SUPPLEMENT

TO THE

MANUAL

OF INSTRUCTIONS FOR THE

SURVEY OF DOMINION LANDS

Department of the Interior

OTTAWA.

SUPPLEMENT

TO THE

Manual of Instructions

FOR THE

Survey of Dominion Lands

ASTRONOMICAL, GEODETIC, AND OTHER TABLES

PROBLEMS CONNECTED WITH THE SYSTEM OF SURVEY

Issued by authority of the Honourable the Minister of the Interior

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PREFACE.

THE first Manual of Instructions for the survey of the Dominion Lands, a small 12mo pamphlet of thirty-two pages, was prepared in 1871 by Col. J. S. Dennis, Surveyor-General; the title was "Manual showing the System of Survey adopted for the Public Lands of Canada in Manitoba and the North-West Territories, with Instructions to Surveyors." It was published by authority of the Honourable the Secretary of State, the Dominion Lands office being then a branch of his department. The Manual contained only one table, "showing the departure in running 81 chains 50 links at any course from 1 to 60 minutes."

The second edition was prepared in 1881, under the direction of Mr. Lindsay Russell, Surveyor-General, by Dr. Deville ; it was considerably enlarged, forming a large octavo book of 86 pages. By that time the need of tables specially adapted to the survey of Dominion Lands had become imperative : thirteen tables were calculated by Dr. Deville and Dr. King and were appended to that edition.

A number of editions followed, the fourth, published in 1892, containing six additional tables, or nineteen altogether. The fifth and sixth editions, issued in 1903 and 1905 respectively, contained only eight tables. The tables left out were seldom used and it was considered that when needed they could be consulted in 1892 edition.

The fourth edition (1892) having become scarce, a reprint of the tables has become necessary. Owing to the nature of its contents, revised issues of the Manual proper are required at frequent intervals. To save reprinting the tables—in which there is no change—every time a new edition of the Manual is issued, they are now published separately, as a supplement, and will no longer appear in the future editions of the Manual proper. The construction and use of the tables are fully explained. Problems connected with the system of survey, originally published by Dr. King in the Report of the Department of the Interior for 1891, are appended.

An index to the notation gives those of the symbols which are most frequently used.

INDEX TO THE NOTATION.

A	time interval.
a	equatorial diameter of the earth.
b	polar diameter of the earth.
c	earth's compression.
D	declination.
e	eccentricity.
$H.C.R.$	horizontal circle reading.
h	altitude of a star.
L	latitude.
l	elevation above sea level.
M	longitude.
N	length of normal to the meridian.
P	polar distance; also radius of parallel of latitude.
$R.A$	right ascension.
$R.r$	radius of curvature.
T	time.
t	hour angle.
Z	azimuth or bearing.

CONSTRUCTION AND USE OF THE TABLES.

TABLE I.

Length of Arcs of Meridians, Parallel, &c., in different Latitudes.

(Dr. King.)

According to Col. A. R. Clarke, R.E., in his "Comparison of Standards of Length" (1866), the spheroid of revolution most nearly approaching the form of the earth has for its major or equatorial semi-axis 20926062 feet, and for its minor or polar semi-axis 20855121 feet.

Representing the major and minor axis by a and b respectively, we have for the compression, $c = \frac{a-b}{a} = \frac{1}{294 \cdot 98}$, and the eccentricity e is given by the formula $e^2 = \frac{a^2 - b^2}{a^2} = \frac{1}{148}$ nearly.

The unit of measure in the Dominion Lands surveys is the Gunter's, or sixty-six feet chain. The equatorial semi-axis in chains is 317061·545 +

Representing by L the geographical latitude of a place, or the angle which its vertical line makes with the plane of the equator, we have for the radius of curvature of the meridian

$$R = \frac{a(1-e^2)}{(1-e^2 \sin^2 L)^{\frac{3}{2}}},$$

for the length of the normal to the meridian terminated by the minor axis

$$N = \frac{a}{(1-e^2 \sin^2 L)^{\frac{1}{2}}},$$

and for the radius of the parallel of latitude L

$$P = N \cos L.$$

The length in chains of one second of latitude is equal to $R \sin 1''$; one second of the great circle perpendicular to the meridian is equal to $N \sin 1''$; and one second of longitude is equal to $P \sin 1''$. The logarithms of these quantities are placed in the second, third and fourth columns of Table I. They have been calculated by means of the logarithmic expansions of R and N.

Thus putting n for $\dfrac{a-b}{a+b}$ we have

$$\log(R \sin 1'') = \log\left[a(1-n)^2(1+n)\sin 1''\right] - 3\mu n \cos 2L + \frac{3}{2}\mu n^2 \cos 4L + \text{etc.}$$

where μ is the modulus of the common system of logarithms, and powers of n higher than the second are neglected as being insensible in the eighth decimal place.

Substituting the value of a in chains, as given above, and taking

$$n = \frac{a-b}{a+b} = \frac{1}{588{\cdot}96}, \text{ we get}$$

$$\log(R \sin 1'') = 0{\cdot}18597916 - 0{\cdot}00221218 \cos 2L + 0{\cdot}00000188 \cos 4L.$$

In calculating the last two terms by logarithms five places are sufficient.

For $N \sin 1''$ we have

$$\log(N \sin 1'') = \tfrac{1}{3}\log(R \sin 1'') + \tfrac{2}{3}\{\log a + \log \sin 1'' + 2\mu n\}$$
$$= \tfrac{1}{3}\log(R \sin 1'') + 0{\cdot}12546215.$$

For $P \sin 1''$

$$\log P \sin 1'' = \log(N \sin 1'') + \log \cos L$$

The calculation has been made to eight places of decimals to ensure accuracy in the seventh place. In tabulating, the eighth figure has been dropped.

The calculation of the logarithms of $R \sin 1''$ and $N \sin 1''$ has also been made directly from the formulæ for R and N, by the use of a subsidiary angle.

Thus, finding an angle ψ such that $\sin \psi = e \sin L$, we have

$$R \sin 1'' = a(1-e^2)\sec^3 \psi \sin 1''$$
$$N \sin 1'' = a \sec \psi \sin 1''$$

Seven figure logarithms were used, and consequently the results could not be depended upon to the seventh figure, but they have been serviceable as a check upon the series computation.

Log $N \sin 1''$, log $P \sin 1''$ and log $R \sin 1''$ are given in the table for every 10′ of latitude from 42° to 70°. Their values for intermediate latitudes can be obtained by simple interpolation. Where, however, log $P \sin 1''$ is required with accuracy for an intermediate latitude, it is better first to obtain log $N \sin 1''$ for that latitude by interpolation from the table and then to add log cos L.

Under the heading "Chains in 1″" are given the natural numbers corresponding to the logarithms of $R \sin 1''$ and $P \sin 1''$. These natural numbers are useful in reducing small differences of latitude and longitude to chains by simple multiplication, being preferable in many cases to the logarithms.

The converse operation of reducing short distances north and south or east and west to seconds of latitude or longitude may be performed by multiplying by the quantities in the two columns headed "seconds in one chain." These columns contain the reciprocals of the quantities in the columns "chains in one second."

In the last two columns of the table are given the lengths of one degree of latitude and longitude in English miles.

Radius of Curvature of a Section of the Spheroid inclined at any angle to a Meridian.

In some operations it is necessary to find the radius of curvature of the trace on the earth's surface of a "straight" or "transit" line, making a given angle with the meridian.

Representing this radius of curvature by S, and θ being the angle with the meridian, we have the formula

$$\frac{1}{S} = \frac{\cos^2\theta}{R} + \frac{\sin^2\theta}{N}$$

and introducing an auxiliary angle X determined by the formula

$$\tan X = \sqrt{\frac{R \sin 1''}{N \sin 1''}}\,\tan\theta, \text{ we have}$$

$$S \sin 1'' = N \sin 1'' \,\frac{\sin^2 X}{\sin^2\theta}$$

a formula adapted for ready calculation by means of logarithms.

Radius of Spherical Curvature.

The mean of the values of S when θ is given all possible values is $\sqrt{NR}$. This is the radius of curvature of the surface or the radius of the sphere to the surface at a given point. Its logarithm is readily found from Table I, being the arithmetical mean of the logarithms of N and R.

Table II.

Corrections to Table I for change in Elements of Figure of Earth.

(Dr. King.)

In Table I the data used are Clarke's 1866 values, viz. :—

$$a = 20926062 \text{ feet}$$
$$n = \frac{1}{588{\cdot}96}$$

and all the following tables are based on Table I, and therefore on these values. Clarke's later values (Geodesy, 1888) are,

$$a = 20926202 \text{ feet}$$
$$n = \frac{1}{585{\cdot}93}$$

If, for any purpose, it is desired to use these values, Table I can be corrected by means of Table II, which has been computed thus :

Differentiating the formulæ,

$\log R \sin 1''$

$$= \log a + \log \sin 1'' - \mu(n + \tfrac{3}{2}n^2) - 3\mu n \cos 2L + \tfrac{3}{2}\mu n^2 \cos 4L$$

$\log N \sin 1''$

$$= \log a + \log \sin 1'' + \mu\left(n - \frac{n^2}{2}\right) - \mu n \cos 2L + \tfrac{1}{2}\mu n^2 \cos 4L$$

and putting $\frac{1}{n} = p$, we have

$$d(\log R \sin 1'') = \mu\frac{da}{a} + \mu n^2 dp + 3\mu n^2 \cos 2L dp$$

$$d(\log N \sin 1'') = \mu\frac{da}{a} - \mu n^2 dp + \mu n^2 \cos 2L dp$$

μ being the modulus of the common system of logarithms. Terms involving the cubes and higher powers of n are insensible and may be neglected.

To change Clarke's earlier to his later values, we have

$$da = +140 \text{ (feet)}$$
$$dp = -3{\cdot}03$$
$$a = 20926062 \text{ (feet)}$$
$$n = \frac{1}{588{\cdot}96}$$
$$\text{and } \mu = 0{\cdot}43429448$$

whence $d \log (R \sin 1'') = -{\cdot}00000089 - {\cdot}00001138 \cos 2L$

$d \log (N \sin 1'') = +{\cdot}00000670 - {\cdot}00000379 \cos 2L$

These quantities are tabulated in Table II, with the proper signs of application to log R sin 1″ and log N sin 1″ in Table I.

Table III.

Latitudes of Base and Correction Lines and Lengths of Arcs of Meridian, Parallel, &c., for First and Second Systems of Survey.

(Dr. King.)

This table is constructed for the first and second systems of survey only. It accordingly stops at the 13th Base, Township 48, north of which there are no surveys under these systems.

Each township measuring 489 chains each way, the 1st correction line is 978 chains north of the 49th parallel.

The latitude of the 1st correction line is therefore

$$49° + \frac{978}{R \sin 1''}.$$

Here R sin 1″ must be taken from Table I for the middle latitude between the 1st base and the 1st correction line. For accuracy it is therefore necessary to compute an approximate difference of latitude, using an approximate value of R sin 1″. For instance R sin 1″ may be taken from the table for latitude 49°.

The approximate difference of latitude being thus determined, the middle latitude is found from it (this being a sufficiently close approximation), and the final R sin 1″ is taken from Table I for that latitude. Then dividing 978 by this we have a very close approximation to the difference of latitude between the base and the correction line.

From the latitude thus obtained of the 1st correction line, that of the 2nd base line is found by a similar process, and so on in succession as far as the table extends.

The table is checked by applying the same process to a longer distance than 978 chains. For example, the latitude of the 6th base can be directly determined from that of the first by using 9,780 chains instead of 978. When long distances are thus taken, a second approximation to the middle latitude may become necessary.

The columns log N sin 1″ and log R sin 1″ are taken from Table I by interpolation, and log P sin 1″ is found by adding log cos L to log N sin 1″.

The width of a township along a base line is 489 chains. The longitude corresponding to this length measured along the parallel of latitude is given in the column headed "Longitude covered by 489 chains westing," not only for the base lines but also for the correction lines.

The longitude for 489 chains, along a base line, is the longitude covered by one range of townships. Along a correction line it does not correspond to the longitude covered by a range, since the width of a township along a correction line is greater or less than 489 chains according as the township north or south of the correction line is considered. The tabulated quantity, however, for correction lines can be used to calculate the narrowing or widening of sections at the correction lines.

The township width 489 chains is measured along the base line which has such azimuth that its terminal point falls in the same latitude as its initial point.

Thus every township corner along a base line has the same latitude, and the base line is a succession of chords of the latitude circle.

The difference of longitude between one township corner and the next is given by the formula

$$dM = \frac{489}{P \sin 1''}$$

It is assumed here that the chord of the arc of the latitude circle is equal to the arc. That the difference between the chord and the arc is inappreciable may be shown thus :

By spherical trigonometry

$$\sin \frac{\text{chord}}{2N} = \sin \frac{dM}{2} \cos L$$

$$\text{whence chord} = N \cos L dM - N \cos L \sin^2 L \frac{dM^3}{24}$$

$$= \text{arc} - \text{arc} \times \frac{dM^2}{24} \sin^2 L$$

So that the difference between the chord and the arc is equal to

$$\text{arc} \times \frac{dM^2}{24} \sin^2 L$$

dM being in a circular measure.

For a chord of 489 chains this amounts to less than one-hundredth of a link.

The chord always lies north of the arc. The distance between them is greatest at their midde points, amounting there to about 10 links. Hence, at the international boundary line, which is the first base line, since the actual territorial boundary is the curve, and the base line a series of chords, the road allowance which lies along the north side of this base is increased in width by 10 links at the middle of the chords.

The non-coincidence of the chord and arc also has the effect of increasing and decreasing the widths of roads on correction lines. This will be referred to again.

In the first column of Table III are given, for convenience, the numbers of the townships corresponding to the several base and correction lines. Thus the sixth base is the northern boundary of Township 20, and so on.

Table IV.

Latitudes of Base and Correction Lines, &c., for Third and Fourth Systems of Survey.

(Dr. King.)

This is exactly similar to Table III, except that it is made for the third system of survey, where the widths of townships are 486 instead of 489 chains, and their depths, in a north and south direction, 483 instead of 489 chains.

This table also applies, without change, to the fourth system (British Columbia).

In this table, as well as in Table III, the latitudes given are those of the line of posts on the south side of the road allowance. To get the latitude of the posts north of the road on correction lines, the latitude of the correction line, as given in the table, must be corrected by adding the equivalent in latitude of the width of the road, *i.e.*, one chain and a-half for the first and second systems (Table III), and one chain for the third system (Table IV).

Table V.

Chord Azimuths, &c., for Base Lines, First and Second Systems of Survey.

(Dr. King.)

The extremities of the township chord, as above stated, are in the same latitude. Hence the chord is equally inclined to the meridians passing through its terminal points, and its azimuth, east or west of north, is equal to the complement of half the change in azimuth, that is, of half the " convergence of meridians."

Let dZ represent the change in azimuth or convergence of meridians, dM the difference of longitude, and L the latitude.

Then, by spherical trigonometry,

$$\tan \tfrac{1}{2} dZ = \tan \tfrac{1}{2} dM \sin L$$

whence, by expansion of the tangents in terms of the arcs,

$$dZ = dM \sin L + \frac{dM^3}{12} \sin L \cos^2 L$$

or, if dZ and dM be expressed in seconds,

$$dZ = dM \sin L + \frac{dM^3}{12} \sin L \cos^2 L \sin^2 1''$$

The second term is inappreciable, amounting in latitude 51° to less than one ten-thousanth of a second.

$$\therefore \; dZ = dM \sin L$$

The convergence or "deflection" (dZ), given in Table V, is thus calculated from the difference of longitude (dM) in Table III.

The "chord azimuth" is the complement of half the deflection.

The chord azimuth and the deflection are given in the table in degrees, minutes and seconds, as well as in decimals of a degree, for sexagesimally and decimally divided instruments respectively.

In the survey of a base line, the surveyor, when he arrives at a township corner, deflects his line to the north through an angle equal to the "deflection," and thus establishes in azimuth the chord across the next range of townships.

This deflection angle may be turned with the instrument, but more readily by the use of the "deflection offsets" in the table. The tabulated offset is the linear distance in inches between one of the chords and the prolongation of the other, at one chain from the township corner.

Their distance apart at any point is found by multiplying the tabulated offset by the distance, expressed in chains, of the point from the township corner.

For example, if the instrument is standing on the prolongation of the first chord at 5 chains past the corner, and the back picket be 15 chains on the other side of, that is, behind the corner, then the instrument must be moved north five times, and the back picket south fifteen times, the "deflection offset for one chain." The line of the instrument and picket is now in the correct bearing for the prolongation of the base line.

The angle is thus turned as accurately as a straight line can be produced with the instrument, and much more accurately than the angle can be measured with the graduated arc, while the setting of the instrument at the corner (which may be in low ground, unsuitable for accurate line production) is rendered unnecessary.

"Longitude covered by one range" in the seventh column is merely the longitude in the seventh column of Table III, reduced to time by dividing by 15. This gives the number of seconds which a watch will gain or lose on local time in being carried across a range. The gain or loss in travelling over any other distance along the base line is proportional to the distance. The column is added for astronomical purposes, especially the determination of azimuth by observation of Polaris at any hour angle.

This Table V applies to the first and second systems of survey.

Table VI.

Chord Azimuths, &c., for Base Lines, Third and Fourth Systems of Survey.

(Dr. King.)

This table is exactly similar to Table V, but is made for the third system of survey.

The calculation is made by the same formulæ, changing only the width of the range, which is 486, instead of 489 chains, and using the latitudes of the base lines from Table IV, instead of those from Table III.

$$dM = \frac{486}{P \sin 1''}, \qquad dZ = dM \sin L$$

This table also applies to the fourth system.

Table VII.

Chord Azimuths, Jogs, &c., for Correction Lines, First and Second Systems of Survey.

(Dr. King.)

This table gives quantities for correction lines similar to those given in Table III for base lines. This table applies to the first and second systems of survey.

The correction lines are posted on both sides of the road. The chord azimuths and deflections are given for the south side of the road, which is that side for which the latitudes of correction lines are given in Table III.

The calculation of the chord azimuth for correction lines is somewhat different from that for base lines.

For the base lines we have

$$dM = \frac{489}{P \sin 1''}$$

$$\text{deflection} = dM \sin L$$

For the correction lines, one range is not 489 chains, but the distance between meridians which include 489 chains on the nearest base line.

Hence in the formulæ—

$$dM = \frac{489}{P \sin 1''}$$

$$\text{and deflection} = dM \sin L = \frac{489}{P \sin 1''} \sin L$$

we must take $P \sin 1''$ for the next base line south of the correction line, if the difference of longitude and the deflection for the south side of the correction line road are required; while for the north side of that road we must take $P \sin 1''$ for the next base line north. L of course, is the latitude of the correction line itself.

The length of one range on the correction line is $dM \times P \sin 1''$.

If, then, P_1 and P_2 represent the radius of parallel for the base lines next north and south, respectively, P that for the correction line itself

$$dM_1 = \frac{489}{P_1 \sin 1''}$$

$$dM_2 = \frac{489}{P_2 \sin 1''}$$

and we have for the length of one range on the correction line

$$\text{North side} = \frac{489}{P_1 \sin 1''} \times P \sin 1''$$

$$\text{South side} = \frac{489}{P_2 \sin 1''} \times P \sin 1''$$

The values of these quantities are tabulated in the seventh and eighth columns of Table VII.

For extreme accuracy $P \sin 1''$ for the north side of the road should be taken out for a latitude greater by 1·50 chains, or 0″·98 greater than that tabulated in Table III; but the difference in the result would be almost inappreciable.

The difference of length of the township lines north and south of the correction line road gives the overlap or jog.

The jog for one range is given in the ninth column of the table. As this jog occurs in each range of townships, its value at any range is the product of the jog for one range by the number of ranges.

The excess of the length of the north side over, or the defect of the south side from 489 chains, is the linear divergence or convergence of the township lines. Since there are twelve half sections in a township side, the convergence or divergence for one-half section is one-twelfth of the convergence or divergence for the township, or one-twenty-fourth of the jog, the excess of the north side and the defect of the south side being very nearly, though not quite, equal.

This convergence or divergence for one half section is entered in the tenth column of the table. It is used in the second system, where the surplus or deficiency caused by the convergence of meridians is divided equally among all the quarter-sections. Hence, in surveying a correction line under the second system, the width of each quarter section (exclusive of the roads) is forty chains *plus* or *minus* this tabulated quantity. The surplus or deficiency on the township line midway between the base and the correction line is half of that on the correction line.

In the first system the whole of the surplus or deficiency is thrown into the western tier of quarter sections. This surplus or deficiency is the difference between 489 chains and the quantities in the seventh and eighth columns of Table VII. For example, on the north side of the road on the 1st correction line the surplus is 1·75 chains, and the westerly quarter section of the township is therefore 41·75, all the others being 40 chains.

It is to be observed that in all cases the whole divergence or convergence is applied to the section itself, and that the road allowance retains its width of 1 chain or 1½ chains, with the exception of the roads on correction lines, which are subject to a widening or narrowing as hereinafter explained.

Table VIII.

Chord Azimuths, Jogs, &c., for Correction Lines, Third and Fourth Systems of Survey.

(Dr. King.)

This table gives for the third and fourth systems the same quantities as are given in Table VII for the first and second systems.

The surplus or deficiency is in all cases divided equally among all the quarter sections.

Table IX.

Latitudes, and Widths in Chains, of Northern Boundaries of Sections in First and Second Systems of Survey.

(Dr. Deville.)

This table gives the latitudes in degrees, minutes and seconds for the northern boundaries of all sections in the first and second systems.

The sections numbered in the second column are those adjacent to the eastern boundary of the township. The latitudes of interior sections lying west of these are the same. Thus the northern boundaries of sections 14, 15, 16, 17 and 18 have the same latitude as the north boundary of 13, and so for the other east and west tiers of sections.

These latitudes are computed by converting the latitudes given in Table III into degrees and decimals, and interpolating for the intermediate lines.

The logarithmic secant and tangent of the latitude are given in the table for use in calculation of azimuth observations.

In the last column of the table are given the widths of the north boundaries of the quarter sections (in the second system of survey). These are calculated for the correction lines in the manner explained under Table VII, and for the intermediate lines by interpolation.

Table X.

Latitudes, and Widths in Chains, of Northern Boundaries of Sections in Third and Fourth Systems of Survey.

(Dr. Deville.)

This table gives for the third system the same quantities as are given in Table IX for the first and second.

The table may also be applied to the fourth system by correcting the latitudes of the alternate section lines, viz., the north boundaries of section 1, 13 and 25 in each township, by subtracting therefrom 0°.0001, the equivalent in arc of 50 links. The change in the logarithmic secant and tangent is inappreciable, as these logarithms are given to only five places of decimals. The widths of quarter sections in the last column must be increased by 50 links.

Table XI.

To Reduce Chains to Decimals of a Township Side.

(Dr. King.)

This is a short table giving the equivalents of chained distances in terms of a township side, for township sides of the first and second systems (489 chains), for east and west lines of the third and fourth systems (486 chains) and for north and south lines of these last systems (483 chains). The table is useful in calculating the difference in azimuth of an east or west line between a township corner and any other point upon it, and for similar purposes.

Table XII.

Correction to Widths of Roads on Correction Lines on account of Curvature.

(Dr. King.)

The township corners on the north and south sides respectively of the road on correction lines lie on two circles of latitude, which are one and a-half chains apart in the first and second systems, and one chain apart in the third system. The township sides are chords of these circles, and therefore lie north of them.

Hence, since on account of the jog the township corners north and south of the road are not opposite to one another, the township side south of the road will pass the township corner north of the road at a distance less than the theoretical one chain; while the township side north of the road will pass the corner south of the road at a distance greater than one chain.

The correction to the width of the road on this account for various lengths of the jog, is given in the table. The width of the road at points other than the township corners, varies in proportion to the distance.

This table may be used where it is required to establish the posts on one side of a correction line, by offsets from the other side.

The calculation of the differences of width is made as described below for Table XIII, the difference being merely the offset from the township chord to the parallel.

In Table XII are also given corrections to the chord azimuths and deflection offsets on correction lines (given in Table VII), when the north side of the road allowance is surveyed instead of the south. The correction is small and of little importance in surveying, except in the case of the second system of survey, where the correction lines were surveyed instead of the base lines, as the basis of the townships, across four ranges before closing, and the azimuth was consequently of importance.

In the first system the correction line is surveyed across two ranges as a trial line, and afterwards corrected to the true line; and in the third system the correction line is only surveyed across one range at a time, and as a trial line. In these systems, therefore, the azimuth used in the survey is of little importance.

Table XIII.

Difference of Latitude between Township Corners and Section and Quarter Section Corners.

(Dr. King.)

This table is used when it is required to find accurately the latitude of any point within a township, as when it is desired by connecting with an astronomically determined latitude point to find the error of the survey lines.

If Z be the initial azimuth of the township chord, Z^1 its azimuth at a distance x from the corner of the township, L the the latitude of the township corner, L^1 the latitude of a point on the chord distant x from the corner.

Then by spherical trigonometry.

$$\frac{\cos L^1}{\cos L} = \frac{\sin Z}{\sin Z^1}$$

whence $\tan \frac{L^1 - L}{2} \tan \frac{L^1 + L}{2} = \tan \frac{Z^1 - Z}{2} \cot \frac{Z^1 + Z}{2}$

putting $Z = \frac{1}{2}(\pi - \theta)$

$Z^1 = \frac{1}{2}(\pi - \theta^1)$

where θ and θ^1 are expressed in circular measure, and are very small, so that their cubes may be neglected. Also $L^1 - L$ is very small, and $L^1 + L$ is very nearly equal to $2L$.

Then $L^1 - L = \frac{\theta - \theta^1}{2} \frac{\theta + \theta^1}{4} \cot L = \frac{\theta^2 - \theta_1^2}{8} \cot L$

and $\theta =$ convergence of meridians for one township chord ;

$\therefore \theta = \frac{c}{N} \tan L$, c being the length of the chord, and $\frac{\theta_1}{\theta} = \frac{c - 2x}{c}$,

whence $\theta^2 - \theta_1^2 = \frac{4(c - x)x}{c^2} \theta^2$

Therefore $L^1 - L = \frac{(c - x)x}{2N^2} \tan L$

or difference of latitude in chains $= R(L^1 - L) = \frac{R}{2N^2} x(c - x) \tan L$

The computation has been made for the first system of survey, but may be used for any system without sensible error.

Table XIV.

Finding the Time by Transits across the Vertical of Polaris.

(Dr. Deville.)

This table is for the determination of the watch error by the observation of the transits of the Pole Star and another star across the same vertical.

Let L be the latitude of the place, $R.A.$ and $D.$ the right ascension and declination of the Pole Star, $R.A'.$ and D' the same quantities for the other star, T and T' the watch times of transit of each of the stars across the same vertical, p the distance from the pole to this vertical, and t the hour angle of the time star at the instant it was observed. The value of p is never greater than the polar distance of the Pole Star ; the hour angle t for a time star far from the pole is also a small quantity. Disregarding terms which contain powers of p and t above the second, we have *

$$t = p\ (\tan L - \tan D').$$

This value, when p is known, is readily calculated by taking $(\tan L - D')$ from a table of natural tangents. The logarithmic form of the formula may also be employed :

$$t = p \frac{\sin (L - D')}{\cos L \cos D'}$$

In using either formula it must be remembered that a south declination is negative.

Table XIV gives the value of $\log p$ expressed in seconds of time.

The arguments are the declination of the time star D', and the time interval A, of which the value is :

$$A = (R.A'. - R.A.) - (T' - T)$$

A is taken in the column at the left of the table for time stars of north declination, and at the right of the table for stars of south declination.

The table was calculated for a value of D equal to 88° 51′. For other values, a correction must be added to $\log p$; it is given in Table XV.

The time obtained by means of this table is sufficiently accurate for all practical purposes, except the determination of longitudes.

The table may also be employed for calculating the azimuth of Polaris when the sidereal time is known. The hour angle of Polaris is used as argument 'A' and the latitude of the place instead of 'Declination North'. The azimuth in minutes of arc is

$$\frac{p \sec L}{4}$$

The result is accurate within a few seconds of arc.

Table XIV was computed by the following formula :—

$$p = P \sin A + \frac{P^2}{2} \sin 2A \tan D'$$

where P is the polar distance of Polaris.

---

* Determination of time by transits across the Vertical of Polaris, by E. Deville—Transactions of the Royal Society of Canada, 1888.

Example.—On the 15th April, 1903, on the north boundary of township twenty, range two, west of the fifth meridian, the following transits were observed across the same vertical :—

Polaris	6^h 33^m 27^s
Alpha Canis Majoris	6 36 42

Chronometer keeping sidereal time—Required the chronometer error.

R.A'. = 6*h* 40*m* 52·9*s*	*T'* = 6*h* 36*m* 42*s*	*L* (Table IV) = 50° 45′	
R.A. = 1 23 24·7	*T* = 6 33 27	*D'* = − 16 35	*D* 88° 47′ 25″
R.A'. − *R.A.* = 5 17 28·2	*T'* − *T* = +3 15	*L* − *D'* = 67 20	
T' − *T* = + 3 15·0			
A = 5 14 13·2			

CALCULATION BY LOGARITHMS.

Log *p* for 5*h* 10*m* (Table XIV)	= 2·4300
Difference for 4*m* 13*s*	= + ·0017
Correction for 88° 47′ 25″ (Table XV)	= + ·0220
Log sin (*L*—*D'*)	= 9·9651
Log sec *L* (Table X)	= 0·1988
Log sec *D'*	= 0·0185
Log *t*	= 2·6361
t	= 432·6
	= 0*h* 7*m* 12·6*s*
R. A'.	= 6 40 52·9
Sidereal time of transit	= 6 33 40·3
T'	= 6 36 42·0
Chronometer error	= − 3 1·7

CALCULATION BY NATURAL TANGENTS.

Nat. tan *L*	= 1·2239
Nat. tan *D'*	= —0·2978
Tan *L*—tan *D'*	= 1·5217

Log *p* for 5*h* 10*m* (Table XIV)	= 2·4300
Difference for 4*m* 13*s*	= + ·0017
Correction for 88° 47′ 25″ (Table XV)	= + ·0220
Log (tan *L* − tan *D'*)	= ·1823
Log *t*	= 2·6360
t	= 432·5*s*
	= 0*h* 7*m* 12·5*s*
R. A'.	= 6 40 52·9
Sidereal time of transit	= 6 33 40·4
T'	= 6 36 42·0
Chronometer error	= − 3 1·6

TABLE XV.

Correction for Declination of the Pole Star to be added to the values of Table XIV.

(Dr. Deville.)

This table gives the correction to be added to the value of log *p* in Table XIV when the declination of Polaris differs from 88° 51′; the correction, which is merely the difference between the logarithm of the polar distance of Polaris, expressed in seconds of time, and the logarithm of 276 is positive when the declination is less than 88° 51′, and negative when it is greater than 88° 51′.

TABLE XVI.

For Converting the Logarithm Tangent of Small Arcs into Logarithms of Seconds of Arc.

