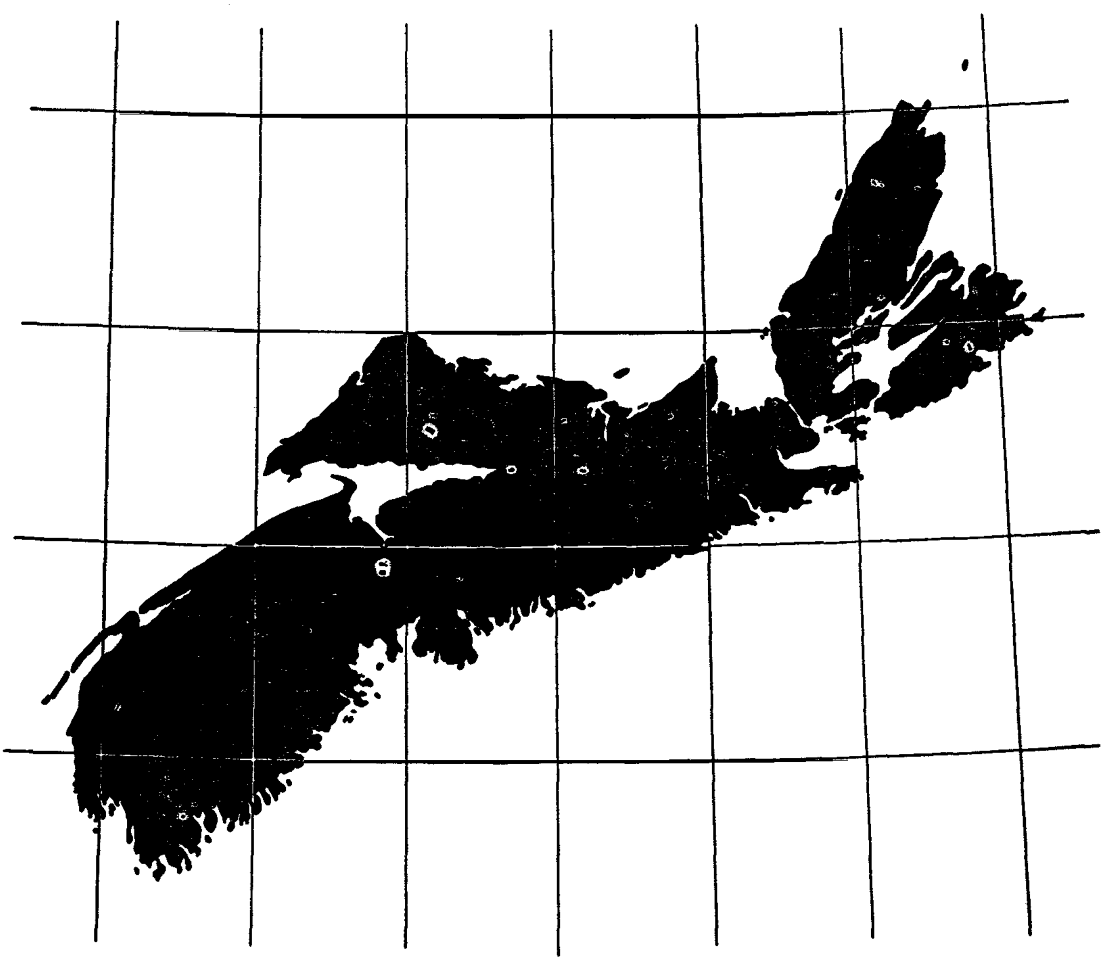
The NOVA SCOTIAN SURVEYOR



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THOUGHTS ON SURVEY MONUMENTS

The importance if survey monuments has been recognized since biblical times, as in "Thou that not remove thy neighbor's landmark, which they in old times have set" (Deuteronomy 19:14) and "Cursed be he that removeth his neighbor's landmark" (Deuteronomy 27:17).

The Canada Land Survey Act defines a monument as "a post, stake, peg, mound, pit, trench or any other object, thing or device used under this Act or under the Dominion Lands Surveys Act, Chapter 117 of the Revised Statutes of Canada 1927, to mark a boundary of surveyed lands". Within this rather all-embracing definition we can divide survey monuments into four types:

(a) Natural monuments such as trees, lakes, rivers, etc.

(b) Artificial monuments such as iron posts, brass plugs, wooden pegs, etc.

(c) Witness monuments which are artificial monuments placed as near as possible to the proper site of a corner when it is impossible or undesirable to monument the true position.

(d) Record monuments such as a clause occurring in a deed or a legal description, as in "South 40 degrees West to the property line of J. S. Farquharson, Esq."

A good monument should possess the quality of being easily found, positive of identification, permanent, stable in position and capable of providing a precise indication of the limit or extent of the property being described.

Artificial and natural monuments each have certain advantages over the other. Generally speaking, a natural monument, such as a river or large boulder, is more permanent than an iron bar, which in time will rust away. A stake is easier to move than a mature oak tree; hence, again, the natural monument is more permanent. On the other hand, a field may contain many large boulders or oak trees but an iron post would be quite distinctive and would leave no doubt as to the correct position of the corner. Good natural monuments rarely occur precisely at the required corner. In general, the natural object serves better as an accessory to the artificial monument rather than as the monument itself.

