NAUTICAL CHARTING APPLICATIONS OF PHOTOGRAMMETRY AND REMOTE SENSING

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ABSTRACT:

This paper describes a practical application of photogrammetry and remote sensing in the context of nautical chart compilation and revision.

Photogrammetry represents a detailed, accurate and cost effective source of data in the nearshore zone particularly in U.K. home waters.

Satellite imagery is also used to resolve problems arising from the receipt of conflicting data and in many parts of the world forms the basis for coastline or positioning of dangers to navigation.

The advantages and limitations of various types of imagery are considered from a hydrographic point of view. A number of case studies are presented in order to illustrate a variety of charting applications.

KEYWORDS: Photogrammetry, Space Imagery, Nautical Charting, Navigation.

1. INTRODUCTION

The purpose of this paper is to describe a practical use of photogrammetry and remote sensing in a production environment, namely as a source of data for nautical chart compilation and revision.

The advantages and limitations of aerial photography and various types of satellite imagery are considered from a hydrographic point of view and a number of case studies presented.

2. BACKGROUND

The Hydrographer is concerned with the collection, compilation and dissemination of certain categories of data relating to the marine environment, mainly hydrographic, geophysical and meteorological. Some of these data are measured in the field by his own personnel, but the majority are collected from other sources outside his direct control. The data are collected on behalf of the Royal Navy for a variety of defence needs, and also in support of navigation in general.

In order to meet the needs of the Royal Navy and international shipping, Hydrographer publishes a series of 3350 navigational charts affording worldwide cover together with associated publications such as Sailing Directions, Lists of Lights and Radio Aids, and Tidal Prediction Tables. The series of charts is subject to maintenance by Admiralty Notices to Mariners and regular New Editions. It is highly regarded by the mariners of the world, and is considered pre-eminent among other world series. However, the Admiralty chart will only retain its place if it carries up-to-date information which is well presented in a convenient form.

Hydrographer's basic aim is to maintain the Admiralty chart series in an accurate, adequate and up-to-date condition. However, this is an immense task which cannot be fully met by the resources currently available to hydrographic surveyors or likely to be available in the future. Only 20% of the UK continental shelf has been surveyed to modern standards. Comparative figures for the rest of the world are not available, but in many cases the situation is even worse. It is still true to say that some of the world's largest vessels pass through waters which were last surveyed more than 100 years ago or, indeed, which have never been surveyed. It is for this basic reason that hydrographic offices have become interested in the application of photogrammetry and remote sensing to nautical charting.

3. USES OF PHOTOGRAMMETRY

The use of photogrammetry within the Hydrographic Office is well established and aerial photography has long been recognised as a valuable source of data in the nearshore zone. Information is provided for the benefit of both the hydrographic surveyor and nautical chart compiler.

Photogrammetry is capable of providing a variety of hydrographic data in a cost effective fashion. The Hydrographic Office makes use of large scale colour photography acquired at a low tidal state. This photography is processed on traditional analogue stereo plotters such as the Wild A8 and B8 and also using an Intergraph Inter Map Analytic system.

Where mapping is deficient, topographic information can be derived emphasizing items of significance to the mariner. Coastline can be plotted as an accurate contour at Mean High Water Springs together with a detailed depiction of the intertidal zone, including drying heights. Where the water is sufficiently clear, submerged features such as rock and coral pinnacles can be detected. Nearshore depths can be accurately measured applying a correction for the effect of the refraction of light through seawater.

While photogrammetry does not in any way replace the hydrographic surveyor it has most to contribute in those areas which are dangerous, difficult or time consuming to survey by traditional methods.

An accurate photoplot which shows all photographically visible dangers in the nearshore zone reduces the requirement to survey here and hence risk damage to the survey vessel. Drying areas can only be surveyed at limited times and adverse weather can further impede progress. The use of photogrammetry, once the initial photographic coverage and ground control have been obtained can progress the plotting work without interference from external influences and at a rate which can be reliably estimated. In addition and significantly, modern photogrammetric techniques can achieve accuracies on a par with hydrographic surveying practices.

