SOME PROBLEMS OF THE SURVEYING PROFESSION AS SEEN BY A RETIRED ENGINEER

By Carroll F. Merriam*

(Presented at a meeting of the Surveying and Mapping Section, B.S.C.E., held on April 5, 1961.)

Your chairman has referred to a past president of this Society, the late Charles M. Allen, as having made the introduction which led me to thirty very satisfying years in the employ of the Pennsylvania Water & Power Company in Baltimore, Maryland. I can assure you that if it had not been for the unusual experience with the engineering department of this company I should not be speaking before you this evening. I consider myself extremely fortunate to have profited by the encouragement of a public utility executive who had extraordinary foresight and who permitted me great latitude of interest and activities. If the views that I express seem to you a bit starry-eyed and idealistic, please consider the happy circumstances which have led me to believe as I do, and kindly appraise these thoughts accordingly. Realizing that I have never as far as surveying is concerned been faced with the problems of making both ends meet financially, I do not wish to assume a position of dictating to practical men as you are.

The one excuse that I have for taking the time of busy men, is that I am not a busy man myself. Generally my week's work is done by 10 o'clock each Sunday morning, having wound two clocks. In whatever of the week there is left after that, I have opportunity for contemplation, experimentation, fragmentation of the woodpile, elimination of dandelions and other minor distractions. Yet with all this leisure, and in spite of the long boring winter evenings that friends predicted would be my fate on retirement to a little Maine Coast fishing village, bedtime usually finds me at the drafting board, the computer or the typewriter engrossed in some study so interesting that I am reluctant to set it aside.

My own interest in surveying began as a mere incidental in connection with the development of a controlled base for property surveys for the power company. One thing led to another and in 1938 I was asked by Abel Wolman, then chairman of the Maryland State

* Past President of The American Congress on Surveying and Mapping.

Planning Commission, to serve on the committee charged with drawing up the enabling act authorizing the use of statewide plane coordinates, an act which in addition to following the pattern of the so-called "model law," established a Bureau of Control Surveys and Maps. In spite of the fact that I have never considered myself either a surveyor or a mapper, I was accepted into membership of the American Congress on Surveying and Mapping at its first public meeting in 1940 and fourteen years later became its tenth president. Thus I have had opportunity to gather many impressions from a wide range of contacts.

The impression that stands out in my mind most vividly is that surveyors, in contrast to the freedom from pressure that I have enjoyed both before and after retirement, are so pressed and harassed either because of the actual job at hand, or else worrying where the next job is going to come from, that they have little time to consider the larger aspects of their profession. One of my respected professors had an apt expression when confusion reigned in his class in shop management, "Gentlemen, let's sit down and see where we stand." It might be well for surveyors to do the same. There is always the possibility of settling into a rut.

I don't mean to imply that surveying has become stuck in the mud, far from it, although I must admit that many people including some deans of engineering colleges regard surveying as a subject so outmoded that it is hardly worthy to hold a position in engineering. A common view appears to be that surveyors should now be turned loose to ply their trade along with the butcher, the baker and the candlestick maker. The answer to those who hold doubts as to the progress that is being made in surveying is to see for themselves the exhibits at our annual meeting in Washington, to hear the papers discussed, and to talk with the men who are attracted to this annual assembly. If a trip to Washington is out of the question, the magazine "Surveying and Mapping" should convince the most skeptical that the profession is far from passing over to the status of a trade.

That we are advancing at a rapid pace is not subject to debate. The facts are clear; and I shall not attempt to review the accomplishments which continue to astonish me. Instead I shall turn to the other side of the picture, and pose for you one question which seems to me vital. Are we making comparable progress on all fronts, or are we blind to those sectors where we may be lagging? This is my

main theme. While I am no longer in a position to give you an authoritative dissertation on the latest applications of photogrammetry, the measurement of distances by the speed of light, the use of the self levelling level, new and improved instrumentation, electronic computers, optical tooling, and a long list of others, I can still ask you to stop and consider whether in our rapid advance we are still leaving stones unturned along the path.