When bodies of water are used as natural monuments such monuments have a tendency to change position. A line described as "South 40 degrees West to the ordinary high water mark of Rideau Lake" would vary in length over the years, depending on the fluctuations of the weather pattern. This movement is much more serious with rivers, which tend to erode old banks and deposit new ones. This creates endless problems for owners and surveyors alike.

A curious situation occurring in Canada where river boundaries are used in describing Indian Reserves. The federal Department of Justice holds that boundaries are surveyed according to, the original plan and description, and when, in the plan, a distance was specified to an artificial monument at the high water mark on a river bank, that distance holds, regardless of the movement of the river bank. Certain provinces, on the contrary, claim that the rights of a riparian owner follow the gradual wanderings of the river. The inevitable clash of rights is occurring and to date no one knows who is correct.

Record monuments depend for their efficiency and usefulness on the natural or artificial monuments which distinguish them on the ground. These may be iron bars at the extremities of the course in question, or improvements such as fence lines, cut lines, etc.

It has been well established in law that survey monuments hold over distances, direction or area, provided that the monument is mentioned in the deed or plan, the monument is identifiable, and the monument is stationary and undisturbed. Monuments that are widely different from their description, such as a wooden stake found where an iron bar was described, may not hold in law. Dimensions of monuments generally need not be precise; the various descriptions of iron pipe (inside versus outside dimensions, etc.) are often quoted as precedents where a monument was allowed that varied somewhat from its description.

When a conflict in monuments occurs it is desirable that the surveyor governs his actions by the same rules that would obtain in any subsequent judicial process. In this regard, numerous court judgments have been handed down to support the following order of importance of evidence in redefining boundaries:

(1) Natural monuments or boundaries have priority over artificial or record monuments.

(ii) Artificial monuments have priority over record monuments.

(iii) Where two monuments, in all other respects equal, are in conflict, the one more closely agreeing with measurements quoted by the original surveyor in his plan or in his field notes becomes controlling.

(iv) Evidence in the form of fences or boundary improvements which can reasonably be related back to the time of the original survey will become contolling where the true survey lines are uncertain.

Accessories to monuments, such as bearing trees, pits, mounds, etc., are considered in law as part of the monument itself. It is, of course, presumed that a search for the monument will include a search for all accessories, for it often happens that the accessories are the only means of identifying the corner.

CLOSING REMARKS TO THE DISCUSSION
LEGAL SURVEYS AND ACCURACY SPECIFICATIONS

T. J. BLACHUT

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The purpose of this discussion, initiated over a year ago, was to draw attention of the readers to one of the important questions in the field of legal survey.
This question may have a definite bearing on the organization of legal survey and its role in the general survey of the country. Primarily, we had hoped to stimulate individual thinking and to encourage a "private" exchange of opinions on the subject among the readers. From various comments, one may conclude that this goal has been achieved to a satisfactory degree. in addition, a number of concrete, and often contradictory, opinions have been presented in the journal, and it was felt that some closing remarks should be made by the editor before winding up this discussion.

Of course, we did not intend to use the published comments as a kind of "pool" to decide whether or not land characteristics should be considered in setting the accuracy specifications in legal survey. With all due enthusiasm and belief in democratic institutions and proceedings, one recognizes that technical questions must be settled by reasoning and not by voting. Undoubtedly, the subject under discussion is as unsuitable for solution by a majority vote as in the question of the value for the flattening coefficient of the earth. Nevertheless, it is interesting to note that the large majority of those who cared to send in their comments were of the opinion that the accuracy specifications in legal surveys ought to depend upon land characteristics. This does not mean, of course - and I am afraid that this caused an understandable objection from one of the contributors - that each **individual** parcel of land should be surveyed to a different accuracy, corresponding to its value. Rather, the legal survey system is expected to define classes of land, forming larger areas or even entire regions each of a specific characteristic, to which different accuracy specifications would apply.

In my own opinion, a uniform accuracy for legal surveys throughout the country (disregarding the characteristics of the land, and consequently its value) a purely speculative approach that would be extremely difficult to put into practical operation if any substantial degree of accuracy is expected. Such an approach has probably never been carried out anywhere with proven uniformity, not even in countries where legal survey regulations fail to provide different accuracy specifications for various land categories. Is it really thinkable that parcels of land in the Rocky Mountains at an altitude of 10,000 feet, or in muskeg areas, could be staked out and surveyed to the same accuracy as an the center of Vancouver or, for this matter, of Banff or Ashcroft, even if "only" a 1:5,000 relative accuracy is required? But we all know that, for various reasons, even this limited accuracy can hardly be reached, for example, in the densly forested Gatineau Hills, which are just a few miles outside of Ottawa.

Some confusion in these matters is probably caused by a misconception of the meaning of accuracy specifications. Whatever the specified accuracy tolerance is, it must be met. Not only must the surveying method and instruments be chosen accordingly, but the survey program and results must provide a reasonable proof that the required accuracy was really achieved. Closure errors at the higher-order control points, independent checks, etc., may provide such proofs. The use of a precise measuring procedure and accurate instruments alone does not constitute such a proof. Therefore, a specification that stipulates, e. g., a relative accuracy of 1:5,000, but does not forsee the methods of proving and enforcing the required tolerance, or a specification that states, in conditional form, that "a relative accuracy of 1:5,000 **should** be secured", must be regarded as en accuracy guide rather than a specification. Use of accuracy guides only is often justifiable, particularly in reconnaissance-type mapping operations, but it must be realized that it is equivalent to accepting variable accuracy tolerances depending upon various circumstances, the most important ones being the characteristics of the terrain and its value.