The use of photogrammetry thus enables the surveyor to concentrate his efforts on the deeper water areas. However, even in the inshore zone some measure of field surveying is always necessary since there are limitations on applying aerial survey. The photography will seldom, if ever, be flown at a tidal state corresponding with chart datum. A combination of good weather and low tide is notoriously difficult to come by. As a result the waterline on a photogrammetric plot will inevitably be some distance landwards of the true drying line at Lowest Astronomical Tide (LAT). Water clarity is seldom ideal particularly in the sediment-laden waters of the UK. Best results are obtained in rocky areas such as the Hebrides, but it is rare to achieve measurement of water depth greater than 10 meters. Under such circumstances the fact that navigation dangers cannot be seen does not imply that they do not exist.

Photography taken over water can lead to problems of sunflare if the sun angle is greater than about 40 degrees and large water areas can make photography very difficult to use with a traditional analog stereoplotter. Extensive drying areas may be lacking in texture on photography making good stereo interpretation difficult. The completeness of the photogrammetric survey of such areas may be limited accordingly.

4. USES OF REMOTE SENSING

Until the mid 1980's the usefulness of satellite data as a cartographic tool was seriously limited by poor resolution. However three forms of high resolution imagery are now commercially available and are regularly employed in a charting context. These are Landsat Thematic Mapper (TM), SPOT (Multispectral and Panchromatic) and Spacelab photography (Metric Camera and Large Format Camera).

These various types of satellite imagery provide valuable data for charting at scales of around
1:75 000 and smaller. Satellite imagery is not seen as providing a definitive survey but rather as a cost effective source where alternatives are unavailable. Imagery can be particularly useful in the planning stage of a survey. For example in developing a new port possible deep water routes through inshore reefs can be detected. The hydrographic surveyor need not spend time in surveying and exploring possible routes which in the event are unlikely to permit the safe passage of vessels.

A major advantage of space imagery over conventional aerial photography is the vast area covered on one scene. This enables offshore islands and reefs at a considerable distance from the mainland to be accurately positioned. The spectral discrimination provided by the various wavebands of Landsat and SPOT imagery is also an advantage. The near infra-red provides a clear coastline whereas the blue/green waveband permits identification of underwater features in depths of up to 20 metres in ideal conditions.

Satellite imagery provides a valuable means of detecting coastal and shallow water features where their previous existence was unknown. This is of particular significance in remote areas where imagery can also help to improve the delineation of features sketched by early surveyors.

At present much of our work involves the use of hard copy, products in film positive format. The geometric accuracy of both SPOT and TM photographic products has been found to be very good. In areas of reliable coastline the imagery consistently gives an excellent fit to a Transverse Mercator projection. Considerable success has been achieved in identifying and correctly positioning coastline and submerged dangers to navigation. In the absence of known depths it is not possible to provide absolute values but the identification of shoal areas in poorly surveyed waters is of significant value to the charting task.

The use of digital SPOT and Landsat data is also currently under investigation. Known depths are used for calibration with the aim of deriving reliable bathymetric contours in areas where surveyed data is unreliable or non-existent.

Spacelab photography, both Metric Camera and Large Format Camera, is processed using traditional photogrammetric techniques with successful results.

The information available from satellite sensors is
therefore of considerable importance to the charting of remote areas where alternative sources are inadequate or non-existent. However, there are a number of factors which limit the use of remote sensing and which fall into four main categories.

The first of these is image resolution. For example the spatial resolution of SPOT with a pixel size of 10 by 10 metres is such that small pinnacle features which could be extremely hazardous may not be detected.

Water clarity is a second limitation. Most of the work done to date with imagery has

been in equatorial regions where clear water allows detection of underwater features. High levels of suspended sediment in many coastal waters effectively prevents any information about water depth being extracted.

