point "B." Flag "A" is rolled up in order to stop the photography of the floats stuck in the eddy at that point. All the floats that are coming through are caught and hung up in Big Eddy and all flags but one are rolled up. A second flag is put out, the floats are again launched, and another sequence of photographs is started. The crew of the pickup boat radios in that all floats are picked up, all flags are rolled up and the photographic crew finishes the obliques and/or other flight requests. On return to base, they check their watches and wait for further instructions. Ground and boat crews read the gages and prepare the the floats for the next run.

The operation of flag moving was a guide rather than an absolute order on flight line limit, because the airplane crew could see and therefore knew the whereabouts of the floats far better than the ground or boat crews. In fact, under certain conditions and unforeseen action of the floats, coverage depended entirely upon the photographers. Consequently, as the job progressed, more and more of this responsibility was transferred to them.

In closing, although this method could not give the complete data that is procurable by a boat crew when they can reach all parts of a river cross section, it did give very satisfactory results under otherwise impossible conditions. Further, because the photography was used in other phases of the project, the cost prorated to float observation was small.

THE MEASUREMENT OF WATER CURRENT VELOCITIES BY PARALLAX METHODS*

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Introduction

WHILE examining vertical serial photographs of the Bay of Fundy and Minas Basin areas of Nova Scotia, some anomalous stereoscopic effects were noted in channels and near capes where strong tidal currents are known to exist. It was noticed that the water surface appeared to be elevated into mounds, flanked in some cases by curved depressions. This effect was assumed to be due to movement of the water surface between succeeding exposures of the stereo pairs. The extreme muddiness of the water results in sufficient surface configuration to enable the same portion of the surface to be identified in succeeding prints, and a stereoscopic effect is thus produced. It occurred to the author that it might be possible to measure the velocity and to plot the direction of the current by "contouring" the elevated water surface. The method proved feasible and with suitable special procedures might be adapted to hydrographic or military surveys.

An intensive search of the literature revealed that similar effects had been noted and used by an English research team during the war. They were interested in depth determination only, and apparently did not go any further. The place was the Rangoon River and infrared photographs were used.

Possible Uses

The most obvious use for this technique is in the charting of coastal and estuarian tidal currents. A number of points suggest themselves at once for enhancing the value of the data obtained.

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1. A relatively slow aircraft must be used to allow for a maximum displacement of the water surface between exposures.

2. The time of the tide must be carefully noted. For areas such as Digby Gut, photostrips should be taken every fifteen minutes or half hour from dead high to dead low water. In this way a record of current action for one tidal cycle could be obtained.

3. If the water is not sufficiently opaque, the surface could be dusted with powder or dye. This could be done on a dry run with the current, carrying out photography on the return run.

The possible military applications of this technique are obvious. As in most photographic reconnaissance and intelligence work the greatest value lies in obtaining data without having access to the area in question.

General

The Bay of Fundy is noted for its high tides and accompanying strong tidal currents and rips. It is particularly well known for the proposal to harness the tides for power development by damming off the Passamaquoddy Bay area.

