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Currents at the Columbia River Mouth

Color photos and color floating targets help to chart surface currents in areas where conventional methods are not applicable.

ABSTRACT: Two series of aerial color photographs, one set during a flood tide and the other during an ebb, were taken of drifting surface targets in the area surrounding the mouth of the Columbia River to determine the pattern of surface currents. Targets were color-coded vinyl air mattresses launched from a moving ship at known positions. Discolorations of the water and convergence lines marked by foam were also photographed and aided in the interpretation of the surface currents. The photogrammetric survey allowed nearly simultaneous surface current data to be obtained from separate areas around the mouth of the Columbia River, and produced quantitative current data in areas that are impossible to sample by more conventional methods.

INTRODUCTION

THE OCEANIC REGION surrounding the mouth of the Columbia River and modified by this river's effluent has been under study by the Department of Oceanography, University of Washington, since 1961 under contract support from ONR and AEC. Since 1963 the survey work in the effluent area has concentrated on determining the changes in the water mass structure over small areas and short time spans. Rapid and repeated sampling over small grids of stations has been used to determine these water mass changes in response to tidal action in the system.

Preliminary analyses of the oceanographic data from time studies have indicated that vertical oscillations of isosaline surfaces at tidal periods occur only at specific stations near the mouth of the river. A lateral migra-

tion of sloping isosaline surfaces, rather than internal waves, was suspected of causing the apparent vertical motion. In order to establish the preceding as fact, it was necessary to ascertain the distribution of currents over an area of approximately 274 km² (80 square nautical miles) as well as their variation with the local winds and the tidal ebb and flow of the river. Current measurements were made from a single moored vessel, but data gathered in this manner proved insufficient for describing such a large and active body of water.

The photogrammetric technique for measuring currents as outlined by Keller (1963), Forrester (1960), and Cameron (1952, 1962) appeared feasible as a method for monitoring surface currents in the Columbia River effluent area. Time-lapse aerial photographs are used to determine the position of drifting targets against a background of fixed references such as anchored navigational buoys and land masses. Two time increments for detecting motion of the targets are used with the aerial photographic work. The longer of the two increments is dependent upon the plan of the survey and is controlled by the investigator. This increment represents the

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time between successive camera runs over the surveyed area. The displacement of the drifting targets determined from photographs on successive passes over the area and the time separating these passes are used to generate trajectories of the drifting targets and to determine their speeds along each segment of their trajectories. The trajectories obtained in this manner are integrations of the true paths described by the targets, and become less representative of the true paths as the time between successive camera runs increases.

The shorter time increment is determined by the time required by the aircraft to cover a horizontal distance equivalent to 40 per cent of the length represented in an aerial photograph. This increment represents the time separating successive photographs with 60 per cent overlap on a single camera run. Successive overlapping photographs constitute stereo pairs and the motion of drifting targets can be determined in the overlap section by stereographic analysis. The motions of the targets determined by this method are applicable only for the time period separating the stereo pair and cannot be used to describe the integrated trajectories, but they can be used to produce small discontinuous trajectory segments along the integrated trajectory.

METHOD

A commercial firm, Pacific Aerial Surveys, Inc. of Seattle, Washington, with facilities for photogrammetric surveying performed the necessary aerial photographic work. The area under study includes a congested shipping channel area and required using targets that could not possibly endanger shipping or be considered a nuisance if they became beached. Size, mechanical strength, visibility, color, ease of handling, cost, and resistance to sailing before the wind were also considerations in the choice of suitable targets. Vinyl air mattresses, approximately 56 by 165 cm., filled with fresh water until rigid possessed all the desirable characteristics. These mattresses weighed approximately 40 kg when filled and floated awash with approximately 2 per cent buoyancy. They could be readily identified in photographs having 1:20,000 scale taken from an altitude of 3.05 km. Pacific Aerial Surveys, Inc. conducted a visibility test of the mattresses under ideal conditions and were able to photograph these targets from heights exceeding 4.57 km. All photographic work was done using a Wild camera with Kodachrome II® aerial film. This equipment produced excellent 24.1 by 24.1 cm. color

transparencies for determining the positions of the targets.

The photogrammetric survey was tentatively scheduled for *Brown Bear* cruise 371, 14-26 September, 1965. On the morning of 16 September, the required combination of tide, daylight hours, low sea state, low winds, and perfect visibility with no cloud cover occurred. The routine oceanographic effort on the cruise was halted and the aerial photographic team was called to the project area.

