

CHAPTER 144

Interpretation of Shoreline Position from Aerial Photographs

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Abstract

A review of some of the potential sources of error associated with the use of aerial photographs to map shoreline change is presented. The influence of both tides and waves in the estimation of the position of the wet sand line on the subaerial beach is included. The use of the relatively new digital photogrammetry as applied to shoreline mapping is discussed and suggested as having the potential for being a superior method for this application.

Introduction

Aerial photographs have been used extensively to determine shoreline positions and erosion rates. Several different features on the beach and backshore have been used as reference lines, including the bluff or dune line, the seaward vegetation line, and the water line. The latter is usually defined as the wetted line where there is a marked contrast between the wet and dry sand. This latter feature is sometimes referred to as the "wet sand line", or the "high water line". Various investigators have described formalized methods for using this line to monitor shoreline change, including Stafford (1971), Dolan et al. (1978), and Leatherman (1983). Each of these methods share basically similar techniques which include the identification of the wet sand line, the digitizing of the line, and the measurement of change, either relative to an earlier shoreline position, or relative to a reference line offshore.

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Once the shoreline position has been determined, the rate of erosion (or accretion) can be computed by determining the change between two or more shorelines over a known period of time.

It is well recognized that the use of aerial photographs in combination with the wet sand line has inherent inaccuracies. When dealing with erosion rate these errors can be reduced by simply using a relatively long period between dates of photography. As an example, consider the case where the error in identification of shoreline position for each date is +/- 50 ft. If the time between photo sets is 10 years, then the maximum potential error is 10 ft/yr (100 ft divided by 10 years). However, if the time between these photos is 50 years, this error is reduced to 2 ft/yr. Thus, where possible, one should attempt to maximize the time between photo dates. In North Carolina, where only two dates are used to determine shoreline erosion rates, a minimum of forty years between dates is usually employed.

The above discussion also makes it clear why one must be extremely careful to minimize errors when using aerial photographs and the wet sand line to compute short term erosion rates (i.e., less than 10 years).

In partial recognition of the potential errors associated with this technique to measure shoreline change rates, some investigators use multiple dates of photography and either a linear regression, or some other statistical technique to model the rate of change. The advantage of using a series of dates is that the errors associated with any one date is reduced. A discussion of the pros and cons of these different statistical tools for computing shoreline change rates is beyond the scope of this paper. For the analysis which follows we will assume that this rate is computed by simply looking at the difference beyond two dates. This is sometimes referred to as the "end point method".

Sources of Error

The process of measuring shoreline change from aerial photographs has several potential sources of error:

1. distortions in the photographs,
2. the georeferencing of "permanent features",
3. human error in measuring and digitizing,
4. corrections for tides, and
5. corrections for wave setup and runup.

Crowell, et al. (1991) present a thorough review of mapping accuracy as applied to shoreline change. Of particular interest in this review is the discussion of the errors associated with the aerial photos (including distortion and corrections for camera angle) and the procedures used to tie the photos to the ground.

In order to fix the aerial photograph in space it is necessary to georeference it to known features. The degree to which this is done with accuracy will of course have a significant impact on the overall accuracy of the analysis. For example, if USGS topographic maps are used to georeference the photos, one is limited to the accuracy of these maps; approximately +/- 40 ft. This error can be reduced if ground referenced points are surveyed at the site using traditional means, or GPS. One can reasonably reduce this error to +/- 1-2 ft (or less) with careful survey techniques.

The actual procedure by which the photos are digitized will also effect the probable error. For many investigations of shoreline change the photos are enlarged and the shoreline digitized directly. While this technique is relatively fast and inexpensive, it does not take advantage of the higher accuracy available from using photogrammetric techniques and analytical stereoplotters. While the former is more time consuming, it nonetheless will yield far better measurements of shoreline position as determined from the wet sand line. We estimate that a careful operator on an analytical stereoplotter can consistently determine shoreline position to within +/- 5 ft with surveyed ground control for the georeferencing. This is in contrast to an estimated error of +/- 50 ft using the more conventional techniques of digitizing directly from the photographs and USGS topographic maps for control. These error estimates represent a combination of the error involved in both georeferencing, identifying the wet dry line, and human error in digitizing this line.

Thus, for the determination of the rate of shoreline change for a period of 50 years between photographs, the larger of these two potential errors (+/- 50 ft) could produce an error in rate of up to 2 ft/yr. Alternatively, the lesser error would be 0.2 ft/yr. Depending upon the particular application, this may justify the additional effort required by the use of the analytical stereoplotter for the measurements.