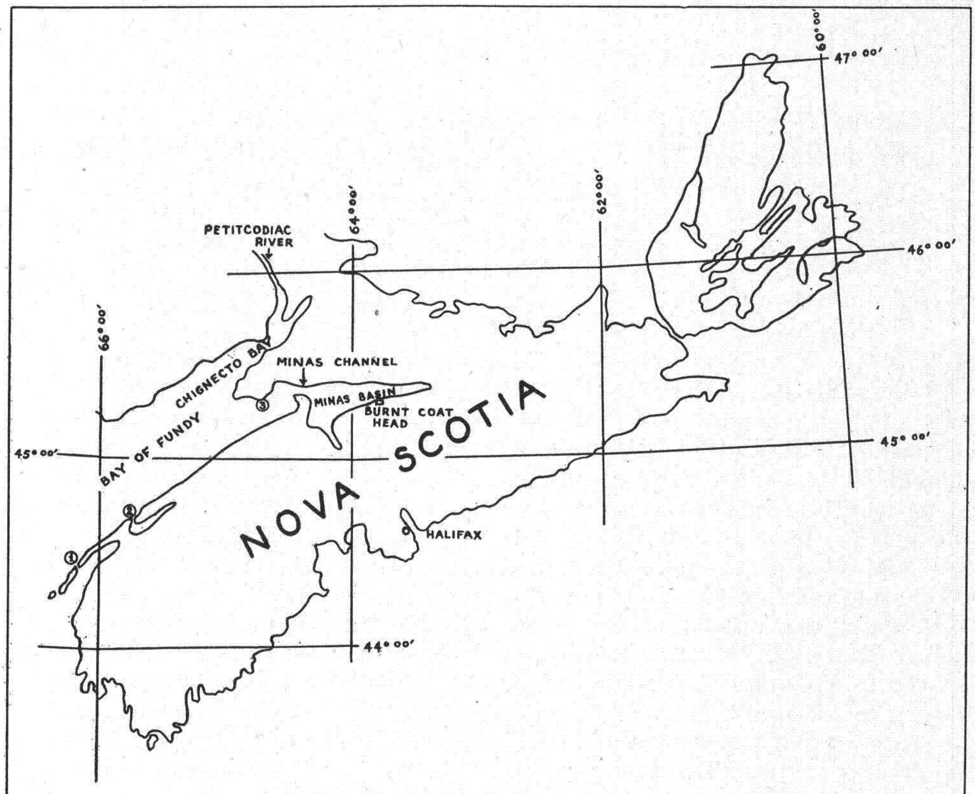


Fig. 1

The high tides are the result of the location and configuration of the Bay and its extensions, Minas Basin and Chignecto Bay (see Figure 1). The main section to the westward has the form of a funnel open to the southwest and narrowing eastward to Cape Chignecto where it splits into two arms, which also narrow toward their heads. Chignecto Bay extends northeast and is continued by the relatively narrow channel of the Petitcodiac River. The eastward ex-

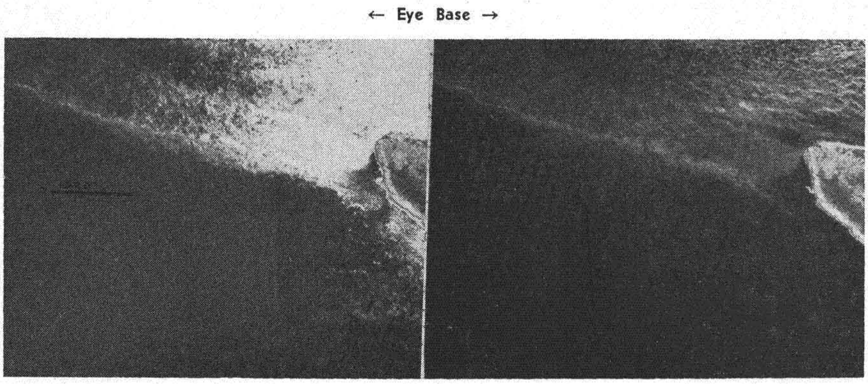


FIG. 2. Petite Passage, Nova Scotia. R.C.A.F. Photographs.

tension has a constriction, Minas Channel, between Cape Spencer and Cape Split, but beyond this extends far eastward to the vicinity of Truro. As the tidal wave moves up the bay it is constricted laterally and gains in height. In Chignecto Bay the constriction increases rapidly, and in the Petitcodiac River, the wave becomes visible to the observer in the famous tidal bore, which under fa-

FIG. 3. Digby Gut, Nova Scotia. See Appendix. R.C.A.F. Photographs.

vorable conditions attains a height of several feet. The Minas Basin has even higher tides than Chignecto Bay, but due to its greater eastward extension the maximum height occurs at Burnt Coat Head about two-thirds of the way to the head of the Bay. By the time the tidal crest has reached this point the tide has been falling for some time at Cape Sable and beginning to fall in Minas Basin; hence the crest is lower from Noel to Truro.

It has been estimated that two cubic miles of water pass through Minas Channel at each tide. The movement of such masses of water produces tidal currents and rips of great intensity, especially in channels and around capes. The areas described in this paper are shown in Figure 1. They are Petite Passage, Digby Gut and Cape Spencer. In each place parallax effects were noted and measured. Numerous others have been noted in other parts of the district.

Procedure

An examination of Figures 2, 3 and 4 (Stereo pairs of Petite Passage, Digby Gut, and Cape Spencer) will reveal the stereoscopic effect described above.