(Dr. Deville.)

This gives the logarithm of the ratio of a small arc expressed in seconds of arc, to its tangent; by adding it to the log tangent, the logarithm of the arc is obtained, and the arc itself is found with a table of logarithms of numbers, without having to compute proportional parts. This table is intended to replace the table printed on the record of astronomical observations, when the instrument employed is divided sexagesimally.

TABLE XVII.

$$Log\ \frac{1}{1-m}$$

These tables are useful in abridging the work of reduction of time azimuth observations on Polaris; they give at once the value of log $\frac{1}{1-\tan P \tan L \cos t}$ when log tan P tan L cos t is known.

TABLE XVIII.

Deflection of a Trial Line for Deviations from 1 to 149 Links at the end of Eighty-one Chains.

This is useful in deflecting trial lines. It gives the angular deflection of a line for deviations of 1 to 149 links at the end of eighty-one chains.

TABLE XIX.

Correction in Links for Slope Measurements.

The correction in links to slope measurements is given for one and for eight chains, tapes of these lengths being those in general use on Dominion Land Surveys. The table is used in connection with a clinometer. See clauses 263-264 of the Manual of Instructions for the Survey of Dominion Lands.

TABLE XX.

Table for Laying Out Roads One Chain Wide.

This table is intended for laying out roads; it gives for roads one chain wide the distance to the opposite limit at road corners when the survey is made along one of the limits. For wider or narrower roads, the tabular distance is proportionally increased or decreased. When the survey is made along the middle of the road, the distance of the corners on each side is one half of the tabular distance. See clauses 129-130 of the Manual of Instructions for the Survey of Dominion Lands.

THE ASTRONOMICAL FIELD TABLES.

DESCRIPTION OF THE TABLES.

(Dr. Deville.)

The Field Tables are for the determination of the astronomical meridian, on subdivision surveys, by observation of the Pole Star, and incidentally for finding the time. Owing to the apparent motion of the Star, the tables are issued for short periods, otherwise the errors would become excessive. Their use is fully explained in the Manual of Survey (Appendix B).

Table for finding the Pole Star and the Astronomical Meridian.—The table is entered with the sidereal time as argument. The first column gives the number of minutes to be added to or subtracted from the latitude for obtaining the altitude of the star. In the second column is the argument, the local sidereal time for every ten minutes. In the other columns are the bearings of the Star for every twentieth township up to township 80.

The object of the table is twofold. In the first place it serves to find the Star in daytime. The telescope of the transit instrument is turned in the direction of the Star by means of the tabular bearing and is set to the altitude taken from the table. The Star can then be located near the centre of the telescope's field. This presupposes that the direction of the meridian is known approximately, which is the case on subdivision surveys. When it is not known, recourse is had to the map of "Astronomical Bearings of Magnetic North in Western Canada." With a Watts transit, the vernier of the horizontal circle is set to read the astronomical bearing of magnetic north, the lower clamp is released and the instrument turned in azimuth until the points of the compass' needle coincide with the index marks. The lower clamp being now fastened and the vernier clamp released, the readings of the horizontal circle are approximately astronomical bearings. In this form of intrument, the compass has frequently an index error, which it is well to ascertain and to allow for.

The latitude is required for calculating the altitude of the Star: it is taken with sufficient accuracy for the purpose from the diagram showing, in the centre, the number of the township, and on the right side, the latitude.

The second object of the table is, after the Star has been found and observed, to ascertain its bearing: the table is not absolutely accurate, but the precision is ample for subdivision surveys.

Sidereal Time at Noon, Mountain Time.—As a first approximation for setting the Surveyor's watch from standard time clocks, this table gives the sidereal time at noon, mountain time for the 15th of each month.

Time Stars—The exact local sidereal time and the error of the watch may be obtained by observing the meridian transit of a " time star ". The table gives the approximate polar distance of each star, from which the altitude is calculated for setting the telescope; it gives also the sidereal time of meridian transit for each month.

The Sun's Apparent Right Ascension and Variation for one hour at Greenwich Apparent Noon.—Another method of obtaining the sidereal time is to observe the meridian transit of the Sun. The table gives the Sun's apparent right ascension at Greenwich apparent noon and its variation for one hour. For calculating the variation from Greenwich apparent noon, the longitude is required: this is taken, in hours and tenths, from the diagram of townships, meridians and ranges.

This table is copied from the Nautical Almanac.

Longitude in Hours and Tenths.—From this diagram the longitude in hours and tenths for every township up to township 80, and for every range as far as the seventh meridian, is obtained at a glance. It is used, as already explained, for the interpolation of the sun's apparent right ascension.

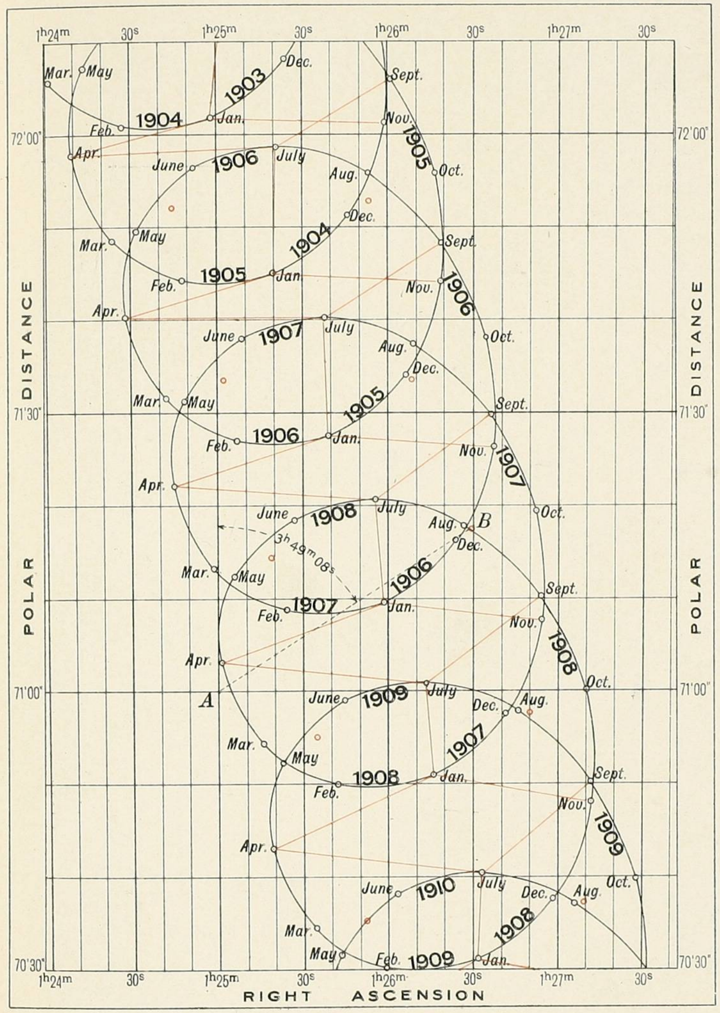
Latitude and Convergence per Section.—The diagram shows at a glance for every township, up to township 80, the latitude, and the convergence of the meridians for one section in minutes and hundredths. The convergence serves to refer an observed bearing to the meridian of the centre of the township or to any other meridian, as explained in the Manual of Survey. The latitude is used, as previously mentioned, for calculating the altitude of Stars for daylight observations.

Astronomical Bearings of Magnetic North in Western Canada.—This map is intended, as already explained, for setting the transit theodolite to read astronomical bearings by means of the compass attached to the standard. The method is fully described in the Manual of Survey (Appendix B).

The Apparent Motion of the Pole Star.

The path described by the Pole Star on the celestial sphere from 1903 to 1910 is shown on Plate 1: it is the combined effect of precession, nutation, aberration and proper motion. The motion in the course of a single year is considerable: between the first of June and the end of December, it is over fifty seconds of arc. If a mean annual value were adopted for calculating the field tables, the resulting error in azimuth in township 80 would

APPARENT MOTION OF THE POLE STAR PLATE I



The periods covered by each table are outlined in red.
The mean position of the Pole Star adopted for each table is indicated by a small red circle.

be three-quarters of a minute. Even by dividing the year into two periods and calculating two field tables for each year, the error in azimuth due to the difference between the mean and the actual position of the Star could not well be reduced to less than half a minute.

It will be observed that the Star crosses its path again and again. At the beginning of September, it is at the same place as at the end of October in the preceding year; again, about the first of August, it returns where it was in November two years before. By taking advantage of this peculiarity, and using the same tables for short periods in two and three successive years, the maximum difference between the actual positions of the Star and the mean positions selected for calculating the tables, can be considerably reduced. Under the system adopted, there are two sets of tables. One set is for January, February and March of one year and for April, May and June of the following year: the other set is for November and December of one year, September and October of the next year, and July and August of the next following year. The maximum difference between the mean and actual positions of the Star is about thirteen seconds, which, in township 80, corresponds to an error of twenty-three seconds in azimuth or about a third of a minute. The periods covered by the tables are outlined in red on Plate 1, the mean positions being indicated by small red circles. This maximum error could be reduced further by adopting for the tables periods consisting of fractional parts of months instead of whole months as at present: this may be done later.

Computation of the Tables.

The Auxiliary Table.—Neglecting terms which contain powers of the Polar distance above the third, the bearing of the Pole Star is given by the formula:

$$\begin{aligned} Z = & -P \sec L \sin t \\ & - \tfrac{1}{2}P^2 \sin 1' \sec L \sin 2t \tan L \\ & - \tfrac{1}{3}P^3 \sin^2 1' \sec L \sin t \left\{(1 + 4 \tan^2 L) \cos^2 t - \tan^2 L\right\} \end{aligned}$$

The maximum value of the third term at the extreme limit of the table is about three seconds. The table being liable to an error of twenty-three seconds by reason of the difference between the mean and actual position of the Star, this term is disregarded in the computation.

The maximum values of the second term are 1·09 minutes for township 0 (Latitude 49°), and 1·27 minutes for township 80 (Latitude 55° 54′).

An auxiliary table is first computed for an assumed position of the Pole Star, even figures being taken for the sake of simplifying the calculations. For the right ascension, it is essential to take a figure ending in 0^m or 5^m, say $1^h\ 25^m$ or $1^h\ 30^m$, so as to save one-half of the calculations, those from $t = 12^h$ to $t = 24^h$ serving for the interval $t = 0^h$ to $t = 12^h$. At this time, for instance (1907), a right ascension of $1^h\ 25^m$ and a polar distance of 71′ may be taken.

Table for the Bearing of the Pole Star. The first term of the bearing is tabulated from $13^h\ 25^m$ to $1^h\ 25^m$, sidereal time, ($t = 12^h$ to $t = 24^h$), for each of the townships 0, 20, 40, 60, and 80. For each township $P \sec L$ is a constant factor which is multiplied by the several values of $\sin t$.

The second term, which, it has been shown, does not exceed 1′.27, is found with ample accuracy by a graphic process.

Table for the Altitude of the Pole Star. Disregarding terms containing powers of P above the second, the quantity to be added to the latitude for obtaining the altitude is given by the formula

$$h - L = P \cos t - \tfrac{1}{4}P^2 \sin 1' \tan L\ (1 - \cos 2t)$$

This expression being a function of the latitude, a separate calculation would be required for each of the townships 0, 20, 40, 60 and 80, if great accuracy were aimed at, but considering that the term which contains L is small, and moreover, that this part of the field tables is intended merely for setting the telescope of the transit for finding the Star, it is sufficiently accurate to use a mean value for the latitude and to calculate a single table.

The first term, $P \cos t$, has already been tabulated under the form $P \sin t$ for the table of bearings – the second term,

$$\tfrac{1}{4}P^2 \sin 1' \tan L\ (1 - \cos 2t)$$

is found by a graphic process.

The auxiliary table serves for a number of years; it is printed for the use of the computers.

Computation of the Field Tables. The auxiliary table having been computed for the position A, Plate 1, of the Star, it is required to derive from it any other table; for instance, the table for the periods of November and December, 1906, September and October, 1907, and July and August, 1908, the mean position B of the Pole Star for these periods being

$$R.A. = 1^h\ 26^m\ 29^s$$
$$P = 71'{\cdot}3$$

The corrections to the auxiliary table could be found by means of the differential formulæ, by taking

$$dt = 1^m\ 29^s$$
$$dP = 0'{\cdot}3$$

Terms of the third order, that is to say those containing P^2, can be neglected.

It is more convenient, however, to deal with the matter in a different way.

Let O, Fig. 1, be the Pole, Z the zenith, S the Pole Star and A the point for which the auxiliary table is calculated. Through O, draw OB parallel and equal to AS, and let us imagine another circumpolar star in B. The azimuth of the Pole Star is, within the limit of accuracy of the tables, equal to the azimuth of A plus or minus the azimuth of B, as the case may be. The polar distance, p, of the imaginary star B being very small, its azimuth may be taken as equal to

$$p \sin t \sec L$$

t being the hour angle of B.

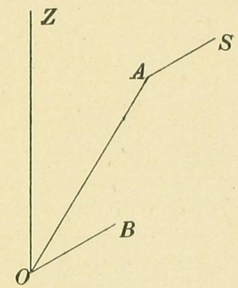


FIG. 1.

This is equivalent to disregarding terms of the third order in the calculation by the differential formulæ.

The polar distance of the star B is the distance AB, Plate 1; by scaling it on the plate it is found equal to 32″·4 or 0′·54. The right ascension of the star B is equal to the right ascension of A, Fig. 1, $1^h\ 25^m$, plus or minus the angle AOB, as the case may be. This angle is measured on Plate 1: in the present case its value is 57° 17′, or

$$3^h\ 49^m\ 08^s$$

and the right ascension of the imaginary star B is

$$1^h\ 25^m + 3^h\ 49^m\ 08^s = 5^h\ 14^m\ 08^s$$

The correction to the table for the altitude of the Pole Star is obtained in a similar way, being equal to

$$p \cos t$$

These two corrections $p \sin t \sec L$ and $p \cos t$, are found by a graphic process.

DIAGRAMS OF THE ALTITUDE AND BEARING OF THE POLE STAR.

GRAPHIC REPRESENTATION OF EQUATIONS.

(Dr. Deville.)

Before explaining the theory of this abacus, it is necessary to recall a few of the principles of the graphic representation of equations. An exhaustive investigation of the subject has been made by d'Ocagne :* what is needed for our purpose may be summed up as follows :

If, in the equation of a curve :

$$(1) \qquad f_1(x, y, \alpha_1) = 0$$

successive increments are given to the parameter α_1, to each of these increments corresponds a different curve : the equation thus defines a system of curves (α_1).

In the same way, the equations :

$$(2) \qquad f_2(x, y, \alpha_2) = 0$$

$$(3) \qquad f_3(x, y, \alpha_3) = 0$$

define the systems of curves (α_2) and (α_3). When three of these curves taken respectively in each of the systems intersect in one point, the corresponding values of the variables $\alpha_1\ \alpha_2\ \alpha_3$ satisfy the equation :

$$F(\alpha_1, \alpha_2, \alpha_3) = 0$$

resulting from the elimination of x and y between the equations (1), (2) and (3). The value of any one of the variables can thus be obtained by means of the other two. For instance, if we wish in Fig. 2 to find the value of α_3 corresponding to $\alpha_1 = 2$ and $\alpha_2 = 4$, we follow to their intersection the curves marked "2" in the system (α_1) and "4" in the system (α_2) : the curve of the system (α_3) passing through this point being marked "5", this number is the required value of α_3.

This kind of abacus is the one most frequently met with, although by no means the best. Usually one of the variables, α_1, is taken as x and another, α_2, as y ; α_1 is thus represented by a series of parallels to the y axis, α_2 by a series of parallels to the

* Traité de Nomographie, by Maurice d'Ocagne, Paris—Gauthier—Villars.

x axis and α_3 by a series of curves. The use of this abacus requires simultaneous interpolation by estimation between three pairs of lines, an operation not susceptible of much precision. The accuracy may to some extent be increased by drawing more lines, but a limit is soon reached beyond which the number of lines becomes confusing.

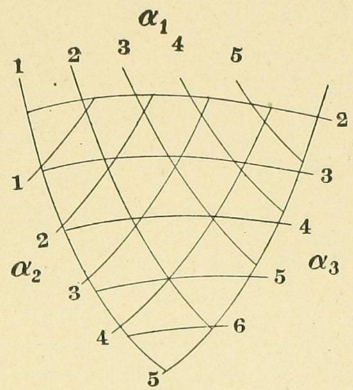


FIG. 2.

To shorten writing, let f_n, φ_n, ψ_n, be written instead of $f_n(\alpha_n)$, $\varphi_n(\alpha_n)$, $\psi_n(\alpha_n)$, and let us consider the particular case when equations (1), (2), (3), assume the form

$$(4) \qquad \begin{aligned} x f_1 + y\varphi_1 + \psi_1 &= o \\ x f_2 + y\varphi_2 + \psi_2 &= o \\ x f_3 + y\varphi_3 + \psi_3 &= o \end{aligned}$$

Each of these equations defining a system of straight lines, their resultant after the elimination of x and y

$$(5) \qquad \begin{vmatrix} f_1 & \varphi_1 & \psi_1 \\ f_2 & \varphi_2 & \psi_2 \\ f_3 & \varphi_3 & \psi_3 \end{vmatrix} = o$$

is represented by three systems of straight lines. Thus an abacus consisting of straight lines only can be constructed whenever the equation to be represented can be put in the form of equation (5).

By the application of the principle of duality, this figure can be transformed into a correlated one such that to straight lines shall correspond points. Each of the equations (4) which, in the first figure, defines a system of straight lines tangent to their envelope, defines in the second figure points distributed upon a curve, their bearer, as in Fig. 2. Equation (5), which in the first figure means that three straight lines are copunctal, means in the correlated figure that three points are costraight. Instead of following, as in Fig. 2, the lines (α_1) and (α_2) to their intersection and finding the line of the system (α_3) which passes through this point, the mode of employment of the new kind of abacus (Fig. 3)

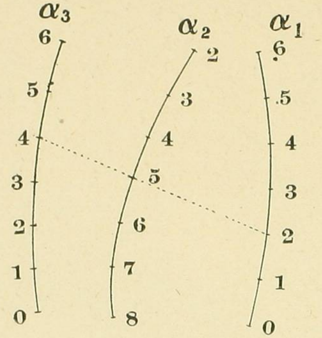


FIG. 3.

consists in joining by a straight line the points (α_1) and (α_2) and reading the graduation at the intersection of the bearer of (α_3). The abacus has gained in simplicity, consisting only of three lines, and the interpolation by estimation instead of being simultaneous between three pairs of lines is now made three times in succession between two divisions of a graduation, a process susceptible of considerable precision.

A convenient way of effecting the transformation is to employ *parallel* instead of *cartesian* co-ordinates. The parallel co-ordinates u and v of a straight line are the distances AM, BN, (Fig. 4) of its intersections by two parallel lines from the origins

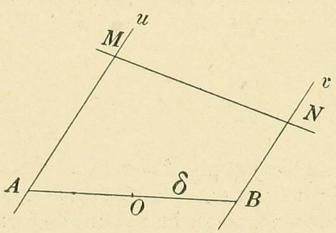


FIG. 4

A and B selected on these parallels. In this system, an equation of the first degree :

(7) $$au + bv + c = 0$$

defines a point of which the cartesian co-ordinates may be found

as follows : Taking O, centre of AB, as origin, OB as axis of x, a parallel through O to AM and BN as axis of y and designating by δ the distance OB, we have*

(8) $$x = \delta \frac{b-a}{b+a}$$

(9) $$y = \frac{-c}{b+a}$$

DIAGRAM OF THE BEARING OF THE POLE STAR.

The relation between the azimuth, hour angle and polar distance of the Pole Star and the latitude may be put in the form :

$$Z \cos L = P \sin t + \frac{P^2}{2} \tan L \sin 2t \sin 1'$$

---

* Equation (7) gives for $u = o$:

$$v = \frac{-c}{b}$$

and for $v = o$:

$$u = \frac{-c}{a}$$

Taking $AC = \frac{-c}{a}$ and $BD = \frac{-c}{b}$, the point defined by equation (7) is P, intersection of AD and BC (Fig. 5).

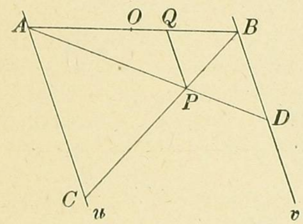


FIG. 5.

Similar triangles give the following proportions :

$$\frac{AQ}{AB} = \frac{QP}{BD}$$

and $$\frac{BQ}{BA} = \frac{QP}{AC}$$

Substituting the values of the different lines, the equations become

$$\frac{\delta + x}{2\delta} = \frac{y}{\frac{-c}{b}}$$

$$\frac{\delta - x}{2\delta} = \frac{y}{\frac{-c}{a}}$$

hence : $$\delta + x = 2\delta \frac{by}{-c}$$

$$\delta - x = 2\delta \frac{ay}{-c}$$

The surveys of Dominion Lands extend from the 49th parallel of latitude to about township 84, in latitude 56°20′, an interval of 7°20′. A mean value of the latitude may therefore be adopted for the last term of the above expression, which is always small.* Denoting by L_o this mean value, the equation may be written:

$$\frac{P \sin t + \frac{P^2}{2} \tan L_o \sin 2t \sin 1'}{tZ} - \cos L = O$$

now put :

(10) $$P \sin t + \frac{P^2}{2} \tan L_o \sin 2t \sin 1' = \frac{u}{l_1}$$

(11) $$-\cos L = \frac{v}{l_2}$$

and the equation becomes :

(12) $$\frac{u}{Zt l_1} + \frac{v}{l_2} = o$$

The value of u is calculated by (10) for hour angle intervals of 10 minutes and laid out on the axis of u, Au, (Fig: 6), but the sidereal time instead of the hour angle is marked opposite the divisions of the graduation. This time is equal to the sum of

---

Adding up and dividing by 2δ, we have :

$$1 = y\left(\frac{b+a}{-c}\right)$$

or $$y = \frac{-c}{b+a}$$

Subtracting the second equation from the first one gives :

$$2x = 2\delta y\left(\frac{b-a}{-c}\right)$$

Replacing y by its value and dividing by 2 :

$$x = \delta\left(\frac{b-a}{b+a}\right)$$

*Designating by L_1 and L_2 the extreme values of L, the value of L_o which causes the least maximum error in the azimuth is given by the expression

$$\tan L_o = \frac{\tan L_1 \cos L_2 + \tan L_2 \cos L_1}{\cos L_1 + \cos L_2}$$

In the present case $L_o = 53°\ 17'$. The error is a maximum for townships 0 and 84 and for hour angles of 3 or 9 hours: it is then equal to 0′·22.

the hour angle and right ascension of the Star. The modulus l_1 is the length of one minute of arc on Au; it is selected arbitrarily so as to give suitable proportions to the figure.

In the same way, the values of v or $-\cos L$ are laid out below B on the axis of v, Bv, v being negative. The modulus l_2 is the length of cos 0° ; like the modulus l_1, it is selected so as to give

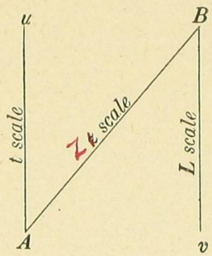


FIG. 6.

suitable proportions to the figure. The number of the township corresponding to the latitude is marked on the divisions of the graduation.

The cartesian co-ordinates of the points defined by (12) are given by (8) and (9) :

(13) $$x = \delta \frac{Zl_1 - l_2}{Zl_1 + l_2}$$

$$y = o$$

y being equal to zero, the line AB is the bearer of the Z scale. The values of x might be calculated from (13) and laid out from the centre of AB, but the graduation can be constructed in a more simple manner. In the first place, we observe that for $Z = o$, $x = -\delta$; so the zero of the graduation is at A. For $Z = \infty$, $x = \delta$; so the figurative point is at B. Now the scale defined by (13) is a linear scale; therefore it is the image of a regular scale and as its figurative point is at B on the line Bv, it is obtained by laying out a regular scale on a parallel to Bv and projecting it on AB from a projection apex on Bv. This is done as follows :

Join township 84, (Fig. 7) on the v scale, to $7^h 26^m$ ($t = 6^h$) of the u scale. The intersection C with AB is the end of the useful part of the Z scale. The value of Z in this case is $\frac{P}{\cos 56°\ 20'}$, let us say 129′·5. With a suitable scale, measure from A on Au a length AD of 129·5. Select on Bv a proper projection apex G; join AG and GC. Through D draw a parallel DM to AG and through the point M where it intersects GC produced, draw MN parallel to Av. The scale used for measuring AD if laid on MN with its zero at N, has its point $129'{\cdot}5$ at M; therefore its projection from G on AC gives the required Z scale.

For values of t between 12^h and 24^h, the graduations of both t and Z would fall beyond A and increase the size of the figure: this is avoided by changing the sign of u in (10). We have then two graduations for sidereal time on Au, and two graduations for

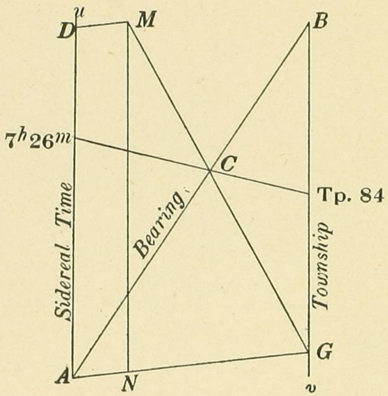


FIG. 7.

bearing on AB; the second graduations are printed in red to distinguish them. A specimen of the abacus will be found at back cover.

ABACUS OF THE ALTITUDE OF THE POLE STAR.

The altitude, h, of a star in terms of the latitude, hour angle and polar distance is given by the formula

$$\sin h = \sin L \cos P + \cos L \sin P \cos t$$

Let:
$$h = L + x$$

then: $\sin L \cos x + \cos L \sin x = \sin L \cos P + \cos L \sin P \cos t$

P and x are very small. Developing this expression in terms of the powers of P and x, and discarding the terms which contain powers above the second, we find:

$$x = P \cos t - \frac{P^2}{2} \tan L \sin^2 t$$

As before, we adopt a mean value, L_o, for $\tan L$.* Allowing $0'.75$ for refraction, we may write:

$$H = h + 0'{\cdot}75$$

Expressing H, L and P in minutes we have

$$L + P \cos t - \frac{P^2}{2} \tan L_o \sin^2 t \sin 1' - H + 0'{\cdot}75 = 0$$

Putting

(14) $$\frac{u}{l_1} = L$$

(15) $$\frac{v}{l_2} = P \cos t - \frac{P^2}{2} \tan L_o \sin^2 t \sin 1'$$

the equation becomes

(16) $$\frac{u}{l_1} + \frac{v}{l_2} - H + 0'{\cdot}75 = 0$$

The scale of u, (14), is a regular scale of modulus l_1, properly selected, for one minute of latitude. It is laid out on Au, but instead of measuring multiples of l_1, and numbering them in minutes of latitude, we measure multiples of nl_1, n being the

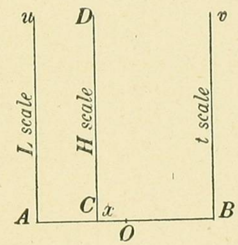


FIG. 8.

number of minutes of latitude in a township, and mark the township number opposite the divisions of the graduation. The scale of v, given by (15), is also a regular scale laid out on Bv with an appropriate modulus l_2; instead of the hour angle, the sidereal time is marked opposite the divisions of the graduation.

* The mean value causing the least maximum error in the altitude is the mean of the extreme values of $\tan L$; it corresponds to $L_o = 52° 59'$. he maximum error for $t = 6^h$ or 18^h, and for township 0 or 84 is $0'{\cdot}175$.

The cartesian co-ordinates of the points of the H scale, defined by (16), are given by (8) and (9):

$$x = \delta \frac{l_1 - l_2}{l_1 + l_2}$$

$$y = (H - 0'{\cdot}75) \frac{l_1 l_2}{l_1 + l_2}$$

x being a constant, the bearer of the H scale is a parallel CD (Fig. 8) to the axes, drawn at a distance x from the centre of AB. The H scale is a regular scale of modulus $\frac{1}{l_1} + \frac{1}{l_2}$, commencing at $0'{\cdot}75$ below the line AB.

The abacus has been made in two parts placed one over the other. The sidereal time scale is identical in both. The divisions of the altitude and township scales have been so arranged that they coincide, but they bear different numbers. The numbers of the second part are printed in red. A specimen of the abacus will be found at back cover.

PROBLEMS.

PROBLEMS CONNECTED WITH THE SYSTEM OF SURVEY.

(Dr. King.)

Correction for Height above Sea Level.

The tables have been calculated from the dimensions of the earth surface at sea level.

The township sides are actually measured on surfaces elevated above sea level, and therefore the differences of latitude and longitude calculated from the tables are greater than those actually covered by the township sides.

Any measured distance may be reduced to sea level by subtracting the correction $\frac{l}{r}x$, x being the distance, l the elevation above sea level, and r the radius of curvature of the line under consideration.

In general N (see Table I) can be used instead of r.

Base lines when the system of survey is exactly followed are established by direct measurement from the 49th parallel, northward along an initial meridian.

Hence the latitude of a base line should be less than that given in table by $(L - 49°)\frac{l}{R}$ where l is the mean elevation of the initial meridian between the 49th parallel and the base under consideration.

Many base lines, however, have been established, not by this direct measurement, but by the survey of township meridians from other bases. If the actual latitudes of these base lines are required, account must be taken of the elevations of all the north and south lines through which the connection with the 49th parallel has been made. It is obvious, however, that the average elevation of the country above the sea will give a sufficiently accurate result, since the small errors due to difference of elevation are masked by errors of survey.

On the base lines the effect of elevation above sea level is to decrease the difference of longitude covered by one range, and this must be allowed for in establishing an initial meridian by means of chainage along a base line, or in estimating the accuracy of measurement of a base line by its closing on an initial meridian, since the initial meridians, except the first, have been placed on even degrees of longitude (every fourth degree).

The correction for elevation above sea level is, in latitude 51°, 0·00382 chains for one mile distance at an elevation of 1,000 feet, and varies directly as the elevation and distance. It changes somewhat with the latitude, but slightly, and the correction in any particular case may be taken as the same as that for latitude 51°. If extreme accuracy be required, the formula given above, $\frac{l}{r}x$ may be used.

The error in the length of township chords of course involves an error in deflection angles and azimuths, but this is too small to be appreciable.

Latitudes and Longitudes of Points in the System.

By "points in the system" I mean the corners of specified sections, or points referred to them by connecting lines. In the latter case the lines, if short, may be reduced to latitude and longitude by means of "latitude and departure" from a traverse table, and by using Table XIII.

Thus the problem is reduced to the determination of the latitude and longitude of any section corner.

Latitude.

The latitude of the section corner can be at once found by interpolation from Table III or Table IV, according as the section is in the first, second or third system.

It must be remembered that in the first and second systems, the section posts on a meridian are 81·50 chains apart, and that in the third system they are alternately 81 and 80 chains.