We can take as our point of beginning just a personal hobby of mine. When I first became associated with the U. S. Coast & Geodetic Survey and because of interest shown in the work was asked to become what they term a collaborator my reaction was that even at headquarters they failed to see the full importance of future potentialities. To be sure the men of the Survey have done excellently in adhering to the principles laid down by their founder, Ferdinand Hassler, a century and a half ago, but I find on looking over the text of the first paper that I was asked to give before the American Congress on Surveying and Mapping, even then I questioned seriously whether my friends in the Survey fully appreciated what lies beyond. The foundation is well laid, but I fear that few see the cathedral that is to rise upon it. To be sure the need for an accurate base for maps is well appreciated, but do we see the importance of this same framework as affecting the lives and fortunes of Smith and Jones? It is merely an extension of the same idea, to use that framework which holds maps together, to establish the true relation between surveys of property. When we accomplish this we shall be fairly on the way to solve one of the pressing and incidentally distressing problems of modern society.

The immediate answer is that this is too much to expect, merely impractical wishful thinking. Certainly at present we must admit that in by far the majority of situations, the ideal tie to horizontal control is out of the question. The cost is generally too great for the job to bear. The reason—because in only a relatively few locations is there sufficient density of control.

Should we let the matter drop here, thus taking a defeatist attitude? We must keep in mind that there are cases where a tie to established triangulation stations is relatively easy. The question is whether surveyors are alert to recognize these situations and take advantage of them, and so bring us a step nearer the ultimate goal?

If the stumbling block is insufficient density, how then can it best be overcome? Right now I am well aware of the density required for general application of plane coordinates for property surveys, and it is obvious that it is not reasonable to assume that the U. S. Coast and Geodetic Survey should undertake the entire burden of providing it. There must be some point at which the federal government leaves off and the state takes over. In many states this line of demarkation has already been established and there is set up within these states some form of organization, which is to the state what the Coast & Geodetic Survey is to the nation. Under the leadership of inspired engineers, some cities, such as Baltimore as far back as 1895, appreciated the importance of a fixed and stable base for property surveys and made wise provisions which in the light of more than a half century of experience have proved excellent investments. Unfortunately the states which have been willing to look to the future in this respect appear to be few in number. Is this failure a stone we are leaving unturned?

In the states that can be ranked as progressive, and I certainly consider my native state of Massachusetts in that category, are we taking all the advantage that we can to obtain the desired density of control points? You know more about that than I do.

Where, in general, can surveyors in the less progressive states look for help? What state agency is at present doing the major amount of surveying, has on hand the greatest wealth of survey records, and is in the best position to profit by further advance in control surveys? I believe that there is not a state in the Union where the answer would not be the Highway Department. Still in at least one of these New England states, and even after 16 years since the adoption of plane coordinate systems, highway surveys are still made with reference to a magnetic or even an arbitrary meridian while as far as position on the face of the earth is concerned, they are "free floating." Beyond the purpose for which they were made they are without permanent value. Now from the point of view of road construction alone, and considering only the requirements of the immediate present, such a policy is good economy. Why burden the road with additional cost that doesn't add a cent to its value as a means of transportation?

This is true, but just consider an ordinary right of way map. Regard the amount of work that has gone into the delineation of

property lines alone. Think of what this would mean if all this information were to be recorded with reference to an established cadastral base and so made a permanent record available to land surveyors. To be sure plans are filed in county court houses where they may be looked at and studied by surveyors, but there is no ready means by which surveyors could with confidence take advantage of what has been done, and be sure that the final result will be in harmony with the surveys of adjacent properties. Have we failed to impress upon highway commissions the vast potentialities of savings for the public, as well as eventually for the taxpayers, if with a little foresight they could plan for future economy.

