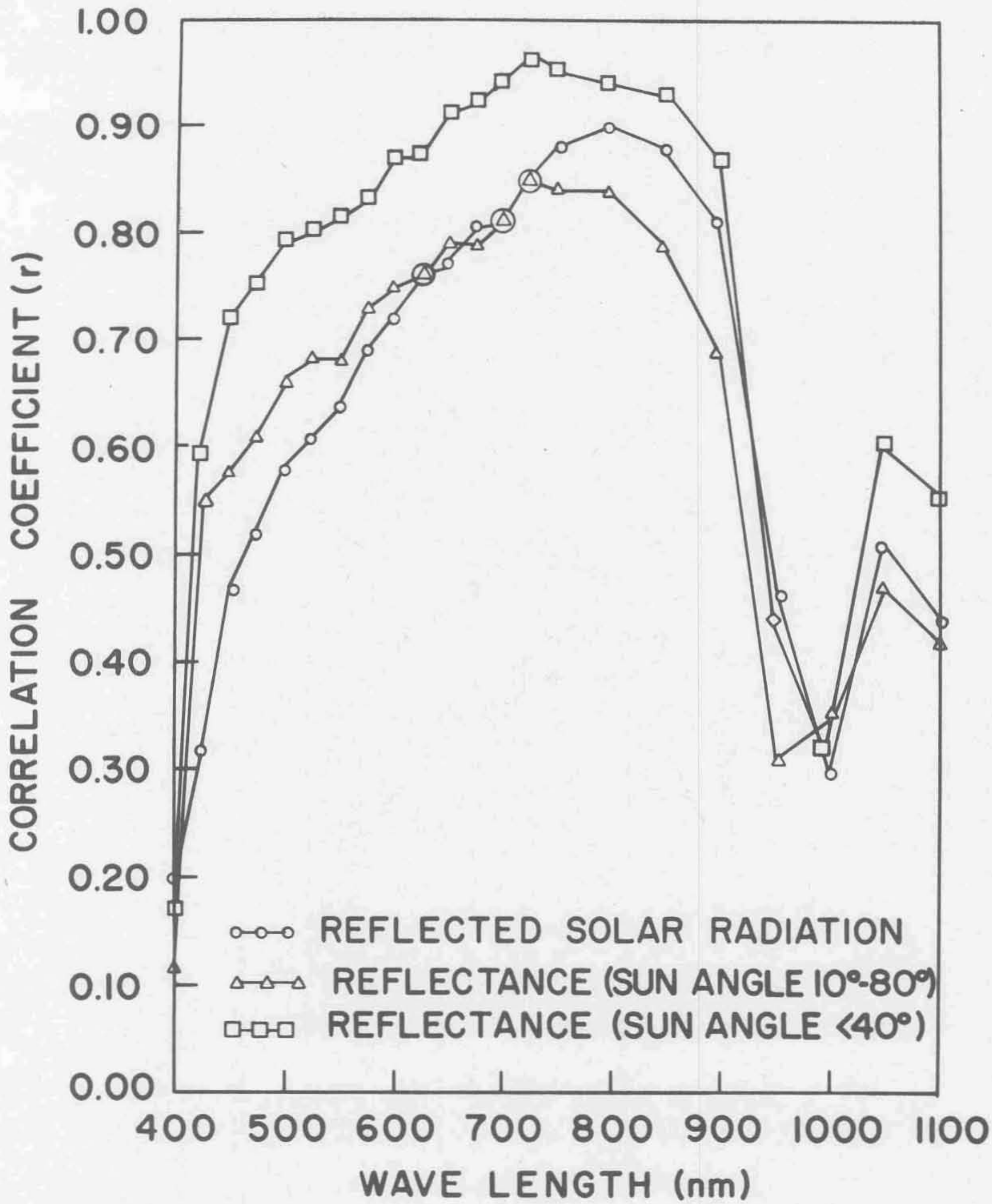

Figure 1. A plot of the correlation coefficient of the relationship between surface suspended sediment and the reflected solar radiation by wave length.