Mattresses were filled with potable water from the ship's tanks and a V-shaped course was run across the mouth of the river (Figure 1) while color-coded mattresses were launched approximately every half mile. Aerial photographic runs over the area were commenced as the *Brown Bear* completed its launching track. Successive runs were made on this day photographing the floating targets as they moved in response to the surface current during the flooding tide.

Conditions on the next day were also promising with clear skies, northwest winds at approximately 2.57 m/sec (5 knots) and 6- to 8-sec period swell of $\frac{1}{4}$ to 1 m. in height. During the morning ebb the targets were set along a W-shaped track (Figure 2) at a spacing of one-half mile on the outside leg and one-fourth mile spacing on the inner legs. The inner point of the W track was placed well into the mouth of the river to concentrate targets in the main stream of the flow of the ebb tide. Unfortunately, last-minute mechanical failure in the aircraft delayed the initial photographic run until 1.75 hours after the last target drop. This time lag between target launch and photography produced a void in the trajectory data as targets placed centrally in the river mouth moved out of the area of photographic coverage or were too far removed from their origin to allow determination of their trajectory.

The photographic program consisted of flying predetermined flight lines over the area (Figure 3) taking sequence exposures with 60 per cent and 20 per cent overlap. The flight lines were arranged to cover all possible areas that might contain the targets and to make best use of the available fixed reference points for position control.

RESULTS

The trajectories of individual targets determined from successive photographic series are shown for flood current conditions in Figure 1. Velocities determined from point-to-point displacement and time recorded on the photographic film are displayed along the

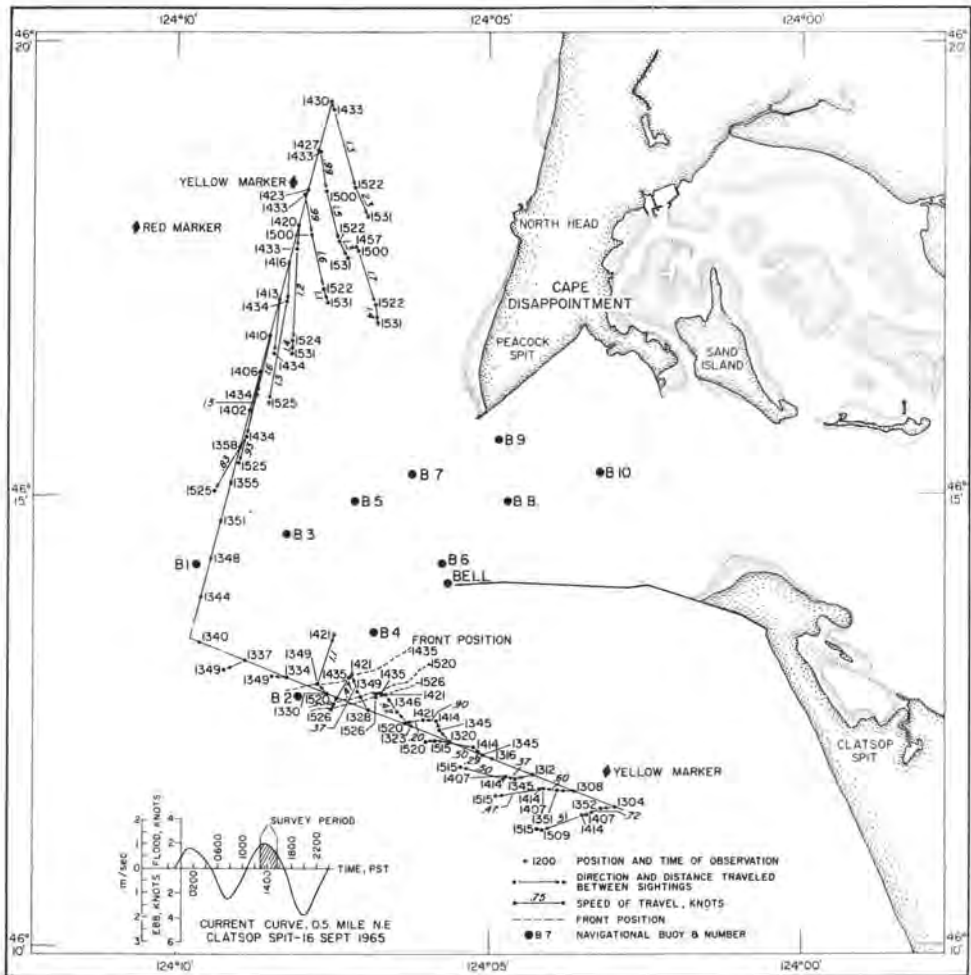


FIG. 1. Drift of surface targets during flood current at Columbia River entrance.