The latitude can also be taken directly from Table IX or Table X.

Since the section corners are presumed to be at a distance of even sections from the north and south boundaries of the township, being established by survey from those boundaries, the latitude found as above must, when the section corner is not on the meridian outline of the township, be increased by the correction given by Table XIII.

In the first system the sections are not measured on meridians from the north or south boundary of the township, but on lines parallel to the eastern boundary of the township. Hence, theoretically, the difference of latitude between the given corner and the township outline should be decreased in the ratio of cosine azimuth of the section line to unity; but this correction is practically insignificant. The correction for sea level may also be applied.

Longitude, Third System.

In the second and third systems, the section lines are true meridians from the base line north and south two townships. Hence the longitude of a section corner is the same as that of the corresponding corner on the base line from which the township has been surveyed.

Then if dM be the longitude covered by one range on that base line, and if n be the number of the range in which the section lies, m the number of sections lying between the given section and the eastern boundary of the township, the number of ranges which intervene between the initial meridian and the eastern boundary of the given section is $n-1+\frac{m}{6}$, and the difference in longitude between it and the initial meridian is $\left(n-1+\frac{m}{6}\right)dM$. This added to the longitude of the initial meridian gives the longitude of the eastern boundary of the section.

The longitude of the Principal or first Meridian is 97° 27′ ~~08″·4~~. 30″

The longitudes of the Second, Third, Fourth, &c., Meridians are 102°, 106°, 110°, 114°, &c., subject to certain errors of survey, which cannot be discussed at present.

The difference of longitude should be corrected for height above sea if precision is required. This can be done by multiplying it by $\left(1-\frac{l}{N}\right)$.

For example:

The N.E. corner of Sec. 16, Tp. 23, R. 17, W. of the Fourth Meridian (third system of survey). Here $n=17$, $m=3$, and the township is surveyed from the 7th base, for which we find from Table IV $dM = 8'\ 22''\cdot411 = 502''\cdot411$. Therefore longitude of of the section line

$$=110° + (502''\cdot411 \times 16\tfrac{3}{6}) = 112°\ 18'\ 09''\cdot78.$$

The corner is three sections, *i.e.*, 242 chains north of the 5th correction line, and its latitude is therefore (from Table IV)

$$50°\ 34'\ 20''\cdot77 + 10'\ 28''\cdot88 \times \frac{242}{966} = 50°\ 34'\ 20''\cdot77 + 157''\cdot55$$
$$= 50°\ 36'\ 58''\cdot32$$

Longitude, First System.

In the first system the procedure for the longitude is a little different. The section lines are drawn parallel to the east side of the township, so that the difference of longitude between the section line and the east boundary of the township is not the same as on the base line, but is equal to the actual distance from the boundary of the township divided by $P \sin 1''$, $P \sin 1''$ being taken from Table I for the actual latitude of the section post. Thus using the same notation as before

difference of longitude from initial meridian

$$= (n-1)dM + \frac{81\cdot50 \times m}{P \sin 1''}$$

dM being taken from Table III (1st system) for the governing base line, or it may be calculated by the equivalent formula

$$\text{difference of longitude} = \left(n - 1 + \frac{m}{6}\right)dM + \frac{Q}{P \sin 1''}$$

where $Q = 2m\ (40 - w)$, w being the width of quarter sections as taken from the last column of Table IX.

Longitude, Second and Fourth Systems.

Longitudes in the 2nd system are calculated in the same way as those in the 3rd, taking dM from Table III instead of Table IV. In the 4th system the process is the same as for the 3rd system, and the same table is used—Table IV.

Effect of Errors of Survey.

An error in the latitude of the base line, or an error in the longitude of the initial meridian, of course increases or decreases by the amount of the error the latitude or longitude of the section corner. Similarly a chainage error on the base line affects the longitude directly. In the computation all known errors of this kind must be allowed for.

An error in the latitude of the base line also affects the longitude covered by 486 chains (or 489 chains measured along the base line), since 486 chains covers less longitude if the base line be moved north. The manner in which the effect of an error of this kind may be estimated will be best shown by an example.

Suppose the 6th base line (3rd system) to be placed 10 chains too far north, we find from Table IV

$$dM \text{ for 6th base line} = 498\cdot662$$
$$dM \text{ for 6th correction line} = 500\cdot527$$

The 6th correction line is two townships, *i.e.*, 966 chains north of the 6th base line, and the difference in dM for these lines is $1''\cdot865$. Therefore, dM for the actual position of the 6th base line, 10 chains north of its theoretical position, is

$$498''\cdot662 + 1''\cdot865 \times \frac{10}{966} = 498''\cdot681$$

The correction, in the case supposed, to dM for one range is $0''\cdot019$, and in 29 ranges (about the distance apart of two initial meridians) it amounts to $0''\cdot019 \times 29 = 0''\cdot55$, or 54 links.

GIVEN THE LATITUDE AND LONGITUDE OF A POINT, TO FIND ITS POSITION WITH REGARD TO THE SURVEY SYSTEM, *i.e.*, *to find in what section it is, and the township and range, and its distance from the N. E. corner of the section.*

Second, Third and Fourth Systems.

This is the converse of the preceding problem. The first step is to find, in the manner explained above, the latitude of the section line next north of the given latitude. The difference between these two latitudes is reduced to chains by Table I. This gives the distance (x) in chains to be measured from the point to find the north boundary of the section.

The number of sections by which the section line is north of the southern boundary of the township in which it lies is to be noted. Call this number a, and the number of the township t.

We also know the number of the nearest base line, *i.e.*, the base line on which depends the survey of township t. From Table IV we take out dM for this base line.

From the given longitude of the point subtract the longitude of the initial meridian. Divide the difference by dM, with quotient n and remainder r. Divide r by $\frac{dM}{6}$ with quotient b and remainder s. S reduced from seconds of longitude to chains by Table I, with argument, latitude of the given point, gives the distance (y) to be measured east from the point to find the eastern line of the section.

We now know that the given point is x chains south and y chains west of the north-east angle of some section in township No. t and range No. $(n+1)$ west of the initial meridian; and also that the northern boundary of the section is a sections north of the southern boundary of the township, and that the eastern boundary is b sections west of the eastern boundary of the township.

It is now easy by means of a skeleton township diagram to determine the numbers of the section, *e.g.*, if $a = 5$, $b = 3$, the section is 28.

Without a township diagram, the section number can be found from the formula.

$$\text{No. of section} = \tfrac{1}{2}\{12a - 5 \pm (2b - 5)\}$$

The upper sign being taken when a is odd, and the lower when a is even. These two rules are comprised in the general formula.

$$\text{No. of section} = \tfrac{1}{2}\{(12a - 5) - (-1)a(2b - 5)\}$$

The calculation for the second system is the same as above, using the proper tables for that system. It is also the same for the fourth system.

In this manner have been computed the positions of a great many section corners in British Columbia (fourth system of survey) with reference to points along the line of the Canadian Pacific Railway, the latitudes and longitudes of these points having been first determined by a traverse survey.

First System of Survey.

The procedure in this system is the same as above, except that the total difference of longitude from the eastern boundary of the township (instead of the nearest section line) must be reduced to chains, and from the chain distance must be subtracted the nearest multiple of 81·50.

Fractional Township or Range between parts of the Country Surveyed under different Systems of Survey.

Townships of the first and second systems adjoin each other without overlap or deficiency, since the townships in these two systems are of the same dimensions. Similarly of the third and fourth systems.

But where townships surveyed under the latter systems abut on townships of the first or second system, a fractional township or range occurs. It is only necessary to consider the case of the third system abutting on the first or second, since the fourth does not occur in juxtaposition with these latter systems.

Fractional Township.

Townships of the third system are 6 chains shorter, measured north and south than the others. The townships in both cases are measured north from the 49th parallel, and hence the third system falls short of the other by 6 chains for each township. and the northern boundary of a township of the third system is therefore south of the northern boundary of the same township of the first or second system by 6 chains multiplied by the number of the township.

Thus the 5th correction line (Tp. 18), as surveyed under the third system, is $6 \times 18 = 108$ chains south of its position under the second system. For twelve ranges west of the Second Meridian, the territory from the 5th correction line northward to the 8th correction line was surveyed under the second system, while the country south of the former line has been surveyed under the third system. There is therefore an additional township (measuring 108 chains from north to south) lying between Township 18 of the third system and Township 19 of the second system. (This fractional Township is called Township 19A, and is subdivided according to the third system. See Manual of Surveys.

Fractional Range.

Townships of the third system are 3 chains narrower (measured east and west along the base line) than those of the first and second systems. The overlap of the latter systems over the third, however, is not equal to 3 chains multiplied by the number of ranges, but exceeds this, since the widths are laid off along base lines which lie in different latitudes, and hence the convergence of meridians comes into play.

The readiest method of calculating this overlap is as follows:—

Let dM_1 be the longitude covered by one range of the base line in the first or second system as found from Table III.

Let dM be the same quantity for the base line of the third system (from Table IV).

Then $dM_1 - dM$ is the difference of the longitude between the exterior meridians of range one, as surveyed under the two systems.

The difference of longitude at the eastern boundary of the nth range will be

$$(n - 1)(dM_1 - dM)$$

This reduced to chains is

$$(n - 1)(dM_1 - dM)\ P \sin 1''$$

$P \sin 1''$ being taken from the proper table for the latitude of the base or section line on which the overlap is required.

First Example.

The meridian outline between Ranges 12 and 13, west of the 2nd Meridian, from Township 19 to Township 22, inclusive, is the western boundary of a tract of country surveyed under the second system of survey. Required the width of Range 13, as surveyed under the third system, on the northern boundaries of Townships 19, 20, 21 and 22.

The base line on which this meridian outline is based, is the 6th base line, or northern boundary of Township 20.

$$\begin{array}{rl} \text{From Table III, } dM_1 = & 8'\ 21''\cdot972 \\ \text{" IV, } dM = & 8'\ 18''\cdot662 \\ \hline \text{whence } dM_1 - dM = & 3''\cdot310 \end{array}$$

and at the eastern boundary of the thirteenth range, the difference of longitude is $3\cdot310 \times 12 = 39''\cdot72$.

We have then for the northern boundary of Township 19 (third system):

$$\begin{array}{rl} \text{Log } 39\cdot72 = & 1\cdot5990092 \\ \text{Table IV, Log } P \sin 1'' = & 9\cdot9896352 \\ \hline & 1\cdot5886444 \\ \text{Nat. number} = & 38\cdot783 \end{array}$$

For the northern boundary of Township 20:

$$\begin{array}{rl} \text{Log } 39\cdot72 = & 1\cdot5990092 \\ \text{Log } P \sin 1'' = & 9\cdot9888297 \\ \hline & 1\cdot5878389 \\ \text{Nat. number} = & 38\cdot711 \end{array}$$

For the northern boundary of Township 21:

$$\begin{array}{rl} \text{Log } 39\cdot72 = & 1\cdot5990092 \\ \text{Log } P \sin 1'' = & 9\cdot9880192 \\ \hline & 1\cdot5870284 \\ \text{Nat. number} = & 38\cdot639 \end{array}$$

For the northern boundary of Township 22:

$$\begin{array}{rl} \text{Log } 39\cdot72 = & 1.5990092 \\ \text{Log } P \sin 1'' = & 9\cdot9872086 \\ \hline & 1\cdot5862178 \\ \text{Nat. number} = & 38\cdot567 \end{array}$$

Hence the north boundaries of Townships 19, 20, 21 and 22, surveyed under the third system in Range 13, have their eastern tiers of section narrowed by 38·783, 38·711, 38·639 and 38·567, respectively.

Now, the full widths of these sections when regular is got from Table X, by multiplying the "width of quarter section" by 2.

Thus, the width of the eastern tier of sections in Range 13 is:

For Township	19,	$80\cdot15 - 38\cdot78 = 41\cdot37$	chains
" "	20,	$80\cdot\ \ - 38\cdot71 = 41\cdot29$	"
" "	21,	$79\cdot85 - 38\cdot64 = 41\cdot21$	"
" "	22,	$79\cdot70 - 38\cdot57 = 41\cdot13$	"

These widths must be increased by one chain for road, if the widths from post to post are required.

For the township lines to the north of the correction line, viz.: 23, 24, 25 and 26, the width of Range 13 may be found in the same way, using the dM from Tables III and IV for the seventh base instead of the sixth.

If the width of the section on the north side of the sixth correction line is required, that is, the south boundary of Township 23, it must be remembered that here, on account of the correction line being thrown south, from the less depth of the townships of the new system, the southern boundary of Township 23 of the third system, which is brought from the seventh base, intersects the second system south of the correction line, *i.e.*, on a line brought from the sixth base.

Therefore we have

$$\begin{array}{rl} \text{For the second system, Table III, } dM_1 \text{ 6th base} = & 8'\ 21''\cdot972 \\ \text{" third " " IV, } dM \text{ 7th " } = & 8'\ 22''\cdot411 \\ \hline \therefore\ dM_1 - dM = & -\ \ \cdot439 \\ \text{and for twelve ranges } 12\ (dM_1 - dM) = & -\ 5''\cdot268 \end{array}$$

With the difference of longitude $5''\cdot268$ and the $P \sin 1''$ for the sixth correction line, third system, we get the required jog.

It will be noticed that the overlap is negative, *i.e.*, there is a surplus.

The heavy lines represent the second system, the dotted ones the third. The line A^1B^1 is the one which we have just considered; it falls to the east of AB, but to the west of CD.

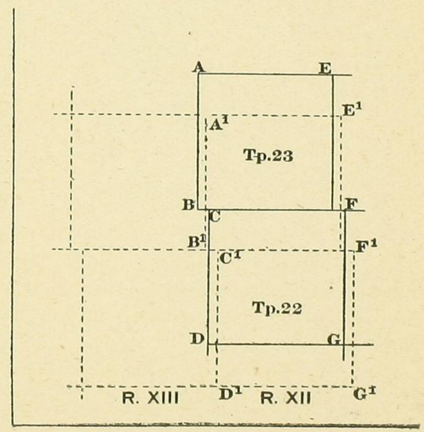


Fig. 9.

The lines in the figure are all township lines. Thus it will be seen that there is a small piece of land, B^1C, which is in fact a township of itself. Its designation would be Township 23 A, Range 12.

Second Example.

Required the depth, north and south, of Township 27, Range 19, west of the Principal Meridian.

The north boundary of Township 26 is the northern boundary of a tract of country surveyed under the first system.

Since each township of the third system is 6 chains shorter north and south than one of the first system, the northern boundary of Township 26 in the third system is $6 \times 26 = 156$ chains south of the same boundary under the first system.

Therefore the distance from the north boundary of Township 26, first system, to the north-east angle of Section 12, Township 27, third system, is $161 - 156 = 5$ chains.

Since 1·50 chains must be allowed for road, 3·50 chains is the available width of the strip of land

FRACTIONAL SECTIONS ADJOINING AN INITIAL MERIDIAN.

The longitude of the Principal Meridian at the intersection of the 4th Base is 97° 27′ 30″·0.

The 2nd, 3rd, &c., Initial Meridians were laid down by survey from it, with the intention to place them at each fourth degree of longitude—102°, 106°, 110°, &c. The actual longitudes, by astronomical observation, of such as have been determined, are:

2nd Initial Meridian at the north boundary of Sec. 13, Tp. 15, 102° 00′ 16″·5.

4th Initial Meridian at the 14th correction line, 110° 00′ 15″·0.

5th Initial Meridian at the north boundary of Sec. 13, Tp. 24, 114° 00′ 01″·5.

The discrepancies from the intended values are due in part to error in the assumed longitude of the Principal Meridian, in part to errors of survey. The longitudes of these meridians at points other than those stated, will of course vary with the azimuthal error in surveying the meridians.

The width of the last range in seconds on a given base line when closing on an Initial Meridian is got by subtracting from the difference in longitude (in seconds) between the Initial Meridians, the nearest integral multiple of dM from Table III or Table IV (according to the system of survey in question).

Thus for the width of the last range on the 5th Base Line between the 2nd and 3rd Initial Meridians (third system of survey) we have from Table IV, $dM = 494''·988$ for one range. Assuming that the 3rd Initial Meridian is midway between the 2nd and 4th, or in longitude 106° 00′ 15″·75, we divide 4° 00′ 15″·75, or 14415″·75, by 494″·988, with quotient 29 and remainder 61·10. That is, the width of Range 30 on the 5th Base, or the difference of longitude between the 3rd Initial Meridian and the meridian forming the eastern boundary of Townships 15, 16, 17 and 18, Range 30, is 61″·10. This can be converted into chains by multiplying by $P \sin 1''$ for the section line whose length is required, whether the southern boundary of Township 15, or the northern boundary of Township 18, or any of the intermediate township or section lines.

If the width of the last broken section be required, and if the remainder, after subtracting the integral multiple of dM is greater than one-sixth of dM, integral multiples of $\frac{1}{6}$ dM (difference of longitude covered by one section on the base line) must be subtracted until the remainder is less than $\frac{1}{6}$ dM. This remainder may then be converted to chains by multiplying by $P \sin 1''$ taken out of the Table for the latitude of the line under consideration. The reason for this is that the widths in seconds of longitude are the same for all sections from the base to the correction line (in the third system). The results should be corrected for the height of the base line above sea level, as ~~hereinafter~~ already further explained.

SOLUTIONS OF SOME PROBLEMS IN PRACTICAL GEODESY.

GIVEN THE LATITUDE AND LONGITUDE OF A POINT ON THE EARTH'S SURFACE, AND THE DISTANCE AND AZIMUTH THEREFROM OF A SECOND POINT, *required the latitude and longitude of the second point and the azimuth of the first point as seen from the second.*

The earth being considered a sphere, with radius equal to the normal at the place (N), the distance (K) may be reduced to arc by the formula

$$u'' = \frac{K}{N \sin 1''}$$

Then we have a spherical triangle formed by the two points and the north (or south) pole of the earth, the sides being the co-latitudes of the points ($90° - L$ and $90° - L'$) and u''; and the angles being the azimuths counted from the north of the points from one another, and the difference of longitude. Any three of these parts being given, the triangle may be solved by the usual formulæ of spherical trigonometry.

Since, however, the side u'' is very small compared with the radius of the sphere, and therefore the triangle cannot be accurately solved without logarithms of many decimal places, a more practical solution can be obtained by expanding the difference of latitude, &c., in series :—

We then have for distances not much exceeding 20 miles

$$L' = L + u'' \cos Z - (u'' \sin Z)^2 \sin 1'' \tan L$$

$$M' = M - (u'' \sin Z) \sec L$$

$$Z' = 180° + Z + (u'' \sin Z) \sec L \sin \tfrac{1}{2}(L + L')$$

where L and M are the latitude and longitude respectively of the first point

L' and M' those of the second point

Z the azimuth of the second as seen from the first

Z' " " " first " " second

Longitudes being counted towards the west, and azimuths from the *north through east* from 0° to 360°.

Correction for Spheroidal Figure.

The above formulæ are derived on the assumption that the earth is a sphere. The solution for the spheroid can be obtained by applying a correction to the difference of latitude. There is no correction necessary, to the order of the approximation of the formulæ given above, to either the difference of longitude or the difference of azimuth.

The spherical solution being made on a sphere whose radius is equal to the normal (N) at the place, which is the radius of the great circle perpendicular to the meridian, while the latitude is measured along the meridian, whose radius of curvature is R, the difference of latitude found as above must be multiplied by $\frac{N}{R'} = 1 + e^2 \cos^2 L$ nearly, or in other words $L' - L$ must be numerically increased by $e^2 \cos^2 L(L' - L)$.

The spheroidal formulæ then become

$$L' = L + u'' \cos Z - (u'' \sin Z)^2 \sin 1'' \tan L$$
$$+ e^2 \cos^2 L\{u'' \cos Z - (u'' \sin Z)^2 \sin 1'' \tan L\}$$
$$M' = M - (u'' \sin A) \sec L'$$
$$Z' = 180° + Z + (u'' \sin Z) \sec L'' \sin \tfrac{1}{2}(L + L')$$

The values of $e^2 \cos^2 L$ for different latitudes are:—

L	$e^2 \cos^2 L$	L	$e^2 \cos^2 L$	L	$e^2 \cos^2 L$	L	$e^2 \cos^2 L$	L	$e^2 \cos^2 L$
42	·000376	48	·000305	54	·000235	60	·000170	66	·000113
43	365	49	293	55	·224	61	160	67	104
44	353	50	282	56	213	62	150	68	096
45	341	51	270	57	202	63	140	69	088
46	329	52	258	58	191	64	131	70	080
47	317	53	247	59	181	65	122		

More Accurate Formulæ for Long Distances.

The above formulæ serve for distances not greater than say twenty miles. For longer distances, up to one hundred miles, the formulæ are (*see* "Lee's Table and Formulæ, Professional Papers of the United States' Engineers; and United States' Coast and Geodetic Survey, 1875", Appendix No. 19)—

$$L' - L = KB \cos Z - K^2 C \sin^2 Z - (\delta L)^2 D + K^2 hE \sin^2 Z$$
$$M' - M = \frac{K \sin A}{N' \sin 1'' \cos L'}$$
$$Z' = 180° + Z - (M' - M)\frac{\sin \frac{1}{2}(L + L')}{\cos \frac{1}{2}(L' - L)} + (M' - M)^3 F$$

Where K = the distance

$B = \frac{1}{R \sin 1''}$ for the latitude of the initial point,

$C = \frac{\tan L}{2NR \sin 1''}$ " " "

$D = \frac{\frac{3}{2} e^2 \sin L \cos L \sin 1''}{(1 - e^2 \sin^2 L)\frac{3}{2}}$ " " "

$E = \frac{1 + 3 \tan^2 L}{6N^2}$ " " "

$h = KB \cos Z$ or the first term of the expression for difference of latitude.

δL is an approximate value of $L' - L$ computed from the first and second terms of the expression.

$N' \sin 1''$ is taken for the latitude of the terminal point.

$\log F$, for latitude 45° = 7·840; for latitude 50° = 7·792; for latitude 55° = 7·723.

$\log e^2 = 7{\cdot}8305006$

$\log \sin 1'' = 4{\cdot}6855749$

The computation can be made by means of Table I, but more conveniently by means of the tables of the values of B, C, D and E, which are given in the United States Coast Survey Appendix above named.

It is to be noted that in the formulæ given in that appendix, the azimuth is counted from the south through west, while in those I have given for the shorter distances it is counted from north through east, conformably to the general practice in Dominion Land surveys. Hence as Z is increased by 180°, the sign of cos Z and sin Z is changed.

Formulæ in Terms of Rectangular Co-ordinates.

Suppose the latitude and longitude (L and M) of one point to be known, and the second point to be referred to the first by rectangular co-ordinates, y in the direction of the meridian and x perpendicular to it, y being positive when measured north from the first point, and x positive when measured west.

$$\text{Then } L' = L + \frac{y}{R \sin 1''} - \tfrac{1}{2} \sin 1'' \tan L' \left(\frac{x}{N \sin 1''}\right)^2 \frac{N \sin 1''}{R \sin 1''}$$

$$M' = M + \left(\frac{x}{N \sin 1''}\right) \sec L'$$

$$Z' = 180° + Z - \left(\frac{x}{N \sin 1''}\right) \tan L'$$

The expression for L' contains L', the quantity sought, in the last term. The value of L' to be used in computing this term is the approximate value of L' obtained from the first two terms

$$L + \frac{y}{R \sin 1''}$$

These formulæ may be used for differences of latitude and longitude on a traverse survey consisting of a number of short lines.

The co-ordinates with reference to the meridian of one of the points may be computed by summing the "latitudes and departures" taken from an ordinary traverse table for the several courses.

GIVEN THE LATITUDES AND LONGITUDES OF TWO POINTS, *to find the length and direction of their joining line.*

Let L and L' be the latitudes
M and M' be the longitudes

Then $(L' - L)$ multiplied by the factor $e^2 \cos^2 L$ given in the table on page 56, is the correction to the latitude to reduce it from the spheroid to the sphere. Half of this correction is to be applied to each latitude, in such direction as to bring them nearer together.

We then have, calling these corrected latitudes l and l', and $(L' - L)e^2 \cos^2 L = \beta$,

$$l = L + \frac{\beta}{2}$$

$$\tan Z = \frac{-(M' - M) \cos l'}{l' - l - \frac{1}{2} \sin 1'' (M' - M)^2 \cos^2 l' \tan l}$$

$$l' = L' - \frac{\beta}{2}$$

$$K = -\frac{(M' - M) \cos l'}{\sin Z} N \sin 1''$$

$$Z' = 180° + Z - (M' - M) \sin \frac{l + l'}{2}$$

$N \sin 1''$ should be taken for the mean latitude $\frac{L + L'}{2}$; so also $e^2 \cos^2 L$, although the difference in this latter will be inappreciable unless the difference of latitude is great.

KNOWING THE LATITUDE AND THE AZIMUTH *of one point from the other, to find the distance.*

Calculate β and l and l' as in the last case.

Find the auxiliary angles θ and $\theta - u$ from the equations

$$\tan \theta = -\frac{\tan l}{\cos Z}$$

$$\sin (\theta - u) = \frac{\sin l'}{\sin l} \sin \theta$$

Whence u is known; then $K = u \, N \sin 1''$

That value of θ is to be taken which is less than 90°, *i.e.*, if $\tan \theta$ be positive (when $\cos Z$ is negative) θ will be a positive less than 90°. If $\tan \theta$ be negative, θ will be a negative angle. In the latter case the formula

$$\sin (\theta - u) = \frac{\sin l'}{\sin l} \sin \theta$$

$$\text{becomes } \sin (\theta + u) = \frac{\sin l'}{\sin l} \sin \theta$$

θ in this last being taken positively.

GIVEN THE LATITUDE OF ONE POINT, THE AZIMUTH FROM THIS TO THE OTHER, AND THE DIFFERENCE OF LONGITUDE, *to find the distance.*

That is, given L, $M' - M$, and Z to find L', Z' and K.

Let dM be the difference of longitude. The auxiliary angle θ is computed by the formula

$$\tan \theta = -\sin l \tan Z$$

$$\text{and } \tan a' = \frac{\tan L \sin (\theta - dM)}{\sin \theta}$$

$$\beta = (a' - L)e^2 \cos^2 \tfrac{1}{2}(a' + L)$$

$$L' = a' + \beta, \quad l = L + \frac{\beta}{2}, \quad l' = L' - \frac{\beta}{2}$$

$$K = -dM \frac{\cos l'}{\sin A} N \sin 1''$$

Trigonometrical Levelling.

To find the elevation of one station above another by observation of the apparent altitude.

Let K represent the distance apart of the two stations, C the angle subtended by the arc joining the two stations at the earth's centre (*i.e.*, more properly at the centre of the curvature of the arc):

Let m = the coefficient of refraction

dh = difference of height of the two stations

S = radius of curvature of the arc joining the stations

E = measured angle of elevation

Then $C = \dfrac{K}{S \sin 1''}$

$$dh = \frac{K \sin \{E + (\frac{1}{2} - m) C\}}{\cos \{E + (1 - m) C\}}$$

S, the radius of curvature of the arc, is found from R and N, given the azimuth of the arc, in the manner explained under Table I, but for ordinary purposes

$N \sin 1''$ or $R \sin 1''$ may be used instead of $S \sin 1''$.

m varies in different places, being greater at the sea coast than in the interior. It runs from about ·065 to about ·080. Where accuracy is required it must be found by observation in the locality, by the method of reciprocal zenith distances, or otherwise.

Taking its value at ·070, the above formula becomes:

$$dh = \frac{K \sin (E + 0{\cdot}43\ C)}{\cos (E + 0{\cdot}93\ C)}$$

If the angle observed be an angle of depression instead of elevation, we have, calling the observed angle D:

$$dh = \frac{-K \sin (D - 0{\cdot}43\ C)}{\cos (D - 0{\cdot}93\ C)}$$

TABLES.

TABLES.

TABLE I.

Radii of Curvature of Meridians and Parallels, &c.

Latitude.	log N sin 1″.	log P sin 1″.	log R sin 1″.	Chains in 1″. Lati-tude.	Chains in 1″. Longi-tude.	Seconds in one Chain. Lati-tude.	Seconds in one Chain. Longi-tude.	English Miles in one Degree. Lati-tude.	English Miles in one Degree. Longi-tude.
° ′						″	″		
42 00	0·1873775	0·0584510	0·1857461	1·5337	1·1441	0·6520	0·8741	69.02	51·48
42 10	3818	73144	7589	1·5338	1·1411	0·6520	0·8764	69·02	51·35
42 20	3860	61711	7717	1·5338	1·1381	0·6520	0·8787	69·02	51·21
42 30	3903	50212	7845	1·5339	1·1351	0·6520	0 8810	69·02	51·08
42 40	3946	38645	7973	1·5339	1·1320	0·6519	0·8834	69·03	50·94
42 50	3988	27009	8101	1·5339	1·1290	0·6519	0·8857	69·03	50·81
43 00	4031	15306	8230	1·5340	1·1260	0·6519	0·8881	69.03	50·67
43 10	4074	0·0503534	8358	1·5340	1·1229	0·6519	0·8905	69·03	50·53
43 20	4117	0·0491693	8487	1·5341	1.1199	0·6519	0·8930	69 03	50·39
43 30	4160	79782	8615	1·5341	1·1168	0·6518	0·8954	69·04	50·26
43 40	4203	67802	8744	1·5342	1·1137	0·6518	0·8979	69·04	50·12
43 50	4245	55750	8872	1·5342	1·1106	0·6518	0.9004	69·04	49 98
44 00	4288	43629	9001	1·5343	1·1075	0·6518	0·9029	69·04	49·84
44 10	4331	31437	9129	1·5343	1.1044	0·6518	0·9054	69·04	49·70
44 20	4374	19173	9258	1·5344	1·1013	0·6517	0·9080	69·05	49·56
44 30	4417	0·0406838	9387	1·5344	1·0982	0 6517	0·9106	69·05	49·42
44 40	4460	0·0394430	9515	1·5344	1·0951	0.6517	0·9132	69·05	49·28
44 50	4503	81949	9644	1·5345	1·0919	0 6517	0·9158	69·05	49·14
45 00	4546	69396	9773	1·5345	1·0888	0·6517	0·9185	69·05	49·00

45 10	4588	56768	0·1859901	1·5346	1·0856	0·6516	0·9211	69·06	48·85
45 20	4631	44067	0·1860030	1·5346	1·0824	0 6516	0·9238	69·06	48·71
45 30	4674	31292	0159	1·5347	1·0793	0·6516	0·9266	69 06	48·57
45 40	4717	18442	0288	1·5347	1·0761	0·6516	0 9293	69·06	48·42
45 50	4760	0·0305517	0416	1·5348	1·0729	0·6516	0 9321	69·06	48·28
46 00	4803	0·0292516	0545	1·5348	1·0697	0·6515	0·9349	69·07	48·14
46 10	4846	79439	0673	1·5349	1·0665	0·6515	0·9377	69 07	47·99
46 20	4889	66285	0802	1·5349	1·0632	0·6515	0·9405	69·07	47·85
46 30	4932	53054	0931	1·5349	1·0600	0·6515	0·9434	69·07	47·70
46 40	4974	39745	1059	1·5350	1·0568	0·6515	0·9463	69·07	47·55
46 50	5017	26358	1188	1·5350	1 0535	0·6515	0·9492	69 08	47·41
47 00	5060	0·0212893	1316	1·5351	1·0502	0·6514	0 9522	69·08	47·26
47 10	5103	0·0199349	1445	1·5351	1·0470	0·6514	0 9551	69 08	47·11
47 20	5146	85726	1573	1·5352	1·0437	0·6514	0 9581	69·08	46·97
47 30	5188	72021	1701	1·5352	1·0404	0·6514	0·9612	69·08	46·82
47 40	5231	58237	1829	1.5353	1·0371	0·6514	0·9642	69·09	46·67
47 50	5274	44372	1957	1·5353	1·0338	0·6513	0·9673	69·09	46·52
48 00	5316	30425	2085	1·5354	1.0305	0·6513	0·9704	69·09	46·37
48 10	5359	16396	2214	1·5354	1·0272	0·6513	0·9736	69·09	46.22
48 20	5402	0·0102285	2341	1·5354	1·0238	0·6513	0·9767	69·09	46·07
48 30	5444	0·0088090	2469	1·5355	1·0205	0·6513	0·9799	69·10	45 92
48 40	5487	73812	2598	1·5355	1·0171	0.6512	0·9831	69·10	45·77
48 50	5530	59449	2725	1·5356	1·0138	0·6512	0·9864	69·10	45·62
49 00	5572	45001	2852	1·5356	1·0104	0·6512	0·9897	69 10	45·47
49 10	5615	30469	2980	1·5357	1·0070	0 6512	0·9930	69·11	45·32
49 20	5657	15849	3106	1·5357	1·0037	0·6512	0·9964	69·11	45 16
49 30	5699	0.0001143	3234	1·5358	1·0003	0·6511	0·9998	69·11	45·01
49 40	5742	9·9986351	3361	1·5358	0·9969	0·6511	1·0031	69·11	44·86
49 50	5784	71470	3488	1·5358	0·9935	0·6511	1·0066	69·11	44·71
50 00	5826	56501	3615	1·5359	0·9900	0·6511	1·0101	69·12	44 55
50 10	5869	41444	3742	1·5359	0·9866	0·6511	1 0136	69 12	44·40
50 20	5911	26296	3870	1·5360	0·9832	0 6510	1·0171	69·12	44·24
50 30	5953	9·9911058	3995	1·5360	0·9797	0·6510	1·0207	69·12	44·09
50 40	5995	9·9895730	4122	1·5361	0·9763	0·6510	1·0243	69·12	43·93

TABLE I.—*Continued.*

Radii of Curvature of Meridians and Parallels, &c.

