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Accuracy Standards for Topographic Mapping

THERE ARE SEVERAL standards for vertical accuracy of topographic mapping that can be quoted, the most common of which is "90 percent of points tested shall be within one-half a contour interval of their correct elevation plus the elevation equivalent to a shift of the contour through the permissible horizontal error." This is a clearer way of stating it than the method that reads "not more than 10 percent of the tested points shall be in error of more than one-half a contour interval of . . . ". In both instances, it is stated that the 10 percent of the points having error in excess of one-half a contour interval shall not have errors exceeding a full contour interval. Tracy (6) says that opinions regarding these specifications are of two types. One is that the majority of topographic maps published would prove to be less accurate than required by the National Standards. The other is that the time will come when the allowances of errors will be reduced. A review of more recent opinions shows the same doubts about the standards exist, some saying the standards are too stringent, others saying they are not stringent enough (1, 2, 3, 4, 8). This continued review of the National Standards is in order as new tools and methods are applied to the production of topographic maps.

ABSTRACT: *It is believed that the National Standards for Topographic Mapping are designed to produce a tool for planning and estimating, and that there is a body of opinion that suggests these Standards can be more stringent, thereby extending the usefulness of the map. This paper defends the present standards on the basis of the increased costs involved in achieving a higher standard. No objection is made to the suggestion that standard deviation be used to state the standards, nor is its adoption seen as reason for completely abandoning the present standards.*

The standards seem to allow plenty of error so it is surprising to find there are still those who feel the standard is too demanding, especially in view of the improved map production that is available. This is further supported by Thompson and Davey (2) who point out that the Europeans use more stringent standards. Great Britain and Germany both do, Germany being the most stringent.

One must doubt that this opinion of the standard being too demanding is shared by those who make topographic maps by classical methods. After all, it is not difficult to limit stadia errors to say ± 0.2 ft. vertically, and even though there will be considerably more error in the contours due to interpolation between stadia shots, one still feels compelled to believe he can arrive reasonably close to the given standard. One is especially impressed with the feeling of safety that the student or person with limited experience has of the method, for it is next to impossible to convince him that he can expect something this far from perfection. The uninitiated will not appreciate the realism of the standards until he has attempted to see through undergrowth around streams, terraces and steep terrain while attempting to map to a one or two foot interval. For these conditions he will come to find out the standards are demanding enough, or, if not, perhaps a little on the permissive side and realistically reflecting some reasonable factor-of-safety between the possible and the probable.

The photogrammetrist on the other hand, cannot help but find the standard next to impossible in areas with heavy vegetation. On open ground he should be convinced that his point-by-point solution of the contour is superior to the interpolation of the classical method, even though there is a lower precision in individual vertical points. In sum, these people would be expected to find the Standards too restrictive, especially when using photography flown as high as economy will permit and field control that is not without error.

If this is the way various groups are inclined to judge the standards one should be able to conclude that the National Standards are realistic. Practical mapping, which will consider precision along with cost, will likely use all of the factor of safety implied in the standards. This is borne out when one notes other more permissive specifications like "85 percent of all elevations interpolated shall be within one-half a contour interval and not more than 5 percent of all elevations shall show errors *in excess* of the contour interval" (6).

An interesting alternative that suggests some flexibility is "for traverse closures of 1/10,000, 90 percent of the points less than one-half contour interval, for closures of 1/5,000, 80 percent of the points and of 1/1,000, 70 percent of the points" (6). This is hardly helpful because the vertical precision then depends on the horizontal precision which, itself, is difficult to decide. One might just as well use scale, size of area to be mapped, and plotting precision, for these should control the horizontal precision.

The literature has suggested that several specifications may be needed according to the use being made of the map (2) (4). The categories of use are: (1) research, (2) engineering, (3) planning and inventory. Because expenditures can be supported in the same order, it is obvious that specifications should reflect that fact. Research specifications can be tailor-made for each project. Planning is probably satisfied by the current specifications. The difficult one is engineering for it too often happens that areas needing critical evaluation are identified by the planning map. It would seem that two mapping efforts might be needed, each with its own specification.