path line segments. The time covered by the total survey period is shown against the tidal current curve for the Columbia River mouth.

The surface water north of the river moved southward along the coast to enter the river during the flood. The photographs of this area show a band of discolored water lying adjacent to the beach in the surf zone. This discoloration could be due to suspended sediment, but it was not visible south of Clatsop Spit, or on the second day of photographing when nearly identical surf and wind conditions were present. However, just north of the project area high concentrations of phytoplankton, possibly *Chaetoceros armatum*, appear in the surf zone and produce a distinct discoloration of the water. The southward transport of water along the beach detected by the drifting mattresses is suspected of moving diatom-laden water into

the area to produce the discoloration. The current pattern during the flooding tide indicates that the area north and northwest of the river mouth contributes considerable water to the estuary of the river. The region directly downchannel from the mouth also must supply surface water during the flood. However, targets seeded in this latter area failed to show in the photographs owing to a combination of sun glint and the arrangement of flight line paths, and were not trackable during the survey.

The targets on the south side of the jetty moved seaward, westward, away from Clatsop Spit. Previous observations in this area have indicated that cold high-salinity surface water is present in the light of Clatsop Spit and represents a region of upwelled water. Coastal upwelling occurs along Oregon and Washington during much of the summer and

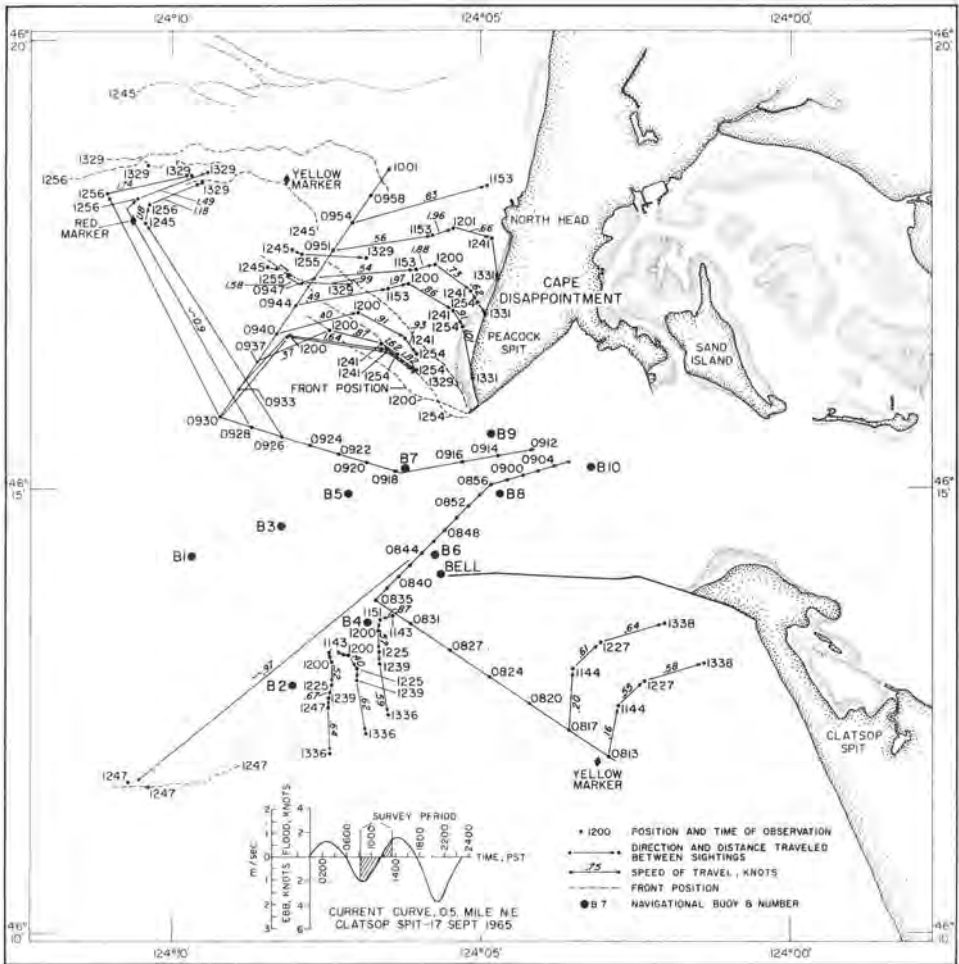


FIG. 2. Drift of surface targets during ebb current at Columbia River entrance.

early fall as a result of wind-driven currents moving the coastal waters offshore. The upwelling in the bight of the south jetty and Clatsop Spit is enhanced by local currents moving the water offshore during the flood. The mixing between the river water and oceanic water requires a shoreward transport of salt to replace that which is mixed with the river effluent and transported offshore from the immediate area by hydraulic, tidal, and wind-driven forces. Upwelling and the transport of upwelled water toward the central core of flow helps to fulfill this requirement.

The surface velocities south of the river's mouth are approximately one-fourth to one-third of the channel velocity and appeared to be part of an eddy system associated with the inflow in the main channel. Velocities north of the main channel are of approximately the same magnitude as those forecasted for the

river. The currents measured for this short period of the flood were made under nearly perfect conditions of low sea state and winds. Considerable modification of their magnitude and direction would be expected if strong winds and accompanying sea state from varying directions were present.

The effect of convergence lines streaming away from the ends of the breakwaters on the motion of the surface targets is evident along the southern edge of the channel near buoy No. 4 and buoy No. 2 (Figure 1). One target moving to the northwest at approximately 0.205m/sec (0.4 knots), a direction and speed comparable with other targets in the same vicinity, was trapped by a convergence and then sent backward as the interface progressed to the southeast. A second target, behind the first, was also trapped by the same convergence and reversed in its migration as