Thirdly, atmospheric contamination, and in particular cloud is often present and significantly reduces the amount of useful data that can be obtained from any particular image.

Finally, tidal considerations are very important as far as hydrographic applications of imagery are concerned. The vertical datum of Admiralty charts is LAT and all hydrographic features are charted relative to this. The fixed orbits and repeat cycles of satellites mean that it is unlikely that an overpass will coincide with a low tide. Tidal height for particular images can however be accurately calculated and the usefulness of future images can be predicted.

5. CASE STUDIES

To date, imagery has been used to improve detail in some way or other on about 60 Admiralty charts. A number of examples are presented here in order to illustrate this practical application of remote sensing in a production environment.

The most common use for satellite imagery in the Hydrographic Office is to aid the compilation of a new chart for a region where there is a paucity of source data. The imagery is used to verify existing chart detail, to identify major errors in the depiction of coastline, and to identify islands and reefs which are uncharted or out of position. Landsat Thematic Mapper imagery is being used in this way to provide data for a series of new charts covering the Red Sea. Figure 1 illustrates the area around Al Qunfidha. Although a small portion of the current Admiralty chart is based on a 1918 survey the majority of this area has never been adequately surveyed. Figure 2 shows the chart overlaid with reefs, shoals and coastline derived from Landsat TM imagery. Many of these features are either uncharted or significantly out of position. Even in Home Waters source data may on occasion be lacking. For example a SPOT scene has been used to provide details of channels and sandbanks in the eastern part of the Solway Firth to assist in the compilation of a new edition of chart 1346, published in 1989. This area had never been previously surveyed and on the former edition of the chart very little detail was shown.

A second use may arise when a Hydrographic Note is received from a mariner reporting an error or omission from a chart. Imagery may then be used to verify the report and to delimit and position the feature to enable it to be correctly charted. Lighthouse Reef near Belize in Central America provides a good example. An extract from a former Admiralty chart of the area, current as recently as 1988, is shown at Figure 3.

Although modern aerial photography was available covering the entire reef there was no way of accurately locating it in relation to the mainland and ships' reports had indicated that the reef was mischarted by up to 1 mile. The old chart was based on 19th century surveys. A stereo pair of black and white Spacelab photographs was available and absolute orientation based upon 10 control points yielded planimetric accuracies of around 40 metres. The pecked line shows the reef edges as derived from the Spacelab photography. Not only has this photography enabled Lighthouse Reef to be accurately positioned, it has provided a means of controlling the larger scale conventional aerial photography which has been used for detailed plotting. A new chart, 959, covering this area at 1:125 000 was published in 1989.

Thirdly, satellite imagery may be used to resolve problems arising from conflicting information. A SPOT scene has enabled the main entrance to Saint Louis, a port in Senegal, West Africa to be accurately charted. The best available alternative data shows the entrance to be over 2 nautical miles north of its true position. In another recent example Space Shuttle photography (Large Format Camera) has been used to confirm the correct positions in the vicinity of Corfu.

6. CONCLUSION

Photogrammetry, as an integral part of coastal hydrographic surveying and charting, is a powerful and versatile tool. Satellite Imagery in its various forms provides a significant and cost effective means of supporting small scale nautical chart compilation and revision. In areas of clear water where existing surveys are inadequate, imagery can provide the basic data to be included in new charts.