Latitude.	log N sin 1″.	log P sin 1″.	log R sin 1″.	Chains in 1″. Lati-tude.	Chains in 1″. Longi-tude.	Seconds in one Chain. Lati-tude.	Seconds in one Chain. Longi-tude.	English Miles in one Degree. Lati-tude.	English Miles in one Degree. Longi-tude.
° ′						″	″		
50 50	0.1876037	9·9880309	0.1864248	1·5361	0·9728	0·6510	1·0279	69·13	43·78
51 00	6079	64797	4374	1·5362	0·9693	0·6510	1·0316	69·13	43·62
51 10	6121	49192	4500	1·5362	0·9659	0·6510	1·0353	69·13	43·46
51 20	6163	33493	4626	1·5363	0·9624	0·6509	1·0391	69·13	43·31
51 30	6205	17701	4751	1·5363	0·9589	0·6509	1·0429	69·13	43·15
51 40	6247	9·9801813	4877	1·5363	0·9554	0·6509	1·0467	69·14	42·99
51 50	6289	9·9785830	5002	1·5364	0·9519	0·6509	1·0506	69·14	42·83
52 00	6330	69750	5127	1·5364	0·9484	0·6509	1·0544	69·14	42·68
52 10	6372	53574	5252	1·5365	0·9448	0·6508	1·0584	69·14	42·52
52 20	6413	37299	5376	1·5365	0·9413	0·6508	1·0624	69·14	42·36
52 30	6455	20926	5501	1·5366	0·9378	0·6508	1·0664	69·15	42·20
52 40	6496	9·9704454	5625	1·5366	0·9342	0·6508	1·0704	69·15	42·04
52 50	6538	9·9687882	5749	1·5366	0·9307	0·6508	1·0745	69·15	41·88
53 00	6579	71208	5873	1·5367	0·9271	0·6507	1·0786	69·15	41·72
53 10	6620	54435	5997	1·5367	0·9235	0·6507	1·0828	69·15	41·56
53 20	6661	37558	6120	1·5368	0·9199	0·6507	1·0870	69·16	41·40
53 30	6703	20579	6244	1·5368	0·9163	0·6507	1·0913	69·16	41·24
53 40	6744	9·9603495	6367	1·5369	0·9127	0·6507	1·0956	69·16	41·07
53 50	6785	9·9586307	6490	1·5369	0·9091	0·6507	1·0999	69·16	40·91
54 00	6825	69012	6612	1·5370	0·9055	0·6506	1·1043	69·16	40·75
54 10	6866	51612	6735	1·5370	0·9019	0·6506	1·1088	69·16	40·59
54 20	6907	34104	6857	1·5370	0·8983	0·6506	1·1132	69·17	40·42
54 30	6948	9·9516488	6979	1·5371	0·8946	0·6506	1·1178	69·17	40·26
54 40	6988	9·9498764	7101	1·5371	0·8910	0·6506	1·1223	69·17	40·09
54 50	7029	80928	7222	1·5372	0·8873	0·6505	1·1270	69·17	39·93
55 00	7069	62982	7343	1·5372	0·8837	0·6505	1·1316	69·17	39·77
55 10	7109	44924	7464	1·5373	0.8800	0·6505	1·1363	69·18	39·60
55 20	7150	26754	7585	1·5373	0·8763	0·6505	1·1411	69·18	39·44
55 30	7190	9·9408470	7705	1·5373	0·8727	0·6505	1·1459	69·18	39·27
55 40	7230	9·9390072	7825	1·5374	0·8690	0·6505	1·1508	69·18	39·10
55 50	7270	71557	7945	1·5374	0·8653	0·6504	1·1557	69·18	38·94
56 00	7310	52927	8065	1·5375	0·8616	0·6504	1·1607	69·19	38·77
56 10	7349	34177	8184	1·5375	0·8579	0·6504	1·1657	69·19	38·60
56 20	7389	9·9315310	8304	1·5376	0·8541	0·6504	1·1708	69·19	38·44
56 30	7429	9·9296324	8422	1·5376	0·8504	0·6504	1·1759	69·19	38·27
56 40	7468	77218	8541	1·5376	0·8467	0·6503	1·1811	69·19	38·10
56 50	7508	57987	8659	1·5377	0·8429	0·6503	1·1863	69·20	37·93
57 00	7547	38635	8777	1·5377	0·8392	0·6503	1·1916	69·20	37·76
57 10	7586	9·9219158	8894	1·5378	0·8354	0·6503	1·1970	69·20	37·59
57 20	7625	9·9199557	9012	1·5378	0·8317	0·6503	1·2024	69·20	37·43
57 30	7664	79829	9128	1·5378	0·8279	0·6503	1·2079	69·20	37·26
57 40	7703	59974	9245	1·5379	0·8241	0·6502	1·2134	69·20	37·09
57 50	7742	39991	9361	1·5379	0·8203	0·6502	1·3190	69·21	36·92
58 00	7780	9·9119877	9477	1·5380	0·8166	0·6502	1·2247	69·21	36·75
58 10	7819	9·9099633	9593	1·5380	0·8128	0·6502	1·2304	69·21	36·57
58 20	7858	79257	9709	1·5381	0·8090	0·6502	1·2362	69·21	36·40
58 30	7896	58747	9824	1·5381	0·8051	0·6502	1·2420	69·21	36·23
58 40	7934	38102	0·1869938	1·5381	0·8013	0·6501	1·2479	69·22	36·06
58 50	7972	17321	0·1870052	1·5382	0·7975	0·6501	1·2539	69·22	35·89
59 00	8010	9·8996403	0167	1·5382	0·7937	0·6501	1·2600	69·22	35·72
59 10	8048	75347	0280	1·5383	0·7898	0·6501	1·2661	69·22	35·54
59 20	8086	54150	0393	1·5383	0·7860	0·6501	1·2723	69·22	35·37
59 30	8123	32812	0506	1·5383	0·7821	0·6501	1·2786	69·23	35·20
59 40	8161	9·8911331	0619	1·5384	0·7783	0·6500	1·2849	69·23	35·02
59 50	8198	9·8889706	0731	1·5384	0·7744	0·6500	1·2913	69·23	34·85
60 00	8236	67936	0843	1·5385	0·7705	0·6500	1·2978	69·23	34·67
60 10	8273	46018	0955	1·5385	0·7667	0·6500	1·3044	69·23	34·50
60 20	8310	23952	1066	1·5385	0·7628	0·6500	1·3110	69·23	34·32

TABLE I.—*Concluded.*

Radii of Curvature of Meridians and Parallels, &c.

Latitude.		log N sin 1″.	log P sin 1″.	log R sin 1″.	Chains in 1″.		Seconds in one Chain.		English Miles in one Degree.	
					Lati-tude.	Longi-tude.	Lati-tude.	Longi-tude.	Lati-tude.	Longi-tude.
°	′						″	″		
60	30	0.1878347	9·8801735	0.1871176	1·5386	0·7589	0·6500	1·3177	69 24	34·15
60	40	8384	9·8779367	1287	1·5386	0·7550	0·6499	1·3245	69·24	33·97
60	50	8420	56845	1397	1·5386	0·7511	0·6499	1·3314	69·24	33·80
61	00	8457	34169	1506	1·5387	0·7472	0·6499	1·3384	69·24	33·62
61	10	8493	9·8711336	1615	1·5387	0·7432	0·6499	1·3454	69·24	33·45
61	20	8529	9·8688345	1724	1·5388	0·7393	0·6499	1·3526	69·24	33·27
61	30	8565	65194	1832	1·5388	0·7354	0·6499	1·3598	69·25	33·09
61	40	8601	41882	1940	1·5388	0·7315	0·6498	1·3671	69·25	32·92
61	50	8637	9·8618406	2048	1·5389	0·7275	0·6498	1·3745	69·25	32·74
62	00	8673	9·8594766	2155	1·5389	0·7236	0·6498	1·3820	69·25	32·56
62	10	8708	70958	2261	1·5390	0·7196	0·6498	1·3896	69·25	32·38
62	20	8744	9·8546982	2368	1·5390	0·7156	0·6498	1·3973	69·25	32·20
62	30	8779	9·8522835	2474	1·5390	0·7117	0·6498	1·4051	69·26	32·03
62	40	8814	9·8498516	2579	1·5391	0·7077	0·6497	1·4130	69·26	31·85
62	50	8849	74022	2684	1·5391	0·7037	0·6497	1·4210	69·26	31·67
63	00	8884	49352	2789	1·5391	0·6997	0·6497	1·4291	69·26	31·49
63	10	8919	9·8424503	2893	1·5392	0·6957	0·6497	1·4373	69·26	31·31
63	20	8954	9·8399475	2997	1 5392	0·6917	0·6497	1·4456	69·26	31·13
63	30	8988	74262	3099	1·5393	0·6877	0·6497	1·4540	69·27	30·95
63	40	9022	48866	3202	1·5393	0·6837	0·6497	1·4626	69·27	30·77
63	50	9056	9·8323288	3305	1·5393	0·6797	0·6496	1·4712	69·27	30·59
64	00	9090	9·8297512	3407	1·5394	0·6757	0·6496	1·4800	69·27	30·41
64	10	9124	71546	3508	1·5394	0·6717	0·6496	1·4888	69·27	30·23
64	20	9158	45389	3609	1·5394	0·6676	0 6496	1·4978	69·27	30·04
64	30	9191	9·8219035	3709	1·5395	0·6636	0·6496	1·5069	69·28	29·86
64	40	9224	9·8192482	3809	1·5395	0 6596	0·6496	1·5162	69·28	29·68
64	50	9258	65730	3909	1·5395	0·6555	0·6495	1·5256	69 28	29·50
65	00	9291	38774	4008	1·5396	0 6514	0·6495	1·5351	69·28	29·32
65	10	9323	9·8111610	4106	1·5396	0·6474	0·6495	1·5447	69·28	29·13
65	20	9356	9·8084240	4205	1·5396	0·6433	0·6495	1·5544	69·28	28·95
65	30	9389	56659	4302	1·5397	0·6392	0·6495	1·5644	69·29	28·77
65	40	9421	28862	4399	1·5397	0·6352	0·6495	1·5744	69·29	28·58
65	50	9453	9·8000850	4496	1·5397	0·6311	0·6494	1·5846	69·29	28·40
66	00	9485	9·7972618	4592	1·5398	0·6270	0·6494	1·5949	69·29	28·21
66	10	9517	44164	4688	1·5398	0·6229	0·6494	1·6054	69·29	28·03
66	20	9549	9·7915485	4783	1·5398	0·6188	0·6494	1·6160	69·29	27·85
66	30	9580	9·7886577	4877	1·5399	0·6147	0·6494	1·6268	69·29	27·66
66	40	9612	57439	4972	1·5399	0·6106	0·6494	1·6378	69·30	27·48
66	50	9643	9·7828065	5065	1·5399	0·6065	0·6494	1·6489	69·30	27 29
67	00	9674	9·7798454	5158	1·5400	0·6023	0·6494	1·6602	69·30	27·11
67	10	9705	68602	5250	1·5400	0·5982	0·6493	1·6716	69·30	26·92
67	20	9735	38506	5342	1·5400	0·5941	0·6493	1·6833	69·30	26·73
67	30	9766	9·7708163	5434	1·5401	0·5900	0·6493	1·6951	69·30	26·55
67	40	9796	9·7677568	5525	1·5401	0·5858	0·6493	1·7070	69·31	26·36
67	50	9826	46718	5615	1·5401	0·5817	0·6493	1·7192	69·31	26·17
68	00	9856	9·7615610	5705	1·5402	0·5775	0·6493	1·7316	69·31	25·99
68	10	9886	9·7584241	5795	1·5402	0·5734	0·6493	1·7441	69·31	25·80
68	20	9916	52605	5883	1·5402	0·5692	0·6492	1·7569	69·31	25·61
68	30	9945	9·7520699	5972	1·5403	0·5650	0·6492	1·7698	69·31	25 43
68	40	0·1879974	9·7488520	6059	1·5403	0·5609	0·6492	1·7830	69·31	25·24
68	50	0·1880004	56064	6147	1·5403	0·5567	0·6492	1·7964	69·31	25·05
69	00	0032	9·7423324	6233	1·5404	0·5525	0·6492	1·8100	69·32	24·86
69	10	0061	9·7390298	6319	1·5404	0·5483	0·6492	1·8238	69·32	24·67
69	20	0090	56983	6405	1·5404	0·5441	0·6492	1·8378	69·32	24·49
69	30	0118	9·7323371	6490	1·5405	0·5399	0·6492	1·8521	69·32	24·30
69	40	0146	9·7289406	6574	1·5405	0·5357	0·6491	1·8666	69·32	24·11
69	50	0174	55244	6658	1·5405	0·5315	0·6491	1·8814	69·32	23·92
70	00	0202	9·7220719	6741	1·5405	0·5273	0·6491	1·8964	69·32	23·73

TABLE II.

Corrections to be applied to the Logarithms of R sin 1″ and N sin 1″ in Table I, for Clarke's later values of the dimensions of the earth.

Latitude.	d (log R sin 1″).	d (log N sin 1″).	Latitude.	d (log R sin 1″).	d (log N sin 1″).
°			°		
42	−0·0000021	+0·0000063	56	+0·0000034	+0·0000081
43	17	64	57	37	82
44	13	66	58	41	84
45	09	67	59	45	85
46	05	68	60	48	86
47	−0·0000001	70	61	51	87
48	+0·0000003	71	62	55	88
49	07	72	63	58	89
50	11	74	64	61	90
51	15	75	65	64	91
52	19	76	66	67	93
53	23	77	67	70	93
54	26	79	68	73	94
55	30	80	69	76	95
			70	78	96

TABLE III.

Latitudes, &c., of Base and Correction Lines. First and Second Systems of Surveys.

No. of Township.	Number of Line.	Latitude.			Log N sin 1″.	Log P sin 1″.	Log R sin 1″.	Longitude covered by 489 Chains of westing.	
		°	′	″				′	″
0	1st Base	49	00	00·00	0·1875572	0·0045001	0·1862852	8	03·959
2	Correction		10	36·86	5618	0·0029573	2989		05·681
4	2nd Base		21	13·70	5662	0·0014047	3122		07·421
6	Correction		31	50·52	5707	9·9998425	3256		09·177
8	3rd Base		42	27·33	5751	9·9982704	3391		10·951
10	3rd Correction	49	53	04·12	0·1875797	9·9966886	0·1863527	8	12·743
12	4th Base	50	03	40·89	5842	9·9950968	3662		14·552
14	Correction		14	17·64	5887	9·9334951	3797		16·379
16	5th Base		24	54·37	5932	9·9918831	3931		18·225
18	Correction		35	31·08	5976	9·9902611	4064		20·089
20	6th Base	50	46	07·77	0·1876021	9·9886289	0·1864198	8	21·972
22	Correction		56	44·44	6065	9·9869863	4331		23·875
24	7th Base	51	07	21·09	6110	9·9853334	4466		25·796
26	Correction		17	57·72	6154	9·9836700	4599		27·737
28	8th Base		28	34·33	6199	9·9819961	4733		29·698
30	8th Correction	51	39	10·92	0·1876243	9·9803116	0·1864867	8	31·678
32	9th Base		49	47·49	6287	9·9786163	4998		33·680
34	Correction	52	00	24·04	6332	9·9769104	5131		35·701
36	10th Base		11	00·57	6376	9·9751934	5264		37·744
38	Correction		21	37·08	6420	9·9734657	5395		39·808
40	11th Base	52	32	13·57	0·1876464	9·9717267	0·1865529	8	41·894
42	Correction		42	50·04	6508	9·9699768	5661		44·001
44	12th Base		53	26·49	6552	9·9682156	5791		46·130
46	Correction	53	04	02·92	6595	9·9664429	5920		48·282
48	13th Base		14	39·33	6640	9·9646592	6055		50·456

TABLE IV.

Latitudes, &c., of Base and Correction Lines. Third System of Survey.

No. of Township.	Name of Line.	Latitude. °	′	″	Log N sin 1″.	Log P sin 1″.	Log R sin 1″.	Longitude covered by 486 Chains. ′	″
0	1st Base	49	00	00·00	0·1875572	0·0045001	0·1862852	8	00·990
2	Correction		10	29·05	5617	0·0029764	2987		02·681
4	2nd Base		20	58·07	5661	0·0014431	3119		04·388
6	Correction		31	27·08	5705	9·9999003	3251		06·112
8	3rd Base		41	56·08	5749	9·9983480	3383		07·852
10	3rd Correction		52	25·05	5794	9·9967861	3518		09·610
12	4th Base	50	02	54·01	5833	9·9952143	3650		11·385
14	Correction		13	22·96	5883	9·9936329	3786		13·178
16	5th Base		23	51·88	5927	9·9920418	3918		14·988
18	Correction		34	20·77	5971	9 9904407	4050		16·816
20	6th Base		44	49·65	6015	9·9888297	4182		18·662
22	Correction		55	18·51	6059	9·9872086	4314		20·527
24	7th Base	51	05	47·35	6103	9·9855774	4446		22·411
26	Correction		16	16·17	6147	9·9839365	4578		24·313
28	8th Base		26	44·98	6191	9·9822842	4710		26·235
30	8th Correction		37	13·76	6235	9·9806224	4842		28·176
32	9th Base		47	42·53	6279	9·9789500	4974		30·136
34	Correction		58	11·26	6322	9·9772671	5103		32·117
36	10th Base	52	08	39·98	6366	9·9755737	5235		34·118
38	Correction		19	08·69	0·1876409	9·9738694	0·1865364	8	36·139
40	11th Base		29	37·37	0·1876453	9·9721545	0·1865496	8	38·181
42	Correction		40	06·04	6497	9·9704288	5628		40·245
44	12th Base		50	34·69	6540	9·9686921	5757		42·329
46	Correction	53	01	03·31	6582	9·9669442	5883		44·436
48	13th Base		11	31·92	6626	9 9651855	6015		46·564
50	13th Correction		22	00·52	6670	9·9634156	6147		48·714
52	14th Base		32	29·09	6712	9·9616342	6273		50·887
54	Correction		42	57·65	6756	9·9598417	6405		53·083
56	15th Base		53	26·19	6799	9·9580375	6534		55·302
58	Correction	54	03	54·71	6841	9·9562218	6660		57·545
60	16th Base		14	23·21	6884	9·9543945	6789	8	59·811
62	Correction		24	51·69	6927	9·9525554	6918	9	02·102
64	17th Base		35	20·15	6969	9·9507044	7044		04·417
66	Correction		45	48·59	7012	9·9488415	7173		06·758
68	18th Base		56	17·01	7054	9·9469665	7298		09·123
70	18th Correction	55	06	45·42	7096	9·9450792	7424		11·515
72	19th Base		17	13·82	7139	9·9431798	7553		13·932
74	Correction		27	42·20	7181	9·9412680	7679		16·376
76	20th Base		38	10·55	7223	9·9393437	7805		18·847
78	Correction		48	38·89	7264	9 9374066	7928		21·345
80	21st Base		59	07·20	7305	9·9354569	8051		23·871
82	Correction	56	09	35·49	7347	9·9334945	8177		26·424
84	22nd Base		20	03·77	7390	9·9315192	8306		29·006
86	Correction		30	32·03	7431	9·9295307	8429		31·618
88	23rd Base		41	00·28	7472	9·9275290	8552		34·258

TABLE IV.—*Concluded.*

Latitudes, &c., of Base and Correction Lines. Third System of Survey.

No. of Township.	Name of Line.	Latitude. °	′	″	Log N sin 1″.	Log P sin 1″.	Log R sin 1″.	Longitude covered by 486 Chains. ′	″
90	23rd Correction		51	28·51	0·1877513	9·9255140	0·1868675	9	36·929
92	24th Base	57	01	56·70	7554	9·9234856	8798		39·630
94	Correction		12	24·89	7595	9·9214436	8921		42·362
96	25th Base		22	53·07	7637	9·9193880	9047		45·125
98	Correction		33	21·22	7678	9·9173186	9170		47·919
100	26th Base		43	49·36	7718	9·9152351	9290		50·747
102	Correction		54	17·48	7759	9·9131376	9413		53·607
104	27th Base	58	04	45·57	7799	9·9110259	9533		56·500
106	Correction		15	13·66	7839	9·9088998	9653	9	59·427
108	28th Base		25	41·73	7879	9·9067591	9773	10	02·389
110	28th Correction		36	09·78	7919	9·9046039	0·1869893		05·386
112	29th Base		46	37·81	7959	9·9024339	0·1870013		08·418
114	Correction		57	05·83	7999	9·9002490	0133		11·487
116	30th Base	59	07	33·83	8039	9·8980490	0253		14·593
118	Correction		18	01·81	8078	9·8958337	0370		17·735
120	31st Base		28	29·77	8117	9·8936029	0487		20·917
122	Correction		38	57·71	8157	9·8913568	0607		24·136
124	32nd Base		49	25 64	8196	9·8890948	0724		27·396
126	Correction		59	53·55	0·1878235	9·8868170	0·1870840	10	30·695
128	33rd Base	60	10	21·45	0·1878274	9·8845231	0·1870959	10	34·035
130	Correction		20	49·32	8313	9·8822131	1075		37·416
132	34th Base		31	17·18	8352	9·8798867	1190		40·840
134	Correction		41	45·03	8390	9·8775435	1306		44·307
136	35th Base		52	12·86	8428	9·8751837	1419		47·817
138	Correction	61	02	40·67	8467	9·8728071	1535		51·372
140	36th Base		13	08·46	8504	9·8704132	1649		54·973
142	Correction		23	36·24	8542	9·8680020	1763		58·619
144	37th Base	61	34	04·01	0·1878580	9·8655732	0·1871876	11	02·313

TABLE V.

Chord Azimuths, Deflections, Deflection Offsets, &c., for Base Lines. First and Second Systems of Survey.

No. of Base Line.	Chord Azimuth Sexagesimal.	Chord Azimuth Decimal.	Deflection Sexagesimal.	Deflection Decimal.	Deflection Offset for Chain Distance.	Longitude covered by one Range.	No. of Township.
	° ′ ″	°	′ ″	°	Inches.	s.	
1	89 56 57·4	89·9493	6 05·2	0·1014	1·402	32·3	0
2	55·1	·9486	09·8	·1027	1·420	32·5	4
3	52·8	·9480	14·5	·1040	1·438	32·7	8
4	50·4	·9473	19·2	·1053	1·456	33·0	12
5	48·0	·9467	24·0	·1067	1·474	33·2	16
6	89 56 45·6	89·9460	6 28·8	0·1080	1·493	33·5	20
7	43·1	·9453	33·8	·1094	1·512	33·7	24
8	40·6	·9446	38·8	·1108	1·531	34·0	28
9	38·1	·9439	43·8	·1122	1·551	34·2	32
10	35·5	·9432	49·0	·1136	1·570	34·5	36
11	89 56 32·9	89·9425	6 54·3	0·1151	1·591	34·8	40
12	30·2	·9417	59·6	·1165	1·611	35·1	44
13	27·5	·9410	7 05·0	·1180	1·632	35·4	48

TABLE VI.

Chord Azimuths, Deflections, Deflection Offsets, &c., for Base Lines. Third System of Survey.

No. of Base Line.	Chord Azimuth Sexagesimal.	Chord Azimuth Decimal.	Deflection Sexagesimal.	Deflection Decimal.	Deflection Offset for one Chain Distance.	Longitude covered by one Range.	No. of Township.
	° ′ ″	°	′ ″	°	Inches.	s.	
1	89 56 58·5	89·9496	6 03·0	0·1008	1·394	32·1	0
2	56·3	·9490	07·5	·1021	1·411	32·3	4
3	54·0	·9483	12·0	·1033	1·429	32·5	8
4	51·7	·9477	16·6	·1046	1·447	32·8	12
5	49·4	·9471	21·3	·1059	1·465	33·0	16
6	47·0	·9464	26·1	·1072	1·483	33·2	20
7	44·6	·9457	30·9	·1086	1·501	33·5	24
8	42·1	·9450	35·8	·1099	1·520	33·7	28
9	39·6	·9443	40·8	·1113	1.539	34·0	32
10	37·1	·9436	45·9	·1127	1·558	34·3	36
11	34·5	·9429	51·0	·1142	1·578	34·5	40
12	31·9	·9422	56·2	·1156	1·598	34·8	44
13	29·3	·9415	7 01·5	·1171	1·619	35·1	48
14	26·6	·9407	06.9	·1186	1·639	35·4	52
15	23·8	·9399	12·4	·1201	1·660	35·7	56
16	21·0	·9392	18·0	·1217	1·682	36·0	60
17	18·2	·9384	23·7	·1232	1·704	36·3	64
18	15·3	·9376	29·4	·1248	1·726	36·6	68
19	12·4	·9368	35·3	·1265	1·749	36·9	72
20	09·4	·9359	41·3	·1281	1·772	37·3	76
21	06·3	·9351	47·4	·1298	1·795	37·6	80
22	03·2	·9342	53·6	·1316	1·819	37·9	84
23	00·1	·9335	59·8	·1333	1·843	38·3	88
24	89 55 56·9	·9325	8 06·3	·1351	1·867	38·6	92
25	53·6	·9316	12·8	·1369	1·892	39·0	96
26	50·3	·9306	19·5	·1387	1·918	39·4	100
27	46·8	·9297	26·3	·1406	1·944	39·8	104
28	43·4	·9287	33·3	·1426	1·971	40·2	108
29	39·9	·9277	40·3	.1445	1·998	40·6	112
30	36·2	·9267	47·6	·1465	2·026	41·0	116
31	32·6	·9257	54·9	·1486	2·054	41·4	120
32	28·8	·9247	9 02·4	·1507	2·083	41·8	124
33	25·0	·9236	10·0	·1528	2·112	42·3	128
34	21·1	·9226	17·9	·1550	2·142	42·7	132
35	17·1	·9214	25·9	·1572	2.173	43·2	136
36	13·0	·9203	34·1	·1595	2·204	43·7	140
37	08·8	·9191	42·4	·1618	2·236	44·2	144

TABLE VII.

Chord Azimuths, Deflections, Deflection Offsets, Jogs, &c., for Correction Lines.
First and Second Systems of Survey.

No. of Correction Line.	Chord Azimuth Sexagesimal.	Chord Azimuth Decimal.	Deflection Sexagesimal.	Deflection Decimal.	Deflection Offset for one chain distance.	Length of one Range on Correction Line. North side of Road.	Length of one Range on Correction Line. South side of Road.	Jog.	Convergence or Divergence on Half Section.	No. of Township.
	° ′ ″	°	′ ″	°	in inches	chains	chains	chains	links	
1	89 56 56·9	89·9491	6 06·2	0·1017	1·406	490·751	487·266	3·485	14·5	2
2	54·6	·9485	10·8	·1030	1.424	·773	·244	·529	14·7	6
3	52·3	·9479	15·5	·1043	1·442	·796	·222	·574	14·9	10
4	49·9	·9472	20·2	·1056	1·460	·818	·200	·618	15·1	14
5	47.5	·9465	25·0	·1069	1·478	·841	·177	·664	15·3	18
6	89 56 45·1	89·9459	6 29·8	0·1083	1·497	490·865	487·154	3·711	15·5	22
7	42·7	9452	34·7	·1096	1·516	·888	·131	·758	15·7	26
8	40·2	·9445	39·7	·1110	1·535	·913	·107	·806	15·9	30
9	37·6	·9438	44·8	·1124	1·554	·937	·083	·854	16·1	34
10	35·0	·9430	50·0	·1139	1·574	·962	·058	·904	16·3	38
11	89 56 32·4	89·9423	6 55·2	0·1153	1·594	490 987	487·034	3·953	16·5	42
12	29·7	·9416	7 00·6	·1168	1·615	491·012	·008	4·004	16·7	46

TABLE VIII.

Chord Azimuths, Deflections, Deflection Offsets, Jogs, &c., for Correction Lines. Third System of Survey.