Once it is agreed that the specified accuracy **tolerance must be observed, under all circumstances, as it otherwise loses its meaning,** the implication of uniform accuracy requirements throughout the country becomes much clearer and acquires its full weight. Proper understanding of the basic meaning of accuracy specification is the prerequisite in this discussion, which otherwise becomes meaningless.

There are further questions closely connected with the above point that, unfortunately cannot enter into here. Let us only mention **en passant** that the quality of the control, accepted as a proof of meeting the accuracy tolerances, is also an important factor. In this regard, the usual closure error of a traverse loop is not a very reliable control, nor an indication of the accuracy achieved.

As has been stated by C. C. Lindsay, an accuracy of 1:10,000 or better is required in city areas. If uniform accuracy were required throughout the country, as advocated in some of the submissions, should this accuracy requirement be extended to completely uninhabited and perhaps worthless regions? By using modern surveying equipment, such as the geodimeter, this relative accuracy can be achieved more readily in rugged country, and often at less expense than an accuracy of 1:5,000 when using conventional "chaining". Should a 1:10,000 tolerance then be uniformly accepted, since the accuracy requirements within cities would not he satisfied otherwise? By reasoning this way, one cannot avoid the conclusion that the availability of technical means alone, permitting the achievements of certain accuracies is not sufficient ground for accepting given accuracy standards.

An abstract desire "as good accuracy as possible" just for accuracy's sake is not a dependable argument either. There is is no doubt that, in legal survey, an accuracy of 1:10,000 would be more desirable than an accuracy of 1:5,000. The reason, however, why one is not prepared to specify uniformly this higher accuracy is purely economic. One is prepared to pay for 1:10,000 accuracy in cities and developed areas, but one does not see the reason why one should pay a sum of money sometimes higher than the value of the land for the survey of less developed areas, as it was remarked in the discussion. I am referring to the relative accuracy of 1:10,000 to achieve a better contrast, but similar argumentation for any other accuracy specification is equally valid. Today, we have at our disposal a variety of technical means, each with its own characteristic accuracy performance, and, therefore, any single accuracy figure seems quite arbitrary and accidental. Why then should a relative accuracy of 1:5,000 be uniformly accepted throughout the country? Is it just because, at one stage of technological development, one could achieve this accuracy in distance measurement with an acceptable outlay of energy and means?

At this point, an important consideration must be introduced into the discussion. Generally speaking, the accuracy of surveying existing boundaries does not affect, in the least degree, the physical size of the property. In all legal survey systems known to me, the rightful monument defines the location and extension of the property. The survey only provides numerical or graphical information concerning the property but obviously always to a certain degree of approximation. Only when the boundary monuments are destroyed does the physical redefining of the property boundaries become a problem and, in this case, existence of a relatively precise survey system is helpful.

However, to be meaningful, a survey system must also refer to a certain number of fixed and reliable points in the terrain. The question then arises whether the property rights cannot be better secured in remote areas by an appropriate monumentation of boundaries than by a necessarily scanty and isolated survey of the property. Use of photographs, particularly of aerial photographs, is an additional measure that may be considered. The fact that the physical boundary monuments constitute the primary evidence of the location and size of the property has, in my opinion, extremely important consequences. First of all, it removes from purely legal-survey considerations, the necessity of high accuracy standards, and secondly, it permits varying the surveying accuracy to better suit the local conditions and other important economic, including technical, considerations.

In addition, the value of the property seldom depends upon its exact size, up to the last square foot. As a rule, it is a compromise between the price set by the owner and the price that the potential buyer is prepared to pay. If the proprietor is interested in precise knowledge of the shape and size of his land, no one can prevent him from hiring a surveyor and having his property measured to any physically obtainable accuracy, and first of all, from marking his boundary in a permanent and indestructible way. This also applies to land owners in remote regions who hope that their property will acquire a great value in the future. In any event, the argument that a uniform accuracy specification should be applied throughout the country, because some remote lands may change in value in the future, does not sound convincing. After all one does not build auto, routes everywhere in anticipation of the possibility that some of the present roads may become primary communication arteries.

The argumentation for differentiated accuracy specifications, depending upon the land characteristic (value), is based on considerations of general efficiency and economy that rule human activity in any domain. Various authors seem to be surprised that any opposite point of view could even be considered and, consequently simply sated their opinion without analyzing the reasons in more detail.