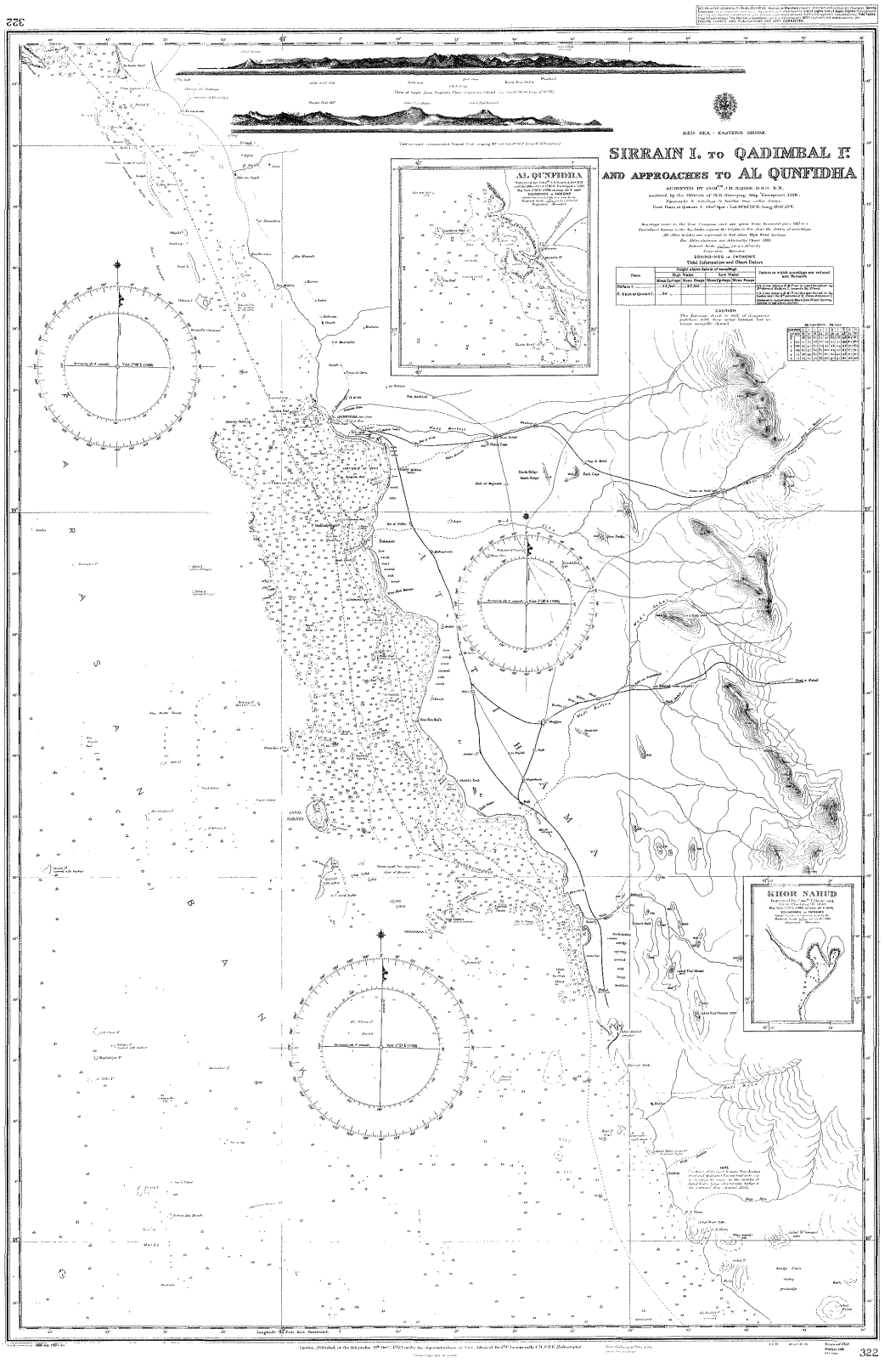

Figure 1: The current British Admiralty chart 322 of the Red sea around Al Qunfidha.