No. of Correction Line.	Chord Azimuth Sexagesimal.	Chord Azimuth Decimal.	Deflection Sexagesimal.	Deflection Decimal.	Deflection Offset for one chain distance.	Length of one Range on Correction Line. North side of Road.	Length of one Range on Correction Line. South side of Road.	Jogs.	Convergence or Divergence on Half Section.	No. of Township.
	° ′ ″	°	′ ″	°	inches	chains	chains	chains	chains	
1	89 56 58·0	89·9494	6 04·0	0·1011	1·397	487·719	484·297	3·421	0·143	2
2	55·7	·9488	08·5	·1024	1·413	·740	·276	·463	·144	6
3	53·5	·9482	13·0	·1036	1·429	·762	·255	·507	·146	10
4	51·2	·9475	17·6	·1049	1·446	·784	·233	·551	·148	14
5	48·8	·9469	22·3	·1062	1·464	·806	·212	·594	·150	18
6	46·4	·9462	27·1	·1075	1·482	·829	·188	·641	·152	22
7	44·0	·9455	31·9	·1089	1·500	·852	·167	·685	·154	26
8	41·6	·9449	36·8	·1102	1·519	·875	·144	·731	·155	30
9	39·1	·9442	41·8	·1116	1·539	·899	·120	·779	·157	34
10	36·5	·9435	46 9	·1130	1·559	·923	·097	·826	·159	38
11	34·0	·9428	52·0	·1144	1·580	·947	·072	·875	·161	42
12	31·4	·9420	57·2	·1159	1·601	·972	·047	·925	·164	46
13	28·7	·9413	7 02·5	·1174	1·622	487·997	484·024	3·973	·166	50
14	26·0	·9405	07·9	·1189	1·641	488·023	483·998	4·025	·168	54
15	23·3	·9398	13·4	·1204	1·662	·049	·972	·077	·170	58
16	20·5	·9390	19.0	·1219	1·682	·075	·946	·129	·172	62
17	17·6	·9382	24·7	·1235	1·704	·102	·919	·183	·174	66
18	14·8	·9374	30·4	·1251	1·726	·130	·892	·238	·177	70
19	11·8	·9366	36·3	·1267	1·748	·158	·865	·293	·179	74

TABLE VIII.—*Concluded.*

Chord Azimuths, Deflections, Deflection Offsets, Jogs, &c., for Correction Lines. Third System of Survey.

No. of Correction Line.	Chord Azimuth Sexagesimal.	Chord Azimuth Decimal.	Deflection Sexagesimal.	Deflection Decimal.	Deflection Offset for one chain distance.	Length of one Range on Correction Line. North side of Road.	Length of one Range on Correction Line. South side of Road.	Jogs.	Convergence or Divergence on Half Section.	No. of Township.
	° ′ ″	°	′ ″	°	inches	chains	chains	chains	chains	
20	89 56 08·8	89·9358	7 42·3	0·1284	1·772	488·187	483·837	4·350	0·181	78
21	05·5	·9349	48·3	·1301	1·796	·215	·809	·406	·184	82
22	89 56 02·7	·9341	54·5	·1318	1·821	·245	·779	·466	·186	86
23	89 55 59·6	·9332	8 00·8	·1336	1·846	·275	·750	·525	·189	90
24	56·3	·9323	07·3	·1354	1·870	·306	·720	·586	·191	94
25	53·1	·9314	13·8	·1372	1·894	·338	·690	·648	·194	98
26	49·7	·9305	20·5	·1390	1·919	·369	·658	·711	·196	102
27	46·3	·9295	27·3	·1409	1·945	·402	·627	·775	·199	106
28	42·9	·9286	34·2	·1428	1·971	·434	·594	·840	·202	110
29	39·3	·9276	41·3	·1448	1·999	·469	·561	·908	·204	114
30	35·7	·9266	48·5	·1468	2·027	·503	·528	4·975	·207	118
31	32·1	·9256	55·8	·1488	2·056	·538	·493	5·045	·210	122
32	28·3	·9245	9 03·3	·1509	2·086	·574	·458	·116	·213	126
33	24·5	·9234	11·0	·1531	2·114	·610	·422	·188	·216	130
34	20·6	·9224	18·8	·1552	2·143	·648	·385	·263	·219	134
35	16·6	·9213	26·8	·1574	2·173	·686	·348	·338	·222	138
36	89 55 12·5	89·9201	9 35·0	·1597	2·205	488·726	483·309	5·417	0·225	142

TABLE IX.

Latitude, with Logarithms of Secant and Tangent for the North Boundary of each Section, and the widths of Quarter Sections on such Boundaries.

First and Second Systems of Survey.

Township.	Section.	Latitude *L*.	Sec *L*.	Tan *L*.	Quarter Section.
		° ′ ″			
	36	49 00 00·00	0·183 06	0·060 84	40·000
1	1	00 53·07	18	0·061 06	39·988
	12	01 46·14	31	29	·976
	13	02 39·22	44	51	·964
	24	03 32·29	57	74	·952
	25	04 25·36	70	97	·940
	36	05 18·43	83	0·062 20	·928
2	1	06 11·50	96	42	·915
	12	07 04·57	0·184 09	64	·903
	13	07 57·65	22	87	·891
	24	08 50·72	35	0·063 09	·879
	25	09 43·79	48	32	·867
	36	10 36·86	61	54	{39·855 40·146
3	1	11 29·93	74	77	40·134
	12	12 23·00	87	0·064 00	·122
	13	13 16·07	99	23	·110
	24	14 09·14	0·185 12	45	·097
	25	15 02·21	25	68	·085
	36	15 55·28	38	90	·073
4	1	16 48·35	51	0·065 13	·061
	12	17 41·42	64	35	·048
	13	18 34·49	78	58	·036
	24	19 27·56	90	81	·024
	25	20 20·63	0·186 03	0·066 04	·012
	36	21 13·70	16	26	40·000
5	1	22 06·77	29	49	39·988
	12	22 59·84	42	71	·976
	13	23 52·90	55	94	·964
	24	24 45·97	69	0·067 16	·951
	25	25 39·04	82	39	·939
	36	26 32·11	94	61	·927

TABLE IX.—*Continued.*

Latitude, with Logarithms of Secant and Tangent, &c.

Township.	Section.	Latitude *L.* ° ′ ″	Sec *L.*	Tan *L.*	Quarter Section.
6	1	49 27 25·18	0·187 07	0·067 84	39·915
	12	28 18·25	21	0·068 07	·902
	13	29 11·31	34	29	·890
	24	30 04·38	47	52	·878
	25	30 57·45	59	74	·866
	36	31 50·52	73	97	{39·854 40·148
7	1	32 43·59	86	0·069 20	40·136
	12	33 36·65	99	42	·124
	13	34 29·72	0·188 12	65	·111
	24	35 22·79	26	88	·099
	25	36 15·86	38	0·070 11	·087
	36	37 08·92	51	33	·074
8	1	38 01·99	64	56	·062
	12	38 55·06	78	78	·050
	13	39 48·13	91	0·071 01	·037
	24	40 41·19	0·189 04	24	·025
	25	41 34·26	18	46	·013
	36	42 27·33	31	69	40·000
9	1	43 20·40	44	91	39·988
	12	44 13·46	57	0·072 14	·976
	13	45 06·53	70	37	·963
	24	45 59·59	83	60	·851
	25	46 52·66	96	82	·939
	36	47 45·72	0·190 09	0·073 05	·926
10	1	48 38·79	23	27	·914
	12	49 31·86	36	50	·902
	13	50 24·92	49	72	·889
	24	51 17·99	62	95	·877
	25	52 11·05	76	0·074 19	·865
	36	53 04·12	89	41	{39·852 40·150
11	1	53 57·18	0·191 02	64	40·138
	12	54 50·25	16	86	·125
	13	55 43·31	29	0·075 09	·113
	24	56 36·38	42	32	·100
	25	57 29·44	55	54	·088
	36	58 22·50	69	77	·075

TABLE IX.—*Continued.*

Latitude, with Logarithms of Secant and Tangent, &c.

Township.	Section.	Latitude *L.* ° ′ ″	Sec *L.*	Tan *L.*	Quarter Section.
12	1	49 59 15·57	0·191 82	0·075 99	40·063
	12	50 00 08·63	95	0·076 23	·050
	13	01 01·70	0·192 08	45	·038
	24	01 54·76	22	68	·025
	25	02 47·83	35	91	·013
	36	03 40·89	49	0·077 13	40·000
13	1	04 33·95	62	36	39·988
	12	05 27·01	76	58	·975
	13	06 20·08	89	81	·963
	24	07 13·14	0·193 02	0·078 03	·950
	25	08 06·20	16	27	·938
	36	08 59·26	29	50	·925
14	1	09 52·33	42	72	·913
	12	10 45·39	55	95	·900
	13	11 38·45	69	0·079 17	·888
	24	12 31·51	83	40	·875
	25	13 24·58	96	63	·863
	36	14 17·64	0·194 09	85	{39·850 40·152
15	1	15 10·70	23	0·080 08	40·139
	12	16 03·76	36	31	·127
	13	16 56·82	49	54	·114
	24	17 49·88	63	77	·101
	25	18 42·94	77	99	·089
	36	19 36·00	90	0·081 22	·076
16	1	20 29·07	0·195 03	45	·063
	12	21 22·13	17	67	·051
	13	22 15·19	31	90	·038
	24	23 08·25	44	0·082 13	·025
	25	24 01·31	57	36	·013
	36	24 54·37	71	59	40·000
17	1	25 47·43	85	81	39·987
	12	26 40·49	98	0·083 04	·975
	13	27 33·55	0.196 11	27	·962
	24	28 26·61	25	50	·949
	25	29 19·67	39	72	·937
	36	30 12·72	52	95	·924

TABLE IX.—*Continued.*

Latitude, with Logarithms of Secant and Tangent, &c.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
18	1	50 31 05·78	0.196 66	0·084 17	39·911
	12	31 58·84	80	40	·899
	13	32 51·90	93	63	·886
	24	33 44·96	0·197 06	86	·873
	25	34 38·02	20	0·085 09	·861
	36	35 31·08	34	32	{39·848 40·153
19	1	36 24·14	47	54	40·140
	12	37 17·19	61	77	·128
	13	38 10·25	75	0·086 00	·115
	24	39 03·31	88	22	·102
	25	39 56·37	0·198 02	45	·089
	36	40 49·42	15	68	·077
20	1	41 42·48	29	91	·064
	12	42 35·54	43	0·087 14	·051
	13	43 28·60	56	37	·038
	24	44 21·65	70	60	·026
	25	45 14·71	84	82	·013
	36	46 07·77	97	0·088 05	40·000
21	1	47 00·83	0·199 11	28	39·987
	12	47 53·88	25	50	·974
	13	48 46·94	39	73	·961
	24	49 39.99	52	96	·949
	25	50 33·05	65	0·089 19	·936
	36	51 26·10	79	42	·923
22	1	52 19·16	93	65	·910
	12	53 12·22	0·200 07	88	·898
	13	54 05·27	21	0·090 10	·885
	24	54 58·33	35	33	·872
	25	55 51·38	48	56	·859
	36	56 44·44	62	79	{39·846 40·155
23	1	57 37·49	75	0·091 02	40·142
	12	58 30·55	89	25	·129
	13	50 59 23·60	0·201 03	48	·116
	24	51 00 16·66	17	70	·103
	25	01 09·71	31	93	·090
	36	02 02·76	45	0·092 16	·078

TABLE IX.—*Continued.*

Latitude, with Logarithms of Secant and Tangent, &c.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
24	1	51 02 55·82	0·201 59	0·092 39	40·065
	12	03 48·87	72	62	·052
	13	04 41·93	86	84	·039
	24	05 34 98	0·202 00	0·093 07	·026
	25	06 28·04	14	30	·013
	36	07 21·09	28	53	40·000
25	1	08 14·14	42	76	39·987
	12	09 07·19	56	99	·974
	13	10 00·25	69	0·094 22	·961
	24	10 53·30	83	44	·948
	25	11 46·35	97	67	·935
	36	12 39·40	0·203 11	90	·922
26	1	13 32·46	25	0·095 13	·909
	12	14 25·51	39	36	·896
	13	15 18·56	53	59	·883
	24	16 11·61	67	82	·870
	25	17 04·67	81	0·096 04	·857
	36	17 57·72	95	28	{39·844 40·157
27	1	18 50·77	0·204 09	51	40·144
	12	19 43·82	23	73	·131
	13	20 36·87	36	96	·118
	24	21 29·92	50	0·097 19	·105
	25	22 22·97	64	42	·092
	36	23 16·02	78	65	·078
28	1	24 09·08	92	88	·065
	12	25 02·13	0·205 06	0·098 11	·052
	13	25 55·18	20	34	·039
	24	26 48·23	34	57	·026
	25	27 41·28	48	79	·013
	36	28 34·33	62	0·099 02	40·000
29	1	29 27·38	76	25	39·987
	12	30 20·43	90	48	·974
	13	31 13·48	0·206 04	71	·961
	24	32 06·53	19	94	·947
	25	32 59·58	33	0·100 17	·934
	36	33 52·62	47	40	·921

TABLE IX.—*Continued.*

Latitude, with Logarithms of Secant and Tangent, &c.

Township.	Section.	Latitude L.			Sec L.	Tan L.	Quarter Section.
		°	′	″			
30	1	51.	34	45·67	0·206 61	0·100 63	39·908
	12		35	38·72	75	86	·894
	13		36	31·77	89	0·101 09	·881
	24		37	24·82	0·207 03	32	·868
	25		38	17·87	17	54	·855
	36	51	39	10·92	0·207 31	0·101 78	39·842
41	36	52	37	31·80	0·216 79	0·116 99	39·918
42	1		38	24·84	94	0·117 22	·904
	12		39	17·88	0·217 09	45	·891
	13		40	10·92	24	69	·877
	24		41	03·96	38	92	·863
	25		41	57·00	53	0·118 15	·850
	36		42	50·04	68	38	{39·836 40·166
43	1		43	43·08	82	61	·152
	12		44	36·11	96	84	·138
	13		45	29·15	0·218 11	0·119 08	·124
	24		46	22·19	26	30	·111
	25		47	15·23	40	54	·097
	36		48	08·26	55	77	·083
44	1		49	01·30	70	0·120 00	·069
	12		49	54·34	85	24	·056
	13		50	47·38	0·219 00	46	·042
	24		51	40·41	14	70	·028
	25		52	33·45	29	93	·014
	36		53	26·49	44	0·121 16	40·000
45	1		54	19·53	58	40	39·986
	12		55	12·56	73	62	·972
	13		56	05·60	88	86	·958
	24		56	58·63	0·220 03	0·122 09	·945
	25		57	51·67	18	32	·931
	36		58	44·70	33	56	·917
46	1	52	59	37·74	48	79	·903
	12	53	00	30·78	63	0·123 02	·890
	13		01	23·81	77	25	·876
	24		02	16·85	92	49	·862
	25		03	09·88	0·221 07	71	·848
	36		04	02·92	21	95	{39·834 40·168

TABLE IX.—*Concluded.*

Latitude, with Logarithms of Secant and Tangent, &c.

Township.	Section.	Latitude L.			Sec L.	Tan L.	Quarter Section.
		°	′	″			
47	1	53	04	55·95	0·221 36	0·124 19	40·154
	12		05	48·99	51	41	·140
	13		06	42·02	66	65	·126
	24		07	35·06	81	88	·112
	25		08	28·09	96	0·125 12	·098
	36		09	21·12	0·222 11	34	·084
48	1		10	14·16	26	58	·070
	12		11	07·19	41	81	·056
	13		12	00·23	56	0·126 04	·042
	24		12	53·26	71	28	·028
	25		13	46·30	86	51	·014
	36		14	39·33	0·223 00	74	40·000

TABLE X.

Latitude, &c., for the North Boundary of each Section.
Third System of Survey.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
	36	49 00 00·00	0·183 06	0·060 84	40·000
1	1	00 52·75	19	0·061 06	39·988
	12	01 44·84	31	28	·976
	13	02 37·59	44	51	·964
	24	03 29·68	57	73	·953
	25	04 22·43	69	95	·941
	36	05 14·53	82	0·062 17	·929
2	1	06 07·28	95	40	·917
	12	06 59·36	0·184 08	62	·905
	13	07 52·11	20	85	·893
	24	08 44·21	33	0·063 07	·882
	25	09 36·96	46	29	·870
	36	10 29·05	59	51	{39·858 {40·143
3	1	11 21·89	71	74	·131
	12	12 13·89	84	96	·119
	13	13 06·63	97	0·064 18	·107
	24	13 58·72	0·185 10	41	·095
	25	14 51·46	23	63	·084
	36	15 43·56	35	85	·072
4	1	16 36·30	48	0·065 08	·060
	12	17 28·40	61	30	·048
	13	18 21·14	74	52	·036
	24	19 13·24	87	74	·024
	25	20 05·98	0·186 00	97	·012
	36	20 58·07	12	0·066 19	40·000
5	1	21 50·81	25	42	39·988
	12	22 42·91	38	64	·976
	13	23 35·65	51	86	·964
	24	24 27·74	64	0·067 08	·952
	25	25 20·48	77	31	·940
	36	26 12·58	90	53	·928
6	1	27 05·32	0·187 03	76	·916
	12	27 57·41	15	98	·904
	13	28 50·15	28	0·068 20	·892
	24	29 42·25	41	43	·880
	25	30 34·99	54	65	·868
	36	31 27·08	67	87	{39·858 {40·145

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
7	1	49 32 19·82	0·187 80	0·069 10	40·133
	12	33 11·91	93	32	·121
	13	34 04·65	0·188 06	54	·109
	24	34 56·75	19	77	·097
	25	35 49·49	32	99	·085
	36	36 41·58	45	0·070 21	·073
8	1	37 34·32	58	44	·060
	12	38 26·41	71	66	·048
	13	39 19·15	84	89	·036
	24	40 11·25	97	0·071 11	·024
	25	41 03·99	0·189 10	33	·012
	36	41 56·08	23	56	40·000
9	1	42 48·82	36	78	39·988
	12	43 40·91	49	0·072 00	·976
	13	44 33·65	62	23	·964
	24	45 25·74	75	45	·951
	25	46 18·48	88	68	·939
	36	47 10·56	0·190 01	90	·927
10	1	48 03·30	14	0·073 12	·915
	12	48 55·41	27	35	·903
	13	49 48·15	40	57	·891
	24	50 40·23	53	79	·879
	25	51 32·97	66	0·074 02	·867
	36	52 25·05	79	24	{39·855 {40·147
11	1	53 17·79	93	47	·135
	12	54 09·88	0·191 06	69	·122
	13	55 02·62	19	92	·110
	24	55 54·70	32	0·075 14	·098
	25	56 47·44	45	36	·086
	36	57 39·53	58	59	·073
12	1	58 32·27	71	81	·061
	12	59 24·36	84	0·076 03	·050
	13	50 00 17·10	98	26	·037
	24	01 09·18	0·192 11	48	·024
	25	02 01·92	24	71	·012
	36	02 54·01	37	93	40·000

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
13	1	50 03 46·75	0·192 50	0·077 16	39·988
	12	04 38·84	63	38	·975
	13	05 31·58	77	60	·963
	24	06 23·66	90	83	·951
	25	07 16·40	0·193 03	0·078 05	·939
	36	08 08·49	16	28	·926
14	1	09 01·23	29	50	·914
	12	09 53·31	43	72	·902
	13	10 46·05	56	95	·890
	24	11 38·14	69	0·079 17	·877
	25	12 30·88	82	40	·865
	36	13 22·96	96	62	39·853 40·149
15	1	14 15·70	0·194 09	85	·137
	12	15 07·78	22	0·080 07	·124
	13	16 00·52	35	30	·112
	24	16 52·60	49	52	·099
	25	17 45·34	62	75	·087
	36	18 37·42	75	97	·074
16	1	19 30·16	89	0·081 20	·062
	12	20 22·24	0·195 02	42	·050
	13	21 14·98	15	64	·037
	24	22 07·06	28	87	·025
	25	22 59·80	42	0·082 09	·012
	36	23 51·88	55	32	40·000
17	1	24 44·61	69	54	39·988
	12	25 36·70	82	77	·975
	13	26 29·43	95	99	·963
	24	27 21·51	0·196 09	0·083 22	·950
	25	28 14·24	22	44	·940
	36	29 06·33	35	67	·925
18	1	29 59·06	49	89	·913
	12	30 51·14	62	0·084 12	·901
	13	31 43·87	76	34	·888
	24	32 35·96	89	56	·876
	25	33 28·69	0·197 02	79	·863
	36	34 20·77	16	0·085 01	39·851 40·150

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
19	1	50 35 13·50	0·197 29	0·085 24	40·138
	12	36 05·58	43	46	·125
	13	36 58·31	56	69	·113
	24	37 50·40	69	91	·100
	25	38 43·13	83	0·086 14	·088
	36	39 35·21	96	36	·075
20	1	40 27·94	0·198 10	59	·063
	12	41 20·02	23	81	·050
	13	42 12·75	37	0·087 04	·038
	24	43 04·84	50	27	·025
	25	43 57·57	64	49	·013
	36	44 49·65	77	72	40·000
21	1	45 42·38	91	94	39·987
	12	46 34·46	0·199 04	0·088 17	·975
	13	47 27·19	18	39	·962
	24	48 19·27	31	62	·950
	25	49 12·00	45	84	·937
	36	50 04·08	58	0·089 07	·925
22	1	50 56·81	72	29	·912
	12	51 48·89	85	52	·899
	13	52 41·62	99	74	·887
	24	53 33·70	0·200 13	97	·874
	25	54 26·43	26	0·090 20	·862
	36	55 18·51	40	42	39·849 40·152
23	1	56 11·24	53	65	·140
	12	57 03·32	67	87	·127
	13	57 56·05	81	0·091 10	·114
	24	58 48·12	94	32	·102
	25	59 40·85	0·201 08	55	·089
	36	51 00 32·93	21	77	·076
24	1	01 25·66	35	0·092 00	·064
	12	02 17·74	49	22	·051
	13	03 10·47	62	45	·038
	24	04 02·54	76	68	·025
	25	04 55·27	90	90	·013
	36	05 47·35	0·202 03	0·093 13	40·000

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
25	1	51 06 40·08	0·202 17	0·093 35	39·987
	12	07 32·15	31	58	·975
	13	08 24·88	44	81	·962
	24	09 16·96	58	0·094 03	·949
	25	10 09·69	72	26	·936
	36	11 01·76	85	48	·924
26	1	11 54·49	99	71	·911
	12	12 46·56	0·203 13	93	·898
	13	13 39·29	27	0·095 16	·885
	24	14 31·36	40	39	·873
	25	15 24·09	54	61	·860
	36	16 16·17	68	84	{39·847 {40·154
27	1	17 08·90	82	0·096 07	·141
	12	18 00·97	95	29	·129
	13	18 53·70	0·204 09	52	·116
	24	19 45·77	23	74	·103
	25	20 38·50	37	97	·090
	36	21 30·58	51	0·097 19	·077
28	1	22 23·31	64	42	·064
	12	23 15·38	78	65	·051
	13	24 08·11	92	87	·039
	24	25 00·18	0·205 06	0·098 10	·026
	25	25 52·91	20	33	·013
	36	26 44·98	33	55	40·000
29	1	27 37·71	47	78	39·987
	12	28 29·78	61	0·099 00	·974
	13	29 22·50	75	23	·962
	24	30 12·57	89	46	·949
	25	31 05·29	0·206 03	69	·936
	36	31 59·37	17	91	·923
30	1	32 52·09	31	0·100 14	·910
	12	33 44·17	44	36	·897
	13	34 36·89	58	59	·884
	24	35 28·96	72	82	·871
	25	36 21·68	86	0·101 05	·858
	36	37 13·76	0·207 00	27	{39·846 {40·156

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
31	1	51 38 06·48	0·207 14	0·101 50	40·143
	12	38 58·56	28	72	·130
	13	39 51·28	42	95	·117
	24	40 43·35	56	0·102 18	·104
	25	41 36·07	70	41	·091
	36	42 28-15	84	63	·078
32	1	43 20·87	99	86	·065
	12	44 12·94	0·208 12	0·103 08	·052
	13	45 05·66	26	31	·039
	24	45 57·74	40	54	·026
	25	46 50·46	54	77	·013
	36	47 42·53	68	99	40·000
33	1	48 35·25	82	0·104 22	39·987
	12	49 27·32	96	45	·974
	13	50 20·04	0·209 10	68	·961
	24	51 12·11	24	90	·948
	25	52 04·83	38	0·105 13	·935
	36	52 56·90	52	35	·922
34	1	53 49·62	66	58	·909
	12	54 41·68	80	81	·896
	13	55 34·40	94	0·106 04	·883
	24	56 26·47	0·210 08	26	·869
	25	57 19·19	22	49	·856
	36	58 11·26	36	72	{39·843 {40·158
35	1	59 03·98	51	95	·145
	12	59 56·05	65	0·107 17	·132
	13	52 00 48·77	79	40	·119
	24	01 40·83	93	63	·106
	25	02 33·55	0·211 07	86	·092
	36	03 25·62	21	0·108 08	·079
36	1	04 18·34	36	31	·066
	12	05 10·41	50	54	·053
	13	06 03·13	64	77	·040
	24	06 55·19	78	99	·026
	25	07 47·91	92	0·109 22	·013
	36	08 39·98	0·212 06	45	40·000

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L*.			Sec *L*.	Tan *L*.	Quarter Section.
		°	′	″			
37	1	52	09	32·70	0·212 21	0·109 68	39·987
	12		10	24·77	35	90	·974
	13		11	17·49	49	0·110 13	·960
	24		12	09·55	63	36	·947
	25		13	02·27	77	59	·934
	36		13	54·34	92	81	·921
38	1		14	47·06	0·213 06	0·111 04	·907
	12		15	39·12	20	27	·894
	13		16	31·84	34	50	·881
	24		17	23·91	49	73	·868
	25		18	16·63	63	96	·855
	36		19	08·69	77	0·112 18	{39·841 40·160
39	1		20	01.41	92	41	·147
	12		20	53·47	0·214 06	64	·134
	13		21	46·19	20	87	·120
	24		22	38·25	34	0·113 09	·107
	25		23	30·97	49	32	·093
	36		24	23·03	63	55	·080
40	1		25	15·75	77	78	·067
	12		26	07·81	92	0·114 01	·053
	13		27	00·53	0·215 06	24	·040
	24		27	52·59	20	46	·027
	25		28	45·31	35	69	·013
	36		29	37·37	49	92	40·000
41	1		30	30·08	64	0·115 15	39·987
	12		31	22·15	78	38	·973
	13		32	14·86	92	61	·960
	24		33	06·93	0·216 07	83	·946
	25		33	59·64	21	0·116 06	·933
	36		34	51·71	35	29	·920
42	1		35	44·42	50	52	·906
	12		36	36·48	64	75	·893
	13		37	29·19	79	98	·879
	24		38	21·26	93	0·117 21	·866
	25		39	13·97	0·217 08	44	·853
	36		40	06·04	22	66	{39·839 40·162

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L*.			Sec *L*.	Tan *L*.	Quarter Section.
		°	′	″			
43	1	52	40	58·75	0.217 37	0·117 89	40·149
	12		41	50·82	51	0·118 12	·135
	13		42	43·53	66	35	·122
	24		43	35·59	80	58	·108
	25		44	28·30	95	81	·095
	36		45	20·37	0·218 09	0·119 04	·081
44	1		46	13·08	24	27	·068
	12		47	05·14	38	49	·054
	13		47	57·85	53	73	·041
	24		48	49·92	67	95	·027
	25		49	42·63	82	0·120 18	·014
	36		50	34·69	96	41	40·000
45	1		51	27·40	0·219 11	64	39·986
	12		52	19·46	25	87	·973
	13		53	12·17	40	0·121 10	·950
	24		54	04·23	55	33	·946
	25		54	56·94	69	56	·932
	36		55	49·00	84	79	·919
46	1		56	41·71	98	0·122 02	·905
	12		57	33·77	0·220 13	25	·891
	13		58	26·48	28	48	·878
	24		59	18·54	42	70	·864
	25	53	00	11·25	57	93	·851
	36		01	03·31	71	0·123 16	{39·837 40·164
47	1		01	56·02	86	39	·151
	12		02	48·08	0·221 01	62	·137
	13		03	40·79	15	85	·123
	24		04	32·85	30	0·124 08	·110
	25		05	25·56	45	31	·096
	36		06	17·62	59	54	·082
48	1		07	10·33	74	77	·068
	12		08	02·38	89	0·125 00	·055
	13		08	55·09	0·222 04	23	·041
	24		09	47·15	18	46	·027
	25		10	39·86	33	69	·014
	36		11	31·92	48	92	40·000

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
49	1	53 12 24·63	0·222 63	0·126 15	39·986
	12	13 16·69	77	38	·972
	13	14 09·40	92	61	·958
	24	15 01·45	0·223 07	84	·945
	25	15 54·16	22	0·127 07	·931
	36	16 46·22	36	30	·917
50	1	17 38·93	51	53	·903
	12	18 30·99	66	76	·889
	13	19 23·70	81	99	·875
	24	20 15·75	96	0·128 22	·861
	25	21 08·46	0·224 10	45	·848
	36	22 00·52	25	68	39·834 40 166
51	1	22 53·23	40	91	·153
	12	23 45·28	55	0·129 14	·139
	13	24 37·99	70	37	·125
	24	25 30·04	85	60	·111
	25	26 22·75	0·225 00	83	·097
	36	27 14·81	14	0·130 06	·083
52	1	28 07·52	29	30	·069
	12	28 59·57	44	53	·055
	13	29 52·28	59	76	·042
	24	30 44·33	74	99	·028
	25	31 37·04	89	0·131 23	·014
	36	32 29·09	0·226 04	45	40·000
53	1	33 21·80	19	68	39·986
	12	34 13·85	34	91	·972
	13	35 06·56	49	0·132 14	·958
	24	35 58·61	63	37	·944
	25	36 51·32	79	60	·930
	36	37 43·37	93	83	·917
54	1	38 36·08	0·227 08	0·133 07	·903
	12	39 28·13	23	30	·890
	13	40 20·84	38	53	·875
	24	41 12·89	53	76	·861
	25	42 05·60	68	99	·847
	36	42 57·65	83	0·134 22	39·833 40·169

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
55	1	53 43 50·36	0·227 99	0·134 45	40·155
	12	44 42·41	0·228 13	68	·140
	13	45 35·11	29	91	·126
	24	46 27·16	44	0·135 14	·112
	25	47 19·86	59	38	·098
	36	48 11·92	74	61	·084
56	1	49 04·62	89	84	·070
	12	49 56·68	0·229 04	0·136 07	·056
	13	50 49·38	19	30	·042
	24	51 41·43	34	53	·028
	25	52 34·13	49	77	·014
	36	53 26·19	64	0·137 00	40·000
57	1	54 18·89	79	23	39·986
	12	55 10·94	95	46	·972
	13	56 03·64	0·230 10	69	·958
	24	56 55·70	25	92	·944
	25	57 48·40	40	0·138 16	·930
	36	58 40·45	55	39	·915
58	1	59 33·15	70	62	·901
	12	54 00 25·20	85	85	·887
	13	01 17·90	0·231 01	0·139 08	·873
	24	02 09·96	16	31	·859
	25	03 02·66	31	55	·845
	36	03 54 71	46	78	39·831 40·171
59	1	04 47·41	62	0·140 01	·157
	12	05 39·46	77	24	·142
	13	06 32·16	92	48	·128
	24	07 24·21	0·232 07	71	·114
	25	08 16·91	23	94	·100
	36	09 08·96	38	0·141 17	·085
60	1	10 01·66	53	41	·071
	12	10 53·71	68	64	·057
	13	11 46·41	84	87	·043
	24	12 38·46	99	0·142 10	·028
	25	13 31.16	0·233 14	34	·014
	36	14 23·21	29	57	40·000