I should like to single out two such opinions that appear to me of great importance to our discussion. One refers the accuracy specifications in legal survey to the scale of maps presented for given areas (Wright of England and others). Indeed, in countries where legal survey provides the most valuable, and often the unique, general surveying data in addition to the information on ownership conditions, the mutual dependence between the accuracy specification and the prescribed mapping scale is to be expected. Of course one must consider a legal survey map as a very complete map of the area, showing not only the property boundaries but also all other planimentric features with buildings and artificial details. Such maps are produced in a uniform projection system and cover the whole country in the systematic manner of topographical maps. The scale of legal survey maps in city areas is usually 1:1,000 with 1:5,000 and 1:10,000, or even smaller, for countrysides and more remote areas.
As legal survey specifications call for different mapping scales for distinct districts, so they require also different surveying accuracies. This approach, consistent with common practice in any type of surveying, has, moreover, a distinct economic advantage so far as the subject of our discussion is concerned, and this is another opinion that I think one should stress. The breaking down of accuracy specifications according to land characteristics makes possible a much wider selection of technical means for the solution of the legal-survey problems.

Some of these means, as for instance, photogrammetry, are very different and cannot be adequately squeezed into the existing, and maybe obsolete, accuracy specifications. Photogrammetry, as applied to legal survey may be inferior in certain cases and much superior in others. As Sven G. Moller rightly stated, the accuracy in surveying is important, but it is only one of many elements that must be considered when designing a purposeful and efficient survey system. And the basic concept of any such system must permit inclusion of those present and future techniques that may offer distinct economic or other factual advantages. Therefore, the present discussion ought to lead, in my opinion, to the discussion of the fundamental concept of legal survey in the first place. Only in this wider context could the necessity of differentiation in accuracy specifications and the real advantage of such an approach be brought to light in a more complete fashion. In this regard, the discussion carried out in our journal may have fallen somewhat short. But after all, what discussion can cover all aspects of the discussed question? Moreover, there is no reason why we should not return to this subject in a somewhat modified form.

LEGAL SURVEYS AND ACCURACY SPECIFICATIONS

Col W. F. Roberts

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Our moderator, Mr. Blachut, has asked my opinion on "Should accuracy specifications adopted in Legal Surveys depend upon the land characteristics (e.g. value) or not?" Note that he has used value as one criterion and with reference to that I want to take the affirmative. Am I not correct in assuming our past history has dictated, and many of our present surveyors believe, that value of land dictates accuracy?

Is it not true when offered an opportunity to survey a lot on Main Street you are elated? In fact you change that weather-faded shirt and pants for a new shirt, and pressed pants, retaining the old boots as a sign of experience, and proudly appear on the main street in public view of your friends. Do you not use your best instruments, maybe a twenty-second-reading theodolite, and a new chain (not tested) instead of your old rusty one? Your instrument set-ups are painstakingly made even to the extent of loosening the tripod nuts to eliminate strain in case a college student might be looking on. Each chain length is sighted in for line and your chain-men after a previous pep-talk are most diligent and careful. You may even go to targets or subtense bar if next door to your bank manager. In all, you have achieved good public relations and increased your precision from 1/1,000 to 1/8,000 and are a bit conceited with your efforts. The more valuable the land, the better the public relations, the higher the relative accuracy achieved and the higher your fee.

Yes, value of the land controls accuracy!

Knowing our moderator and his methodical approach to each subject, I feel I should be entitled to a second thought and thus take the negative approach. Is the procedure I have just described not just a degree of sloppiness wrapped in a representative factor, ambiguous and misunderstood by yourself an d incoherent to your client? Is it ethical to call it accuracy? There is no room for sloppiness in our profession. There is room for degrees of accuracy.

May I quote from a recent textbook published in the United States.

8-56 Value of Property. There is much merit to the viewpoint that the value, cost, or potential of a property should not be a consideration of the care with which the survey is made. Who can predict the value of a tract of land a few years or a hundred years from now? Also at times, expensive structures are erected on relatively inexpensive land. *Curtis M. Brown and Winfield H. Eldridge "Evidence and Procedure for Boundary Location," John Wiley and Sons, Inc., New York and London.

Value then must become one of many factors, along with instrument procedure, distance measurement, etc., in determining the magnitude of allowable error. Our main concern must be directed toward the density of coordinated monumentation, size of property, understanding of significant figures. Accuracy can then be shown as a +/- a unit of measure understandable by the client.

Government agencies have devised and published tables of traverse closures to suit their needs in control surveys, usually involving large land areas. Private surveyors have not had the same advantages and have attempted erroneously to apply these standards of accuracy to legal surveys. We now require our own degree of accuracy to become professional. The answer is not simple: I do not have it. But we in New Brunswick feel that precision is not the standard to use in assessing cadastral surveys. Certainty of replacement when monuments have been obliterated is far more important.

Since it is impossible to replace lost monuments without some error in position, we are forced to accept an uncertainty in remonumentation. The question is, how large an uncertainty can we tolerate? Many factors, cost being an important one, dictate tolerance for different classes of land. We are considering the following:-

Downtown areas of major cities	0.05 to 0.10 feet
Residential areas of major cities	0.3 to 0.5 feet
Suburban areas	0.5 to 1.0 feet
Farm land	1.0 to 2.0 feet
Timber land	2.0 to 5.0 feet

In order to meet these standards it will usually be necessary to have a density of monumentation to suit a particular survey method, having a particular precision. Under these circumstances the surveyor can apply the same precision to any survey problem.

The topic is basic. Are you on the affirmative side for the dollar or for your profession?