Perhaps we should consider the problem a step further. Commissions are not altogether their own masters. Above them stand the taxpayers. What are surveyors doing to convince the general body of taxpayers that the present policy of failing to provide for the future is penny wise but pound foolish? Of course the politician is to be considered, but remember that the Coast & Geodetic Survey was founded by a man who had the courage to tell politicians exactly where they got off in no uncertain terms. Thanks to the fact that he did not yield to political pressure, the modest beginnings made over a century ago still meet modern standards and did not have to be done over again at great expense. We now benefit as a result of the strength of character shown by a man who would not compromise between scientific truth and expediency. Should we not still follow his example?

How may this task best be picked up where the Coast & Geodetic Survey ought to leave off and the state take over. There are conventional methods which require somewhat specialized knowledge of geodesy, specialized equipment for running precise traverses, and specialized talent. The new methods for measuring distances by the speed of light are coming into use and proving valuable for extending control nets. But are we aware what can be accomplished by more modest equipment, less advanced mathematical knowledge and skill? For example can the average common or garden variety of surveyor help himself by a little triangulation now and then? Can a central agency build up a valuable collection of basic control data without specialists in the field of high order surveying, or even without instruments of high precision? My answer is "yes," because I have seen it done.

However, to accomplish this it is first necessary to accept a somewhat new concept as applied to plane surveying. It is an elementary concept found at the outset of any course in analytic geometry, and even in school texts on algebra. It is merely that a straight line can be defined by an equation in the form $x = ay + b$. If a surveyor takes a sight from a point having known coordinates and observes the azimuth, then all of the information is available for describing that sight by an equation of the first degree. Now, if two sights are taken on a common intersection point, the unknown coordinates of that point may readily be found by solving two simultaneous equations. All of the complication of the oblique triangle is entirely eliminated.

Why has this not been commonly practiced previously? For a very definite reason; which is that equations in the above form are not convenient for solutions by logarithms. Now here is a snag which has led me to an interesting observation. I have found, by and large, that surveyors have been surprisingly slow to appreciate the introduction of a new element which greatly alters the situation. This is the advent of the desk computer. Too often the surveyor looks to the computer as a handy and quick substitute for logarithms. He is quick to see that the machine combined with use of natural functions, is more rapid than use of logs, but unfortunately he is all too prone to follow the same mathematical procedure, oblivious to the fact that the machine frees him from a serious limitation that you cannot add and subtract with logs. Consequently, many simple and useful formulas are disregarded by the surveyor.

Let us now look beyond the solution of a single oblique triangle. Let us suppose that three or more sights have been taken on a common intersection point. Mathematically a precise solution is impossible because of ever present error and the fact that we have more equations than there are unknowns for which to solve. That is a common dilemma and in spite of application of least squares we can at best arrive only at the most probable result. Should we stop there?

Please understand that I am in no way critical of procedure used by the Coast & Geodetic Survey at national level. The adjustment of large triangulation networks is a specialty in which the Survey excels, but when we come to work at state level again a new element comes into the picture. This is the use of plane coordinates which enable a surveyor with no knowledge beyond that of plane

surveying to make surveys of as much as 140 miles in extent with a maximum scale error of less than one part in 10,000. By proper supplementary corrections this error may be still further reduced to any desired practical limit still without resort to what is commonly known as geodetic surveying.

The use of plane coordinates at state level for applications that would otherwise require geodetic surveying may seem in itself rather unimportant since it would appear to be merely permitting work to be effectively done by men with less specialized training. But there are other factors to be considered. One of the fundamental limitations in adjusting a triangulation net is that the number of data must equal the number of conditions to be met. If more data are available some must be neglected, and the selection has to be made on the basis of first determining which of the given quantities are the most likely to give the strongest solutions. All others must be neglected and there is no assurance that along with them go observations that may actually be more reliable than those that are retained, particularly if in the data actually used there is what your former president termed "snish."