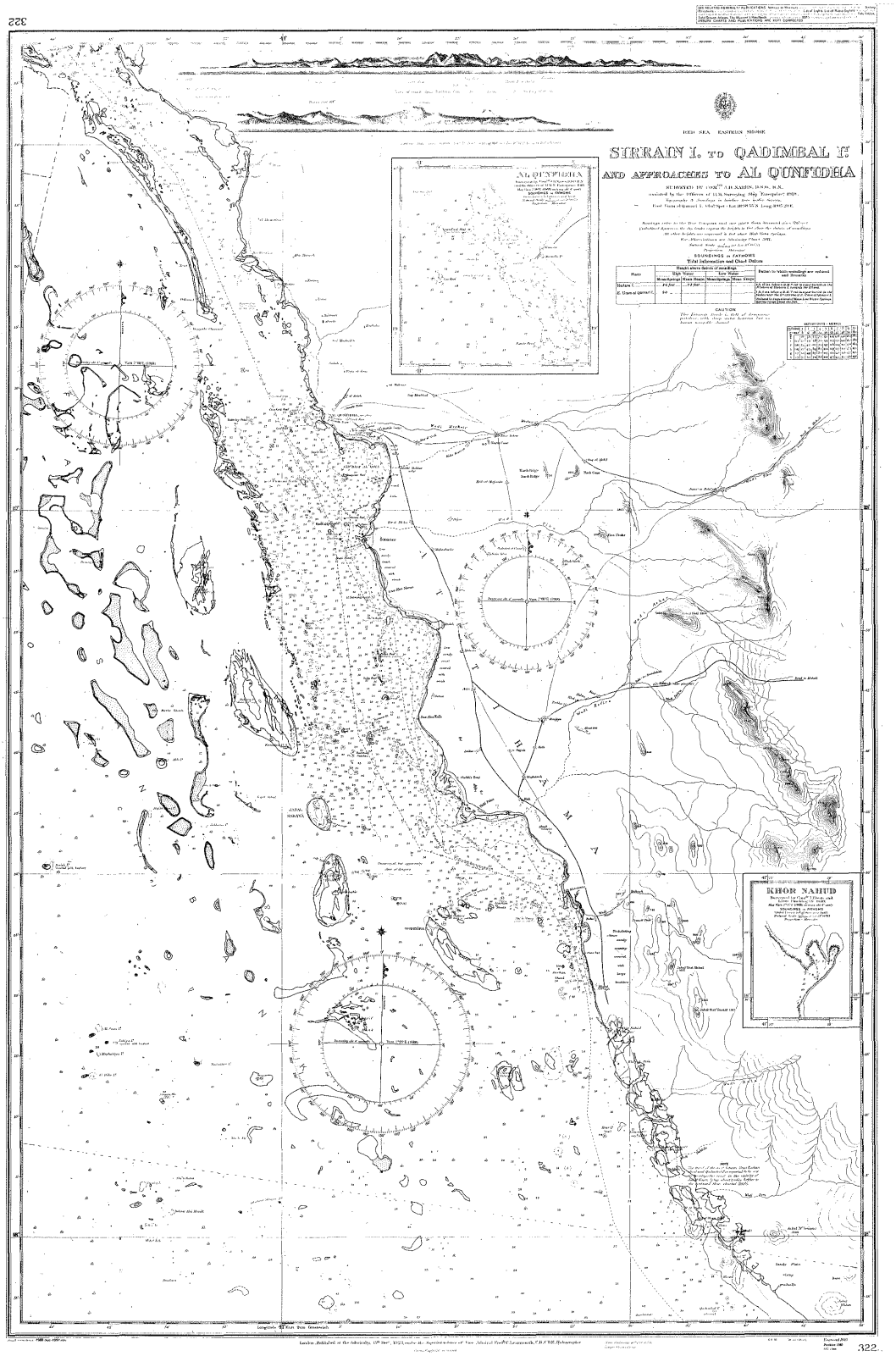

Figure 2: British Admiralty chart 322 overlaid with reefs, shoals and coastline from Landsat TM imagery.