W. J. Quinsey, O. L. S.
Department of Mines, and Technical Surveys, Ottawa

My answer to this question is "no". Value of land maybe permitted to have some influence on accuracy specifications, where difficult terrain is encountered and where the obtaining of higher accuracy on low-value land will unduly increase present survey costs. However, there we other factors that will offset this influence. In general, a uniform minimum accuracy specification would, in my opinion, be desirable for several reasons, as follow:-

1. Land values often increase with population increase and with new land uses that are developed or discovered.

2. Accuracy in measurements is largely habitual rather than selective. For example chainmen are trained, when using plumbobs, to read a tape measurement to the nearest 100th of a foot and when not using plumbobs, to the nearest 10th of a foot. In both cases an error may occur of one or two units of the reading. Nothing is gained by the note taker rounding the reading to its realistic value. Indeed he may make a large error in so doing. Little time is gained by the party chief having his chainmen reduce the precision of their reading. He will have trouble on the next survey where more precision is required. The best policy is to measure as a matter of course, to the accuracy that the equipment used is designed for and easily capable of producing.

3. Where measurements are checked by means of closure rather than by check-chaining, an accidental misreading of a tape length by exactly one foot in a traverse of total length of 5,000 ft. will only be found by performing the survey to an expected accuracy of 1 in 10,000 or better. Accidental misreadings of one foot are just as common as any other type of tape misreading.

Consequently an error of closure of a traverse should be related to the distance between adjacent survey monuments, connected by parts of the traverse, rather than to the total length of the traverse. It may be seen that obtaining accuracy of say, 1 in 5,000, between adjacent survey monuments will require obtaining at least 1 in 10,000 in the traverse.

4. Survey records last much longer than the need for which a survey is originally performed. One's measurements will eventually be checked. Their accuracy may affect the cost of retracement and will undoubtably reflect on one's professional qualifications.

Dr. Gottfried Konecny
Associate Professor
University of New Brunswick

Should accuracy specifications adopted in legal surveys depend upon the land characteristics (e.g. value) or not? The answer is yes, of course. It is evident that city surveys require higher accuracy than surveys of remote lands that cannot be utilized economically. The question becomes more difficult if a quantitative answer is sought.

We must remember that past and present accuracy specifications have been based primarily on the survey method and only secondarily on land characteristics. In North America land survey accuracy specifications are thus based on the most commonly used closed traverse, for which the precision served as a means of checking the relative accuracy of a survey. Also in Europe accuracy specifications are still dominated by survey methods using the chain. They have at least the advantage that they take into account the nature of errors of the method used, and its error propogation. As a consequence modern survey methods such as photogrammetry and electronic distance measurement have been expected to follow the same preconceived specifications, making it difficult in some of the countries to adopt the new methods readily. Thus the question of deciding which specifications are the most realistic with respect to need and economy is very timely.

Once it is established that the value of the property is a valid measure for accuracy specifications, we face anther question. Is it the area of a lot, its shortest or longest distance, or its vicinity to a particular object, that contributes to its value? While for the determination of area the measure of the relative error is satisfactory, the other factors will demand the knowledge of an absolute error.

Since the elements determining the accuracy requirements will generally vary, specifications should take this into account by allowing for both absolute and relative accuracy measures.

An extensive study, perhaps by a study committee with participation from all provinces, should possibly be made. This study could relate cost of survey, land use, and value, to accuracy for a number of test cases or test areas, using various methods of survey.

OBITUARY

Edward Otis Temple Piers, 84, of Halifax, died Tuesday in hospital is Portland, Ore. He was taken ill while visiting his daughter, Mrs. Clayton Loomis.

Born in Wolville in 1882, he was the son of William Temple Piers and Lalia McLapchy.

His wife, the former Katherine Carroll of Waco, Texas, died in 1946.

He was one of the oldest living graduates of Acadia University, having obtained his Bachelor of Arts degree in 1901. He obtained hits bachelor's degree in civil engineering from McGill University in 1903.

In 1910, he became dean of the College of Engineering at McKenzie College in Sao Paulo, Brazil. He returned to Nova Scotia in 1931, and was associated for a short time with the Nova Scotia Department of Highways.

He then joined the staff of the Nova Scotia Technical College, and became the first president of the Provincial Land Surveyors Association of Nova Scotia.

For many years, and up until the time of his death, he was the Brazilian consul in Halifax.

In 1949, he participated in a ceremony conducted by Lord Halifax honoring the Piers grave representing one of the first settlers in Halifax.

He is survived by two daughters, Lalia (Mrs. Clayton Loomis), Portland, Ore., and Ellen of State College, Pennsylvania.

It was through his untiring efforts that the Association of Provincial Land Surveyors of Nova Scotia came into being.

Before the Association was formed many meetings were held in Temple Piers livingroom and there were times in those days in the early 1950's when we were ready to throw in the towel and call it quits, but Temple Piers would not have it. He would say you've got it started, keep at it and it will go. He was always, as I knew him, a Gentleman of the old school.

Many of our older Surveyors who received their licenses in the 1930's can thank him for his determination and help in our many problems. I think that we can justly say that E. O. Temple Piers, P. L. S. C. E. and Professor, was the Father of the Association of Provincial Lend Surveyors of Nova Scotia.