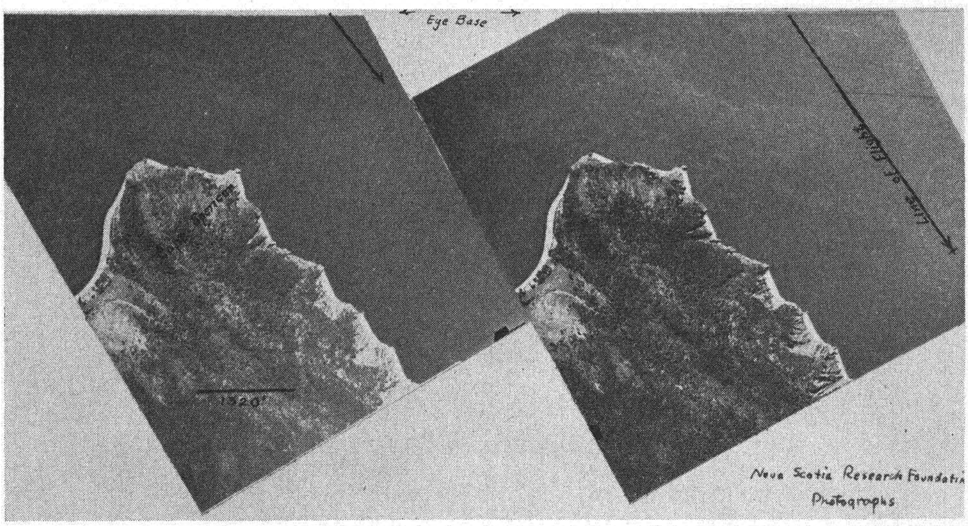
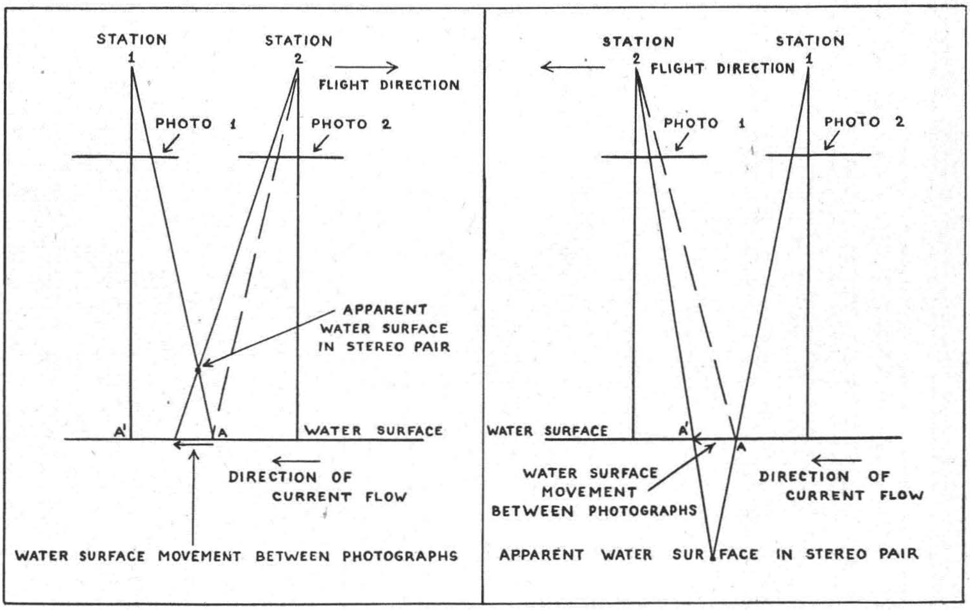


FIG. 4. Cape Spencer, Nova Scotia. Apparent depression of water surface caused by current flowing past Cape Spencer. Nova Scotia Research Foundation Photographs.

If the apparent rise in the water surface at any point is due to displacement of that point by current action during the time interval between the exposures, the amount of displacement is directly proportional to the average current velocity. This value can be measured by reading the differential parallax between the water surface at sea level (or the beach level) and the (apparently) elevated water surface (Figure 5). Knowing the average scale of the photographs, F/H in this case, as $h=0$, and the time interval between exposures, it is a simple matter to calculate the current velocity. The differential parallax in mm. is converted into feet and divided by the time interval, with the resultant velocity in feet per second being converted into miles per hour or knots, as required. As the surface of the water is displaced vertically by an amount proportional to the current velocity, and as this varies from zero at the beach line to a maximum in the center of the channel, it follows that contours can be drawn on the elevated water surface which correspond to current velocities. Eddies and backwater flows are readily discernible and the characteristics of the current can be plotted.

