Early Trigonometry

Calculations

used to

Determine Distances Across Impassable Obstacles

during the early

Government Land Surveys

1858

During the early government land surveys in Nebraska, the deputy surveyors occasionally had to determine the distance across bodies of water or areas that could not be measured by staying on a straight line. In the case of crossing rivers or lakes, when an offset line was not an option, trigonometry had to be used. It was also not always feasible to establish a right angle triangle to easily determine the required distance. Trigonometry involving oblique triangles was then used, but this required a higher degree of math. Usually, only the deputy surveyor was capable of doing such calculations. Without the aid of modern calculators to assist in the calculations, the surveyor carried a book of logarithms. Using logarithms required only having to perform addition and subtraction.

The example that follows are notes taken by U. S. Deputy Surveyor Charles A. Manners while surveying the Base Line between the states of Kansas and Nebraska in 1858. In a stretch of three miles, the crew had to cross the Republican River four times. Normally this river would not have required the use of trigonometry, but during the time of the survey it was at flood stage and was 5' to 8' deep.

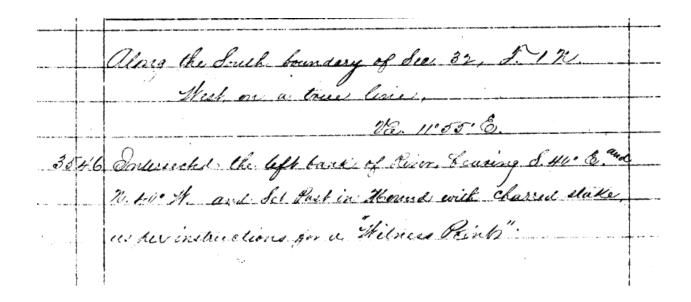
The usual method in using trigonometry was to first establish a witness point on the near side of the non-navigable river where the instrument was then set up over this point. (A "witness point" is the correct term used instead of "meander corner" when the river was not navigable or meandered). The flagman was sent across the river where he established another witness point on the opposite bank. This second point was placed on the surveyed line. From the instrument point, a baseline was established either upstream or downstream along the bank where a temporary point was placed at the far end of the baseline. The baseline was accurately measured with the chain.

While sighting the flagman on the opposite side of the river, the instrumentman turned the angle to the temporary point at the opposite end of the baseline. The instrumentman then moved to the temporary point at the far end of the baseline, sighted the flagman across the river, and turned the angle to the point on the near side of the river where he was initially set up. The crew now had two measured angles and one measured distance of the oblique triangle which was sufficient to determine the other unknown distances and angles through trigonometry using logarithm tables.

The following notes are the Original Government Field Notes of Charles A. Manners describing the four crossings of the Republican River.

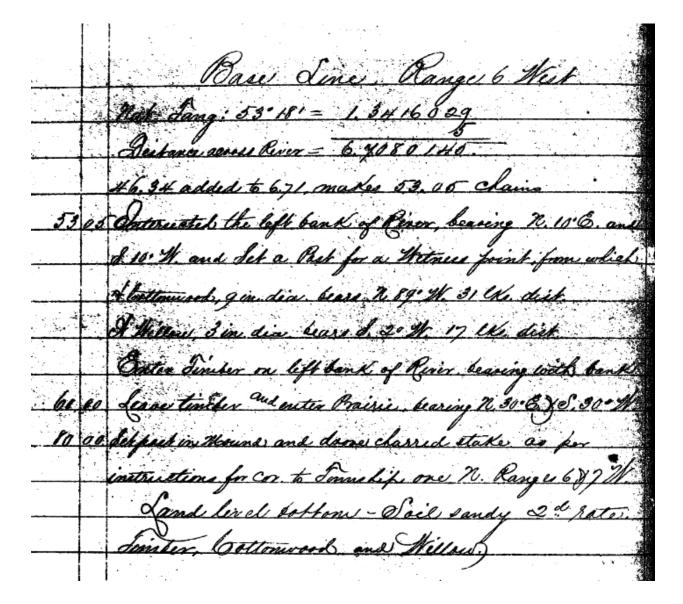
(The retyped notes follow these pages).