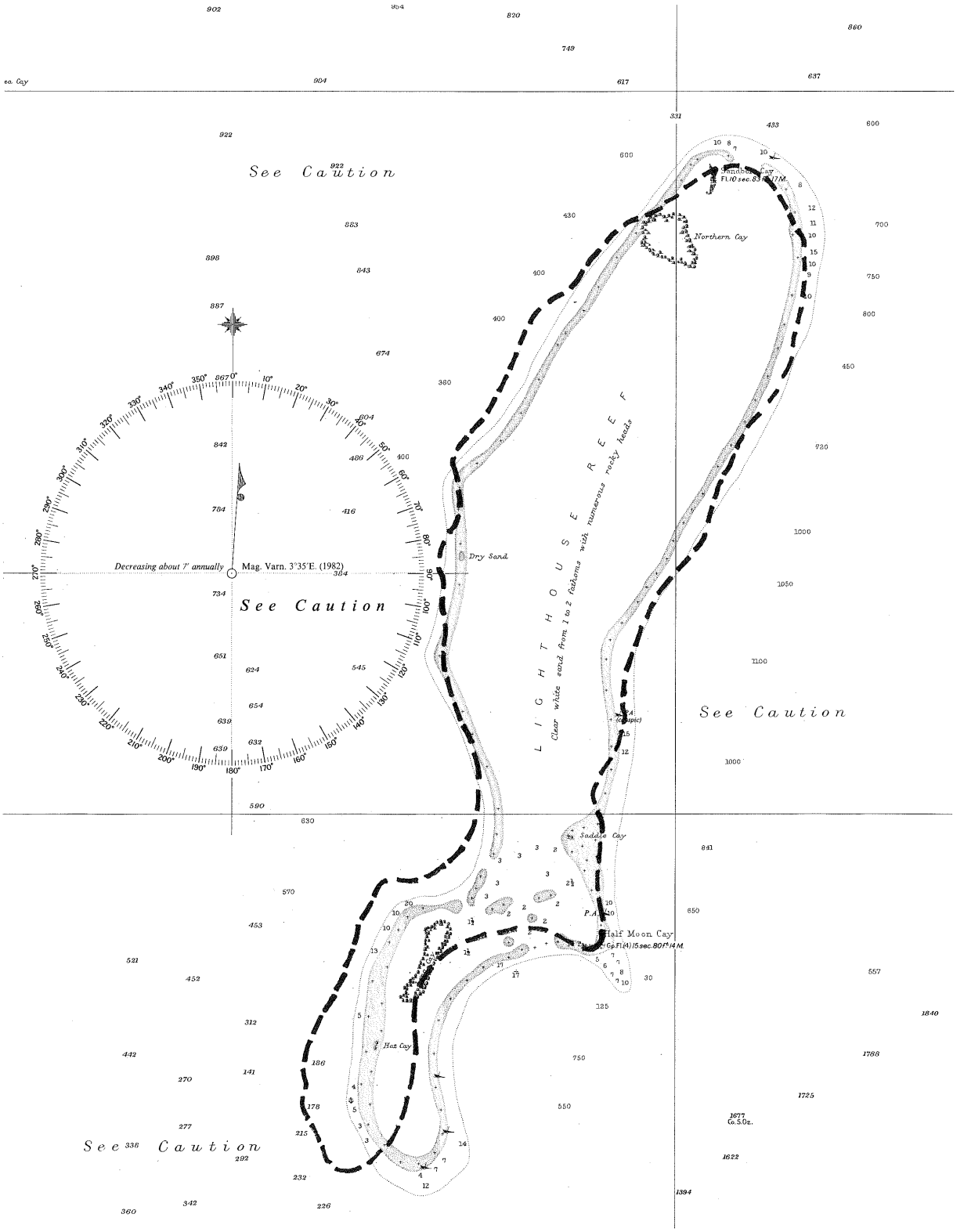

Figure 3: A portion of former British Admiralty chart 959 overlaid with a plot produced from the Metric Camera photography. This confirms the reported inaccuracies of up to 1 mile in the position of Lighthouse Reef.

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