A Projection for Nova Scotia

J. E. Lilly

Geodetic Survey of Canada

I have been asked to talk about the projection or projections best suited for this province, and I propose to start by talking about projections in general and desirable properties of projections.

From our point of view, a projection is a representation of a portion of the earth's surface on a plane. This representation can be considered to be analytical rather than graphical. The position of any point on a plane may be given by plane rectangular co-ordinates (two dimensions), while the position of a point on the earth's surface is given by latitude, longitude, and height above sea level (three dimensions).

To represent the three-dimensional geographic co-ordinates on a plane, we make use of an intermediate reference surface known as a spheroid or an ellipsoid of revolution. The spheroid, which coincides approximately with the sea level surface, is very nearly a sphere but slightly flattened so that the polar diameter is slightly less than the equatorial.

Any point on the earth is represented on the spheroid by the point in which the vertical line at the point in question pierces the spheroid. Quantities measured on the earth's surface are converted to the corresponding quantities on the spheroid before being converted to plane quantities. A projection is established when we have means of transforming geographical to plane co-ordinates and vice versa with a one-to-one correspondence between points on the two surfaces. That is to say, to each point on the earth there must correspond one and only one point on the plane, and conversely, to every point on the plane there must correspond one and only one point on the earth's surface.

Representation of a spheroidal surface on a plane inevitably involves distortion, which may be expressed by a scale factor which is different for different parts of the area concerned. A scale factor is the ratio of the distance between two nearby points on the plane to the distance between the corresponding points on the spheroid. The scale factor must be thus defined in terms of nearby points since a different result would be obtained from points which are far distant from each other. The scale factor is different for different points in the area and may also be different for different directions at the same point. For general survey purposes it is desirable that the scale error should not exceed 1:10,000, or in other words that the scale factor should lie between 0.9999 and 1.0001. Also, the scale factor for any point should be the same in all directions. A projection which meets this last requirement is said to be conformal. Since the scale factor is the same in all directions, it follows that angles with short arms will be the same on the plane and on the spheroid. It must be emphasized however, that this equality of angles does not apply to angles with long arms, of the order of 10 miles or so, since long geodetic lines on the spheroid do not transform into straight lines on the plane. It is also desirable that the transformation of angles, lengths and co-ordinates between the spheroid and the plane should be comparatively simple but this is really of secondary importance. The primary requirements for a satisfactory projection are that the projection should be conformal and that the scale factor should not differ greatly from unity.

It is almost universal practice to make use of some mathematical reference surface in carrying out survey computations. The lengths and angles used in these computations are not the actual quantities as measured but quantities relating to the points on the reference surface which correspond to the points between which measurements were made. The relationship between the physical surface of the earth and the reference surface roust be known to sufficient accuracy to allow for the computation of these quantities. For a survey extending over a very small area the reference surface may be the level surface through one point of the survey and may be regarded as a plane. In this case, angles as measured on the ground are identical with the corresponding angles on the plane and lengths as measured on the ground require only a slope correction to convert them to the corresponding plane lengths. As we extend our survey to greater areas, we will find that computations carried out in this way simply will not fit with our survey measurements. For example, if we consider a triangle with 40-mile sides and measure the three angles, their sum will exceed 180° by nearly 10 seconds. This is not due to errors in survey work, but is due to the fact that our survey is carried out on a surface which is approximately spherical and the three angles of a spherical triangle always total more than 180°. For work involving long distances such as the triangle referred to, computations are usually carried out on the spheroid previously mentioned. In this case, angles measured on the ground are very nearly identical with the corresponding angles on the reference surface but lengths measured on the ground, as well as being corrected for slope, must be corrected for height above sea level. The spheroid nearly coincides with the sea level surface and the vertical lines at the two ends of the line being measured are not parallel but converge toward the center of the earth. Consequently the distance between these verticals measured on the spheroidal surface is less than the distance measured on the level surface through one of the occupied points. Sea level correction is becoming more important as the accuracy of survey measurements increases. The sea level correction is directly proportional to the height above sea level and amounts to one part in 20,000 for a height of 1,000 feet. Much of Nova Scotia is less than 1,000 feet above sea level but this correction may be appreciable in some parts if the province.

Computations on the spheroidal surface are rather complicated and the purpose of a plane co-ordinate system is to represent the spheroidal surface on a plane so that computations may be carried out by the simple methods of plane co-ordinates. Obviously, lengths and angles on the spheroidal surface must be converted to the lengths and angles between the corresponding points on the plane.

From the point of view of the practicing surveyor, it would be ideal if quantities measured on the ground could be applied directly to the plane. But as mentioned previously, this does involve distortion and the question is how much distortion is allowable. Regarding lengths, slope correction is always necessary and is well understood. Sea level correction is also often necessary. Even after reduction to sea level, we still have differences between sea level lengths and plane co-ordinate lengths, and this discrepancy increases as we depart from the central point of a tangent plane projection or from the central line of a conical or cylindrical projection.