The method developed by the Maryland Bureau of Control Surveys and Maps completely eliminates this undesirable feature. Inasmuch as all of the data are retained, no study of strength of figure is required, and furthermore when "snish" does creep in, the effect becomes so obvious that it does not fool anybody, at least for long. I shall not go further into the details since description of the method is available on request in Publication No. 3 of the Maryland Bureau of Control Surveys and Maps.

I have found that by application of the method so described, under some circumstances, use can be made of observations of surprisingly low order of accuracy. Hence, there is an interesting possibility that with proper supervision in compilation and computation, a central agency could collect miscellaneous observations from many and diverse sources without danger of misleading results.

I have in the past seen great concern when coordinates of stations as determined by one survey fail to jibe with those as determined by other surveys. I have witnessed acrimonious debate for example when city surveys of supposedly high order of accuracy have been extended to connect with previously established points of a larger triangulation net. There has been much fuss and fury over a matter

the solution of which has been found to be rather simple as shown in Publication 2 of the above mentioned Maryland Bureau of Control Surveys and Maps. Another danger that faces us is that when connection is made between arcs of triangulation, both adjusted within themselves as well as possible by least squares, discrepancies of appreciable magnitude will show up. From personal experience, I am of the opinion that much of this fear is unfounded and that the little discrepancy that may become evident is rather easily adjusted. My question at this point is whether we are prepared to meet such situations when they arise, with assurance that we shall not make a mountain out of a mole hill?

I personally have great confidence in the ultimate use that is to be made of state-wide plane coordinate systems, but some of my observations regarding their adoption and use to the present time incline to make me feel that the engineering mind has not been as influential as it should be in this scientific age. In the first place, what little experience I have had in urging the passage of enabling acts in two states makes me believe that few legislators have more than a very vague idea what they voted for. Apparently the respect that they have for some outstanding engineers is depended upon, and they are willing to support any bill on the "say so" of these engineers providing it carries no appropriation. Consequently we have lots of enablement without any means of implementation. The result is that in most states there is, at least for the present, practically complete stagnation.

I am not sure that this is a bad sign, because if each state were to be carried away with wild enthusiasm and immediately jumped into poorly considered moves such as publishing coordinates as determined by Tom, Dick, and Harry, untold confusion would certainly be the penalty. I consider it far better to let the law rest in peace, wrapped in mummy cloth until influential engineers and surveyors become sufficiently familiar with risks of impetuous action to cause them to proceed with caution.

It is interesting to trace the history of adoption of plane coordinates. In general, certain eastern seaboard states were the first to act. These states being close to the coast naturally possess an initial start of relatively dense control networks established by the Coast & Geodetic Survey. They are also the states with high population density and high land values. Following the initial start

consisting of Massachusetts, New York, New Jersey, Pennsylvania, Maryland, and North Carolina, the idea began to spread from one state to another in general along both Atlantic and Pacific Coasts. There can be observed contagion which causes one state to follow the lead of those adjacent, the notable exception to this rule being the case of New Hampshire which even yet has not legally adopted the system in spite of the fact that it is the sole remaining "hold out" in New England. Some of the Great Lakes States have recently joined, but in general the vast interior of the country resists invasion. There is probably some connection between such reluctance and the fact that these states were fortunate enough to have rectangular division into townships, sections, quarter sections, etc. Either the need is not felt, or else there is an unfounded fear that state coordinates will be in conflict with the established system. Another curious observation is that the greatest progress in obtaining converts coincided with the latter years of World War II. Since that time only one new state has been added and at the present time only three are considered as about to hit the saw-dust trail. It is sad to think that progress in such a humanitarian endeavor as mapping should throughout history have been so generally associated with times of conflict.