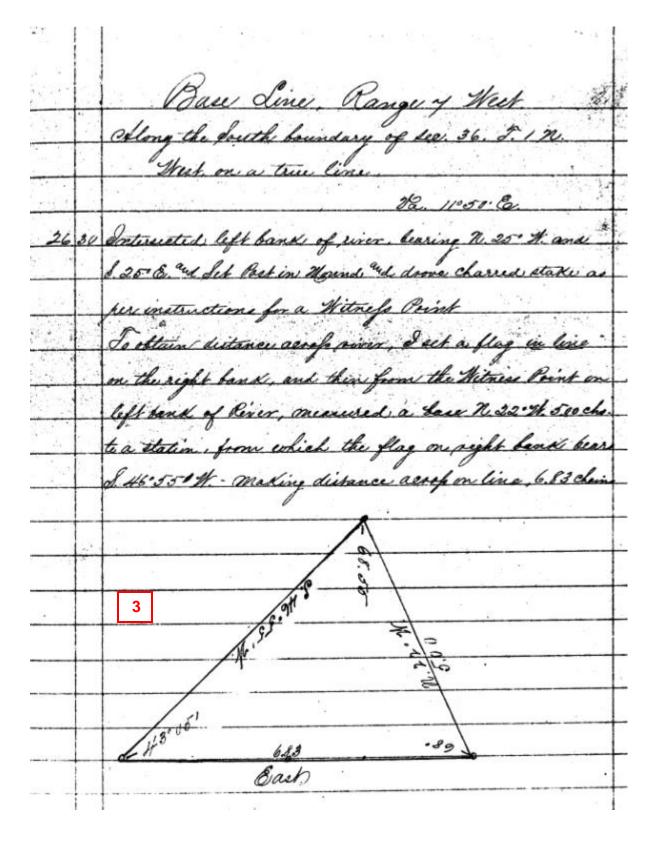
Those notes in blue are for the example at the end.



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Topographic map of the Republican River at Superior, Nebraska.

Along the South boundary of Sec. 32, T1N, [R6W].

West on a true line.

Va. 11°55′ E.

35.46 [chains] – Intersected the left bank of River, bearing S. 40° E. and N. 40° W. and Set Post in Mound with charred stake as per instructions for a "Witness Point".

Base Line. Range 6 West

To obtain the distance across the river, I caused a flag to be set in line on the right bank and then from the Witness Point on the left bank measured a base N. 40°16′ W., 3.84 chains to a Station from which the flag on the right bank bears S. 68°18′ W., making the distance across the river = 9.84 chains.

[Diagram]

As the Sine of $21^{\circ}42' = 9.567904$ Is to the Sine of $108^{\circ}34' = 9.976787$ So is the Base 3.84 0.58433110.5611189.567904

To dist across = 9.84 chains = Log. 0.993214.

45.30 [chains] – Intersected the right bank of the river bearing N. 35° W. and S. 35° E., 5.30 chains West of the ¼ sec. cor. at which point I set Post for a Witness Point and also for a Witness to the ¼ sec. cor. from which

post

A Willow 5 in. dia. bears S. 27° E, 29 links distant.

Base Line. Range 6 West

A Cottonwood 20 in. dia. bears N. 35° W., 249 links distant.

80.00 [chains] – Set post in mound and drove charred stake, as per instructions for cor. to sections 31 & 32.

Land level bottom prairie. Soil sandy 2nd rate.

Scattering Cottonwood & Willow trees skirting the banks of the Stream.

Along the South boundary of Sec. 31, T1N, [R6W].

West on a true line.

Va. 11°50′ East

40.00 [chains] – Set post in mound and drove charred stake, as per instructions for $\frac{1}{4}$ sec. cor.

46.34 [chains] – Intersected the right bank of river bearing N. 10° E., and S. 10° W. and Set a post in Mound and drove charred stake as per instructions for a "Witness point".

To obtain the distance across the river, I set a flag in line on the left bank and from Witness Point on the right measured a base South 5.00 chains to a Station from which the flag on the left bank bears N. 53°18′ W., making the distance across the river 6.71 chains.

Base Line. Range 6 West

Nat. Tang: 53°18′ = 1.341602

5

Distance across river = 6.7080145

46.34 added to 6.71 makes 53.05 chains.

53.05 [chains] – Intersected the left bank of River bearing N. 10° E. and S. 10° W. and Set a Post for Witness point from which

A cottonwood, 9 in. dia. bears N. 89° W., 31 links distant.

A willow 3 in. dia. bears S. 2° W., 17 links distant.

Enter timber on left bank of River bearing with bank.

60.00 [chains] - Leave timber and enter Prairie bearing N. 30° E. and S. 30° W.

80.00 [chains] – Set post in mound and drove charred stake as per instructions for cor. to Township one North, Ranges 6 & 7 West.

Land level bottom – Soil sandy 2nd rate.

Timber, Cottonwood and Willow.

Base Line. Range 7 West

Along the South boundary of Sec. 36, T1N [R7W]. West on a true line. Va. 11°50′ E.

