HINTS TO HYDROGRAPHIC SURVEYORS

A FEW TRICKS IN RECONNAISSANCE

by

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(Extract from *Geodetic Letter* N° 9 - Vol. 2, Washington, November, 1935).

In profiling a line or determining the relative position and elevation of a proposed triangulation station or prominent object, particularly in fairly open country, there are some short cuts available to the reconnaissance engineer which not only reduce the time but also increase the accuracy in obtaining this data. Following is a description of some methods used in the field to this end. Instruments required are a hand azimuth-compass, transit with vertical circle (reading to one minute is sufficient), a tape at least 100 feet in length, and a slide rule. The last mentioned is not necessary, but is of great convenience.

Many times each day, during the course of triangulation reconnaissance, the knowledge of the distance and relative elevation of a water tank, hill, tree, house or some other object, becomes highly desirable, either in determining the position and elevation of the object itself, or the reverse; i. e., the determining of the position and elevation of the observation point from a known object.

The distance and relative elevation of an object not more than 12 miles or so away can be determined in 5 or 10 minutes with an accuracy of about 0.2 mile and 5 to 10 feet of height. No mathematical tables are needed. All that must be known is that the earth's curvature in feet equals 0.574 times the distance squared (in miles) and that an arc of one minute is substended by 1.53 ½ feet at the distance of one mile.

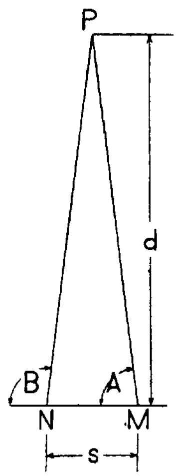

FIG. 1

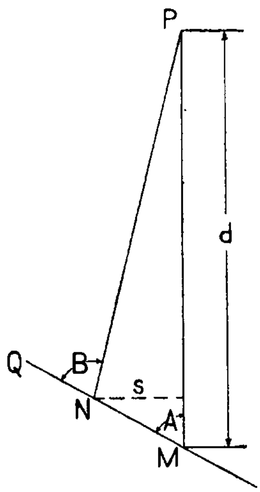

FIG. 2

Consider Figure 1. Required the distance (*d*) from the instrument position at *M* to an object at *P*. (The angle in this figure is greatly exaggerated.) Select a point *N* at a distance of *s* feet from *M* and at about a right angle from *P*. Measure angle *A*; then set over point *N* and measure angle *B*. Angle *P* then is equal to *B* minus *A*. In other words a distance of *s* at the observation point subtends an angle of *P* at the distance *d* of the object concerned. The distance *d* then becomes $s/1.53\frac{1}{2}P$; *d* being in miles, *s* in feet and *P* in minutes. The principle involved here is, of course, very simple. Difficulties arise, however, in actually accomplishing this measurement in the field in a reasonable time and with an accuracy sufficient to make the result of any value. It will readily be seen that the instrument must be very accurately centered over *M* and *N*, which, in windy weather would take considerable time. This difficulty is overcome by first selecting a second distant object *Q* anywhere from about 1/4 mile on up — the further, the better. And this object does not necessarily have to make a right angle with P but any angle — say from 35 degrees to 145 degrees. The nearer this angle is to 90 degrees, however, the more effective will be the base.

The instrument is now set up over M and sighted toward Q (see Figure 2) and the point N lined up with Q at a distance of, say, an even 100 feet. Angle A is now measured using Q and P as sights, and, leaving the plates still reading angle A, the instrument is set over N and the angle B is "unwound" from P to Q, and what remains on the plates (negative in this case) is angle P. In case angle B is measured first, then the value P on the plates will be positive after the mechanical subtraction. If a minute transit is used and the distance d is very great, angle A should be "wound up" three times at M and "unwound" three times at N, leaving a value of $3P$ (negative) on the plates. The 100 foot base (MN) is reduced to the effective base s by multiplying by $\sin A$ (slide rule). If d is about 10 miles, an error in the base of one foot will affect the result only about 0.1 mile; and an error of several inches in the alignment of point N, if Q is at a considerable distance, will have no appreciable effect in the result. Point M need not be marked on the ground at all, and N only with a rock or stick until the instrument can be placed over it. No plumb bob is needed. The instrument can be placed over N by eye closely enough.

