RIVER CURRENT DATA FROM AERIAL PHOTOGRAPHY*

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INTRODUCTION

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When Louis Woodward suggested to me that this story would be of interest to the Society, I felt it advisable to consult the Army Engineers, by reason of certain restrictions in view of possible international publication, and it was decided that the Army Engineers prepare this paper. Official release from the top command for such publication has now been received.

The title of the paper as it appears on the program has been changed since that title is slightly misleading, in that there are no particular problems in the application of photogrammetric procedures to obtain the specific desired data, except one of providing acceptable photography according to accuracy standards required for such purposes.

In our first attempt, three years ago, to provide such photography, we jointly decided that the proper equipment would be the helicopter. This unfortunately turned out to be a complete failure for several reasons. No helicopter pilot with prior experience could be found, and the excessive turbulence of the air at such low altitude over the rapids of the river made it impossible to maintain the camera at anywhere near an acceptable vertical axis. In the second attempt a twin engined Beachcraft was used; this also resulted in failure by reason of speed beyond the critical exposure time, resulting in motion. From these experiences we realized the necessity of finding a suitable plane for the job. We rebuilt a 1931 Model Stinson, powered it with a 450 HP Pratt & Whitney, and found that this ship would cruise safely in tight quarters at 90 feet a second. Our final success must definitely be credited to this airplane and the long experience, understanding and ingenuity of the men who flew it—Mr. F. S. Dearborn and Mr. R. H. Nelson.

In conclusion, I should like to mention that as of today this project has been found to be successful, and if further multiplex procedures at a later date prove it to be so, we will likely continue with other projects on the Columbia and Snake rivers. No doubt this method and procedure in this first attempt is somewhat on the primitive side, furnishing ample opportunity for new ideas and improvements.

As an added item of interest, mention should be made that by reason of turbulent air and the severity of these tight maneuvers for such long periods, consisting of flying continuously along a course similar to that of a figure eight, these men suffered considerable physical distress. After their first experience they found it necessary to refrain from eating until the day's runs had been completed.

We, of course, are happy to have had the opportunity to contribute our experience, our efforts and ingenuity in developing, as far as we know, a new application of aerial photography to a problem of vital importance to our future economy.

FIVE miles upstream from The Dalles, Oregon, the Columbia River enters Fivemile Rapids, to race through a broken, vertical walled channel averaging 200 feet wide. During the highwater period of May and June, the water surface raises 45 feet to top the rocks, and spreads out 1,000 feet or more. At the foot of this rapid is a large circular basin of great depth. This acts as a stilling basin known as Big Eddy, and spills into Threemile Rapids, now tamed by the slackwater of Bonneville Dam. Here, at the head of Bonneville pool, soundings show depths ranging up to 285 feet, of which more than 200 feet are below sea level.

In this area is the proposed site of The Dalles Dam. Where and in what order should the several elements of this structure be placed? This is a design

* Paper read at Eighteenth Annual Meeting of the Society, Hotel Shoreham, Washington, D. C., January 9 to 11, 1952.

problem that is best answered by building a model in which are duplicated the velocity and direction of the river currents. In such a model the various designs can be built, studied and changed until the best solution is attained.

Obtaining the true current velocities and directions of the Columbia River through Fivemile Rapids requires a different approach than the usual method of taking sextant shots from a boat drifting alongside a float. This is especially so at the higher stages, at which times even the best of the river boats dare not approach closer than 1,000 feet to the head of the rapids. To obtain the desired data by using land stationed observers, there are the problems of communication, blind spots, the need for numerous observers, the synchronizing of time, the location of stations, the need for more time for accomplishment, and possible observational errors of time, position and object.

Preliminary studies showed the feasibility of aerial photography. Consequently, arrangements were made and the job accomplished substantially as narrated below.

Quotations were obtained for unit costs of the variable factors in aerial photography, namely, number of negatives, flight time, standby time and mobilization. This type of contract was agreed upon because definite quantities could not be predetermined, plus the fact that each stage of the river presents an entirely different set of conditions and problems.

Fifteen floats were assembled by using two empty fifty-gallon oil drums strapped together, and a plywood panel 3×4 feet was then fastened to the two drums. On each panel was painted a different distinctive black and white design which, at a scale of 1:4,000, would be approximately one hundredth of an inch on the negatives and sufficiently large for easy identification.