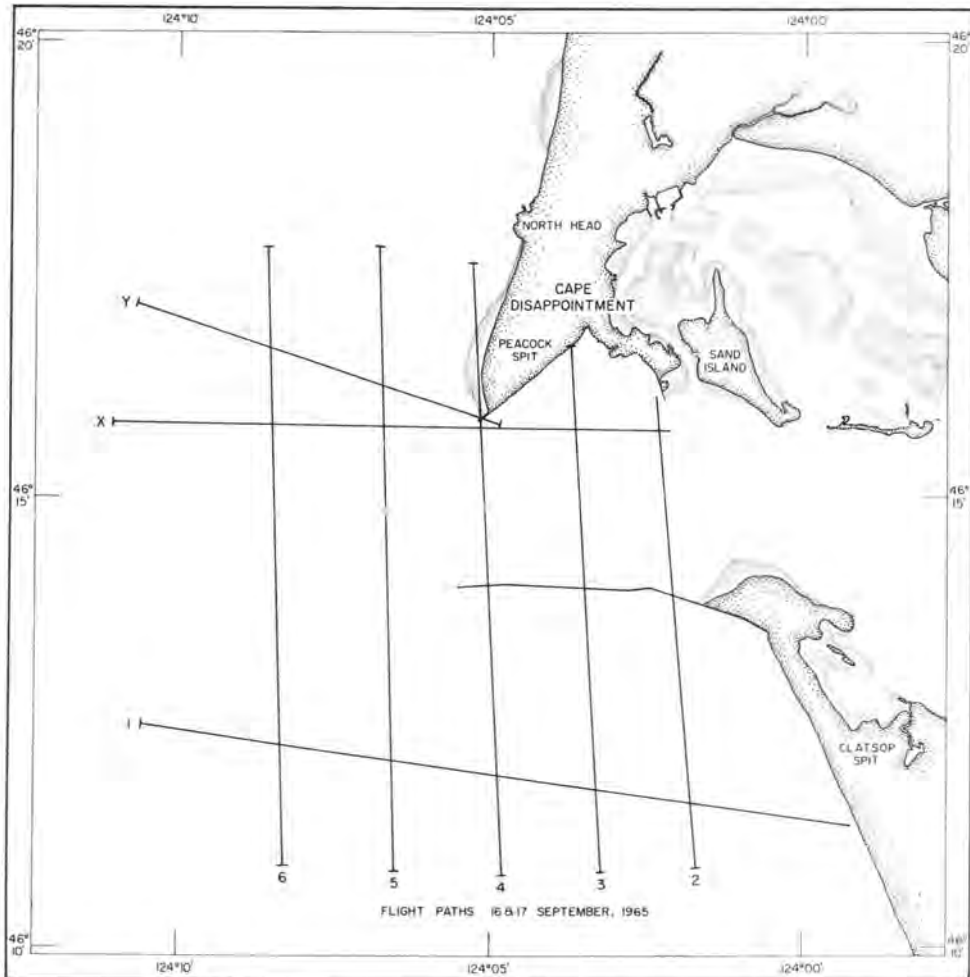


FIG. 3. Flight grid for aerial survey at Columbia River entrance.

the convergence moved contrary to the targets. The trapping of targets in the convergence fronts is also evident north of the river mouth in Figure 2.

The photogrammetric survey on the next day was taken during the latter part of an ebb and the beginning of the flood (Figure 2). Little information was obtained from the photographs on the currents in the channel or south of the channel owing to the late arrival of the photographic crew. The currents in this area were appreciable and the targets were flushed out of the area by the ebb before they could be photographed. Two targets south of the south jetty migrated toward shore, but the remainder of the targets seeded on the same line departed the area and are judged to have gone in the direction of the lightship with the ebb. Considerable

motion seaward from Clatsop Spit must also be present during the ebb to have cleared this area so rapidly. This seaward drift would also enhance the upwelling in the bight of Clatsop Spit much the same as during the flood.

Targets placed upchannel as far as buoy No. 10 were not photographed soon enough to determine their trajectories. Three areas appearing in Figure 2 contain most of these targets, however. Two targets are visible in one photograph near the lightship. These have come either from the south side of the channel or from the line of targets seeded south of the south breakwater. A convergence line extending from the north jetty and progressing toward the northeast contains a tight group of approximately six targets from the north side of the channel; the number is uncertain owing to masking by foam. The

third area near the northwest red marker buoy contains four targets that also came from the northern channel line and appear to be moving under the influence of a convergence interface. The convergence lines tend to group the targets and contain them, for freely moving targets approaching an interface along the same path are stopped in succession and stacked in a group. The motion of the interface is then imposed upon them.