If one man is working alone, the point N can be occupied with the instrument first and M then lined up with N and Q by eye, hooking the tape to the instrument over N and backing up, say 100 feet, and dropping a rock in line at this distance.

For distance d up to about 5 miles, an accuracy of better than 1/4 mile can be determined merely by setting up at M, measuring A, picking up the instrument and pacing 100 feet toward Q and "unwinding" angle B at N. Points P and Q may be the top of a water tank, gable of a house, branch of a tree, rock on a hill or any object on which a fine pointing can be made. A greater accuracy can be obtained by increasing the length of the base, but 100 feet is sufficient for distances up to about 12 miles, and is convenient when a 100 foot tape is used. The relative elevation of P can easily be determined, of course, from the vertical angle to it, after the distance is known. Many times during the profiling of a line the elevation and distance of an intervening possible obstruction are desired. These can be determined with sufficient accuracy by the "pacing" method mentioned above, in about two minutes of time.

In open country, relative elevation of all stations can easily be determined from prominent objects such as water tanks, grain elevators, hills, etc., and in sectionized country where all points can be plotted accurately, there is no need for the measurement of distances, merely of vertical angles. This reconnaissance party has been supplying elevations of all stations after making ties to known sea-level elevations. At times it has been as much as 200 miles between ties, but the elevations have never failed to check better than 25 feet except once when the error was 40 feet.

Once the relative elevations and distances between stations of the reconnaissance are known, there is a very rapid method (in open or fairly open country) in determining the height of signal that will be certain to clear the line. The field work consists only of taking the maximum vertical angle to anything on line from each end of the line; i. e., set up at one station, point the telescope to the other by means of a compass, and tilt the telescope upward until the center horizontal hair just clears everything on line, allowing, of course, for small errors in horizontal pointing, and read the vertical angle. This process is repeated at the other end of the line. The point where these two verticals meet represents the worst possible obstruction in the line, and if signals are computed and erected to clear this point, an obstructed line cannot result. However, if the objects to which these vertical pointings were made from each station are a considerable distance along the line, the computed signal height will be too great. The nearer these two objects are, the more closely the computed signal heights will represent those necessary to just clear the line. It very often happens that the two verticals are taken to the same intervening ridge, line of trees, buildings or other obstacles; or, if not the same, to obstacles fairly close together. When this is true, no better determination of the necessary signal height can be made. It also happens very often that the signal heights computed in this way are equal to or lower than those needed over other lines, and further investigation of the line in question is automatically eliminated.

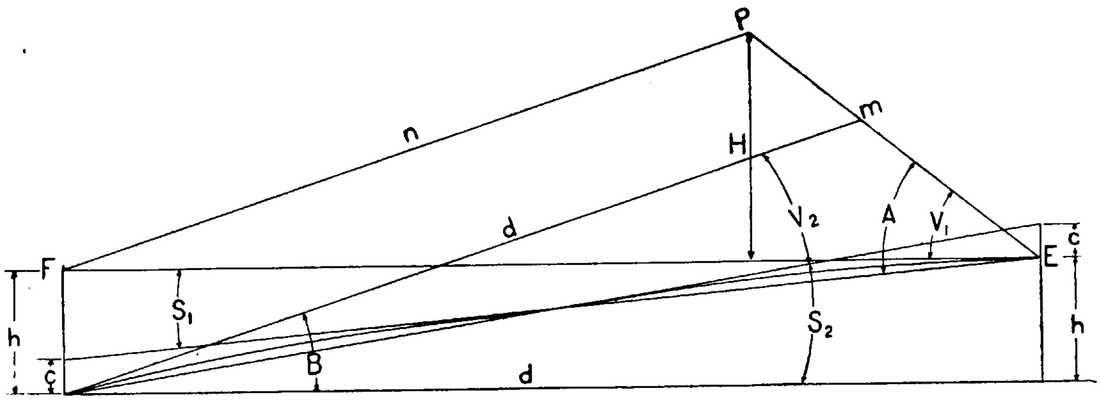

FIG. 3

The solution of this problem is indicated below. Consider Figure 3 :

E and F are the stations at each end of the line in question.

d is the length of the line in miles.