These three types of projection, tangent plane, tangent conical and tangent cylindrical, are the three basic types of projection useful for survey purposes. A projection on a cone or cylinder is essentially a plane projection since the cone or cylinder may simply be unrolled to become a plane. These different projections are suitable for different areas. The tangent plane projection for example is suitable for a circular area, since the scale error is the same for all points at any given distance from the point of tangency. A conical projection is usually applied by the use of a cone which is tangent along a parallel of latitude. In this case, the tangent parallel is identical on the spheroid and on the plane, and distortion remains small for a narrow strip of territory close to this parallel. This conical projection is suitable for an area which has a small range of latitude and considerably larger extent in longitude. In a cylindrical projection, the cylinder concerned may be tangent along the equator or along a meridian, yielding a Mercator or a transverse Mercator projection respectively. If the earth were exactly spherical, the cylinder could be taken as being tangent along any great circle, giving an oblique Mercator projection. The fact that the earth is not exactly spherical introduces complications. However an approximation to an oblique Mercator projection has been developed and used for various areas. The Mercator Projection is suitable for a narrow strip of territory with its main axis lying along the tangent great circle (the equator, a meridian or an oblique great circle as the case may be). A look at the map indicates that a cylindrical projection might be very suitable for Nova Scotia since the province may be fitted into a comparatively narrow area extending some 400 miles in the northeast-southwest direction.

In choosing a projection for any particular area, we must consider the desirability of including the whole area concerned in a single zone; we must consider the amount of distortion we are prepared to tolerate; and we might also consider the complexity of the transformation of observed quantities to plane quantities. The fundamental question is how much distortion is tolerable and what we are prepared to do to restrict distortion to these limits. Angular distortion is very small if we use a conformal projection and limit our length of line to about one mile. Under these circumstances, angular distortion is not likely to exceed one second. For longer lines distortion will be greater, and a correction to observed angles may have to be computed and applied. Linear distortion is another matter and the amount which may be disregarded depends on the accuracy aimed at in our work. For general purposes, it is usually considered that a scale error of 1:10,000 is permissible. This would seem to imply an accuracy limit no better than 1:5,000 as our goal.

Linear distortion may be held within narrow limits by working in a very small area. The whole area of interest may be divided into small areas or zones and each zone represented on a projection of its own. This would lead to difficulty and inconvenience regarding surveys which extend over two or more zones. If we find it impossible to adopt a projection which will restrict our scale error to the desired limits, and at the same time cover the desired area, we must decide whether to divide the area into zones or to accept a larger scale error and apply a scale factor to our measurements. The latter alternative involves additional work and additional opportunity for error, and if the scale factor is changing rapidly along the line concerned, it may be difficult to determine the correct factor to apply to the whole line. The mean of the values for the two end points will usually not be sufficiently accurate.

In considering a choice of projection for Nova Scotia, it seems reasonable to require that the projection shall be conformal and that the scale error shall not exceed 1:10,000. This limits the area which may be covered by a single zone of our projection. The tangent plane projection is limited to a circle 220 miles in diameter. In this case, if the scale factor is 1.0000 at the centre, the scale factor at the outer limit will be 0.9998, corresponding to a scale error of 1:5,000. By deliberately introducing a scale error of 1:10,000 at the centre, these scale factors are changed to 0.9999 at the centre and 1.0001 at the outer limit. To maintain a maximum scale error of 1:10,000 on the conical or cylindrical projection, we are limited to a width of 160 miles. Here too, the scale factor varies from 0.9999 on the centre line to 1.0001 at the outer limit.

For an application to Nova Scotia, the tangent plane projection is quite unsuitable, since the scale error 200 miles from the centre would greatly exceed our limit of 1:10,000. Since a zone in this projection is circular, it is obviously not practical to divide the Province into adjoining or overlapping zones.

The Province could be represented on two zones of a conical projection. The dividing line between the two zones, which would be a parallel of latitude passing near Cape Blomidon and Canso, would actually divide the Province in a rather unsatisfactory fashion. Nevertheless, this projection should be kept in mind as a possibility.

Perhaps the most commonly used projection is the Transverse Mercator. In what is known as the Universal Transverse Mercator or UTM, the zones cover 6° of longitude and have a scale error of 1:2,500 at the centre line and the same error with opposite sign at 155 miles on either side of the centre. This is obviously unsatisfactory for our purpose. A Transverse Mercator projection with three-degree zones would have a satisfactory scale error (maximum 1:10,000) and two such zones would almost cover the province. Small areas at the extreme east and west limits of the province would lie outside these standard zones and consequently would have a scale error slightly exceeding 1:10,000. The dividing line between the two zones, which would be a meridian, would pass approximately 15 miles east of Truro and 30 miles east of Halifax.

Of the projections which have been mentioned, only the oblique cylindrical projection permits the representation of the whole province of Nova Scotia on a single zone if we accept a limiting scale error of 1:10,000. The central axis, which may conveniently he called the Y-axis, will be a straight line in an approximately northeast-southwest direction with the X-axis at right angles thereto. This projection is very nearly conformal, and the scale factor is practically constant along the Y-axis of along any line parallel to the Y-axis but varies as we move at right angles to this axis. If we assume a scale factor of unity at the Y-axis, and if the Y-axis is carefully chosen, the maximum scale error for the province is approximately 1:10,000. This can be reduced to 1:20,000 by the deliberate introduction of a scale error of 1:20,000 at the Y-axis; thus the scale factor will vary from 0.99995 on the Y-axis to 1.00005 at the maximum distance from the Y-axis. Also, at any point the scale factors parallel and perpendicular to the Y-axis will be very nearly equal. This is the condition of conformality; for if the scale factors are equal in all directions, it is clear that angles with short arms on the plane will be equal to the corresponding angles on the spheroid. Hence, angles measured on the ground may be applied directly to the plane, but it must be emphasized again that this is not true of angles with very long arms, of the order of 10 miles or so. Lengths measured on the ground, before being applied to the plane, must be corrected for slope, for height above sea level and for scale factor. I f the accuracy aimed at is comparatively low, say 1:5,000, it may be permissible to neglect the sea level and scale factor corrections, though it is dangerous to neglect a systematic error which may approach half the magnitude of the total allowable error.