Certainly there are attempts made to use the topographic map to solve problems it is incapable of solving. This will continue to happen until the standard of the map is noted in some way. This should be especially true for the private engineer offering mapping services to the public, for then the standard can be set in accordance with the cost and use to be made of the map. It it is an architect's intention to use the map for earth quantities, he can specify areas for more stringent effort, justify the greater cost or make whatever compromises should be made. Not until one is required to declare an actual cost is the question of required accuracy seriously entertained.

We should recognize that those who finance a map and who are not familiar with problems of achieving precision in measuring and mapping expect accuracy. They are not to be blamed if those performing the service have never suggested otherwise. Criticism is then leveled at a map on which a building was laid out with a difference in elevation of 25 feet between corners, but when laid out on the ground is 25 ± 1.3 feet. Had the map carried the note "90 percent of points within plus or minus one-half contour interval," the map user would have understood the satisfaction of the map maker. The user would also have been warned that estimates of excavation can be obtained but final quantities need cross-sections from another source.

One other problem which exists, whether the present specification is retained or whether it is made more permissive or more demanding. Many say the language should be changed to a scientific statistical language whereby only a statement of standard deviation would be required. The points made favoring this are: (1) a universal statistical language is preferred over the specialized empirical one in use; (2) the one in use does not reflect to what extent the errors exceeding one-half a contour interval do exceed that magnitude; (3) the standard deviation completely indicates the error distribution because it behaves with a normal distribution (7).

Although the statistical language is more attractive, it should be clearly understood that if formulas of the type (3),

$$d = 0.3\ (C.I.) + 24t \quad \text{(for 0.02 inch permissible horizontal error)}$$

where

d = standard deviation for 1:24,000 mapping only
$C.I.$ = contour interval
t = slope of ground

are adopted, it is exactly equivalent to the specification now stated, and, as a matter of fact, derived from the current specification. Therefore, one can expect that the two could be said side by side as equivalents. There is no validity in objecting that the current specification does not reflect the slope of ground because the standard deviation itself changes for every portion of the map of different slope. It would be intolerable to assign errors to flatter areas of a map on the basis of average slopes in excess of these flat areas, and not economical to reverse such selection of slope.

It should also be understood with respect to the second point, that very little is guaranteed by the standard deviation about the magnitude of errors exceeding the standard deviation. Inasmuch as the only guarantee given by standard deviation is that *large* errors are not as probable, so errors of any magnitude exceeding it are possible. As a consequence, the maximums suggested by the current standards define maximum errors with greater certainty than with standard deviation.

Something similar to this must be said about the third point. Standard deviation is only significant to a normal distribution. Blunders and systematic errors create skewed distributions and it has been shown by Webster (8) that systematic errors are notably apparent in the photogrammetric method. Like other statistical methods, it is difficult to find criteria for rejecting blunders, if they should be rejected at all. The magnitude of systematic error likely varies between each camera-plotter combination used. Certainly, exhaustive studies would have to be made to be able to assign maximum errors probable in routine mapping.

There appears to be sufficient reason then to write the standards both ways, for then both the frequency and magnitude of error is suggested as well as a maximum.

WEBSTER (8) has concluded that "the vertical accuracy specification adopted under the national standards for mapping will not assure us a product that will produce data for earthwork computation within acceptable tolerances." It is his opinion that ". . . the standard adopted was intended to satisfy the extensive mapping program which produced a relatively small scale type topographic map." He ran tests to see if mapping done photogrammetrically to National Standards would give volumes within ± 3 percent of the actual volumes. It was not surprising that 90 percent of points being off 2.5 feet using a 5-foot contour interval would not do it. The promising discovery was made that if the photogrammetric profile was adjusted to the ground profile, the volume precision was in the order of $+0.6\%$, $+0.9\%$, -0.2%, $+3.0\%$, -1.1% and 1.3%. It would seem proper then to continue mapping at the present high efficiency and doing this very simple adjustment.

To make the specification more stringent will add considerable cost to mapping. One must repeat how difficult it is to do *large*-scale mapping of rough terrain economically using classical methods. It does not seem proper to create higher costs of mapping for the sake of doing a particular task on a highly restricted portion of the map. Rather, the addition of data to these areas of intensive use likely represents the efficient approach.

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Articles for Next Month