I have recently been greatly impressed with the adaption of high speed computers to surveying problems. It is obvious when we consider the tremendous capacity that these machines have, and incidentally the rentals charged, that more and more we shall turn to data processing centers designed to receive the raw product from large numbers of surveying concerns and to deliver in short order the fully adjusted results. The question is whether we are not jumping too rapidly from the time honored hand computation with traditional logarithms to the highly developed data processing devices, which may be all right for surveyors near at hand, but not so convenient for many firms in more remote localities. Are we perhaps neglecting a middle course more suited to the surveyor not fortunately situated so that he can rush his data in and get it back again almost while he waits? I am convinced that before we go too far we should consider how the conventional procedures when using logs, can be greatly simplified by recourse to the ordinary desk computer. For example, do you use the DMD method to compute the area of a polygon of which the coordinates of the corners are already known?

Can you solve this directly on the machine without touching pencil to paper. Still again can you compute a traverse without listing sines and cosines, eastings, westings, northings, and southings? Can you solve for the diagonal distance between two points with given coordinates without setting anything down on paper but the final answer? Can you solve a three point fix without referring to your trigonometric tables except once to look up the cotangents of the observed angles? If you are not so placed that you can get this work done for you almost instantaneously, would you be interested in knowing how your desk computer can be of greater help?

Returning now to the question as to whether the land surveyor of the common or garden variety, not the big firm, can use control surveys more advantageously than at present, we may ask how many surveyors have the impression that suitable triangulation cannot be performed without instruments of high precision. It is interesting to note that there are a number of published coordinates of triangulation stations in the vicinity of Baltimore which have been determined in part if not wholly on the basis of observations made with a one minute transit of not too high quality even before it was damaged by accident. This instrument is still in use and capable of giving results, judged by horizon closures, of about 3 second accuracy, which is about the limit that could be expected from daytime observations. Such accuracy is far above what would be expected by conventional procedure using a comparable number of repetitions. Are transitmen informed as to how such performance can be obtained when conditions warrant?

We are all familiar with the danger of an open end traverse. To insure reliability necessitates a double run—double cost. On the other hand if such traverse can be made to touch on previously established control points, there is in general an appreciable reduction in cost, and at the same time, an increase in dependability.

When the closed traverse fails to close, there is the wild hunt for the "snish," as Prof. Allen would put it. Where does the mistake lie? The chief of party is ready to grasp at any straws in the hope of saving him from running the whole thing over again. Frequently the straws are within reach, provided the instrument man is alert enough to see them. They are side shots on points of determined positions, church steeples, radio towers, air beacons, water tanks, finials on tall buildings, and all kinds of prominent objects springing

up in densely settled communities. But does the chief have the technique to use these aids effectively? It is a question of being ready. It can be done, and quite simply too.

Another striking impression is the contrast that I experience as I return each year from the annual meeting in Washington and pass as I do from an atmosphere of highly developed technique to that of my little corner on the Coast of Maine where the common concept of a surveyor has advanced little since the days of George Washington and where surveyors are not even registered. Among the hundreds of deed descriptions that I have read, I do not recall any other than those that I have written myself in which any meridian other than magnetic has been used. In spite of the fact that the needle has swung 8½ degrees westward since the original layout of the township, very seldom is any mention made of the date of the survey. Deeds many of which are blindly copied for a small fee from transfer to transfer until they become practically meaningless, with references to long since obliterated landmarks and bearing always on the lands of abutters so long dead that nobody has any idea where they lived, frequently bear only coincidental resemblance to the land they purport to describe. Why we may ask has the influence of progress been so little felt in the realm of the small and isolated surveyor? Are we after all fighting a losing battle against the complexities which are impeding the transfer of real estate? As engineers can we not rise to devise some means of bringing order out of the present chaos?