Targets released on the outer northward leg of the *W* track proceeded toward the beach at speeds of .205 to .463 m/sec (0.4 to 0.9 knots). These targets were dropped about 3.70 km off the beach, but without exception they all showed a remarkable affinity for the shore. Their tracks indicate that a large eddy existed over Peacock Spit during the ebb. The water in this eddy circulates in a clockwise pattern and considerable onshore transport is present. The photographs of the beach area along Peacock Spit show a series of current rips that return the onshore transport seaward. The air mattresses that reached the narrow surf zone were beached on the sand and in one exposure some are visible lying high and dry. This onshore transport of water and the alongshore transport during the flood help in accumulating the sand deposits on Peacock Spit.

CONCLUSIONS

The technique of aerial photogrammetry has been used elsewhere and is established as a feasible method for synoptic determination of surface currents over large and inaccessible areas. The region at the mouth of the Columbia River is large and has specific areas unsafe for boat operations. The physical size of the region and rapidity with which water moves in this area makes it nearly impossible to determine adequately the currents by means other than photogrammetry.

The trajectories of the surface targets determined from the aerial photographs show that considerable motion of the surface water exists on either side of the main channel during both ebb and flood. The movement of the water south of the channel aids in maintaining upwelled water in the bight of Clatsop Spit. The motion north of the channel and near the coast shows that substantial southward flow exists on the flood while shoreward transport by a large eddy occurs on the ebb.

The magnitude of the currents either side of the main channel are about one-half of or comparable to the main channel currents.

The magnitude and direction of these currents are not considered permanent and are suspected of changing in response to the prevailing wind. Previous observations of water characteristics indicate that substantial lateral oscillations of tidal period occur in the main core of the current running in and out of the river. Additional current studies of this nature are planned in the coming year to determine the surface velocity field around this main core and to ascertain how oscillations occur with respect to the tidal flow, river freshwater discharge, and the surface wind field.

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