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L*.	Sec *L*.	Tan *L*.	Quarter Section.
		° ′ ″			
61	1	54 15 15·91	0·233 45	0·142 80	39·986
	12	16 07·96	60	0·143 03	·971
	13	17 00·66	76	27	·957
	24	17 52·70	91	50	·943
	25	18 45·40	0·234 06	73	·929
	36	19 37·45	21	96	·914
62	1	20 30·15	37	0·144 20	·900
	12	21 22·20	52	43	·886
	13	22 14·90	68	66	·872
	24	23 06·94	83	89	·857
	25	23 59·64	98	0·145 13	·843
	36	24 51·69	0·235 14	36	{39·829 {40·173
63	1	25 44·39	29	59	·159
	12	26 36·43	45	83	·144
	13	27 29·13	60	0·146 06	·130
	24	28 21·18	75	29	·115
	25	29 13·88	91	53	·101
	36	30 05·92	0·236 06	76	·086
64	1	30 58·62	22	99	·072
	12	31 50·66	37	0·147 22	·058
	13	32 43·36	53	46	·043
	24	33 35·41	68	69	·029
	25	34 28·11	84	93	·014
	36	35 20·15	99	0·148 16	40·000
65	1	36 12·85	0·237 15	39	39·986
	12	37 04·89	30	63	·971
	13	37 57·59	46	86	·957
	24	38 49·63	61	0·149 09	·942
	25	39 42·33	77	33	·828
	36	40 34 37	92	56	·913
66	1	41 27·07	0·238 08	80	·899
	12	42 19·11	24	0·150 03	·884
	13	43 11·80	39	26	·870
	24	44 03·85	55	50	·855
	25	44 56·55	70	73	·841
	36	45 48·59	86	96	{39·827 {40·175

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L*.	Sec *L*.	Tan *L*.	Quarter Section.
		° ′ ″			
67	1	54 46 41·29	0·239 02	0·151 20	40·161
	12	47 33·33	17	43	·146
	13	48 26·02	33	67	·131
	24	49 18·06	49	90	·117
	25	50 10·75	64	0·152 13	·102
	36	51 02·80	80	37	·088
68	1	51 55·49	96	60	·073
	12	52 47·54	0·240 11	84	·058
	13	53 40·23	27	0·153 07	·044
	24	54 32·27	43	31	·029
	25	55 24·96	58	54	·015
	36	56 17·01	74	77	40·000
69	1	57 09·70	90	0·154 01	39·985
	12	58 01·75	0·241 05	24	·971
	13	58 54·44	21	48	·956
	24	59 46·48	37	71	·941
	25	55 00 39·17	53	95	·927
	36	01 31·22	68	0·155 18	·912
70	1	02 23·91	84	42	·898
	12	03 15·95	0·242 00	65	·883
	13	04 08·64	16	89	·868
	24	05 00·69	31	0·156 12	·854
	25	05 53·38	47	36	·839
	36	06 45·42	63	59	{39·824 {40·177
71	1	07 38·11	79	83	·163
	12	08 30·15	95	0·157 06	·148
	13	09 22·84	0·243 11	30	·133
	24	10 14·89	26	53	·118
	25	11 07·58	42	77	·104
	36	11 59·62	58	0·158 00	·089
72	1	12 51·99	74	24	·074
	12	13 44·35	90	47	·059
	13	14 37·04	0·244 06	71	·044
	24	15 29·09	22	94	·030
	25	16 21·78	38	0·159 18	·015
	36	17 13·82	53	41	40·000

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude L.	Sec L.	Tan L.	Quarter Section.
		° ′ ″			
73	1	55 18 06·51	0·244 69	0·159 65	39·985
	12	18 58·55	85	89	·970
	13	19 51·24	0·245 01	0·160 12	·956
	24	20 43·28	17	36	·941
	25	21 35·97	33	59	·926
	36	22 28·01	49	83	·911
74	1	23 20·70	65	0·161 07	·896
	12	24 12·74	81	30	·881
	13	25 05·43	97	54	·867
	24	25 57·47	0·246 13	77	·852
	25	26 50·16	29	0·162 01	·837
	36	27 42·20	45	24	{39·822 40·180
75	1	28 34·89	61	48	·165
	12	29 26·93	77	72	·150
	13	30 19·62	93	95	·135
	24	31 11·65	0·247 09	0·163 19	·120
	25	32 04·34	25	43	·105
	36	32 56·38	41	66	·090
76	1	33 49·07	57	90	·075
	12	34 41·10	73	0·164 13	·060
	13	35 33·79	90	37	·045
	24	36 25·83	0·248 06	61	·030
	25	37 18·52	22	85	·015
	36	38 10·55	38	0·165 08	40·000
77	1	39 03·24	54	32	39·985
	12	39 55·27	70	55	·970
	13	40 47·96	86	79	·955
	24	41 40·00	0·249 02	0·166 03	·940
	25	42 32·69	19	27	·925
	36	43 24·72	35	50	·910
78	1	44 17·41	51	74	·895
	12	45 09·44	67	98	·880
	13	46 02·13	83	0·167 21	·865
	24	46 54·17	0·250 00	45	·850
	25	47 46·86	16	69	·835
	36	48 38·89	32	92	{39·820 40·182

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude L.	Sec L.	Tan L.	Quarter Section.
		° ′ ″			
79	1	55 49 31·58	0·250 48	0·168 16	40·167
	12	50 23·61	64	40	·152
	13	51 16·29	81	64	·137
	24	52 08·33	97	87	·122
	25	53 01·01	0·251 13	0·169 11	·106
	36	53 53·05	30	35	·091
80	1	54 45·73	46	59	·076
	12	55 37·76	62	82	·061
	13	56 30·44	79	0·170 06	·046
	24	57 22·48	95	30	·030
	25	58 15·16	0·252 11	54	·015
	36	59 07·20	27	77	40·000
81	1	59 59·88	44	0·171 01	39·985
	12	56 00 51·92	60	25	·970
	13	01 44·60	77	49	·954
	24	02 36·63	93	72	·939
	25	03 29·31	0·253 09	96	·924
	36	04 21·35	26	0·172 20	·909
82	1	05 14·03	42	44	·893
	12	06 06·06	58	68	·878
	13	06 58·74	75	92	·863
	24	07 50·78	91	0·173 15	·848
	25	08 43·~~56~~46	0·254 08	39	·833
	36	09 35·49	24	63	{39·817 40·185
83	1	10 27·85	41	87	·169
	12	11 20·20	57	0·174 11	·154
	13	12 12·56	74	35	·138
	24	13 04·92	90	58	·123
	25	13 57·27	0·255 06	82	·107
	36	14 49·63	23	0·175 06	·092
84	1	15 41·99	39	30	·077
	12	16 34·34	56	54	·061
	13	17 26·70	72	78	·046
	24	18 19·06	89	0·176 01	·030
	25	19 11·41	0·256 05	25	·015
	36	20 03·77	22	49	40·000

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
85	1	56 20 56·12	0·256 38	0·176 73	39·985
	12	21 48·48	55	97	·969
	13	22 40·83	72	0·177 21	·954
	24	23 33·19	88	45	·938
	25	24 25·54	0·257 05	69	·923
	36	25 17·90	21	93	·908
86	1	26 10·25	38	0·178 17	·892
	12	27 02·61	55	41	·877
	13	27 54·96	71	65	·861
	24	28 47·32	88	88	·846
	25	29 39·67	0·258 05	0·179 13	·830
	36	30 32·03	21	36	39·815 40·187
87	1	31 24·38	38	60	·171
	12	32 16·74	55	84	·156
	13	33 09·10	71	0·180 08	·140
	24	34 01·45	88	32	·125
	25	34 53·81	0·259 05	56	·109
	36	35 46·16	21	80	·093
88	1	36 38·57	38	0·181 04	·078
	12	37 30·87	55	28	·062
	13	38 23·22	71	52	·047
	24	39 15·58	88	76	·031
	25	40 07·93	0·260 05	0·182 00	·015
	36	41 00·28	22	24	40·000
89	1	41 52·63	39	48	39·984
	12	42 44·98	55	72	·969
	13	43 37·34	72	96	·953
	24	44 29·69	89	0·183 20	·937
	25	45 22·04	0·261 06	44	·922
	36	46 14·39	22	68	·906
90	1	47 06·75	40	93	·891
	12	47 59·10	56	0·184 16	·875
	13	48 51·45	73	40	·860
	24	49 43·80	90	65	·844
	25	50 36·16	0·262 07	89	·828
	36	51 28·51	24	0·185 13	39·813 40·190

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
91	1	56 52 20·86	0·262 41	0·185 37	40·174
	12	53 13·21	57	61	·158
	13	54 05·56	75	85	·142
	24	54 57·91	91	0·186 09	·127
	25	55 50·26	0·263 08	33	·111
	36	56 42·60	25	57	·095
92	1	57 34·95	42	81	·079
	12	58 27·30	59	0·187 05	·063
	13	59 19·65	76	30	·048
	24	57 00 12·00	93	54	·032
	25	01 04·35	0·264 10	78	·016
	36	01 56·70	27	0·188 02	40·000
93	1	02 49·05	44	26	39·984
	12	03 41·40	61	50	·968
	13	04 33·75	78	75	·953
	24	05 26·10	95	99	·937
	25	06 18·45	0·265 12	0·189 23	·921
	36	07 10·79	29	47	·905
94	1	08 03·14	46	71	·889
	12	08 55·49	63	95	·874
	13	09 47·84	80	0·190 20	·858
	24	10 40·19	97	44	·842
	25	11 32·54	0·266 15	68	·826
	36	12 24·89	32	92	39·810 40·193
95	1	13 17·24	49	0·191 16	·177
	12	14 09·59	66	41	·161
	13	15 01·93	83	65	·144
	24	15 54·28	0·267 00	89	·128
	25	16 46·63	17	0·192 13	·112
	36	17 38·98	34	38	·096
96	1	18 31·33	51	62	·080
	12	19 23·68	69	86	·064
	13	20 16·02	86	0·193 10	·048
	24	21 08·37	0·268 03	34	·032
	25	22 00·72	20	59	·016
	36	22 53·07	38	83	40·000

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude L.	Sec L.	Tan L.	Quarter Section.
		° ′ ″			
97	1	57 23 45·42	0·268 55	0·194 07	39·984
	12	24 37·76	72	32	·968
	13	25 30·11	89	56	·952
	24	26 22·45	0·269 06	80	·936
	25	27 14·80	24	0·195 05	·920
	36	28 07·14	41	29	·904
98	1	28 59·49	58	53	·888
	12	29 51·84	75	78	·872
	13	30 44·18	93	0·196 02	·856
	24	31 36·53	0·270 10	26	·840
	25	32 28·87	28	51	·824
	36	33 21·22	45	75	{39·808 40·195
99	1	34 13·56	62	99	·179
	12	35 05·91	80	0·197 24	·163
	13	35 58·25	97	48	·147
	24	36 50·60	0·271 14	72	·130
	25	37 42·94	32	97	·114
	36	38 35·29	49	0·198 21	·098
100	1	39 27·63	67	46	·082
	12	40 19·98	84	70	·066
	13	41 12·32	0·272 01	94	·049
	24	42 04·67	19	0·199 19	·033
	25	42 59·01	37	44	·017
	36	43 49·36	54	67	40·000
101	1	44 41·70	71	92	39·984
	12	45 34·05	89	0·200 16	·968
	13	46 26·39	0·273 06	40	·951
	24	47 18·73	24	65	·935
	25	48 11·08	41	89	·919
	36	49 03·42	58	0·201 14	·903
102	1	49 55·76	76	38	·887
	12	50 48·11	94	63	·870
	13	51 40·45	0·274 11	87	·854
	24	52 32·79	29	0·202 12	·838
	25	53 25·14	46	36	·822
	36	54 17·48	64	61	{39·806 40·198

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude L.	Sec L.	Tan L.	Quarter Section.
		° ′ ″			
103	1	57 55 09·82	0·247 81	0·202 85	40·181
	12	56 02·16	99	0·203 10	·165
	13	56 54·50	0·275 16	34	·149
	24	57 46·84	34	59	·132
	25	58 39·18	52	83	·116
	36	59 31·52	70	0.204 08	·100
104	1	58 00 23·87	87	32	·083
	12	01 16·21	0·276 05	57	·066
	13	02 08·55	23	82	·050
	24	03 00·89	40	0·205 06	·033
	25	03 53·23	58	30	·017
	36	04 45·57	76	55	40·000
105	1	05 37·91	93	80	39·984
	12	06 30·25	0·277 11	0·206 04	·967
	13	07 22·59	29	29	·951
	24	08 14·93	46	53	·934
	25	09 07·27	64	78	·918
	36	09 59·61	82	0·207 03	·901
106	1	10 51·96	99	27	·885
	12	11 44·30	0·278 17	51	·869
	13	12 36·64	35	76	·852
	24	13 28·98	53	0·208 01	·836
	25	14 21·32	71	25	·819
	36	15 13·66	89	50	{39·803 40·201
107	1	16 06·00	0·279 06	75	·184
	12	16 58·34	24	99	·167
	13	17 50·68	42	0·209 24	·151
	24	18 43·02	60	49	·134
	25	19 35·36	77	73	·117
	36	20 27·69	96	98	·101
108	1	21 20·03	0·280 13	0·210 23	·084
	12	22 12·37	31	47	·067
	13	23 04·71	49	72	·051
	24	23 57·05	67	97	·034
	25	24 49·39	85	0·211 21	·017
	36	25 41·73	0·281 03	46	40·000

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
109	1	58 26 34·07	0·281 21	0·211 71	39.983
	12	27 26·40	39	95	·967
	13	28 18·74	57	0·212 20	·950
	24	29 11·08	75	45	·933
	25	30 03·42	92	69	·917
	36	30 55·75	0·282 11	95	·900
110	1	31 48·09	29	0·213 19	·883
	12	32 40·43	47	44	·866
	13	33 32·77	65	69	·850
	24	34 25·10	83	93	·833
	25	35 17·44	0·283 01	0·214 18	·816
	36	36 09·78	19	43	{39·800 40·203
111	1	37 02·12	37	68	·186
	12	37 54·45	55	92	·169
	13	38 46·79	73	0·215 17	·152
	24	39 39·12	91	42	·135
	25	40 31·46	0·284 09	67	·118
	36	41 23·79	27	92	·102
112	1	42 16·13	45	0·216 16	·085
	12	43 08·47	63	41	·068
	13	44 00·90	82	66	·051
	24	44 53·14	0·285 00	91	·034
	25	45 45·47	18	0·217 16	·017
	36	46 37·81	36	41	40·000
113	1	47 30·14	54	66	39·983
	12	48 22·48	72	90	·966
	13	49 14·81	91	0·218 16	·949
	24	50 07·15	0·286 09	40	·933
	25	50 59·48	27	65	·916
	36	51 51·82	45	90	·899
114	1	52 44·15	64	0·219 15	·882
	12	53 36·49	82	40	·865
	13	54 28·82	0·287 00	65	·848
	24	55 21·16	18	90	·831
	25	56 13·49	37	0·220 14	·814
	36	57 06·83	55	40	{39·797 40·206

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
115	1	58 57 58·16	0·287 73	0·220 64	40·189
	12	58 50·50	92	89	·172
	13	59 42·83	0·288 10	0·221 14	·154
	24	59 00 35·16	28	39	·137
	25	01 27·50	47	64	·120
	36	02 19·83	65	89	·103
116	1	03 12·16	83	0·222 14	·086
	12	04 04·50	0·289 02	39	·069
	13	04 56·83	20	64	·051
	24	05 49·16	39	89	·034
	25	06 41·50	57	0·223 14	·017
	36	07 33·83	76	39	40·000
117	1	08 26·16	94	64	39·983
	12	09 18·49	0·290 12	89	·966
	13	10 10·82	31	0·224 14	·949
	24	11 03·16	49	39	·931
	25	11 55·49	68	64	·914
	36	12 47·82	86	90	·897
118	1	13 40·15	0·291 05	0·225 15	·880
	12	14 32·48	23	39	·863
	13	15 24·81	42	65	·846
	24	16 17·15	60	90	·828
	25	17 09·48	79	0·226 15	·811
	36	18 01·81	97	40	{39·794 40·209
119	1	18 54·14	0·292 16	65	·192
	12	19 46·47	34	90	·174
	13	20 38·80	53	0·227 15	·157
	24	21 31·13	72	40	·139
	25	22 23·46	90	65	·122
	36	23 15·79	0·293 09	91	·105
120	1	24 08·12	28	0·228 16	·087
	12	25 00·45	46	41	·069
	13	25 52·78	65	66	·051
	24	26 45·11	83	91	·034
	25	27 37·44	0·294 02	0·229 16	·017
	36	28 29·77	21	41	40·000

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
121	1	59 29 22·10	0·294 40	0·229 67	39·983
	12	30 14·43	58	92	·965
	13	31 06·75	77	0·230 17	·948
	24	31 59·08	96	43	·930
	25	32 51·41	0·295 14	68	·913
	36	33 43·74	33	93	·896
122	1	34 36·07	52	0·231 18	·878
	12	35 28·40	71	43	·861
	13	36 20·72	90	69	·843
	24	37 13·05	0·296 08	94	·826
	25	38 05·38	27	2·232 19	·809
	36	38 57·71	46	45	39·791 40·212
123	1	39 50·04	65	70	·194
	12	40 42·36	83	95	·177
	13	41 34·69	0·297 02	0·233 20	·159
	24	42 27·02	21	46	·142
	25	43 19·35	40	71	·124
	36	44 11·67	59	96	·106
124	1	45 04·00	78	0·234 21	·088
	12	45 56·33	97	47	·071
	13	46 48·66	0·298 16	72	·054
	24	47 40·98	35	97	·036
	25	48 33·31	53	0·235 23	·018
	36	49 25·64	73	48	40·000
125	1	50 17·97	91	74	39·982
	12	51 10·29	0·299 10	99	·965
	13	52 02·62	29	0·236 24	·947
	24	52 54·94	48	50	·929
	25	53 47·27	67	75	·912
	36	54 39·59	87	0·237 01	·894
126	1	55 31·92	0·300 05	26	·877
	12	56 24·25	24	51	·859
	13	57 16·57	44	77	·841
	24	58 08·90	63	0·238 02	·824
	25	59 01·22	81	27	·806
	36	59 53·55	0·301 01	53	39·788 40·215

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
127	1	60 00 45·87	0·301 20	0·238·78	40·197
	12	01 38·20	39	0·239·04	·179
	13	02 30·52	58	30	·161
	24	03 22·85	77	55	·143
	25	04 15·47	96	80	·125
	36	05 07·50	0·302 15	0·240 05	·107
128	1	05 59·82	35	31	·089
	12	06 52·15	54	57	·072
	13	07 44·47	73	82	·054
	24	08 36·80	92	0·241 08	·036
	25	09 29·12	0·303 11	33	·018
	36	10 21·45	30	59	40·000
129	1	11 13·77	50	84	39·982
	12	12 06·09	69	0·242 10	·964
	13	12 58·42	88	35	·946
	24	13 50·74	0·304 07	61	·928
	25	14 43·06	27	86	·911
	36	15 35·38	46	0·243 12	·893
130	1	16 27·71	65	38	·875
	12	17 20·03	84	63	·857
	13	18 12·35	0·305 04	89	·839
	24	19 04·67	23	0·244 15	·821
	25	19 57·00	42	40	·803
	36	20 49·32	62	66	39·785 40·218
131	1	21 41·64	81	91	·199
	12	22 33·96	0·306 01	0·245 17	·181
	13	23 26·28	20	42	·163
	24	24 18·61	39	68	·145
	25	25 10·93	59	94	·127
	36	26 03·25	78	0·246 19	·109
132	1	26 55·57	98	45	·091
	12	27 47·89	0·307 17	71	·073
	13	28 40·21	36	96	·055
	24	29 32·54	56	0·247 23	·037
	25	30 24·86	75	48	·018
	36	31 17·18	95	74	40·000

TABLE X.—*Continued.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude L.	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
133	1	60 32 09·52	0·308 15	0·248 00	39·982
	12	33 01·82	34	25	·964
	13	33 54·14	53	51	·946
	24	34 46·46	73	76	·927
	25	35 38·78	93	0·249 02	·909
	36	36 31·10	0·309 12	28	·891
134	1	37 23·43	31	54	.873
	12	38 15·75	51	80	·855
	13	39 08·07	71	0·250 05	·837
	24	40 00·39	90	31	·819
	25	40 52·71	0·310 10	57	·800
	36	41 45·03	30	83	{39·782 {40·221
135	1	42 37·35	49	0·251 09	·202
	12	43 29·67	69	35	·184
	13	44 21·99	88	60	·166
	24	45 14·31	0·311 08	86	·147
	25	46 06·63	28	0·252 12	·129
	36	46 58·94	48	38	·110
136	1	47 51·26	67	64	·092
	12	48 43·58	87	90	·074
	13	49 35·90	0·312 07	0·253 16	·055
	24	50 28·22	26	41	·037
	25	51 20·54	46	67	·018
	36	52 12·86	66	93	40·000
137	1	53 05·18	86	0·254 19	39·981
	12	53 57·49	0·313 05	45	·963
	13	54 49·81	25	71	·945
	24	55 42·13	45	97	·926
	25	56 34·45	65	0·255 23	·908
	36	57 26·76	85	49	·890
138	1	58 19·08	0·314 05	75	·871
	12	59 11·40	24	0·256 00	·853
	13	61 00 03·72	44	27	·834
	24	00 56·03	64	53	·816
	25	01 48·35	84	78	·797
	36	02 40·67	0·315 04	0·257 05	{39·779 {40·224

TABLE X.—*Concluded.*

Latitude, &c., for the North Boundary of each Section.

Township.	Section.	Latitude *L.*	Sec *L.*	Tan *L.*	Quarter Section.
		° ′ ″			
139	1	61 03 32·99	0·315 24	0·257 31	40·205
	12	04 25·30	44	56	·187
	13	05 17·62	64	83	·168
	24	06 09·93	84	0·258 09	·149
	25	07 02·25	0·316 04	35	·131
	36	07 54·56	24	61	·112
140	1	08 46·88	44	87	·093
	12	09 39·20	64	0·259 13	·075
	13	10 31·51	84	39	·056
	24	11 23·83	0·317 04	65	·037
	25	12 16·41	24	91	·019
	36	13 08·46	44	0·260 17	40·000
141	1	14 00·77	63	43	39·981
	12	14 53·09	84	69	·963
	13	15 45·40	0·318 04	95	·945
	24	16 37·72	24	0·261 22	·926
	25	17 30·03	44	48	·908
	36	18 22·35	64	74	·889
142	1	19 14 66	85	0·262 00	·870
	12	20 06·98	0·319 05	26	·852
	13	20 59·29	25	52	·833
	24	21 51·61	45	79	·814
	25	22 43·92	65	0·263 05	·796
	36	23 36·24	85	31	{39·777 {40·228
143	1	24 28·55	0·320 06	58	·208
	12	25 20·87	26	84	·189
	13	26 13·18	46	0·264 10	·170
	24	27 05·50	66	36	·151
	25	27 57·81	86	62	·133
	36	28 50·12	0·321 07	88	·114
144	1	29 42·44	27	0·265 15	·095
	12	30 34·75	47	41	·076
	13	31 27·07	67	67	·057
	24	32 19·38	88	93	·038
	25	33 11·70	0·322 08	0·266 20	·019
	36	34 04·01	28	46	40·000

TABLE XI.

To convert Chains into Decimals of a Township Side.

Chains.	Equivalent Decimal of a Township Side.			Chains.	Equivalent Decimal of a Township Side.		
	Side = 489c.	Side = 486c.	Side = 483c.		Side = 489c.	Side = 486c.	Side = 483c.
1	0·00204	0·00206	0·00207	30	0·06135	0·06173	0·06211
2	·00409	·00412	·00414	40	·08180	·08230	·08282
3	·00613	·00617	·00621	50	·10225	·10288	·10352
4	·00818	·00823	·00828	60	·12270	·12346	·12422
5	·01022	·01029	·01035	70	·14315	·14403	·14493
6	·01227	·01235	·01242	80	·16360	·16461	·16563
7	·01431	·01440	·01449	90	·18405	·18519	·18634
8	·01636	·01646	·01656	100	·20450	·20576	·20704
9	·01840	·01852	·01863	200	·40900	·41152	·41408
10	·02045	·02058	·02070	300	·61350	·61728	·62112
20	·04090	·04115	·04141	400	·81800	·82305	·82816

TABLE XII.

Corrections to be applied to the tabular quantities in Table No. VII when the north side of the road allowance on Correction Lines is run instead of the south; also correction to road allowance on account of curvature.

Number of Correction Line.	Correction to Chord Azimuth.	Correction to Deflection Offset (for one chain distance).	Corrections to Width of Road Allowance on account of Curvature.									
			jog = 30 chs.	jog = 40 chs.	jog = 50 chs.	jog = 60 chs.	jog = 70 chs.	jog = 80 chs.	jog = 90 chs.	jog = 100 chs.	jog = 110 chs.	jog = 120 chs.
	″	inches	lks.	lks.	lks.	lks.	lks.	lks.	lks.	lks.	lks.	lks.
1st....	−1·3	+0·010	2·5	3·2	3·9	4·6	5·2	5·8	6·4	7·0	7·5	7·9
11th....	−1·7	+0·013	2·8	3·7	4·5	5·2	6·0	6·7	7·3	7·9	8·5	8·9
21st....	−2·2	+0·017	3·2	4·2	5·2	6·0	6·9	7·7	8·4	9·1	9·8	10·4
31st....	−2·9	+0·022	3·7	4·8	5·9	6·9	7·9	8·8	9·6	10·4	11·2	11·9

TABLE XIII.

Showing the difference of Latitude between Township Corners and Section and Quarter Section Posts on a Township Chord.

Number of Line.	*dL* For ½ sec. from Corner.	*dL* For 1 sec. from Corner.	*dL* For 1½ secs. from Corner.	*dL* For 2 secs. from Corner.	*dL* For 2½ secs. from Corner.	*dL* For 3 secs. from Corner.
	″	″	″	″	″	″
1st Base	0·02	0·04	0·05	0·06	0·07	0·07
	lks.	lks.	lks.	lks.	lks.	lks.
do	3·2	5·9	8·0	9·5	10·3	10·8
	″	″	″	″	″	″
11th Base	0·02	0·04	0·06	0·07	0·08	0·08
	lks.	lks.	lks.	lks.	lks.	lks.
do	3·6	6·7	9·1	10·8	11·8	12·1
	″	″	″	″	″	″
21st Base	0·03	0·05	0·07	0·08	0·09	0·09
	lks.	lks.	lks.	lks.	lks.	lks.
do	4·2	7·7	10·3	12·3	13·3	13·8
	″	″	″	″	″	″
31st Base	0·03	0·06	0·08	0·09	0·10	0·11
	lks.	lks.	lks.	lks.	lks.	lks.
do	4·8	8·8	12·0	14·4	15·6	16·2

TABLE XIV.

For finding the Time by Transits across the Vertical of Polaris.

A	Declination of Time Star North.													
	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	
H. M.														M. H.
0 10	1·0806	1·0814	1·0821	1·0829	1·0837	1·0846	1·0856	1·0866	1·0878	1·0892	1·0908	1·0929	1·0954	50 11
20	1·3812	1·3820	1·3827	1·3835	1·3844	1·3852	1·3862	1·3872	1·3884	1·3898	1·3914	1·3934	1·3960	40
or 30	1·5566	1·5574	1·5581	1·5589	1·5597	1·5606	1·5616	1·5626	1·5638	1·5652	1·5668	1·5688	1·5713	30 or
40	1·6806	1·6813	1·6821	1·6829	1·6837	1·6846	1·6855	1·6865	1·6877	1·6891	1·6907	1·6927	1·6952	20
12 50	1·7762	1·7770	1·7777	1·7785	1·7793	1·7802	1·7811	1·7822	1·7833	1·7847	1·7863	1·7882	1·7907	10 23
1 00	1·8539	1·8546	1·8554	1·8562	1·8570	1·8578	1·8587	1·8598	1·8609	1·8622	1·8638	1·8658	1·8682	60 10
10	1·9191	1·9198	1·9205	1·9213	1·9221	1·9229	1·9238	1·9248	1·9260	1·9273	1·9288	1·9308	1·9332	50
20	1·9750	1·9757	1·9764	1·9772	1·9779	1·9788	1·9797	1·9807	1·9818	1·9831	1·9846	1·9865	1·9889	40
or 30	2·0238	2·0245	2·0252	2·0259	2·0267	2·0275	2·0284	2·0294	2·0305	2·0316	2·0332	2·0351	2·0375	30 or
40	2·0669	2·0675	2·0682	2·0690	2·0697	2·0705	2·0714	2·0724	2·0734	2·0747	2·9762	2·0780	2·0804	20
13 50	2·1053	2·1060	2·1067	2·1074	2·1081	2·1089	2·1098	2·1107	2·1118	2·1130	2·1144	2·1162	2·1185	10 22
2 00	2·1399	2·1405	2·1412	2·1419	2·1426	2·1434	2·1442	2·1451	2·1462	2·1474	2·1488	2·1505	2·1528	60 9
10	2·1711	2·1718	2·1724	2·1731	2·1738	2·1745	2·1754	2·1762	2·1773	2·1784	2·1798	2·1815	2·1837	50
20	2·1995	2·2001	2·2008	2·2014	2·2021	2·2028	2·2036	2·2045	2·2055	2·2066	2·2079	2·2096	2·2117	40
or 30	2·2254	2·2260	2·2266	2·2272	2·2279	2·2286	2·2293	2·2302	2·2311	2·2322	2·2335	2·2351	2·2372	30 or
40	2·2490	2·2496	2·2502	2·2508	2·2514	2·2521	2·2528	2·2536	2·2545	2·2556	2·2569	2·2584	2·2604	20
14 50	2·2706	2·2712	2·2717	2·2723	2·2729	2·2736	2·2743	2·2751	2·2760	2·2770	2·2782	2·2797	2·2816	10 21
	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	A
	Declination of Time Star South.													

TABLE XIV.—*Concluded.*

For finding the Time by Transits across the Vertical of Polaris.