I would like to mention two projections of this oblique cylindrical type which I discussed in a paper entitled "Skew Plane Co-ordinates", presented at the regional ACSM meeting in Kansas City, Missouri, in 1964. One is the Oblique Mercator Projection, and the other is a modified version which I called the Geodesic Strip Projection.

The Oblique Mercator Projection is discussed by P. D. Thomas in Special Publication No. 251 of the U.S. Coast and Geodetic Survey. Thomas gives formulae which, as he points out, are essentially those developed by Hotine and published in the Empire Survey Review, April 1947. Examples if the use of this projection are contained in a mimeographed publication entitled "Projection Tables for British Commonwealth Territories in Borneo" prepared by the Directorate of Colonial Surveys, England; and in Publication 65-1, part 49, of the U.S. Coast and Geodetic Survey, which refers to southeast Alaska. My discussion of the Oblique Mercator Projection is based very largely on these publications.

The Y-axis may be defined as a line passing through a specified point at a specified azimuth or as a line passing through two specified points. In either case, the true origin of plane co-ordinates and other constants connected with the projection may be computed from the specified data and basic formulae of the projection. It turns out that, for work in the northern hemisphere, the true origin of co-ordinates is slightly south of the equator. This means that in middle latitudes the Y co-ordinate is always large, of the order of 8,000 kilometers or 5,000 miles. Transformation between geographical and plane co-ordinates involves complicated formulae making use of hyperbolic sines, cosines and tangents and isometric latitudes, and in view of the magnitude of the Y co-ordinate computations must be carried to 9 significant figures to assure an accuracy of 0.01 metre. Computation of accurate scale factor Is also quite involved, requiring the knowledge of both plane and geographical co-ordinates.

To avoid these disadvantages of the Oblique Mercator Projection, I proposed a modified version which I called The Geodesic Strip Projection. This projection is defined as follows:

a) the Y-axis is a geodesic on the spheroid and a straight line on the plane.
b) Geodesics perpendicular to the Y-axis are straight lines perpendicular to the Y-axis on the plane.
c) The scale factor for a line AB is given by the following equation:

$$K = K_C + K_C D^2 (X^2_A + X_A X_B + X^2_B)/6$$

Where K is the scale factor

K_C is the assigned scale factor on the Y-axis

D is a projection constant defined in terms of spheroidal parameters and the latitude of the true origin of co-ordinates.

From this the scale factor for a point

$$K = K_C + K_C D^2 X^2/2$$

is easily obtained by equating X_A to X_B. It follows that the scale factor is constant along any straight line parallel to the Y-axis.

The transformation of co-ordinates in this projection is accomplished with the aid of a number of so-called control points conveniently located at intervals of 50 kilometers along the Y-axis. One of these control points is the true origin of plane co-ordinates; the latitude and longitude of this point, and the aximuth of the Y-axis at the point, are specified in the definition of the Y-axis. At any other control point the X co-ordinate is exactly zero, the Y co-ordinate is an exact integral multiple of 50 kilometres, and the latitude, longitude, and azimuth of the Y-axis are computed from these data. To transform the co-ordinates of any other point, use is made of the triangle formed by the point in question, the foot of the perpendicular from this point on the Y-axis and a nearby control point. X and Y co-ordinates are obtained from the solution of this triangle, the necessary scale factor being employed. The scale factor, as indicated in the definition of the projection, may be very simply calculated from plane co-ordinates and may easily be determined by approximations from geographical co-ordinates.

I do not propose to give further details of this projection at this time but I believe it is somewhat more simple than the standard oblique mercator projection and will give just as satisfactory results. The scale factor is constant along the Y-axis and is easily computed for any point from the X co-ordinate of that point.

These two oblique cylindrical projections have much in common. As mentioned previously, they are practically conformal and have a maximum scale error of 1:20,000 (if we exclude Sable Island from our projection). It happens that the Halifax-Dartmouth area is so situated relative to the Y-axis that the scale error in this region is only about 1:100,000.

There is another matter which might be mentioned as applying to both Oblique Mercator and Geodesic Strip Projections and that is the so-called rectification of co-ordinates. As laid out and computed, the Y-axis lies in an azimuth of approximately 60°. If desired, this axis may be rotated to true north and the co-ordinates transformed to the new axes.

The main disadvantage of this rectification, apart from the work involved in rotation, is the fact that computation of scale factor from rectified co-ordinates is much more involved than from skew co-ordinates. It appears to be preferable therefore to use skew co-ordinates unless some special reason exists for rectification.