If the direction of flight is opposite to that of the current, the water surface appears elevated. If flight and current directions are the same, the water surface appears depressed. These relationships are shown graphically in Figures 5 and 5A.

It was pointed out by a physicist friend that in some cases the current was moving obliquely to the line of flight and that only a component would be measured if the above procedure was followed. This new line of thought suggested cases in which no ordinary parallax might exist because the current flow was at right angles to the line of flight. A case was sought and found in the Petite Passage photographs (Figure 2). Reasoning that only y parallax should exist, the photos were turned through 90° and placed under a stereoscope. The land areas were flat and the water depressed as anticipated. This case suggests that



FIGS. 5 and 5A

flights at right angles to current flow might be best for survey purposes because practically all effects other than those due to water movement can be eliminated. Another variation in technique might be the rotation of the prints to make the current direction parallel to the eye base of the stereoscope. This position would give the maximum stereo effect and ensure that the maximum current velocity is measured, rather than a component thereof.

A possible application of this technique to measurement of data from hydraulic models, or wind tunnels, is also suggested. The water surface could be dusted and then successive photographs made from one position with a tripod-mounted camera. The pairs or sequences produced in this way would show stereoscopic effects due solely to water movements. Velocities and directions could be measured as suggested above, and variations plotted which are either very difficult or impossible to measure using present methods.

ACKNOWLEDGEMENT

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Appendix

Digby Gut Measurements: Refer to Figure 3.

Measurement by Abrams Academy Height Finder with Explorer Lens Stereoscope. Parallax values are average of six readings.

Point A. Parallax of water level near two wharves—8.53 mm.

Pt. 1—6.53 mm.
Pt. 2—6.00 mm.
Pt. 3—6.00 mm.
Pt. 4—6.38 mm.

Point B. Parallax of water level near sandspit—6.97.

Because of the differences in parallax between *A* and *B*, tilt was assumed to exist and so for calculating the differential parallax the average of *A* and *B* parallax was used.

An Anson aircraft was used for the photography and an average cruising speed of 120 m.p.h. was assumed for the flight. An exact figure was unobtainable, but if actual surveys were being carried out the calculated ground speed would be available.

The airbase measured from the photographs was 3.09″ and at an average scale of 1″ = 1,320′, this would give an interval of 23.17 seconds between exposures.

$$\left(3.09'' \times 1{,}320 = \frac{4{,}078}{176} = 23.17 \text{ seconds}\right).$$

Point 1. Differential parallax—beach and point 1 = 7.75 − 6.53 = 1.22 mm.

Distance travelled by water between air stations = 1.22/25.4 × 1,320′ = 63.36 feet.

$$\text{Velocity: } \frac{63.36}{23.17} = 2.734 \text{ feet per second}$$

$$\text{Knots: } \frac{2.734 \times 3{,}600}{6{,}080} = \frac{9{,}842.4}{6{,}080} = \textit{1.61 Knots.}$$

Point 2. Differential parallax—beach and point 2 = 7.75 − 6.00 = 1.75 mm.

Distance travelled 1.75/25.4 × 1,320 = 91.08 feet

$$\text{Velocity: } \frac{91.08}{23.17} = 3.93 \text{ feet per second}$$

$$\text{Knots: } \frac{3.93 \times 3{,}600}{6{,}080} = \textit{2.33 Knots.}$$

Point 3. Same as Point 2 = *2.33 Knots*

Point 4. Differential parallax—7.75 − 6.38 = 1.37.

Distance: 1.37/(25.4 − .054) × 1,320 = 71.28

$$\text{Velocity: } \frac{71.28}{23.17} = 3.076 \text{ feet per second}$$

$$\text{Knots: } \frac{3.076 \times 2{,}600}{6{,}080} = \textit{1.82 Knots.}$$

The tide is obviously quite low and the tidal current not at a maximum. The values for maximum Springs given on the chart are three and four knots.