A (Declination of Time Star North) H. M.	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	M. H.
3 00	2·2904	2·2909	2·2915	2·2920	2·2926	2·2933	2·2939	2·2947	2·2955	2·2965	2·2977	2·2991	2·3009	60 8
10	2·3085	2·3091	2·3096	2·3101	2·3107	2·3113	2·3119	2·3126	2·3135	2·3144	2·3155	2·3169	2·3186	50
20	2·3252	2·3257	2·3261	2·3267	2·3272	2·3278	2·3284	2·3291	2·3298	2·3307	2·3318	2·3331	2·3348	40
or 30	2·3404	2·3408	2·3413	2·3418	2·3423	2·3428	2·3434	2·3441	2·3448	2·3457	2·3467	2·3479	2·3495	30 or
40	2·3543	2·3547	2·3552	2·3556	2·3561	2·3566	2·3572	2·3578	2·3584	2·3592	2·3602	2·3614	2·3628	20
15 50	2·3669	2·3673	2·3678	2·3682	2·3686	2·3691	2·3696	2·3702	2·3709	2·3716	2·3725	2·3736	2·3750	10 20
4 00	2·3784	2·3788	2·3792	2·3796	2·3800	2·3805	2·3809	2·3815	2·3821	2·3828	2·3836	2·3846	2·3859	60 7
10	2·3888	2·3892	2·3895	2·3899	2·3903	2·3907	2·3912	2·3916	2·3922	2·3928	2·3936	2·3945	2·3958	50
20	2·3982	2·3985	2·3988	2·3992	2·3995	2·3999	2·4003	2·4008	2·4013	2·4019	2·4026	2·4034	2·4045	40
or 30	2·4065	2·4068	2·4071	2·4074	2·4077	2·4081	2·4084	2·4089	2·4093	2·4098	2·4105	2·4113	2·4123	30 or
40	2·4139	2·4142	2·4144	2·4147	2·4150	2·4153	2·4156	2·4160	2·4164	2·4169	2·4174	2·4181	2·4190	20
16 50	2·4203	2·4206	2·4208	2·4210	2·4213	2·4215	2·4218	2·4222	2·4225	2·4229	2·4234	2·4241	2·4248	10 19
5 00	2·4259	2·4261	2·4263	2·4265	2·4267	2·4269	2·4272	2·4274	2·4277	2·4281	2·4285	2·4291	2·4297	60 6
10	2·4305	2·4307	2·4308	2·4310	2·4312	2·4314	2·4316	2·4318	2·4321	2·4324	2·4327	2·4332	2·4337	50
20	2·4343	2·4344	2·4345	2·4347	2·4348	2·4350	2·4351	2·4353	2·4355	2·4358	2·4361	2·4364	2·4369	40
or 30	2·4372	2·4373	2·4374	2·4375	2·4376	2·4377	2·4378	2·4380	2·4381	2·4383	2·4385	2·4388	2·4391	30 or
40	2·4393	2·4393	2·4394	2·4395	2·4395	2·4396	2·4397	2·4398	2·4399	2·4400	2·4402	2·4403	2·4406	20
17 50	2·4405	2·4405	2·4406	2·4406	2·4406	2·4407	2·4407	2·4408	2·4408	2·4409	2·4409	2·4410	2·4412	10 18
6 00	2·4409	2·4409	2·4409	2·4409	2·4409	2·4409	2·4409	2·4409	2·4409	2·4409	2·4409	2·4409	2·4409	60 5
10	2·4405	2·4405	2·4404	2·4404	2·4404	2·4403	2·4403	2·4403	2·4402	2·4401	2·4400	2·4400	2·4398	50
20	2·4393	2·4392	2·4391	2·4391	2·4390	2·4389	2·4388	2·4387	2·4386	2·4385	2·4383	2·4382	2·4379	40
or 30	2·4372	2·4371	2·4370	2·4369	2·4368	2·4366	2·4365	2·4364	2·4362	2·4360	2·4358	2·4356	2·4352	30 or
40	2·4343	2·4341	2·4340	2·4339	2·4337	2·4336	2·4334	2·4332	2·4330	2·4327	2·4325	2·4321	2·4316	20
18 50	2·4305	2·4303	2·4302	2·4300	2·4298	2·4296	2·4294	2·4292	2·4289	2·4286	2·4282	2·4278	2·4272	10 17
7 00	2·4259	2·4257	2·4255	2·4252	2·4250	2·4248	2·4245	2·4243	2·4240	2·4236	2·4232	2·4226	2·4219	60 4
10	2·4203	2·4201	2·4199	2·4196	2·4194	2·4191	2·4188	2·4185	2·4181	2·4177	2·4172	2·4166	2·4158	50
20	2·4139	2·4136	2·4134	2·4131	2·4128	2·4125	2·4122	2·4118	2·4114	2·4109	2·4103	2·4096	2·4087	40
or 30	2·4065	2·4062	2·4059	2·4056	2·4053	2·4050	2·4046	2·4042	2·4037	2·4032	2·4025	2·4017	2·4007	30 or
40	2·3982	2·3979	2·3975	2·3972	2·3968	2·3965	2·3961	2·3956	2·3951	2·3945	2·3938	2·3929	2·3917	20
19 50	2·3888	2·3885	2·3881	2·3878	2·3874	2·3870	2·3865	2·3860	2·3854	2·3898	2·3840	2·3830	2·3818	10 16
8 00	2·3784	2·3781	2.3777	2·3773	2.3769	2·3764	2·3759	2.3754	2·3748	2·3741	2.3732	2·3722	2·3708	60 3
10	2·3669	2·3665	2·3661	2·3657	2·3652	2·3647	2·3642	2·3636	2·3630	2·3622	2·3613	2·3602	2·3587	50
20	2·3543	2·3538	2·3534	2·3529	2·3524	2·3519	2·3514	2·3508	2·3501	2.3492	2·3483	2·3471	2·3455	40
or 30	2·3404	2·3399	2·3394	2·3390	2·3384	2·3379	2·3373	2·3366	2·3359	2·3350	2·3340	2·3327	2·3311	30 or
40	2·3252	2·3247	2·3242	2·3237	2·3231	2·3225	2·3219	2·3212	2·3204	2·3195	2·3184	2·3171	2·3153	20
20 50	2·3085	2·3080	2·3075	2·3070	2·3064	2·3058	2·3051	2·3044	2·3036	2·3026	2·3015	2·3000	2·2982	10 15
9 00	2·2904	2·2899	2·2893	2·2887	2·2881	2·2875	2·2868	2·2861	2·2852	2·2842	2·2830	2·2815	2·2796	60 2
10	2·2706	2·2700	2·2695	2·2689	2·2682	2·2676	2·2669	2·2661	2·2652	2·2641	2·2629	2·2613	2·2593	50
20	2·2490	2·2484	2·2478	2·2472	2·2465	2·2459	2·2451	2·2443	2·2433	2·2422	2·2409	2·2393	2·2372	40
or 30	2·2254	2·2248	2·2241	2·2235	2·2228	2·2221	2·2213	2·2205	2·2195	2·2184	2·2170	2·2154	2·2132	30 or
40	2·1995	2·1989	2·1982	2·1976	2·1969	2·1962	2·1954	2·1945	2·1935	2·1923	2·1909	2·1892	2·1870	20
21 50	2·1711	2·1705	2·1698	2·1692	2·1684	2·1677	2·1669	2·1659	2·1649	2·1637	2·1623	2·1605	2·1582	10 14
10 00	2·1399	2·1392	2·1385	2·1379	2·1371	2·1363	2·1355	2·1346	2·1335	2·1323	2·1308	2·1290	2·1266	60 1
10	2·1053	2·1046	2·1039	2·1032	2·1025	2·1017	2·1008	2·0999	2·0988	2·0975	2·0960	2·0941	2·0917	50
20	2·0669	2·0662	2·0655	2·0647	2·0640	2·0632	2·0623	2·0613	2·0602	2·0589	2·0573	2·0554	2·0529	40
or 30	2·0238	2·0230	2·0223	2·0216	2·0208	2·0200	2·0191	2·0180	2·0169	2·0156	2·0140	2·0121	2·0096	30 or
40	1·9750	1·9742	1·9735	1·9728	1·9720	1·9711	1·9702	1·9692	1·9680	1·9667	1·9651	1·9631	1·9605	20
22 50	1·9191	1·9183	1·9176	1·9168	1·9160	1·9152	1·9142	1·9132	1·9120	1·9107	1·9090	1·9070	1·9044	10 13
11 00	1·8539	1·8532	1·8524	1·8516	1·8508	1·8500	1·8490	1·8480	1·8468	1·8454	1·8438	1·8417	1·8391	60 0
10	1·7762	1·7755	1·7747	1·7740	1·7731	1·7723	1·7713	1·7702	1·7690	1·7676	1·7660	1·7639	1·7612	50
20	1·6806	1·6798	1·6791	1·6782	1·6774	1·6766	1·6756	1·6745	1·6733	1·6719	1·6702	1·6681	1·6655	40
or 30	1·5566	1·5558	1·5551	1·5543	1·5534	1·5526	1·5516	1·5505	1·5493	1·5479	1·5462	1·5441	1·5414	30 or
40	1·3812	1·3804	1·3797	1·3789	1·3780	1·3771	1·3762	1·3751	1·3739	1·3724	1·3707	1·3686	1·3659	20
23 50	1·0806	1·0798	1·0791	1·0783	1·0774	1·0765	1·0755	1·0745	1·0732	1·0718	1·0701	1·0680	1·0652	10 12
Declination of Time Star South.	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	A

TABLE XV.

Correction for Declination of the Pole Star to be added to the values of Table XIV.

Declination.	Correction.	Declination.	Correction.	Declination.	Correction.	Declination.	Correction.	Declination.	Correction.	Declination.	Correction.
° ′ ″		° ′ ″		° ′ ″		° ′ ″		° ′ ″		° ′ ″	
88 48 40	0·0144	88 49 20	0·0104	88 50 00	0·0062	88 50 40	0·0021	88 51 20	−0·0021	88 52 00	−0·0063
50	·0134	30	·0093	10	·0052	50	·0010	30	− ·0032	10	− ·0074
88 49 00	·0124	40	·0083	20	·0042	88 51 00	·0000	40	− ·0042	20	− ·0085
10	·0114	50	·0073	30	·0031	10	−0·0011	50	− ·0053	30	− ·0095

TABLE XVI.

For Converting the Logarithm Tangent of Small Arcs into Logarithm of Seconds of Arc.

Log Tan.	Log *T*.	Log Tan.	Log *T*.	Log Tan.	Log *T*.
7·920	5·314 42	8·419	5·314 33	8·547	5·314 25
8·071	41	·440	32	·558	24
·157	40	·459	31	·570	23
·221	39	·477	30	·581	22
·269	38	·493	29	·591	21
·309	37	·508	28	·601	20
·342	36	·521	27	·610	19
·371	35	·535	26	·619	18
·396	34				

TABLE XVII.

$$\text{Log}\ \frac{1}{1-m}$$

Log *m*	0	1	2	3	4	5	6	7	8	9	Log *m*
8.60	+0.0 1764	1768	1773	1777	1781	1785	1789	1794	1798	1802	8.60
8.59	+0.0 1723	1727	1732	1736	1740	1744	1748	1752	1756	1760	8.59
58	1683	1687	1691	1695	1699	1703	1707	1711	1715	1719	58
57	1644	1648	1652	1656	1660	1664	1668	1672	1676	1679	57
56	1606	1610	1614	1618	1621	1625	1629	1633	1637	1640	56
55	1569	1573	1576	1580	1584	1587	1591	1595	1599	1602	55
54	1533	1536	1540	1543	1547	1551	1554	1558	1562	1565	54
53	1497	1501	1504	1508	1511	1515	1518	1522	1525	1529	53
52	1462	1466	1469	1473	1476	1480	1483	1487	1490	1494	52
51	1429	1432	1435	1439	1442	1445	1449	1452	1456	1459	51
50	1396	1399	1402	1405	1409	1412	1415	1419	1422	1425	50
8·49	+0·0 1363	1367	1370	1373	1376	1379	1383	1386	1389	1392	8·49
48	1332	1335	1338	1341	1344	1347	1351	1354	1357	1360	48
47	1301	1304	1307	1310	1313	1316	1319	1323	1326	1329	47
46	1271	1274	1277	1280	1283	1286	1289	1292	1295	1298	46
45	1242	1245	1247	1250	1253	1256	1259	1262	1265	1268	45
44	1213	1216	1219	1222	1224	1227	1230	1233	1236	1239	44
43	1185	1188	1191	1193	1196	1199	1202	1205	1207	1210	43
42	1158	1160	1163	1166	1169	1171	1174	1177	1179	1182	42
41	1131	1134	1136	1139	1142	1144	1147	1150	1152	1155	41
40	1105	1107	1110	1113	1115	1118	1120	1123	1126	1128	40
8·39	+0·0 1079	1082	1084	1087	1090	1092	1095	1097	1100	1102	8·39
38	1055	1057	1059	1062	1064	1067	1069	1072	1074	1077	38
37	1030	1033	1035	1037	1040	1042	1045	1047	1050	1052	37
36	1007	1009	1011	1014	1016	1018	1021	1023	1025	1028	36
35	0983	0986	0988	0990	0993	0995	0997	1000	1002	1004	35
34	0961	0963	0965	0967	0970	0972	0974	0977	0979	0981	34
33	0939	0941	0943	0945	0947	0950	0952	0954	0956	0958	33
32	0917	0919	0921	0923	0926	0928	0930	0932	0934	0936	32
31	0896	0898	0900	0902	0904	0906	0909	0911	0913	0915	31
30	0875	0877	0879	0881	0884	0886	0888	0890	0892	0894	30
8·29	+0·0 0855	0857	0859	0861	0863	0865	0867	0869	0871	0873	8·29
28	0836	0838	0839	0841	0843	0845	0847	0849	0851	0853	28
27	0816	0818	0820	0822	0824	0826	0828	0830	0832	0834	27
26	0798	0799	0801	0803	0805	0807	0809	0811	0813	0814	26
25	0779	0781	0783	0785	0787	0788	0790	0792	0794	0796	25

TABLE XVII—*Continued.*

$$\text{Log}\ \frac{1}{1-m}$$

Log *m*	0	1	2	3	4	5	6	7	8	9	Log *m*
8·24	+0·0 0761	0763	0765	0767	0769	0770	0772	0774	0776	0777	8.24
23	0744	0746	0747	0749	0751	0753	0754	0756	0758	0760	23
22	0727	0729	0730	0732	0734	0735	0737	0739	0740	0742	22
21	0710	0712	0713	0715	0717	0718	0720	0722	0723	0725	21
20	0694	0695	0697	0699	0700	0702	0704	0705	0707	0709	20
8·19	+0·0 0678	0680	0681	0683	0684	0686	0687	0689	0691	0692	8·19
18	0662	0664	0665	0667	0669	0670	0672	0673	0675	0676	18
17	0647	0649	0650	0652	0653	0655	0656	0658	0659	0661	17
16	0632	0634	0635	0637	0638	0640	0641	0643	0644	0646	16
15	0618	0619	0621	0622	0624	0625	0627	0628	0629	0631	15
14	0604	0605	0607	0608	0609	0611	0612	0614	0615	0616	14
13	0590	0591	0593	0594	0595	0597	0598	0600	0601	0602	13
12	0576	0578	0579	0580	0582	0583	0584	0586	0587	0589	12
11	0563	0564	0566	0567	0568	0570	0571	0572	0574	0575	11
10	0550	0552	0553	0554	0555	0557	0558	0559	0561	0562	10
8·09	+0·0 0538	0539	0540	0541	0543	0544	0545	0546	0548	0549	8·09
08	0525	0527	0528	0529	0530	0531	0533	0534	0535	0536	08
07	0513	0515	0516	0517	0518	0519	0521	0522	0523	0524	07
06	0502	0503	0504	0505	0506	0507	0509	0510	0511	0512	06
05	0490	0491	0492	0494	0495	0496	0497	0498	0499	0500	05
04	0479	0480	0481	0482	0483	0484	0486	0487	0488	0489	04
03	0468	0469	0470	0471	0472	0473	0474	0476	0477	0478	03
02	0457	0458	0459	0460	0461	0463	0464	0465	0466	0467	02
01	0447	0448	0449	0450	0451	0452	0453	0454	0455	0456	01
00	0437	0438	0439	0440	0441	0442	0443	0444	0445	0446	00
7·9	+0·0 0346	0355	0363	0371	0380	0389	0398	0407	0417	0427	7·9
8	0275	0281	0288	0295	0302	0309	0316	0323	0331	0338	8
7	0218	0223	0229	0234	0239	0245	0251	0257	0263	0269	7
6	0173	0177	0181	0186	0190	0194	0199	0204	0208	0213	6
5	0138	0141	0144	0147	0151	0154	0158	0162	0165	0169	5
4	0109	0112	0114	0117	0120	0123	0125	0128	0131	0134	4
3	0087	0089	0091	0093	0095	0097	0100	0102	0104	0107	3
2	0069	0071	0072	0074	0076	0077	0079	0081	0083	0085	2
1	0055	0056	0057	0059	0060	0061	0063	0064	0066	0067	1
0	0044	0045	0046	0047	0048	0049	0050	0051	0052	0054	0

TABLE XVII.—*Continued.*

$\text{Log}\ \frac{1}{1-m}$

Log m	0	1	2	3	4	5	6	7	8	9	Log m
6·9	+0·0 0035	0035	0036	0037	0038	0039	0040	0041	0042	0043	6·9
8	0027	0028	0029	0029	0030	0031	0032	0032	0033	0034	8
7	0022	0022	0023	0023	0024	0024	0025	0026	0026	0027	7
6	0017	0018	0018	0019	0019	0019	0020	0020	0021	0021	6
5	0014	0014	0014	0015	0015	0015	0016	0016	0017	0017	5
4	0011	0011	0011	0012	0012	0012	0013	0013	0013	0013	4
3	0009	0009	0009	0009	0010	0010	0010	0010	0010	0011	3
2	0007	0007	0007	0007	0008	0008	0008	0008	0008	0009	2
1	0006	0006	0006	0006	0006	0006	0006	0006	0007	0007	1
0	0004	0004	0005	0005	0005	0005	0005	0005	0005	0005	0
5·	+0·0 0000	0001	0001	0001	0001	0001	0002	0002	0003	0003	5·
5· n	10·0 0000	9999	9999	9999	9999	9999	9998	9998	9997	9997	5· n
6·0n	9·9 9996	9996	9996	9995	9995	9995	9995	9995	9995	9995	6·0n
1n	9995	9994	9994	9994	9994	9994	9994	9994	9993	9993	1n
2n	9993	9993	9993	9993	9993	9992	9992	9992	9992	9992	2n
3n	9991	9991	9991	9991	9991	9990	9990	9990	9990	9989	3n
4n	9989	9989	9989	9988	9988	9988	9988	9987	9987	9987	4n
5n	9986	9986	9986	9985	9985	9985	9984	9984	9984	9983	5n
6n	9983	9982	9982	9982	9981	9981	9980	9980	9979	9979	6n
7n	9978	9978	9977	9977	9976	9976	9975	9974	9974	9973	7n
8n	9973	9972	9971	9971	9970	9969	9969	9968	9967	9966	8n
9n	9966	9965	9964	9963	9962	9961	9960	9960	9959	9958	9n
7·0n	9·9 9957	9956	9955	9954	9952	9951	9950	9949	9948	9947	7·0n
1n	9945	9944	9943	9942	9940	9939	9937	9936	9934	9933	1n
2n	9931	9930	9928	9926	9925	9923	9921	9919	9917	9915	2n
3n	9913	9911	9909	9907	9905	9903	9901	9898	9896	9894	3n
4n	9891	9889	9886	9883	9881	9878	9875	9872	9869	9866	4n
5n	9863	9860	9856	9853	9850	9846	9843	9839	9835	9831	5n
6n	9827	9823	9819	9815	9811	9806	9802	9797	9793	9788	6n
7n	9783	9778	9773	9767	9762	9757	9751	9745	9739	9733	7n
8n	9727	9721	9714	9707	9701	9694	9687	9679	9672	9664	8n
9n	9656	9648	9640	9632	9623	9615	9606	9597	9587	9578	9n

TABLE XVII.—*Continued.*

$\text{Log}\ \frac{1}{1-m}$

Log m	0	1	2	3	4	5	6	7	8	9	Log m
8·00n	9·9 9568	9567	9566	9565	9564	9563	9562	9561	9560	9559	8·00n
01n	9558	9557	9556	9555	9554	9553	9552	9551	9550	9549	01n
02n	9548	9547	9546	9545	9543	9542	9541	9540	9539	9538	02n
03n	9537	9536	9535	9534	9533	9532	9531	9530	9529	9528	03n
04n	9526	9525	9524	9523	9522	9521	9520	9519	9518	9517	04n
05n	9515	9514	9513	9512	9511	9510	9509	9508	9507	9505	05n
06n	9504	9503	9502	9501	9500	9499	9497	9496	9495	9494	06n
07n	9493	9492	9490	9489	9488	9487	9486	9485	9483	9482	07n
08n	9481	9480	9479	9477	9476	9475	9474	9473	9471	9470	08n
09n	9469	9468	9467	9465	9464	9463	9462	9460	9459	9458	09n
8·10n	9·9 9457	9455	9454	9453	9452	9450	9449	9448	9447	9445	8·10n
11n	9444	9443	9442	9440	9439	9438	9436	9435	9434	9433	11n
12n	9431	9430	9429	9427	9426	9425	9423	9422	9421	9419	12n
13n	9418	9417	9415	9414	9413	9411	9410	9409	9407	9406	13n
14n	9405	9403	9402	9401	9399	9398	9396	9395	9394	9392	14n
15n	9391	9389	9388	9387	9385	9384	9382	9381	9380	9378	15n
16n	9377	9375	9374	9373	9371	9370	9368	9367	9365	9364	16n
17n	9362	9361	9359	9358	9357	9355	9354	9352	9351	9349	17n
18n	9348	9346	9345	9343	9342	9340	9339	9337	9336	9334	18n
19n	9333	9331	9330	9328	9326	9325	9323	9322	9320	9319	19n
8·20n	9·9 9317	9316	9314	9312	9311	9309	9308	9306	9305	9303	8·20n
21n	9301	9300	9298	9297	9295	9293	9292	9290	9288	9287	21n
22n	9285	9284	9282	9280	9279	9277	9275	9274	9272	9270	22n
23n	9269	9267	9265	9264	9262	9260	9259	9257	9255	9254	23n
24n	9252	9250	9248	9247	9245	9243	9241	9240	9238	9236	24n
25n	9235	9233	9231	9229	9228	9226	9224	9222	9220	9219	25n
26n	9217	9215	9213	9211	9210	9208	9206	9204	9202	9201	26n
27n	9199	9197	9195	9193	9191	9190	9188	9186	9184	9182	27n
28n	9180	9178	9177	9175	9173	9171	9169	9167	9165	9163	28n
29n	9161	9159	9158	9156	9154	9152	9150	9148	9146	9144	29n
8·30n	9·9 9142	9140	9138	9136	9134	9132	9130	9128	9126	9124	8·30n
31n	9122	9120	9118	9116	9114	9112	9110	9108	9106	9104	31n
32n	9102	9100	9098	9096	9094	9092	9090	9088	9086	9083	32n
33n	9081	9079	9077	9075	9073	9071	9069	9066	9064	9062	33n
34n	9060	9058	9056	9054	9052	9049	9047	9045	9043	9041	34n

TABLE XVII.—*Concluded.*

$$\text{Log } \frac{1}{1-m}$$

Log *m*	0	1	2	3	4	5	6	7	8	9	Log *m*
8·35*n*	9·9 9039	9036	9034	9032	9030	9027	9025	9023	9021	9019	8·35*n*
36*n*	9016	9014	9012	9010	9007	9005	9003	9001	8998	8996	36*n*
37*n*	8994	8991	8989	8987	8985	8982	8980	8978	8975	8973	37*n*
38*n*	8971	8968	8966	8963	8961	8959	8956	8954	8952	8949	38*n*
39*n*	8947	8944	8942	8940	8937	8935	8932	8930	8928	8925	39*n*
8·40*n*	9·9 8923	8920	8918	8915	8913	8910	8908	8905	8903	8900	8·40*n*
41*n*	8898	8895	8893	8890	8888	8885	8883	8880	8878	8875	41*n*
42*n*	8873	8870	8867	8865	8862	8860	8857	8854	8852	8849	42*n*
43*n*	8847	8844	8841	8839	8836	8833	8831	8828	8825	8823	43*n*
44*n*	8820	8817	8815	8812	8809	8807	8804	8801	8798	8796	44*n*
45*n*	8793	8790	8787	8785	8782	8779	8776	8774	8771	8768	45*n*
46*n*	8765	8762	8760	8757	8754	8751	8748	8745	8743	8740	46*n*
47*n*	8737	8734	8731	8728	8725	8722	8720	8717	8714	8711	47*n*
48*n*	8708	8705	8702	8699	8696	8693	8690	8687	8684	8681	48*n*
49*n*	8678	8675	8672	8669	8666	8663	8660	8657	8654	8651	49*n*
8·50*n*	9·9 8648	8645	8642	8639	8636	8633	8629	8626	8623	8620	8·50*n*
51*n*	8617	8614	8611	8608	8604	8601	8598	8595	8592	8588	51*n*
52*n*	8585	8582	8579	8576	8572	8569	8566	8563	8559	8556	32*n*
53*n*	8553	8550	8546	8543	8540	8536	8533	8530	8526	8523	53*n*
54*n*	8520	8516	8513	8510	8506	8503	8499	8496	8493	8489	54*n*
55*n*	8486	8482	8479	8476	8472	8469	8465	8462	8458	8455	55*n*
56*n*	8451	8448	8444	8441	8437	8434	8430	8426	8423	8419	56*n*
57*n*	8416	8412	8409	8405	8401	8398	8394	8390	8387	8383	57*n*
58*n*	8380	8376	8372	8368	8365	8361	8357	8354	8350	8346	58*n*
59*n*	8342	8339	8335	8331	8327	8324	8320	8316	8312	8308	59*n*
8·60*n*	9·9 8305	8301	8297	8293	8289	8285	8281	8278	8274	8270	8·60*n*

TABLE XVIII.

Deflection of a Trial Line for Deviations from 1 to 149 Links at the end of eighty-one chains.

Links.	Decimal Division.	Sexagesimal Division.		Links.	Decimal Division.	Sexagesimal Division.		Links.	Decimal Division.	Sexagesimal Division.	
	°	′	″		°	′	″		°	′	″
0	0·000	0	00	35	0·248		51	70	0·495		43
1	·007		25	36	·255	15	17	71	·502	30	08
2	·014		51	37	·262		42	72	·509		33
3	·021	1	16	38	·269	16	08	73	·516		59
4	·028		42	39	·276		33	74	·523	31	24
5	·035	2	07	40	·283	16	59	75	·531		50
6	·042		33	41	·290	17	24	76	·538	32	15
7	·050		58	42	·297		50	77	·545		41
8	·057	3	24	43	·304	18	15	78	·552	33	06
9	·064		49	44	·311		41	79	·559		32
10	·071	4	15	45	·318	19	06	80	·566	33	57
11	·078		40	46	·325		31	81	·573	34	23
12	·085	5	06	47	·332		57	82	·580		48
13	·092		31	48	·340	20	22	83	·587	35	13
14	·099		57	49	·347		48	84	·594		39
15	·106	6	22	50	·354	21	13	85	·601	36	04
16	·113		47	51	·361		39	86	·608		30
17	·120	7	13	52	·368	22	04	87	·615		55
18	·127		38	53	·375		30	88	·622	37	21
19	·134	8	03	54	·382		55	89	·630		46
20	·141		29	55	·389	23	21	90	·637	38	12
21	·149		55	56	·396		46	91	·644		37
22	·156	9	20	57	·403	24	12	92	·651	39	03
23	·163		46	58	·410		37	93	·658		28
24	·170	10	11	59	·417	25	02	94	·665		54
25	·177		37	60	·424		28	95	·672	40	19
26	·184	11	02	61	·432		53	96	·679		44
27	·191		28	62	·439	26	19	97	·686	41	10
28	·198		53	63	·446		44	98	·693		35
29	·205	12	19	64	·453	27	10	90	·700	42	01
30	·212		44	65	·460		35	100	·707		26
31	·219	13	09	66	·467	28	01	101	·714		52
32	·226		35	67	·474		26	102	·721	43	17
33	·233	14	00	68	·481		52	103	·729		43
34	·241		26	69	·488	29	17	104	·736	44	08

TABLE XVIII.—*Concluded.*

Deflection of a Trial Line for Deviations from 1 to 149 Links at the end of Eighty-one Chains.

Links.	Decimal Division.	Sexagesimal Division.		Links.	Decimal Division.	Sexagesimal Division.		Links.	Decimal Division.	Sexagesimal Division.	
	°	'	"		°	'	"		°	'	"
105	0·743		34	120	0·849	50	55	135	0·955	57	17
106	·750		59	121	·856	51	21	136	·962		43
107	·757	45	24	122	·863		46	137	·969	58	08
108	·764		50	123	·870	52	12	138	·976		34
109	·771	46	15	124	·877		37	139	·983		59
110	·778		41	125	·884	53	03	140	·990	59	25
111	·785	47	06	126	·891		28	141	·997		50
112	·792		32	127	·898		54	142	1·004	60	16
113	·799		57	128	·905	54	19	143	·011		41
114	·806	48	23	129	·912		45	144	·018	61	06
115	·813		48	130	·919	55	10	145	·026		32
116	·820	49	14	131	·927		35	146	·033		57
117	·828		39	132	·934	56	01	147	·040	62	23
118	·835	50	05	133	·941		26	148	·047		48
119	·842		30	134	·948		52	149	·054	63	14

TABLE XIX.

Correction in Links to Slope Measurements.

Slope		Correction for		Slope		Correction for	
		100 lks.	800 lks.			100 lks.	800 lks.
°	'			°	'		
1	00	0·0	0·1	22	00	7.3	58·2
2	00	0·1	0·5		30	7·6	60·9
3	00	0·1	1·1	23	00	7·9	63·6
4	00	0·2	2·0		30	8·3	66·3
5	00	0·4	3·0	24	00	8·6	69·2
6	00	0·5	4·4		30	9·0	72·0
7	00	0·7	6·0	25	00	9·4	74·9
8	00	1·0	7·8		30	9·7	77·9
9	00	1·2	9·8	26	00	10·1	81·0
10	00	1·5	12·1		30	10·5	84·0
11	00	1·8	14·7	27	00	10·9	87·2
12	00	2·2	17·5		30	11·3	90·4
13	00	2·6	20·5	28	00	11·7	93·6
14	00	3·0	23·8		30	12·1	96·9
15	00	3·4	27·3	29	00	12·5	100·3
	30	3·6	29·1		30	13·0	103·7
16	00	3·9	31·0	30	00	13·4	107·2
	30	4·1	32·9		30	13·8	110·7
17	00	4·4	35·0	31	00	14·3	114·3
	30	4·6	37·0		30	14·7	117·9
18	00	5·0	39·1	32	00	15·2	121·6
	30	5·2	41·3		30	15·7	125·3
19	00	5·5	43·6	33	00	16·1	129·1
	30	5·7	45·9		30	16·6	132·9
20	00	6·0	48·2	34	00	17·1	136·8
	30	6·3	50·7		30	17·6	140·7
21	00	6·6	53·1	35	00	18·1	144·7
	30	7·0	55·7		30	18·6	148·7

TABLE XX.