26.30 [chains] – Intersected left bank of river bearing N. 25° W. and S. 25° E. and Set Post in Mound and drove charred stake as per instructions for a Witness Point.

To attain distances across river, I set a flag in line on the right bank and then from the Witness Point on left bank of river, measured a base N. 22° W., 5.00 chains to a station from which the flag on right bank bears S. 46° 55′ W., making distance across on line 6.83 chains.

[Diagram]

Base Line. Range 7 West

As Sine is 43°05′ = 9.834460 Is to Sine 68°55′ 9.969909 So is 5.00 ch. Log: = 0.698970 10.068879 To dist across 6.83 Log = 0.834419

6.83 added to 26.30 makes 33.13 chains

33.13 [chains] – Intersected right bank of river bearing N. 25° W. and S. 25° W. and Set post for a Witness Point from which

A Willow 5 in. dia. bears N. 60° W., 7 links distant.

A Willow 5 in. dia. bears S. 64° E., 18 links distant.

Compared measuring chains with Standard and found them correct. July 18, 1858.

40.00 [chains] – Set post in Mound and drove charred stake as per instructions for 1/4 sec. cor.

60.00 [chains] - Leave prairie and enter Timber, bearing S.W. & N. 60° E.

77.00 [chains] – Intersected right bank of River again, bearing N. 25° E. and S. 25° W. and Set post with charred stake as per instructions for a Witness point, from which

A Cottonwood 14 in. dia. bears N. 20° E., 28 links distant.

A Cottonwood 10 in. dia. bears S. 20° W., 22 links distant.

To obtain distance across river, I produced

Base Line. Range 7 West

the line to the left bank and at this point of Intersection, Set a temporary post from which I measured a base N. 19° E., 6.00 chains to a station, from which the Post at the Witness Point on right bank bears S. 40° 45′ E. – making the distance across river = 6.84 chains.

[Diagram]

Nat. Sine 49°15′ = .7575650

6.84 chains added to 77.00 chains makes 83.84 chains Consequently the post on left bank of river is 3.84 chains West of corner to sections 35 and 36, thence at 80.00 [chains] – Corner in river – inaccessible.

Base Line. Range 7 West

As the corner cannot be located in its true place, I select the point where the temporary post stands on the left bank of the River as the nearest suitable Witness point, and there Set post with charred stake as per instructions, 384 links West of the true corner for a Witness Corner to sections 35 & 36 from which

A Cottonwood, 20 in. dia. bears N. 20° E., 213 links distant.

A Cottonwood, 8 in. dia. bears S. 7 1/2° W., 117 links distant.

A Cottonwood 10 in. dia. Bears S. 16° E., 42 links distant.

A Cottonwood, 8 in. dia. bears N. 43° E., 61 links distant.

Land level, sandy bottom – Soil 2nd rate.

Timber chiefly Cottonwood, open woods.

Along the South boundary of Sec. 35, T.1N. [R7W]

West on true line.

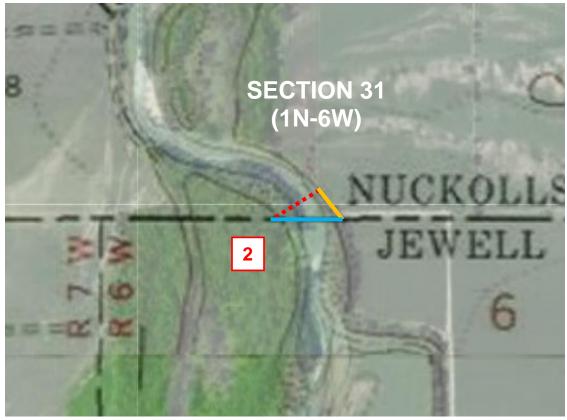
Va. 11°50′ *E.*

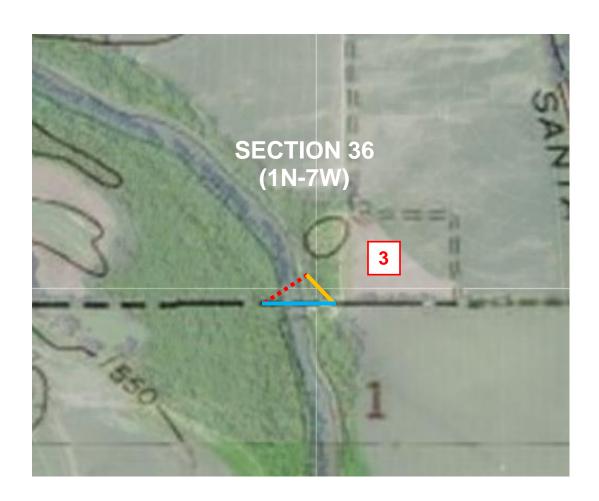
3.84 [chains] – Intersected the left bank of river bearing N. 20° E. and S. 20° W. at the witness corner to Sec's 35 & 36.