A negative scale of from 1:3,000 to 1:4,200 was selected for each float run, depending upon the width of the river on that day. For ease of identification, the larger scale was preferred, but scales approaching the minimum were more often selected and used, especially so for the higher river stages. Also, a smaller scale has the advantage of less cost due to fewer photographs, greater coverage of floats per exposure and a longer interval between exposures.

A slow flying plane was specified in order to give more latitude and less travel in the interval between exposures as well as to reduce the number of exposures, and therefore the cost. At high river stages, an interval of 10 seconds upstream and 15 seconds downstream with forward lap of 55% to 60%, gave two distinct positions for each of the fast moving floats.

A series of river gages was established in the area under study and were read before and after each float run, thereby providing river elevation and volume data.

Ground observation points were established at four critical locations; one at the head of Fivemile Rapids, another part way through Fivemile Rapids, one at its outlet into Big Eddy and the fourth at the outlet of Big Eddy into Threemile Rapids. The observers recorded the time of passing for each float, its approximate lateral position in the river, and any other useful information for later use as a rough check on the aerial photographic data.

A boat with radio communication to the base of operations was stationed above Fivemile Rapids and another below Threemile Rapids, these were used respectively to release and pick up the floats and to relay this information to the base of operations.

The thread of the river in the area under study has three distinct directions, first, Fivemile Rapids through Big Eddy, next, the outlet of Big Eddy to a point part way through Threemile Rapids, and finally, the lower reach of Threemile

Rapids. Consequently, three flight lines were specified. The floats, after traversing Fivemile Rapids, usually hung up in Big Eddy, where they were gathered, taken to the outlet of Big Eddy, and released for passage through Threemile Rapids. Lacking radio transmission contact with the plane crew, a set of signals was arranged to give them instructions.

At the base of operations, near the outlet of Big Eddy, there is a large, open area of flat ground. Here on this ground several points, *A*, *B*, *C* and *D*, on each of three lines were designated, using white paint, sufficiently large to be seen from the air. Each line corresponded to a flight line on the flight map, and each point represented a predetermined position on that flight line. Three white flags, each eight feet square, were used as signals. One flag displayed on any line meant to stand by; a second flag on the line was the signal to proceed with photography; the third flag was used to change the limits of the flight on that line, so that there would always be two or more signals showing. Whenever necessary to stop the photograph for any period, such as when picking up the floats in Big Eddy, only one flag was displayed. Upon the showing of a second flag a new flight sequence was started.

During the period between flight sequences, the plane crew either had time to take obliques or to make a 1:6,000 scale flight of other specified areas of the river.

The 1:6,000 scale photography is used for the base map on which the successive positions of each float are plotted. Selected exposures of this photography giving continuous coverage of the entire reach under study, are enlarged to a scale of 1:2,000. One of these prints is placed on the easel of a reflecting projector and a contact print of the float run series, on which the floats have been identified and intensified, is placed on the face plate of the projector. By matching ground control features in the vicinity of the float, its position and time to the second is transferred to the base sheet. When all floats that fall on that sheet are plotted, a continuous line is drawn connecting the consecutive positions of each float, and beside each position is noted the exact time. There now appears on the base sheet all the elements necessary for determining the current velocity and direction.

This report would not be complete without a description of a typical float run. Preparation includes a constant watch of both river and weather forecasts. About one week prior to the day for which the desired river stage is forecasted, all ground, boat and aerial crews involved are alerted. Early on the morning of the picked day a report is received on weather at the project site. Sufficient ceiling and wind of less than five miles-per-hour being forecast, the photographic crew is notified to report. Ground and boat crews at the site transport the floats to the upstream boat, read the river gages, set their watches with the master clock and take their positions. Upon arrival of the plane crew the flight plans for the day are gone over, their watches are synchronized with the master clock and they take off.

The upstream boat crew indicates by radio that they are on line and ready to release. A flag is unrolled at the point "A" corresponding to the start of flight line number one. The plane is maneuvering into position and the boat is ordered to begin dropping the floats and reports back that they have started. A second flag is unrolled at point "B." The plane flies down stream taking photographs, turns and flies up stream taking photographs. Some floats scurry along, therefore the third flag is unrolled at point "C" and the flag at point "B" is rolled up. The flag is left at point "A" because some floats are caught in an eddy and are slow to come down stream.

A flag is unrolled at point "D" and the flag at point "C" is transferred to 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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