V_1 and V_2 are the maximum verticals in minutes taken from E and F respectively.

S_1 and S_2 are the actual slopes of the lines EF and FE computed at E and F respectively, taking into consideration the difference of elevation between E and F and the curvature over the line EF. It will be seen that these slopes (expressed in minutes in this problem) are different, as the curvature will have a negative effect in one case and positive in the other.

P is the point at which the two maximum verticals meet.

H is the vertical distance between P and the line EF, in feet, and is the signal height necessary at both E and F to clear P.

m is the distance, in miles, from E to the point P.

n is the distance, in miles, from F to the Point P.

A is equal to V_1 minus S_1 and B is equal to V_2 minus S_2. Both A and B are in minutes.

The curvature over the line EF is $.574\,d^2$.

Assuming h to be the difference in elevation between E and F, (F the higher station) expressed in feet, then

$$S_1 = \frac{h - 0.574\,d^2}{1.53\,\frac{1}{2}\,d} \quad \text{and} \quad S_2 = \frac{-h - 0.574\,d^2}{1.53\,\frac{1}{2}\,d}$$

A and B then can be readily computed from the above formulae.

Now, as A and B are relatively very small angles, we have

$$\frac{A}{B} = \frac{n}{m}, \text{ and } m + n = d.$$

m and n can quickly be solved on the slide rule, by setting up the ratio $\frac{A}{B}$ and running the glass along the rule until two quantities are found which add up to d.

H then equals $1.53\,\frac{1}{2}\,mA$ or, for a check, also equals $1.53\,\frac{1}{2}\,nB$.

The height of signal needed to clear P then is H feet at both E and F. In case equal signals are not desired (a higher signal may be needed at one station for some other line, thus making it possible to reduce the signal at the other station) then, for example, if the signal at E is raised 26 feet, the signal at F may be reduced $\frac{n}{m} \times 26$ with safety.

The above solution may appear a bit too formidable for field use, but a very small amount of practice has proven that it can be done easily in three minutes of time. This method of computing signal heights makes it unnecessary to get on the intermediate point for instrument work, and as the maximum verticals taken are to the top of the obstruction, no separate measurement or guessing of tree heights or building heights need be made.

Of course, there are types of country where these methods will be of little use, but it will very rarely occur where at least a modified form of one or all of these methods cannot be employed to advantage.

DETERMINATION OF OFFSHORE POSITION BY SEXTANT ALTITUDE OF MOUNTAIN PEAK.

(From an article by SANFORD L. CLUETT,
published in the *United States Naval Institute Proceedings*, Annapolis, Nov. 1935, p. 1665)

The formula for determining the distance of a mountain peak that lies beyond the horizon is simple; but its solution is too tedious to make it of practical navigational value.

In the March, 1933, issue (page 397) of the U. S. Naval Institute Proceedings, Lieutenant-Commander A. F. FRANCE, U. S. Navy, gives a practical solution of the problem which is taken up to-day Mr. Sanford L. CLUETT.

Let D = distance in nautical miles from observer to top of mountain,
h = height of eye above sea, in feet,
m = observed angle in minutes of arc between horizon and distant peak,
H = height of mountain, in feet,
R = mean radius of the earth (taken at 20,890,590 ft.),
c = coefficient of terrestrial refraction (taken at 0.07269).

But light has a curved trajectory which, within the limits of this problem, may be considered the arc of a circle whose radius we will call R_r. Furthemore $\frac{R}{R_r} = 2c$.

It may easily be established that the general relationship which interconnects the above quantities is the following :

$$O = D^2 + D\ (m\ 2.339 - 2.30\sqrt{h}) - 1.3225\ H + 1.3225\ h.$$

This is the general equation from which graphs may be easily constructed for any height of eye and for any height of mountain.

While the accompanying graph is computed for height of eye of 9 feet, it may be used with sufficient accuracy for any height of eye between 6 feet and 16 feet without entailing graph reading errors greater than 1 mile.

When height of eye is 9 feet, under normal atmospheric conditions the graph is correct to within 0.2 miles.