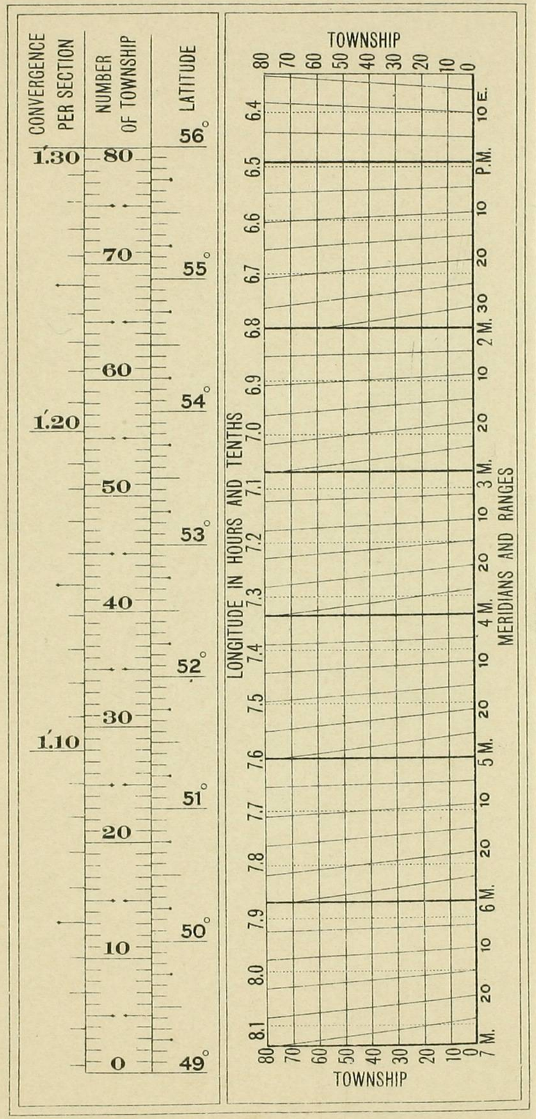
Table for laying out roads one chain wide.

Difference of Azimuth.		Links.	Difference of Azimuth.		Links.	Difference of Azimuth.		Links.
° ′	° ′		° ′	° ′		° ′	° ′	
343 52	16 08	101	275 35	84 25	135	252 34	107 26	169
337 16	22 44	102	274 40	85 20	136	252 04	107 56	170
332 16	27 44	103	273 46	86 14	137	251 35	108 25	171
328 07	31 53	104	272 53	87 07	138	251 06	108 54	172
324 30	35 30	105	272 01	87 59	139	250 38	109 22	173
321 16	38 44	106	271 10	88 50	140	250 10	109 50	174
318 19	41 41	107	270 21	89 39	141	249 42	110 18	175
315 37	44 23	108	269 32	90 28	142	249 15	110 45	176
313 06	46 54	109	268 44	91 16	143	248 48	111 12	177
310 46	49 14	110	267 58	92 02	144	248 22	111 38	178
308 33	51 27	111	267 12	92 48	145	247 56	112 04	179
306 28	53 32	112	266 28	93 32	146	247 30	112 30	180
304 30	55 30	113	265 44	94 16	147	247 05	112 55	181
302 37	57 23	114	265 01	94 59	148	246 40	113 20	182
300 49	59 11	115	264 19	95 41	149	246 15	113 45	183
299 06	60 54	116	263 37	96 23	150	245 50	114 10	184
297 27	62 33	117	262 57	97 03	151	245 26	114 34	185
295 53	64 07	118	262 17	97 43	152	245 03	114 57	186
294 21	65 39	119	261 38	98 22	153	244 40	115 20	187
292 53	67 07	120	260 59	99 01	154	244 16	115 44	188
291 28	68 32	121	260 21	99 39	155	243 53	116 07	189
290 06	69 54	122	259 44	100 16	156	243 31	116 29	190
288 47	71 13	123	259 08	100 52	157	243 07	116 53	191
287 30	72 30	124	258 32	101 28	158	242 47	117 13	192
286 16	73 44	125	257 57	102 03	159	242 25	117 35	193
285 03	74 57	126	257 22	102 38	160	242 03	117 57	194
283 53	76 07	127	256 48	103 12	161	241 42	118 18	195
282 45	77 15	128	256 14	103 46	162	241 21	118 39	196
281 39	78 21	129	255 41	104 19	163	241 01	118 59	197
280 34	79 26	130	255 09	104 51	164	240 40	119 20	198
279 31	80 29	131	254 37	105 23	165	240 20	119 40	199
278 30	81 30	132	254 05	105 55	166	240 00	120 00	200
277 30	82 30	133	253 34	106 26	167			
276 32	83 28	134	253 04	106 56	168			

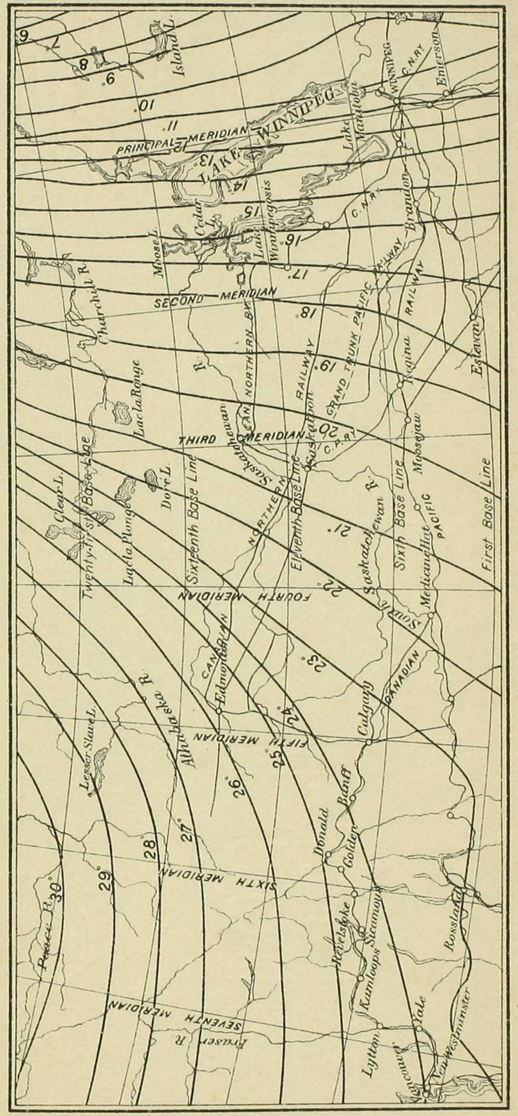
THE SUN'S APPARENT RIGHT ASCENSION

AND VARIATION FOR ONE HOUR AT GREENWICH APPARENT NOON

Day of Month	1909						1910						Day of Month
	January		February		March		April		May		June		
	h m s	s	h m s	s	h m s	s	h m s	s	h m s	s	h m s	s	
1	18 45 33	11.0	20 57 59	10.2	22 47 14	9.4	0 40 00	9.1	2 31 13	9.5	4 33 50	10.2	1
2	18 49 58	11.0	21 02 03	10.2	22 50 59	9.3	0 43 39	9.1	2 35 02	9.6	4 37 56	10.2	2
3	18 54 23	11.0	21 06 06	10.1	22 54 43	9.3	0 47 17	9.1	2 38 52	9.6	4 42 02	10.3	3
4	18 58 47	11.0	21 10 09	10.1	22 58 26	9.3	0 50 56	9.1	2 42 42	9.6	4 46 08	10.3	4
5	19 03 11	11.0	21 14 11	10.1	23 02 09	9.3	0 54 35	9.1	2 46 32	9.6	4 50 15	10.3	5
6	19 07 34	11.0	21 18 12	10.0	23 05 52	9.3	0 58 14	9.1	2 50 24	9.6	4 54 22	10.3	6
7	19 11 57	10.9	21 22 12	10.0	23 09 34	9.3	1 01 53	9.1	2 54 15	9.7	4 58 29	10.3	7
8	19 16 19	10.9	21 26 12	10.0	23 13 16	9.2	1 05 33	9.1	2 58 08	9.7	5 02 37	10.3	8
9	19 20 41	10.9	21 30 10	9.9	23 16 58	9.2	1 09 12	9.2	3 02 01	9.7	5 06 45	10.3	9
10	19 25 02	10.9	21 34 08	9.9	23 20 39	9.2	1 12 52	9.2	3 05 54	9.7	5 10 53	10.3	10
11	19 29 23	10.9	21 38 05	9.9	23 24 20	9.2	1 16 33	9.2	3 09 48	9.8	5 15 02	10.4	11
12	19 33 43	10.8	21 42 02	9.8	23 28 00	9.2	1 20 13	9.2	3 13 43	9.8	5 19 10	10.4	12
13	19 38 03	10.8	21 45 57	9.8	23 31 40	9.2	1 23 54	9.2	3 17 38	9.8	5 23 19	10.4	13
14	19 42 22	10.8	21 49 52	9.8	23 35 20	9.2	1 27 35	9.2	3 21 34	9.8	5 27 28	10.4	14
15	19 46 40	10.8	21 53 46	9.7	23 39 00	9.1	1 31 16	9.2	3 25 31	9.9	5 31 38	10.4	15
16	19 50 58	10.7	21 57 40	9.7	23 42 39	9.1	1 34 58	9.2	3 29 27	9.9	5 35 47	10.4	16
17	19 55 15	10.7	22 01 32	9.7	23 46 18	9.1	1 38 40	9.3	3 33 25	9.9	5 39 56	10.4	17
18	19 59 31	10.7	22 05 24	9.7	23 49 58	9.1	1 42 22	9.3	3 37 23	9.9	5 44 06	10.4	18
19	20 03 47	10.6	22 09 16	9.6	23 53 36	9.1	1 46 05	9.3	3 41 22	10.0	5 48 15	10.4	19
20	20 08 02	10.6	22 13 07	9.6	23 57 15	9.1	1 49 48	9.3	3 45 21	10.0	5 52 25	10.4	20
21	20 12 16	10.6	22 16 57	9.6	0 00 54	9.1	1 53 32	9.3	3 49 20	10.0	5 56 34	10.4	21
22	20 16 29	10.5	22 20 46	9.5	0 04 32	9.1	1 57 16	9.3	3 53 20	10.0	6 00 44	10.4	22
23	20 20 42	10.5	22 24 35	9.5	0 08 11	9.1	2 01 00	9.4	3 57 21	10.0	6 04 53	10.4	23
24	20 24 54	10.5	22 28 23	9.5	0 11 49	9.1	2 04 45	9.4	4 01 22	10.1	6 09 03	10.4	24
25	20 29 05	10.4	22 32 10	9.5	0 15 27	9.1	2 08 31	9.4	4 05 24	10.1	6 13 12	10.4	25
26	20 33 15	10.4	22 35 57	9.4	0 19 05	9.1	2 12 16	9.4	4 09 26	10.1	6 17 21	10.4	26
27	20 37 24	10.4	22 39 43	9.4	0 22 44	9.1	2 16 03	9.4	4 13 29	10.1	6 21 31	10.4	27
28	20 41 33	10.3	22 43 29	9.4	0 26 22	9.1	2 19 49	9.5	4 17 32	10.1	6 25 40	10.4	28
29	20 45 40	10.3			0 30 00	9.1	2 23 37	9.5	4 21 36	10.2	6 29 48	10.4	29
30	20 49 47	10.3			0 33 38	9.1	2 27 25	9.5	4 25 40	10.2	6 33 57	10.4	30
31	20 53 53	10.2			0 37 16	9.1			4 29 45	10.2			31
	20 57 59	10.2	22 47 14	9.4	0 40 54	9.1	2 31 13	9.5	4 33 50	10.2	6 38 06	10.3	



ASTRONOMICAL BEARINGS OF MAGNETIC NORTH IN WESTERN CANADA.



DEPARTMENT OF THE INTERIOR · SURVEYS · CANADA

E. DEVILLE, LL.D.
Surveyor General.

ASTRONOMICAL FIELD TABLES

FOR USE ON

SURVEYS OF DOMINION LANDS

JANUARY, FEBRUARY, MARCH, 1909
APRIL, MAY, JUNE, - - 1910

TABLE FOR FINDING THE POLE STAR AND THE ASTRONOMICAL MERIDIAN.

	Altitude of Pole Star	Sidereal Time (h m)	Bearing of Pole Star Tp. 0	Tp. 20	Tp. 40	Tp. 60	Tp. 80	Degrees
ADD TO LATITUDE	66	0 00	40.3	41.8	43.5	45.4	47.5	
	67	10	35.8	37.2	38.7	40.4	42.2	
	68	20	31.2	32.4	33.7	35.2	36.9	
	68	30	26.6	27.6	28.7	30.0	31.4	0°
	69	40	21.9	22.8	23.7	24.7	25.9	
	70	50	17.2	17.9	18.6	19.4	20.3	
	70	1 00	12.4	12.9	13.5	14.0	14.7	
	70	10	07.7	08.0	08.3	08.7	09.1	
	71	20	02.9	03.0	03.1	03.2	03.4	
	71	30	58.1	58.0	57.9	57.8	57.7	
	70	40	53.3	53.0	52.7	52.4	52.1	
	70	50	48.5	48.0	47.5	47.0	46.4	
	70	2 00	43.7	43.1	42.4	41.6	40.8	
	69	10	39.0	38.2	37.3	36.3	35.2	359°
	69	20	34.3	33.3	32.2	31.0	29.7	
	68	30	29.7	28.5	27.2	25.8	24.2	
	67	40	25.1	23.7	22.3	20.6	18.8	
	66	50	20.6	19.1	17.4	15.6	13.5	
	65	3 00	16.1	14.5	12.6	10.6	08.3	
	63	10	11.8	10.0	07.9	05.7	03.2	
	62	20	07.6	05.6	03.4	00.9	58.2	
	60	30	03.4	01.3	58.9	56.3	53.3	
	59	40	59.4	57.1	54.6	51.7	48.6	
	57	50	55.5	53.1	50.4	47.3	44.0	
	55	4 00	51.8	49.2	46.3	43.1	39.6	
	53	10	48.1	45.4	42.4	39.0	35.3	
	51	20	44.6	41.8	38.6	35.1	31.2	
	49	30	41.3	38.3	35.0	31.4	27.3	358°
	46	40	38.1	35.0	31.6	27.8	23.5	
	44	50	35.1	31.9	28.3	24.4	20.0	
	41	5 00	32.3	28.9	25.3	21.2	16.7	
	39	10	29.6	26.2	22.4	18.2	13.5	
	36	20	27.1	23.6	19.7	15.4	10.6	
	33	30	24.8	21.2	17.2	12.8	07.9	
	31	40	22.6	19.0	14.9	10.5	05.5	
	28	50	20.7	17.0	12.9	08.3	03.2	

	Altitude of Pole Star	Sidereal Time (h m)	Bearing of Pole Star Tp. 0	Tp. 20	Tp. 40	Tp. 60	Tp. 80	Degrees
ADD TO LATITUDE	25	6 00	19.0	15.2	11.0	06.4	01.2	
	22	10	17.4	13.6	09.4	04.7	59.4	
	19	20	16.1	12.2	07.9	03.2	57.9	
	16	30	14.9	11.0	06.7	01.9	56.6	
	13	40	14.0	10.1	05.7	00.9	55.5	
	10	50	13.3	09.3	04.9	00.1	54.7	
	7	7 00	12.7	08.8	04.4	59.5	54.1	
	4	10	12.4	08.4	04.1	59.2	53.8	357°
	1	20	12.3	08.3	03.9	59.1	53.7	
SUBTRACT FROM LATITUDE	2	30	12.4	08.4	04.1	59.2	53.8	
	5	40	12.7	08.8	04.4	59.6	54.2	
	8	50	13.2	09.3	05.0	00.2	54.8	
	11	8 00	13.9	10.0	05.7	01.0	55.7	
	14	10	14.8	11.0	06.7	02.0	56.8	
	17	20	15.9	12.1	07.9	03.3	58.1	
	20	30	17.2	13.4	09.3	04.7	59.6	
	23	40	18.7	15.0	10.9	06.4	01.4	
	26	50	20.4	16.7	12.7	08.3	03.4	
	29	9 00	22.2	18.7	14.8	10.4	05.6	
	32	10	24.3	20.8	17.0	12.7	08.0	
	34	20	26.5	23.1	19.4	15.2	10.7	
	37	30	28.9	25.6	22.0	17.9	13.5	
	40	40	31.4	28.2	24.7	20.8	16.5	
	42	50	34.2	31.1	27.7	23.9	19.7	
	45	10 00	37.0	34.0	30.8	27.1	23.1	358°
	47	10	40.1	37.2	34.0	30.5	26.7	
	49	20	43.2	40.5	37.4	34.1	30.4	
	51	30	46.5	43.9	41.0	37.8	34.3	
	53	40	50.0	47.5	44.7	41.7	38.3	
	55	50	53.6	51.2	48.6	45.7	42.5	
	57	11 00	57.2	55.0	52.6	49.8	46.8	
	59	10	01.0	59.0	56.6	54.1	51.3	
	60	20	05.0	03.0	00.9	58.5	55.8	
	62	30	09.0	07.2	05.2	03.0	00.5	
	63	40	13.1	11.4	09.6	07.5	05.3	359°
	65	50	17.2	15.7	14.1	12.2	10.2	

	Altitude of Pole Star	Sidereal Time (h m)	Bearing of Pole Star Tp. 0	Tp. 20	Tp. 40	Tp. 60	Tp. 80	Degrees
SUBTRACT FROM LATITUDE	66	12 00	21.5	20.1	18.6	17.0	15.1	
	67	10	25.8	24.6	23.3	21.8	20.2	
	68	20	30.2	29.2	28.0	26.7	25.3	
	69	30	34.6	33.8	32.8	31.7	30.5	359°
	69	40	39.1	38.4	37.6	36.7	35.7	
	70	50	43.7	43.1	42.4	41.7	41.0	
	70	13 00	48.2	47.8	47.3	46.8	46.3	
	70	10	52.8	52.5	52.2	51.9	51.6	
	71	20	57.4	57.3	57.2	57.1	56.9	
	71	30	01.9	02.0	02.1	02.2	02.3	
	70	40	06.5	06.8	07.0	07.3	07.6	
	70	50	11.1	11.5	11.9	12.4	12.9	
	70	14 00	15.6	16.2	16.8	17.5	18.2	
	69	10	20.2	20.9	21.7	22.5	23.5	0°
	69	20	24.7	25.5	26.5	27.6	28.7	
	68	30	29.1	30.1	31.3	32.5	33.9	
	67	40	33.5	34.7	36.0	37.4	39.0	
	66	50	37.8	39.2	40.6	42.3	44.1	
	65	15 00	42.1	43.6	45.2	47.0	49.1	
	64	10	46.3	47.9	49.7	51.7	53.9	
	62	20	50.4	52.2	54.1	56.3	58.7	
	61	30	54.4	56.3	58.5	00.8	03.4	
	59	40	58.3	00.4	02.7	05.2	08.0	
	57	50	02.1	04.3	06.8	09.5	12.5	
	56	16 00	05.8	08.2	10.8	13.6	16.8	
	54	10	09.4	11.9	14.6	17.6	21.0	
	52	20	12.9	15.5	18.3	21.5	25.0	
	49	30	16.2	18.9	21.9	25.3	28.9	1°
	47	40	19.4	22.2	25.4	28.8	32.7	
	45	50	22.4	25.4	28.7	32.3	36.3	
	43	17 00	25.3	28.4	31.8	35.5	39.7	
	40	10	28.1	31.2	34.7	38.6	42.9	
	38	20	30.7	33.9	37.5	41.5	45.9	
	35	30	33.1	36.4	40.1	44.2	48.8	
	32	40	35.3	38.8	42.6	46.8	51.4	
	29	50	37.4	40.9	44.8	49.1	53.9	

	Altitude of Pole Star	Sidereal Time (h m)	Bearing of Pole Star Tp. 0	Tp. 20	Tp. 40	Tp. 60	Tp. 80	Degrees
SUBTRACT FROM LATITUDE	27	18 00	39.3	42.9	46.8	51.2	56.1	1°
	24	10	41.0	44.6	48.7	53.2	58.1	
	21	20	42.5	46.2	50.3	54.9	59.9	
	18	30	43.8	47.6	51.8	56.4	01.5	
	15	40	44.9	48.8	53.0	57.7	02.9	
	12	50	45.9	49.7	54.0	58.8	04.0	
	9	19 00	46.6	50.5	54.8	59.6	04.9	
	6	10	47.1	51.1	55.4	00.2	05.6	
	3	20	47.5	51.4	55.8	00.6	06.0	
ADD TO LATITUDE	0	30	47.6	51.6	55.9	00.8	06.2	2°
	3	40	47.5	51.5	55.9	00.7	06.1	
	6	50	47.2	51.2	55.6	00.4	05.8	
	10	20 00	46.7	50.7	55.1	59.9	05.3	
	13	10	46.1	50.0	54.3	59.2	04.5	
	16	20	45.2	49.1	53.4	58.2	03.5	
	19	30	44.1	47.9	52.2	57.0	02.2	
	22	40	42.8	46.6	50.8	55.5	00.7	
	25	50	41.2	45.0	49.2	53.8	59.0	
	27	21 00	39.6	43.3	47.4	52.0	57.0	
	30	10	37.7	41.3	45.4	49.9	54.9	
	33	20	35.6	39.2	43.1	47.5	52.4	
	36	30	33.3	36.8	40.7	45.0	49.8	
	38	40	30.8	34.3	38.0	42.2	46.9	
	41	50	28.2	31.5	35.2	39.3	43.8	
	43	22 00	25.4	28.6	32.2	36.1	40.6	1°
	46	10	22.4	25.5	29.0	32.8	37.1	
	48	20	19.3	22.3	25.6	29.3	33.4	
	50	30	16.0	18.8	22.0	25.6	29.5	
	52	40	12.5	15.3	18.3	21.7	25.5	
	55	50	08.9	11.5	14.4	17.6	21.2	
	56	23 00	05.2	07.6	10.4	13.4	16.8	
	58	10	01.3	03.6	06.2	09.1	12.3	
	60	20	57.3	59.5	01.9	04.6	07.6	
	62	30	53.2	55.2	57.5	00.0	02.8	
	63	40	49.0	50.9	52.9	55.2	57.8	0°
	64	50	44.7	46.4	48.3	50.4	52.7	

TIME STARS

STAR	Magnitude	Sidereal Time of Meridian Transit: Hours and Min. (h m)	1909 Jan. (s)	Feb. (s)	Mar. (s)	1910 April (s)	May (s)	June (s)	Approx. Polar Distance (° ′)
Aldebaran	1	4 30	42	42	41	44	44	44	73 40
Capella	1	5 09	58	58	57	61	61	61	44 05
Rigel	1	5 10	10	10	09	12	12	12	98 18
αOrionis	1	5 50	15	15	14	17	17	17	82 37
Sirius	1	6 41	09	09	08	10	10	10	106 36
Procyon	1	7 34	33	33	33	35	35	35	84 33
Pollux	1.3	7 39	45	46	45	49	48	48	61 45
Spica	1	13 20	23	24	25	28	28	28	100 41
Arcturus	1	14 11	30	31	31	35	35	35	70 21
Antares	1.3	16 23	48	49	49	54	55	55	116 14
Vega	1	18 33	49	50	51	54	55	55	51 18
Altair	1.3	19 46	18	19	20	23	24	25	81 23
αAndrom.	2	0 03	39	39	39	42	43	44	61 25
βCeti.	2	0 39	00	00	00	03	04	05	108 29
βAndrom.	2.3	1 04	37	36	36	39	40	41	54 52
γAndrom.	2.4	1 58	18	17	17	20	21	22	48 06
αArietis	2	2 02	02	01	01	04	05	05	66 58
βTauri	2	5 20	33	32	32	35	35	35	61 28
εOrionis	2	5 31	36	36	35	38	38	38	91 16
βAurigae	2	5 52	52	51	51	55	54	54	45 04
γGemino.	2.3	6 32	28	28	27	30	30	30	73 31
εCanis Maj.	1.6	6 55	04	04	03	05	04	04	118 51
δCanis Maj.	2	7 04	42	42	42	43	43	43	116 15
Castor	2	7 28	48	48	48	51	51	51	57 55
αHydrae	2	9 23	07	08	08	10	10	10	98 16
Regulus	1.3	10 03	32	32	32	36	35	35	77 35
βLeonis	2	11 44	25	26	26	29	29	29	74 55
αOphiuchi	2	17 30	41	41	42	46	47	47	77 23
αCygni	1.6	20 38	17	18	18	21	22	23	45 03
Fomalhaut	1.3	22 52	36	36	36	40	41	42	120 06

To find altitude of star on meridian, subtract Polar Distance from supplement of Latitude, (180°—L).

Stars of first list are visible most of the day with 1½″ object glass.
Stars of second list are visible one hour after sunrise or before sunset.

SIDEREAL TIME AT NOON, MOUNTAIN TIME

Date	h m	Date	h m
15 Jan. 1909	19 38	15 April 1910	1 32
15 Feb. 1909	21 41	15 May 1910	3 30
15 March 1909	23 31	15 June 1910	5 33

DEPARTMENT OF THE INTERIOR
SURVEYS
CANADA

E. DEVILLE, LL.D.
Surveyor General.

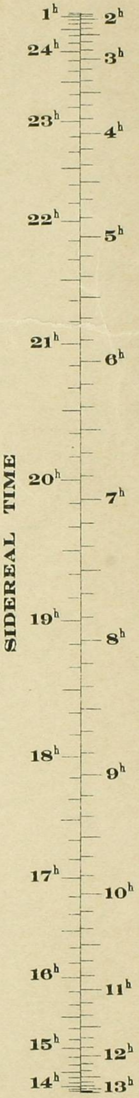
DIAGRAM

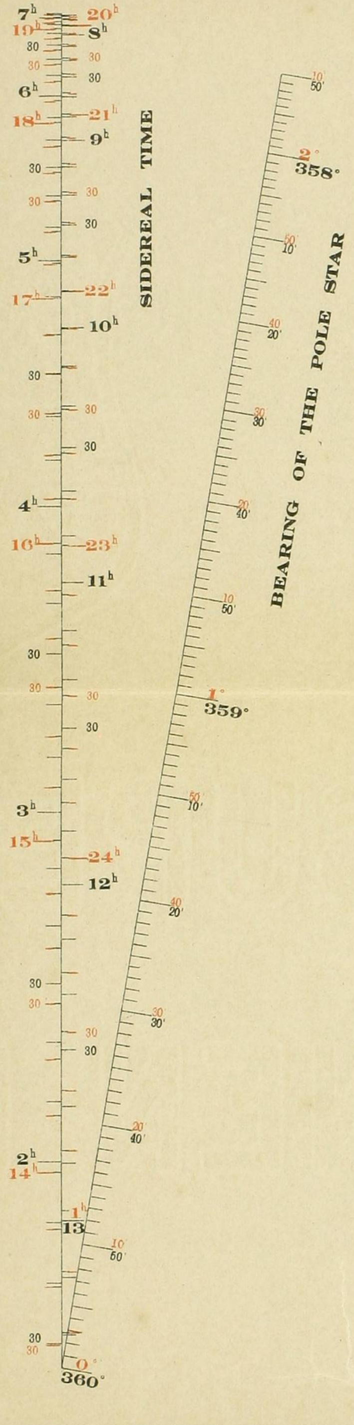
OF THE

ALTITUDE OF THE POLE STAR

January, February and March, 1909.

April, May and June, 1910





DEPARTMENT OF THE INTERIOR
SURVEYS
CANADA
E. DEVILLE, LL.D.
Surveyor General.

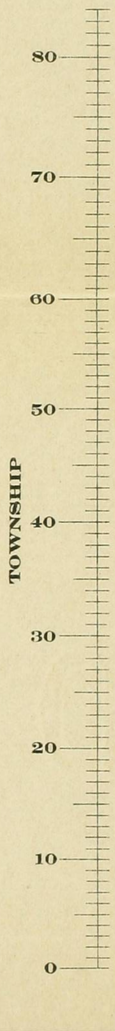
DIAGRAM

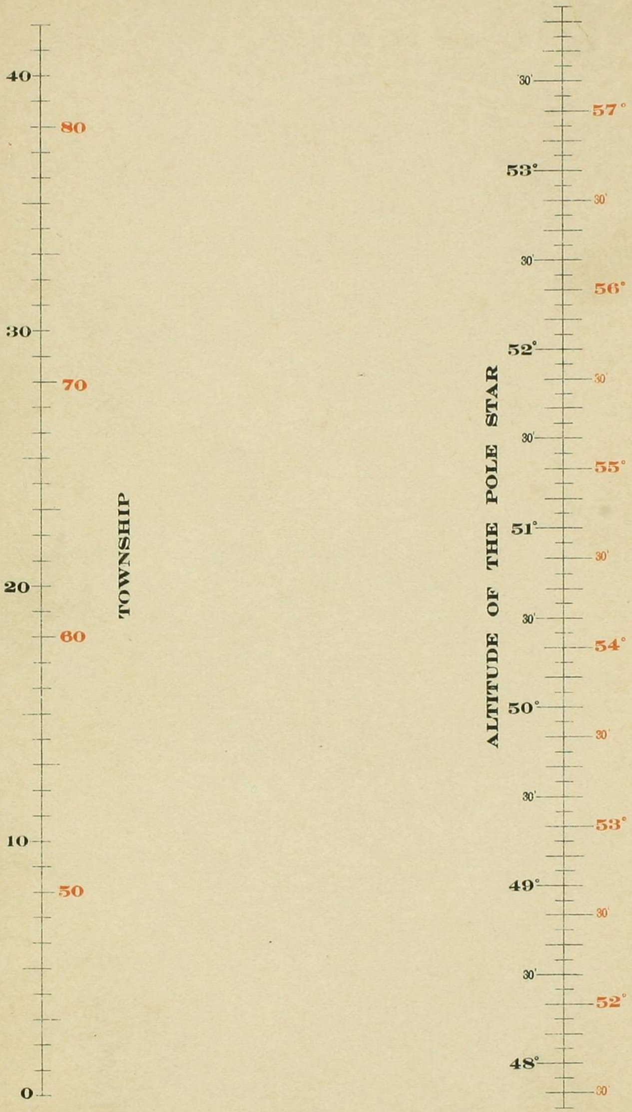
OF THE

BEARING OF THE POLE STAR

January, February and March, 1909.

April, May and June, 1910





TOWNSHIP
0
10
20
30
40
50
60
70
80
ALTITUDE OF THE POLE STAR
48°
49°
50°
51°
52°
53°
52°
53°
54°
55°
56°
57°
30'