I now come to what I consider the most serious aspect of the problems to be met by the profession—reproduction of our own kind. Contrary to the habit of old soldiers, surveyors do die. Some retire before passing out completely but many die in harness. Replacement is necessary in order that the work may go on. One solution would be possibly lower expenditure in man hours per survey resulting from more efficient organization as the work becomes concentrated more into the hands of larger firms. It is however, hardly conceivable that this can be counted upon to fill more than a fraction of the gap between the number of surveyors dropping out and the number of new recruits. A striking fact is that the number of recruits needed far exceeds the proportion of technical graduates that should rightfully be channeled into the field of surveying, assuming that we had dictatorial powers over the lives of young men. It has long been felt that the senior, or four year colleges are not doing much to help

the situation by reducing the number of hours devoted to the subject, assigning surveying courses to the younger and less experienced instructors as the place where they can probably do the least harm, and in general depreciating the respect that this profession should have. As a result, the profession must depend more and more on the junior, or two year, colleges. In my opinion even then a supplement will have to be made up of boys unable to go to any college who will enter the ranks through a course of apprenticeship. Consequently, we have the peculiar situation of a profession which holds high responsibility for safeguarding human welfare, at a time when almost anybody with an ambition can find a place in some college, obliged to fall back upon recruits with far from ideal educational background.

This failure of the senior colleges to fill the demand, combined with the rise of the junior colleges to meet as well as possible a situation that is far from ideal, is the natural result of the tremendous drain of technical school graduates into other more interesting and perhaps more spectacular fields. Consequently, these branches which do not have strong appeal have just got to take the pickings or else pull themselves up to a position of higher respect in the eyes of young men making choice of career. Knowing the responsibility that rests on the shoulders of the surveyor, is he going to continue to suffer this loss of potential man power?

Greater reliance on the junior college gives rise to a new situation. Approach to the profession now becomes a double channel, one a full four years course and the other a two year short cut. The first is a broader technical education with surveying, at present, only a rather unimportant incidental and in the future even less important if the present trend continues; the other is a training specifically for technicians. In some professions the lack of fully qualified men is made up for by the technician grade. To this grade is assigned the more functional work where lack of complete knowledge is not a serious handicap. Perhaps this is the division of labor that is to be expected. Whether or not a similar division of labor in the engineering field is a good thing is a matter concerning which I have grave doubts, but still it is apparently the way the world turns, and we may have to accept it as such.

This double approach is something that we must face whether we like it or not. It is for the educators to evaluate both the advan-

tages and disadvantages of each avenue, and do their best to turn out men as well suited to meet life as conditions permit.

To teachers in the four year colleges, I consider it a responsibility in view of the very limited time that will be allowed for surveying, to concentrate on the more philosophical aspects, generalization of principles common to other branches of engineering, ingenuity in the minimizing of errors, appreciation of the importance of surveying in the social whole, penalties paid for poor surveys, etc., as well as the discipline afforded by study of a branch of engineering in which the factor of ignorance is reduced nearly to the vanishing point. But I should urge particularly, in view of this double avenue of approach, the cultivation of appreciation and understanding of the men not so fortunate as to be able to afford the longer training period, but men who will know how to do many things which the four year man may never learn to do for himself.

Likewise to teachers in the two year colleges, I consider it a responsibility not only to teach technique, but to instill a sense of dignity of mastery of operations seemingly elementary but from which "sermons in stones" may be learned, to develop regard for the part played by those who have had the longer period of preparation and above all to provide the inspiration to aim always for higher things, remembering that in the field of engineering the way upward is not yet closed to those who have had limited opportunities at the beginning.

Of necessity the two groups are bound to meet in the field and office. I can imagine nothing to me so undesirable as the development of a caste system based solely on years of formal education. Scorn on the part of one coupled with envy on the part of the other could break up the fellowship which is characteristic of American engineering. My hope would be that each individual as he enters the profession will seek his appropriate place according to his merits and ability in a thoroughly united brotherhood of engineers.

In closing I should like to pass on to you the words of another of your past presidents, Ira N. Hollis, whose valued personal friendship continues through the surviving members of his family to this very day. When he was asked to speak to the boys taking a course of one of his colleagues, I remember well his theme, "When all factors are taken into consideration, theory and practice will agree."

Those entering the profession of surveying will have two points of view characterized as theory and practice. Let us build our educational system and indoctrination into the ranks so that new recruits will take all factors into consideration and find that harmony of which your past president told us when I was one of his boys.