Leave Timber and enter prairie bearing with the bank.

40.00 [chains] – Set post in Mound and drove charred stake as per instructions for 1/4 sec. cor.







= MEASURED BASE LINE

= RIVER CROSSING (CALCULATED)

= THIRD LEG OF TRIANGLE

River Crossing No. 1

1. Survey to the near bank of the river and set a point for a Witness Corner.

Chaining is now at <u>35.46</u> chains from the last section corner.

- 2. Occupy the Witness Point just established.
- 3. Send the flagman across the river and set a point on the opposite bank of the river for a Witness Corner by sighting across the river on the surveyed line.
- 4. Establish and measure a baseline along the near bank of the river from the first Witness Corner.

Baseline measures to be 3.84 chains.

5. While occupying the Witness Corner on the near bank which is also the first end of the baseline, sight the Witness Corner on the opposite bank and turn the angle to the temporary point at the far end of the baseline.

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Angle = 49^{\circ}44'
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6. Move the instrument to and occupy the temporary point on the far end of the baseline. Sight the other end of the baseline that is also the Witness Point on the near bank. Turn the angle between the Witness Point on the near bank to the Witness Point on the opposite bank.

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Angle = \underline{108°34'} (Supplementary angle = \underline{71°26'}) (Note: The supplementary angles have the same Log value).
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- 7. Two measured angles and one measured line of a triangle are now known.
- 8. Compute the missing angle that is at the Witness Point at the opposite bank.

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180^{\circ} - 108^{\circ}34' - 49^{\circ}44' = 21^{\circ}42' (Or for a check turn the angle after crossing the river).
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9. Obtain the logarithms from tables in the book.

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Sine 21°42' from logarithm tables = 9.567904
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Sine of $108^{\circ}34$ ' (or the supplementary angle $71^{\circ}26$ ') from logarithm tables = **9.976787**

Base distance 3.84 from logarithm tables = 0.584331

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9.976787 + 0.584331 = 10.561118 (Addition)
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$$10.561118 - 9.567904 = 0.993214$$
 (Subtraction)

Logarithm of $0.993214 = \underline{9.84}$ chains (This is the distance across the river between the Witness Points).

9.84 + 35.46 = 45.30 chains. (This is the location of the Witness Corner on the opposite bank).

TABLES

OF.

LOGARITHMS OF NUMBERS

AND OF

SINES AND TANGENTS

FOR EVERY

TEN SECONDS OF THE QUADRANT,

WITH OTHER USEFUL TABLES.

BY ELIAS LOOMIS, A.M.,

PROFESSOR OF MATHEMATICS AND NATURAL PHILOSOPHY IN THE UNIVERSITY OF THE CITY OF NEW YORK, AUTHOR OF A "TREATISE ON ALGEBRA," AND "ELEMENTS OF GEOMETRY AND CONIC SECTIONS."

NEW YORK:

HARPER & BROTHERS, PUBLISHERS, 82 CLIFF STREET.

1848.

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	395	6597	6707	68:7	6927	7037	7145	7256	7366	7476	7586	
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950	7724	7769	7815	7861	7900	7952	7998	8043	8089	8135		1
951	8181	8226	8273	8317	8363	8409	8454	8500	8546	859I		1
952	8637	8683	8728	8774	8819	8865	8911	8956	9002	9047		l
953	9093	9138	9184	9230	9275	9321	9366	9412	9457	9503		ł .
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959	1819	1864	1909	1954	2000	2045	2090	2135	2181	2225		1
960	2271	2316	2362	2407	2452	2497	2543	2588	2633	2678		1
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965	4527	4572	4617	4662	4707	4752	4797	4842	4887	4932		1
966	4977	5022	5067	5112	5:57	5202	5247	5292	5337	5382		1
967	5426	5471	5516	5561	5606	5651	5696	5741	5786	583o		
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973	8113	8157	8203	8247	8291	8336	8381	8425	8470	8514		
974	8559	8604	8648	8693	8737	8782	8826	8871	8916	8960		
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985	3436	3480	3524	3568	3613	3657	3791	3745	3789	3833		
986	3877	3921	3965	4009	4053	4097	4141	4185	4229	4273		
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992	6512	6555	6599	6643	6687	6731	6774	6818	6862	6906		
993	6949	6993	7037	7080	7124	7168	7212	7255	7299	7343		
994	7386	7430	7474	7517	7561	7605	7648	7692	7736	7779		
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