In addition to the errors associated with the photographs, (georeferencing, and digitizing), one must also consider the dynamics of the wet sand line itself. Both the tide and the waves will influence this line. Consider first the influence of the tide. Most shoreline

mapping applications that the authors are aware of have not attempted to make corrections for tide. Generally the time of the photographs is dictated by the logistics of the aircraft and the lighting requirements. At best, some mapping programs attempt to collect the photographs on consistent points on the tide curve, e.g., spring low, mean, spring high, etc. For the historical photographs one generally accepts what is available, and in many cases the time of the photograph relative to the tide may not be known or obtainable.

The magnitude of the error introduced by not correcting for tide can be easily estimated. This error will be a function of the tidal range, the slope of the beach, and the time of the aerial photograph. As an example, consider a beach where the tidal range is 3 ft, the beach slope is 1:20, and the two photographs are taken at high and low tide respectively. The maximum probable error introduced by not correcting for the tide is 60 ft. This error means that if there had been no real change in shoreline position, the analysis would nonetheless have yielded a 60 ft change due to the tidal difference. If the time between the two photographs is 50 years, then this translates into an error of 1.2 ft/yr.

A similar argument can be made for the effect of wave runup and setup on the interpretation of shoreline change. In this case the wave conditions at the time of the aerial photograph will influence the position of the wet sand line. The slope of the beach, wave height, and wave period will all contribute to the relative shoreline position. For example, if one uses a simple model for wave runup, and a beach slope of 1:20, then a relatively small change in wave height and period will produce horizontal differences in shoreline position of approximately 80 ft. In terms of the previously assumed time between photographs of 50 years, this yields a difference in rate of change of 1.6 ft/yr. Again, as with the example for tide, the failure to correct for wave runup will introduce an apparent change in the position of the wet sand line even though there has not been any actual erosion or accretion of the beach.

Summary of Potential Errors

It is clear from the previous discussion that the potential errors in computing the rate of shoreline change from aerial photographs can be significant. Even if one is willing to use ground surveys to control the photographs and photogrammetric techniques to map the position of the wet sand line, there are still the problems associated with waves and tide. The correction for the tide would require some knowledge of the beach slope, and thus some minimum ground measurements at the time of the photographs.

Correction for waves would require this beach profile as well as an estimate of the wave conditions at the time of the photographs. The only alternative is to recognize that the potential for these errors exists, and therefore the interpretation of the data must include reasonable estimates of these errors. The actual error will of course depend upon the techniques employed and the specific conditions at the site.

Digital Photogrammetry

Many of the problems described above can be eliminated by the use of digital photogrammetric techniques to map shoreline change. Digital photogrammetry is a process by which a three dimensional representation of the shoreline is mapped from a pair of stereo aerial photographs. This can be accomplished with an analytical stereoplotter, or alternatively, with the newer techniques using computer controlled scanners to digitize the aerial photographs. There are a number of commercial vendors for these digital systems. We are currently working with a series of products developed by Intergraph Corporation.

As with the more conventional techniques, it is still necessary to have accurate ground control in order to have an accurate model of the beach. However, in place of mapping the wet sand line, it is possible to define the shoreline as a particular datum, such as the mean high water line, or mean lower low water, etc. Since there is a 3-D model of the subaerial beach for each date of photography, there no longer is a need to correct for either tide or waves. In addition, since digital photogrammetry can achieve relatively high resolution (on the order of +/- 0.5 ft), the computation of the rate of shoreline change, even for short time periods, can be reasonably determined.

We are currently working with the Intergraph system to determine both its utility and economics when used to measure shoreline change. The results of this investigation will be presented in future publications.

Conclusions

Aerial photographs will continue to be an important tool in the determination of shoreline change, and in the prediction of future shoreline positions. There are a number of sources of potential error in the current techniques. However, as long as these errors are understood, these techniques can continue to be employed. It is anticipated that the use of digital photogrammetry will, in time, replace today's technology, and thereby

provide a far superior mechanism for determining shoreline change from aerial photographs.

Acknowledgments

This research is currently being supported by grants from the North Carolina Division of Emergency Management, the North Carolina Department of Transportation, the North Carolina Division of Coastal Management, and the Kenan Institute for Engineering, Science, and Technology. The assistance of Intergraph Corporation is also greatly appreciated in this research. Mr. Johnny Martin provided significant help in this research.

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